AN ASSESSMENT OF ECOSYSTEM SERVICES AND DISSERVICES IN URBAN COMMUNITY GARDENS IN BERLIN (GERMANY) AND CAPE TOWN (SOUTH AFRICA)

Thesis submitted in fulfilment

of the requirements for the Degree of

DOCTOR RERUM NATURALIUM

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by

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Accepted (Tag der Verleihung): 19 November 2018

Reviewers: Prof. Dr.rer.nat Aletta Bonn (Hemholtz Centre for Environmental Reserach)
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Abstract

Background: Ecosystem services and disservices research from urban ecological infrastructure currently remain underexplored areas in global literature. Community gardens comprise an even rarer part of this research with few previous studies, as emphasis in research is placed on the 'big and tangible' urban green spaces like urban forests and parks, and more recently allotment gardens. Community gardens, however, are an important ecological infrastructure as they provide a range of ecosystem services to urban residents, and act as key spaces for meeting social and environmental objectives in urban development plans and policies. Considering cities are the predominant domain of human habitation, it is important that more research goes into better identifying ecosystem services and disservices from urban green space types, in light of global and local sustainable urban development goals.

Methods: Using the cities of Berlin and Cape Town as case studies, this study inventories the range of ecosystem services and disservices provisioned by urban community gardens. A total of 26 gardens across both cities were assessed using in-depth field surveys based on indicators derived from the literature and a ranked-scale questionnaire was answered by 46 participants.

Results: Community gardens provide important ecosystem services such as food provisioning, local climate regulation, high species richness of vascular plants, are valued highly by gardeners and local residents for their numerous recreation, tourism and social activities, and foster new principles of socio-environmental thinking and practice in neighbourhoods. Gardens are also found to deliver a few disservices that may influence human health like increasing potentials for allergy problems caused by the spread of pollen from the urban nature in them, and can cause economic impacts if the vegetation damages garden infrastructure. It is important to recognise both the benefits and detriments from these urban green spaces so as to better manage them and minimise their impacts and trade-offs to human well-being.

Conclusion: Outcomes of this research identify new ecosystem services and disservices inventories and make the net benefit of community gardens explicitly known, which gives credence to their value as a legitimate urban land-use by planners and related decision-makers. Findings show community gardens have a very relevant place in German and South African urban ecosystems research, and this project can significantly impact future work by strengthening the foundation from which we base our understanding – the collection and interpretation of new data. Finally, conclusions show that community gardens can contribute to sustainable urban development in local contexts, and promote Great Transition thinking.

Declaration

In my capacity as the researcher and author of the work described in this thesis (with the supervision of Prof. Dr.-Ing. habil. Ulrike Weiland), I recognise and confirm that, to the best of my knowledge, I have completed original work. I declare that where work completed by others has been made use of, it has been duly acknowledged and correctly referenced in the text.

The present work has not been submitted, either domestically or abroad, in the same or similar form to another examination authority for the purpose of a doctoral or other examination procedure and has not yet been published in its entirety.

Tristan Duthie: ______________________________________

University of Leipzig, 2018.

Acknowledgements

I would sincerely like to thank Professor Ulrike Weiland for her constant input and support, supervision, insightful feedback and most of all patience during the course of this research over the past three years. I would also like to thank Professor Weiland for her kindness and help with the challenges of integrating into a foreign country, which can be a difficult task for even the most capable person.

I am grateful to all my colleagues and peers at the Geography Institute for their warm welcoming of me to the university and the pleasant working environment they gave me during my stay.

I would like to thank my colleague and friend, Zhilin Li, for taking me under her wing over the past three years, and for all the invaluable help and support she has given me throughout my stay in Leipzig.

I am thankful to the community gardens in Berlin and Cape Town who were willing to allow me to visit their gardens to conduct my research. I am also grateful to all the people who took the time to answer the questionnaire during site visits.

Thank you to Ms. Felicitas Hanke in the International Centre of Leipzig University for making my stay in Germany as easy and happy as possible.

This research was made possible through financial assistance from the Erasmus Mundus EUROSA Partnership of the European Commission. I thank them for their support.

Finally, I would like to thank my mum and dad for giving me the courage to pursue my doctorate and the support they have showed me throughout my academic career.

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Introduction

1.1. Problem contextualisation

1.1.1 The changing environment

There is no doubt that our environment is changing: it has changed in the past and will continue to change in the future. Throughout the course of the Earth's history, numerous alterations in vegetation cover, biodiversity, geology, hydrology, sea levels and climate have occurred. Such environmental variations are recognised as outcomes of a set of complex interactions between natural and anthropogenic processes and factors, each of which have, and are, operating at different spatial and temporal scales (Thomas, 2004; Rudel, 2008; Henderson-Sellers, 2012). Despite beginnings of humankind being dated 2.4 million years ago (Bocquet-Appel, 2011), human-environment interactions only began to be markedly noticeable around 10 000 years ago with the advent of agriculture, and more recently in our history with the industrial and medical revolutions of the Anthropocene. The rise of an over-populated, urbanised global modern society equipped with agricultural and technological expertise facilitated large-scale rapid and erratic modification of the landscape and its resources by humans, the over-exploitation and over-consumption of natural resources such as clean air, water and biodiversity, and the discharge of pollutants and contaminants into nature which fundamentally altered ecosystems necessary to produce and sustain life (Mbow et al., 2008; Ericksen et al., 2009; Martínez et al., 2011). Moreover, anthropogenic modifications to land cover and ecosystem functioning have resulted in unprecedented acceleration in global environmental changes that have left all living organisms - man, animal, and plants alike - exceedingly vulnerable to the uncertainty of future change. There is little doubt that the Earth's environment is changing and humans are primarily responsible (McCarroll, 2010).

1.1.2. Ecosystems as the foundation of life

Ecosystems are the foundation for all life on Earth, particularly as this pertains to human life and well-being, and a number of benefits and services are acquired from their proper functioning (von Döhren and Haase, 2015). Although the notion of an ecosystem is old, the first time ecosystems became a unit of study was less than a century ago with Tansley (1935) providing initial scientific conceptualisation, Lindeman (1942) doing the first quantitative study within an ecosystem context, and Odum (1953) having collated the first textbook on the concept of ecosystems. The concept of ecosystems is therefore a relatively new research area and management approach in our history. Formally defined by the Convention on Biological Diversity (CBD) as "a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit", the term ecosystem can refer to any functioning unit at any scale, and its boundaries should be subjectively determined by the problem being addressed (UN, 1992). Ecosystems thus amount to a collection of interlinked biotic and abiotic constituent parts, including biological diversity of plants and animals, the physical environment and chemical, biological and ecological processes and functions. Ecosystems are the basis for all life, and species richness, functional groups and genetic diversity are all important aspects of biodiversity that govern the efficiency and magnitude of ecosystem properties and processes (Chapin et al., 1997). Moreover, these biodiversity functions and ecosystem processes are essential for providing natural goods and services that benefit human society, and on which human welfare relies (Gamfeldt et al., 2008). While the relationships of ecosystem properties, processes and functions seem simple in general outline, they are in fact enormously complex interactions – each species has a unique requirement for life, and each species interacts in distinctive ways with the physical and biological environment. Complexity of this system is further enhanced by human activity and demand, which often leads to changing the nature of ecosystems. In the face of unprecedented population growth, global urbanisation and land-use change, people are becoming gradually more aware that global society occupies, and moreover, utilises ecosystems unsustainably within a context of finite resources (Gómez-Baggethun and Barton, 2013; Cilliers et. al., 2014).

1.1.3. Century of the city

Cities are areas of concentrated human activity, made up of layered economic, political, socio-cultural, technological and environmental systems and structures. They are places that epitomise human creativity and ingenuity, where socio-cultural transformations happen, and are driven by engines of economic growth, technological innovation, knowledge production and resource use (Wu, 2010). Yet, cities appropriate vast areas of functioning ecosystems for consumption of nature, and to assimilate large amounts of waste (Gómez-Baggethun et al., 2013). Urbanisation is arguably the most imposing and permanent form of global land transformation, and present rates of urban expansion indicates that the world has entered "the century of the city" (Cilliers et. al., 2014; Xu and Luo, 2015 p.85). Current urbanisation trends show that, while urban areas only occupy 3% of the earth's surface area, 54% of the global population lives in cities, with projections that, by 2050, more than two-thirds of the world's population will inhabit urban areas (UN, 2014) (Figure 1.1).

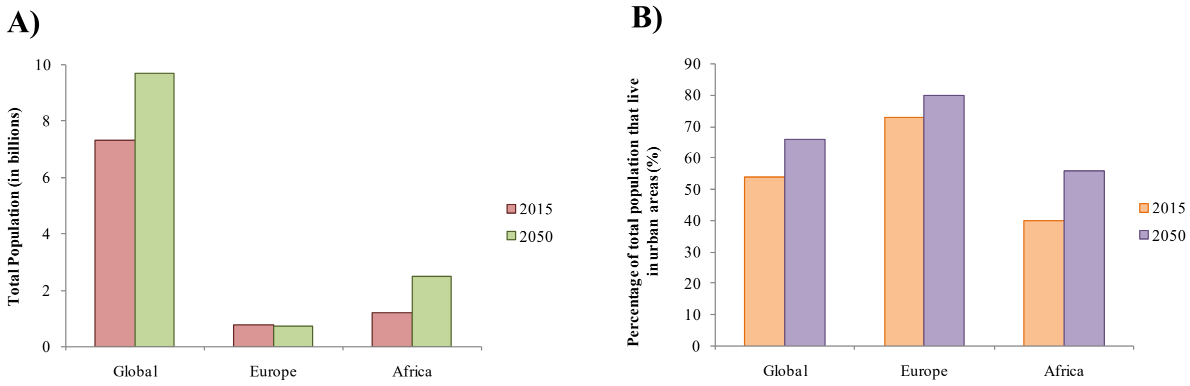


Figure 1.1. A) Total Global, European and African population estimates for 2015 and 2050. B) Percentage population estimates that inhabit urban areas based on 2015 and 2050 projections. Europe and Africa are the only continents that have been compared to Global totals as these two regions are the focus of this study. Source: Adapted from (UN, 2014) by the author.

In addition to its global reach, urbanisation has direct and marked effects on regional and local landscapes (Pickett et al., 2001). The rate at which cities are growing in terms of frequency, population numbers and spatial extent means that not only are more cities being developed, but these urban areas are no longer compact aggregations and are sprawled outwards to encroach on and consume more 'natural' ecosystems and environments (Pickett et al., 2001). Urbanisation influences local and regional climates by creating urban heat island effects at different scales, it brings about excessive consumption and contamination of water, it creates massive amounts of greenhouse gases and air pollution, and is the most striking and permanent form of land change, devastating biodiversity and ecosystems (Wu, 2010; Cilliers et. al., 2014). Consequently, threats towards ecosystems are increased and the ecological footprint of cities – the area of land and water required to provide an urban population indefinitely with all the material and energy resources it needs, and to absorb all the waste it discharges – can be tens to hundreds of times as large as the physical size of the city itself (Luck et al., 2001; Wu, 2010).

The concentration of human populations in cities that are dominated by built infrastructure and technology has fostered the perception that urban societies are increasingly decoupled and independent from nature and ecosystems (Gómez-Baggethun and Barton, 2013). This is reiterated through most definitions of ecological concepts like *communities* and *ecosystems* having a 'natural' bias and disregarding human inclusion, leading to the view that cities and ecosystems are independent entities. Despite this oversight, research has shown that interdependence between cities and ecological systems is inextricable, and just as with any other socio-ecological system, cities depend on ecosystems and their components to sustain long-term conditions for life, health, security, social relations, and welfare (Odum, 1989; Tzoulas et al., 2007; Gómez-Baggethun and Barton, 2013). Furthermore, research agendas relevant to sustainability science now occupy a significant place within many branches of study, including: environmental science, geography, socio-political sciences and economics (Lang et. al., 2012). Within each of these study fields, contemporary issues such as environmental and climate change, sustainable development and urban planning, ecosystem goods and services, and biodiversity conservation are considered essential research areas in the face of an uncertain world for future generations. Yet, while researchers, management practitioners and policy makers have come to realise that very few ecosystems are completely devoid of human influence, urban areas remain fairly neglected as a domain with which to investigate the role of humans in ecosystems - urban habitats therefore represent an open frontier in ecosystems research (Pickett et al., 2001; Gómez-Baggethun et al., 2013). Urban areas, in their role as the main places of habitation for humans, are necessarily the domain in which sustainable solutions will have to be found, and understanding and managing human-nature interactions within the context of urban ecosystems is thus fundamental to the challenge of sustainable development and human well-being.

1.1.4. Sustainable Development and the Great Transition

It has been over two decades since the concept of *Sustainable Development* entered the lexicon of international terminology, stirring countless international meetings, agendas and actions (Raskin et al., 2002). First described by the Brundtland Commission in 1987, sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs, and has become a key challenge and major focus of contemporary science, global political and economic discourse and socio-environmental agenda (WCED, 1987; Cilliers et al., 2014). The notion was directed at the realisation that while the 'environment' is where we live and 'development' is what we do in an attempt to improve our lives within that abode, unparalleled urbanisation, population growth and resource depletion were harming our environment, and thus our capacity to continue to improve going into the future. As Messerli et al. (2000, p.459) suggested at the turn of the century, "we are moving from a century of rapidly growing human impacts on different environments of our planet, to a century with probable further acceleration in the face of human-induced environmental change…we have to rethink the changing relationship between nature and humans from the past, through the present towards a future full of uncertainty".

More recently, the concept of 'The Great Transition' has gained traction within academic and scientific spheres. Although not an entirely new concept, Great Transition thinking and roots began in environmental movements of the late 1960s and early 1970s, starting with the first coinage of the term 'The Great Transition' by Boulding (1965) in his book '*The Meaning of the 20th Century: The Great Transition*' about human civilisation's progression in the 20th century, and thereafter in reports such as '*The Limits to Growth*' for the Club of Rome (Meadows et al., 1972) that spoke to the unsustainable use of Earth's resources by global society. The Great Transition refers to a set of core concepts for understanding the contemporary world and shaping its future through envisaging how economies and societies can deliver positive social and economic outcomes within the limits of the environment (GTI, 2016). Relative to past civilisations, current society recognises that multiple threads of interdependence between commerce and economic globalisation, communications and technology, society and culture, and environment and climate, are binding people and places into a singular global socio-ecological system (GTI, 2016). While this new era of civilisation emerges, worldviews, value systems, demographics and social relations and institutional frameworks from past ways of life have persisted, resulting in contradicting forms of consciousness, knowledge paradigms and political engagements in the global arena. A disjuncture is caused when living in, and dealing with current global realities according to past ways of thinking, lifestyles and routines – the way we think and the way we live has to change.

The Great Transition is the vision of civilisation rooted in a new set of core values, paradigms and concepts for understanding the contemporary world and shaping its future. These values include quality of life and well-being, human solidarity and connectedness, and reverence and responsibility for nature and the environment. Great Transition discourse encourages the development of a new human consciousness and way of viewing the world as it transitions into an indeterminate future. From the perspective of the present, Great Transition thinking distinguishes three possible future global scenarios to the way socio-ecological crises play out and the ways society collectively responds to them - here stated according to GTI (2016):

1. *Conventional Worlds*: These worlds evolve without sharp discontinuity or fundamental transformation from the current status quo, with dominant forces and values continuing to drive globalisation, and development in developing countries striving towards

patterns in more affluent countries. In this scenario, market forces stress free-market solutions, and policy reform underscores political will and international cooperation for sustainable development.

2. *Barbarization Worlds*: These worlds see the erosion of institutions and civilised norms, and conventional approaches to development prove incapable of mitigating economic, social and environmental instability and challenges. In this scenario, an authoritarian response to crises may result in a 'fortress world' of great inequality and a breakdown into spiralling conflict, environmental catastrophe and institutional collapse.
3. *Great Transition Worlds*: These worlds see the ascendance of new values, norms and institutions that emphasise quality of life, solidarity and human-connectedness, and environmental sustainability. In this scenario, the world encourages eco-communalism, democracy and socio-economic prosperity. The focus of the Great Transition is a new sustainability paradigm which embraces global interdependence on the path to a humanistic, community-driven, diverse and environmentally conscious planetary civil society.

The Great Transition thinking advocates that human fulfilment rather than material wealth be the measure of success and well-being. It promotes a sense of connectedness and solidarity that extends beyond one community or nation to future generations and creatures of the biosphere. It encourages a sense of place, attachment, appreciation and responsibility to the natural world (GTI, 2016). A viable Great Transition strategy involves actions that address a multitude of issues at local, regional and national level. A massive and coherent 'global citizens movement' is the essential systemic agent of change that is at the foundation of the Great Transition theory. By constructing a global community of shared risks, opportunities and fate, Great Transition thinking makes a broad socio-cultural and political paradigm shift possible. Despite its potential, Great Transition thinking remains largely latent although it can be seen in emerging movements around the world in local initiatives, post-consumerist sub-cultures, sustainability and environmental justice campaigns, and growing public awareness about sustainability and the future; the challenge remains for this new paradigm to infiltrate the political domain and have influence in an explicit and concrete manner (GTI, 2016).

The theoretical foundations of this thesis are grounded in Great Transition thinking. It takes Great Transition principles of community, connectedness and environmental consciousness and attempts to show how community gardens can be important urban green spaces in which to foster these values. Moreover, effort is made to show how community gardens, although overlooked in urban planning and management agendas, could be critical to addressing socio-economic and environmental challenges through assessing the services and disservices provided to residents by these spaces, and thus illustrating how community gardens have potential to be key to sustainable development objectives as well. Lastly, community gardens could be innocuous spaces in which an impending 'global citizens movements' are built, and therefore potentially hold immense importance to sustainability in cities.

1.2. Problem statement

1.2.1. Ecosystem services

Ecosystem services is a popular buzzword in environmental management and policy making in recent times. This concept draws attention to humankind's dependence on ecosystems and the functions they provide for human livelihoods and well-being (Kull et. al., 2015). Researchers, scientists, policymakers and practitioners have used the concept of ecosystems services as a framework for conceptualising, implementing and managing a wide array of human-environment interactions (Daily, 1997 p.3; Luederitz et. al., 2015). This approach has given extensive rhetorical and scientific power to environmental initiatives in the last two decades. However, despite the popularity of the ecosystem services approach in academic literature, there is a deficiency of research analysing the interactions and interrelations between humans and ecosystems in an urban context, despite the majority of the global population residing in cities.

Ecosystems supply a range of goods and services that are vital to human livelihoods, health, well-being and survival (Costanza et al., 2014). These services provide benefits to human beings that are necessary to maintain the quality of everyday life, for example: food production, climate regulation, air and water filtering, and recreation (Mascarenhas et al., 2015). Ecosystem services are defined as the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods (such as seafood, forage, timber, biomass fuels, natural fibre, and many pharmaceuticals, industrial products and their precursors) both directly and indirectly from ecosystem functions, for human benefit (Costanza et al., 1997; Daily, 1997). Cities are dependent on healthy ecosystems and the beneficial services they provide to maintain economic activity, livelihoods and human well-being. In the last decade, a mounting body of literature has advanced our understanding of ecosystems services in their economic, political, socio-cultural and biophysical dimensions. Yet, despite the fact that over half of the world's population currently live in urban areas, the attention given to urban ecosystem services in the academic literature has remained modest compared to more 'natural' systems like wetlands or forests in remote areas (Gómez-Baggethun et al., 2013; Haase et al., 2014). By considering ecosystem services, urban regions gain valuable opportunities to save on municipal costs and improve service delivery, boost local economies, enhance the quality of life and secure more livelihoods for their residents (TEEB, 2011).

Building on previous categorisations of ecosystem services (Daily, 1997; de Groot et al., 2002), the Millennium Ecosystem Assessment (MA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB 2010) grouped ecosystems services into four categories: Provisioning, Regulating, Habitat/Supporting, and Cultural. Specifically, TEEB (2011) has used these categories and service types relevant to urban areas (see Table 2.1 – page 27).

Provisioning Services

Provisioning services refer to those ecosystem services that describe the material or energy outputs obtained from ecosystems in urban areas. Examples include: food supply, raw materials, fresh water, and medicinal and genetic resources.

Regulating Services

Regulating services are those services that ecosystems provide by regulating processes including the climate, the quality of air, water and soil, or providing flood and disease control etc. Examples include: Local climate and air quality regulation, carbon sequestration, moderation of extreme events, maintenance of soil fertility and prevention of soil erosion, waste water treatment, pollination and biological control.

Habitat or Supporting Services

Habitat or supporting services are those that are necessary for the production of all other ecosystem services. Ecosystems provide habitat and life support for plants and animals and their biodiversity. This category of services therefore reflects an ecosystem's ability to provide habitats for species, and the maintenance of genetic diversity. Examples include: biomass production, nutrient cycling, water cycling, provisioning of habitats for species, maintenance of biodiversity and evolutionary processes.

Cultural Services

Cultural services are those services that provide non-material benefits to people through interaction with ecosystems. Examples include: aesthetic values, recreation and tourism, spiritual enrichment and psychological benefits.

Different habitats and their constituent species provide different types of ecosystem services, and these classifications therefore need to be adapted to specific types of ecosystems. In cities, ecosystem services and the benefits of urban green spaces result from a combination of biophysical and social factors, including land-use, management regimes and accessibility (Langemeyer et al., 2015). Furthermore, the ecosystem services perceived as most important or relevant in a given scale, to people or cities, varies considerably depending on the environmental, socio-economic and cultural realities of each geographic location (Gómez-Baggethun and Barton, 2013; Gómez-Baggethun et al., 2013). These aspects are particularly salient to urban environments, where services provided by ecosystems are fundamental to, and have direct impact on, human health, security, quality of life and well-being.

1.2.2. Ecosystem disservices

The proliferation of research on ecosystems since the turn of the millennium has largely been a "one-legged race" in that much emphasis has focused on the benefits and good facets that ecosystems provide to people, while the negatives have mostly been rarely discussed (Lyytimäki and Sipilä, 2009 p.309; Lyytimäki, 2014; von Döhren and Haase, 2015). Inevitable detriments provided by ecosystems have been left largely unaddressed and a more nuanced inquiry of urban ecosystems needs to take into consideration that the environment provides humans with both good and bad aspects. While no widely agreed upon definition exists, ecosystem disservices are typically understood as functions of ecosystems that are perceived as negative or harmful to human well-being. They can result from natural phenomena such as damages caused by floods, earthquakes and wildfires, as well as man-made disservices caused by, for example, the release of toxins into nature or deliberate anthropogenic manipulation of the environment (Lyytimäki and Sipilä, 2009).

Unfortunately, research agenda has mainly been one-sided and no formal ecosystem disservices categorisation or framework exists in line with the ecosystem services template as highlighted by TEEB (2011). The closest to an existing systematic framework of urban ecosystem disservices in the literature is illustrated by von Döhren and Haase (2015), who base these categories on thematic areas of impact to human livelihoods and well-being (see Table 2.1 – page 27).

Ecological Impacts

Ecological impacting disservices are those disservices that negatively affect ecosystem structure, process and/or the services they provide. Examples include: emissions of volatile organic compounds by urban vegetation, and the displacement of native species by invasive species.

Economic Impacts

Economic impacting disservices are those disservices that negatively affect economic structures and/or process. Examples include: damage to infrastructure by nature and maintenance costs associated with urban vegetation or nature.

Health Impacts

Health impacting disservices are those disservices that negatively affect human health - an important aspect of the quality of life. Examples include: allergies and respiratory problems caused by spread of pollen, vector-spread diseases by animals or urban water bodies, wild or semi-wild animals in urban green spaces can cause anxiety and fear over safety.

Psychological Impacts

Psychological impacting disservices are those disservices that cause negative feelings or discomfort to people, another aspect of human quality of life. Examples include: certain smells, sound and behaviours from plants or animals may be considered a nuisance or cause annoyance, aesthetic and hygiene impact due to animal excrement, aesthetic degradation and unpleasantness due to unkept or overgrown urban vegetation or nature, feeling of insecurity or fear associated with overgrown or dark urban green spaces.

Other General Impacts on Human Well-Being

General impacting disservices on human well-being are those other disservices which are assumed to negatively affect human well-being, not fitting into any of the other categories. Examples include: obstruction of transportation networks by urban green space causing mobility issues, traffic safety issues for transport relating to vegetation debris/litter on surrounding roads, decrease in water quantity associated with water requirements for urban vegetation growth, presence of conserved or protected green areas off-limits to the public can hinder the benefits of those seeking to enjoy nature.

Besides no formal framework existing for the systematic classification of urban ecosystem disservices, there is a further lack of knowledge about the interaction of ecosystem disservices at different spatial or temporal scales, or socio-cultural underpinnings of different perceptions towards ecosystem disservices and how these influence different social groups by factors such as age, gender, income status, cultural background or education level (Lyytimäki, 2014, 2015). Lyytimäki (2015) suggests a possible reason for the inadequate presence of the ecosystem disservices concept in the academic literature as being based on criticisms of the concept, as argued by Shapiro and Báldi (2014) and Villa et al. (2014), that appear to be motivated by fear that this term will compromise conservation efforts in cities by exaggerating the potential or actual harms caused by ecosystems to people and their well-being, thus providing additional arguments for intensive management and exploitation of natural resources. Nevertheless, Lyytimäki (2014, 2015) shows the importance of investigating both ecosystem services and disservices under a common assessment framework in order to establish a balanced and comprehensive impression of the net effects of ecosystem functioning to human well-being in urban areas, and particularly, as this relates to urban planning, urban environmental management and policy-making. Taking into account the full repertoire of both positive and negative ecosystem functions is essential for integrative and effective environmental management, especially when attempting to solve conflicts or controversies related urban planning and management, and sustainable development (Lyytimäki, 2015).

1.2.3. Urban ecosystems and ecological infrastructure

Definitions of cities and their borders are ambiguous, and differ between various regions and countries (Gómez-Baggethun et al., 2013). Moreover, urban environments can be thought of as either one single ecosystem (the city) or as a collection of several individual ecosystems (for e.g. forests, parks and lakes), and the boundaries of these different ecosystems are often unclear (Rebele, 1994; Bolund and Hunhammar, 1999). This is because many of the interactions and material flows necessary to understand the functioning of urban ecosystems extend beyond arbitrary political or biophysically defined boundaries. Yet, such boundary delineations are important when investigating urban ecosystems and the services and disservices they provide from the perspectives of city planning and management. In the context of urban planning and management, urban ecosystems embed both the built and ecological infrastructure of cities.

Specifically, ecological infrastructure refers to all green and blue spaces that are found in urban areas, and these play an important role in delivering ecosystem services and disservices to urban populations at different spatial scales (e.g. to buildings, streets, neighbourhoods and the city as whole) (Gómez-Baggethun et al., 2013; Langemeyer et al., 2015).

Many definitions of urban green and blue space exist, but the concepts can broadly be defined as green spaces being those areas within an urban context that are unsealed, permeable and have surfaces such as soil, grass, shrubs or trees while blue spaces are those areas made up of water (James et al., 2009). These spaces are important from the perspective of urban planning and management as it is in these areas where people in cities most often experience, and moreover realise, their connection to nature and the ecosystems they are a part of. Each city is unique in its existing blue and green spaces, and this is dependent on a number of factors like the surrounding physical environment, urban planning and environmental management. Universally, Bolund and Hunhammar's (1999) seminal work on urban ecosystems categorise seven broadly encompassing green and blue space types in cities:

1) Urban wetlands: Delineated as those areas in cities where a variety of marsh and swamp conditions exist.
2) Urban streams: Defined as those environments where flowing water occurs such as urban rivers and streams, canals, waterways, channels and the riparian zones surrounding these systems.
3) Lakes and sea: Areas where a body of open water exists that is surrounded by urban land. This includes water bodies like lakes, dams and ponds, and in cities adjacent to the sea, coastal waters and oceans.
4) Street trees: Defined as stand-alone trees, usually surrounded by paved ground, along roads.
5) Lawns and parks: Defined as managed open green areas with a mixture of grass, trees and other plants and includes public parks, protected areas, greenways, and public recreation areas such as sports fields, playgrounds and golf courses.
6) Urban forests: Distinguish from parks by their structure, and are seen as being less managed areas with a dense tree stand.
7) Urban gardens: Collectively, urban gardens refer to areas in cities such as public gardens used for growing food (e.g. community gardens and allotments), private residential gardens, green roof gardens, vertical hanging gardens, and green utopias.

Community gardens are the explicit garden type explored in this study and will therefore be further examined in the literature review in Chapter Two.

1.2.4. Aim and objectives

This research aims to identify and inventory both the ecosystem services and disservices emanating from urban community gardens using two unique city landscapes, namely: Berlin and Cape Town as case-study settings. Though a number of extensive global research initiatives pertaining to ecosystem services exist, a small part of this constitutes assessments on ecosystem services in urban contexts, and even less so, the portion of urban research dealing with ecosystem disservices. While urban ecosystem services and disservice research remains a largely unexplored area, urban community gardens comprise an even rarer part of this research. They are a 'forgotten realm', as emphasis is placed on the 'big and tangible' urban green spaces like urban forests, parks and wetlands. Yet community gardens make up an important share of space in urban landscapes by virtue of the fact that many citizens have their main experiences with ecosystem services and disservices in these shared areas in cities where space is often limited and always in conflict with other interests. Community gardens are essential in the context of The Great Transition thinking and Sustainable Development because people are more likely to take action for biodiversity and better behavioural practices if they have direct interaction with the nature that benefits, affects or influences their lives and well-being (Beumer and Martens, 2015). Considering cities are the predominant area of human inhabitation, it is important that more research goes into better understanding the ecosystem service and disservice of community gardens in light of global and local sustainable urban development goals.

The intention of this study is to fill a gap in ecosystem services and disservices research. It aims to elucidate the importance and necessity of identifying and understanding both the ecosystem services and disservices provided by community gardens in urban areas, and how this information can be used to contribute to sustainable urban development. This is imperative, now more than ever, as cities face unprecedented challenges regarding infrastructure requirements, land-use competition and changes, and resource competition and depletion. Improved sustainable urban planning and effective sustainable urban development can therefore not be overstated, especially with the omnipresent threat of climate change to long-term quality of life for people in cities. Despite this research representing a microcosm of possible urban environments in which to understand ecosystem services and disservices, its importance cannot be diminished. With a general paucity of urban ecosystem services and disservices research, and in particular studies originating from less-developed countries (Haase et al., 2014), coupled with the fact that ecosystem services and disservices research is becoming increasingly important to issues such as environmental and climate change, outcomes from this study have the potential to be crucial benchmarks for further urban ecosystem services and disservices research in Germany and South Africa respectively. This is because urban ecosystem services and disservices research needs to be carefully contextualised in relation to specific locations in which the services and disservices are appropriated if insights from relatively small ecosystems studies are to be generalised to a wider understanding of the role of ecosystem services and disservices as essential input to 'real world' sustainable urban planning and development (Luederitz et al., 2015).

The specific objectives of the research are to:

1. Calculate the quantitative share of urban community gardens in Berlin and Cape Town respectively.
2. Identify suitable sampling community gardens in Berlin and Cape Town respectively, from which to assess existing ecosystems services and disservices.
3. Identify and assess which ecosystems services and disservices are provided by the chosen sampling community gardens in Berlin and Cape Town respectively.
4. Demonstrate the relevance and contribution of community gardens to sustainable urban development and the Great Transition.

1.3. Thesis overview

This thesis is structured into seven chapters.

Chapter One presents a general introduction into the background and contextualisation of the study, followed by an outline of the research aim and objectives.

Chapter Two provides a literature review of the current state of the art for urban ecosystem services and disservices. Besides highlighting the importance, role and function of community gardens as valuable urban green spaces that provides essential ecosystem services to urban residents, this chapter also critically discusses past literature on urban ecosystem services and disservices according to four main themes: 1) The categories of services and disservices assessed in the studies; 2) The types of urban green spaces evaluated, 3) The perspectives from which the research was conducted; and 4) The methods used in the assessments. The chapter concludes with past ecosystem services and disservices assessments done in community gardens.

Chapter Three shows the methods that are used in community garden assessments in each city. Using an overarching case study approach, both quantitative and qualitative mixed-methods are used in data collection as this research recognises a compatibility between positivism and interpretivism research philosophies is necessary when dealing with human-nature phenomena such as ecosystem services and disservices as they relate to human well-being. Quantitative methods include GIS techniques used to quantify garden shares of urban area and indicator analysis to gather empirical data on ecosystem services and disservices. Qualitative methods included a closed-ended questionnaire with a ranked scale that was used to gather people's perceptions of which ecosystem services and disservices they felt they experienced in community gardens.

Chapter Four contextualises the chosen case study cities, Berlin and Cape Town, in terms of their existing environmental, socio-economic, and institutional contexts relevant to this investigation, and serves as the first part of the research design that follows in the methods chapter.

Chapter Five describes the results of this research and is organised into four main sections. First, results on the quantification of community garden share in Berlin and Cape Town are presented. Second, results for ecosystem services are shown, organised according to the four ecosystem service categories. Third, ecosystem disservices results are shown, similarly organised according to the five ecosystem disservices categories. Fourth, results are the summarised using Burkhard-type matrices for both cities.

Chapter Six presents a critical discussion on the major findings produced in this research as they correlate to achieving the research objectives. Limitations of the study are further shown, and an outlook regarding the study's implications for research and practice is discussed.

Chapter Seven provides a thesis summary and general conclusions and insights drawn from the research as an ending.

Chapter Two

State of Research

2.1. Introduction

This chapter presents a synthesis of urban ecosystem services and disservices literature. Beginning with an overview of urban community gardens, their definition and history, these spaces are related to ecosystem services and disservices which are then discussed within the framework of urban planning, management and governance. A wide body of literature exists on ecosystem services and disservices, however as the focus of this thesis, only studies regarding ecosystem services and disservices in urban environments is reviewed. A synthesis of past research pertaining to urban ecosystem services and disservices assessments is conducted from a global literature outlook, then focused down to Germany and South Africa perspectives, and finally reviews of ecosystem services and disservices from urban gardens are considered. The purpose of this chapter is to contextualise the research done in this thesis into the broader literature body, specifically to urban ecosystem services and disservices research. Furthermore, this review seeks to highlight any gaps in current research, particularly as these gaps relate to assessments of ecosystem services and disservices generated by community gardens in urban areas.

2.2. The role and function of community gardens as urban ecosystems

2.2.1. Definition of community gardens

Definitions of community gardens are often broad and can have different meanings and limits in different parts of the world. Generally, the term community gardens refer to individual gardens maintained by a group of people who produce agricultural goods like food or flowers collectively on a piece of urban land, primarily (although not necessarily exclusively) for private consumption (Ferris et al., 2001). These spaces are typically located on open land (either privately owned or municipal open space) and are supported by non-governmental agencies, non-profit foundations and neighbourhood clubs which are responsible for costs and maintenance. Community gardens are usually accessible to all inhabitants and passers, but individual garden spaces may be assigned to specific people or gardeners (Drescher et al., 2006; Pleschberger, 2014). Community gardens can occur in a variety of shapes and sizes, can be relatively large or small, can be situated on the ground or on rooftops, can be in planters or on plots, and have gained popularity among a wide range of groups such as prisons, youths, schools, hospitals, elderly, and local residents of neighbourhoods who want to be a part of environmental and community orientated group activities (Guitart et al., 2012).

2.2.2. Historical context and multi-functional purposes of community gardens

The concept of community collective gardening can first be attributed to European cities in the 19th century as an agricultural movement response to periods of crisis and warfare that led to poverty, food shortages and dire living conditions in urban areas (Scheromm, 2015). After the Second World War, a global proliferation of community gardens occurred, including an evolution in their status and function from a food dimension to incorporating both ecological and social dimensions. Increasingly, these garden spaces became about concepts of food and social justice in disadvantaged neighbourhoods, social integration of migrants or other historically disenfranchised people, the protection and care of nature through improved behavioural practices and environmental education, and building conscientious and good citizenship (Agustina and Beilin, 2012; Ghose and Pettygrove, 2014; Shepard, 2014; Scheromm, 2015). Community gardens, and their purposes and uses, are products of a mixture of specific socio-economic and political contexts in cities, and involve different types of actors mobilised around their creation and management: local authorities, public or private enterprises, and neighbourhood associations and city residents. These spaces are a convergence of grass-roots movements, urban planning and environmental protection, and move beyond being merely about the production of food – they provide social, therapeutic, psychological and environmental living functions and characteristics that have been observed in these gardens in cities all around the world (Armstrong, 2001; Salvidar-Tanaka and Krasny, 2004; Agustina and Beilin, 2012; Adevi and Mårtensson, 2013). Urban community gardens are places of social, cultural and cross-generational interaction that foster neighbourly collaboration and where communities can promote nature, biodiversity, agriculture and food security and the preservation of common goods, and oppose increasing privatisation or commercialisation of public space. They are areas where urban society can co-operate, participate and thrive in designing and practicing conscientious new governance strategies, ecological behaviours, environmental education, collective learning and trading and sharing other socio-cultural experiences and knowledge (Urban Gardening Manifest, 2014). They are further spaces where people may experience spiritual enrichment, quietness and shared time and pose a valid space to combat to feelings of solitude, anonymity, marginalisation or crime and violence often experienced in busy city life.

2.2.3. Ecosystem services in community gardens

Although urban community gardens are acknowledged as one resource to expand urban agriculture, they are similar but not synonymous with it, despite the boundaries between these two concepts often being blurry (Guitart et al., 2012). Ubiquitous concerns about food-quality, -cost and -insecurity have raised interest in growing food locally within many cities across the globe, including in community gardens (Corrigan, 2011; Evers and Hodgson, 2011). Far from being simply a public space in which to garden and grow food, community gardens are a unique urban green space in their own right (Middle et al., 2014). Besides their tangible food advantages, community gardens are growing in recognition due to several other benefits and services they provide that include community building, education, skills development and health promotion (Bodel and Anda, 1996; Beilin and Hunter, 2011; Turner, 2011; Guitart et al., 2012; Lanier et al., 2015). Community gardens are therefore often created with multiple underlying motives: to not only cultivate food for nutrition and economic benefit, but also to satisfy a community's needs for contact with nature, education, eco-communalism, civic-activism and community-led movements, social interaction and integration, and neighbourhood renewal (Hou et al., 2009).

As an urban green space, the ability to provide provisioning ecosystem services relating to food production and agricultural output is relatively unique to urban gardens and cultivated land compared to the other categories highlighted by Bolund and Hunhammar (1999). Opportunities to produce food in community gardens contribute to healthier and more sustainable food choices by individuals and community groups, while addressing concerns relating to food security (Evers and Hodgson, 2011). Moreover, local food production has economic outcomes which may have significant impacts in areas of low socio-economic status (Dunn, 2010a; Middle et al., 2014). Potential regulating and supporting ecosystem services provided by community gardens comprise localised temperature regulation, flood mitigation through rainwater interception and run-off infiltration, and biodiversity maintenance for urban bird and insect species (Okvat and Zautra, 2011; Cameron et al., 2012; Middle et al., 2014). While provisioning and regulating ecosystem services provided by community gardens can be significant, especially if realised in high density, in low socio-economic urban areas, cultural ecosystem services play a significant role and hold important value in community interactions with garden space. These encompass benefits such as physical health and mental health advantages, recreation and aesthetic benefits, social inclusion and interaction, community cohesion, environmental education and teaching, and skills development and socio-cultural integration (Niemelä et al., 2010; Middle et al., 2014).

2.2.4. Community gardens as the assessment unit for this project

Community gardens as urban green spaces are often overlooked in terms of legitimate places for social development, environmental management and planning concerns in cities (Beumer and Martens, 2015) despite having a number of inherent characteristics that are advantageous in urban areas like: 1) Community gardens are relatively small compared to other ecological infrastructure types like urban parks or forests that take up a lot of area, so they are space efficient in cities where 'space' is often the most valued resource; 2) They foster a sense of community and connectedness between people and promote eco-communalism; 3) They enhance responsibility towards nature through promoting its management as a common-interest and endorse democratic governance of shared resources because of community garden structure; 4) Community gardens are used as educational spaces on a variety environmental, socio-economic and political matters; and 5) They educate people on the importance of nature in meeting people's needs and quality of life, thereby encouraging sustainable life choices, behaviours and daily practices (Hou et al., 2009; Agustina and Beilin, 2012; Lanier et al., 2015). Based on these intrinsic qualities, community gardens are unique and set apart from other urban ecological infrastructure types regarding their ability to promote Great Transition values and paradigms for a more sustainable future. The idea behind community gardens is that people are more likely to take action for protection of the natural environment and practice better behaviours towards it if they have both direct contact with nature <u>and</u> a sense of responsibility and involved community in looking after that nature (Beumer and Martens, 2015). Human apathy is perhaps the greatest threat to the environment and if we are to safe guard and conserve nature, we have to make sure people care about it which requires a large-scale change in the way humans think and act. Showing people how and why to care about the environment is one of the main purposes of community gardens, therefore community gardens can be important resources for sustainable development objectives in cities from both social and environmental perspectives.

2.3. Integrating ecosystem services and disservices concepts into urban planning, environmental management and governance.

In the face of growing socio-economic and environmental challenges, increasing attention is being paid to urban ecosystems for their potential to offer novel natured-based alternatives or solutions (Camps-Calvet et al., 2016). Urban ecosystem services and disservices are produced and consumed within the context of complex interacting political, social, ecological and technological structures. Understanding how these structures influence urban ecosystem services and disservices is critical for planning, managing and governing ecological infrastructure in cities (Kremer et al., 2016). As it is being increasingly recognised that ecosystem services need to be incorporated into urban design, planning and management, the need to strategically handle urban green and blue space for their services has become of policy importance in many countries around the world (Colding, 2011; Holt et al., 2015).

2.3.1. The role of ecosystem services and disservices in urban planning

Integrating ecosystem services and disservices into urban planning may be a promising approach towards more sustainable development as it supports making these benefits and detriments explicitly known, therefore fostering discussions about trade-offs between socio-economic and environmental aspects of new developments, and how to better manage them (Grêt-Regamey et al., 2017). Many past and current urban planning movements (for e.g. the garden city, smart growth) implicitly recognise ecosystem services (Colding, 2011; Woodruff and BenDor, 2016). More recently, planning research argues that explicitly incorporating ecosystem services into plans has added potential to address environmental protection during the course of urban development (Albert et al., 2016a; Langemeyer et al., 2016, Nin et al., 2016). Moreover, recent planning discourse has made stronger connections between environmental assets and human well-being, illustrating the relationship between ecosystem services provided by urban ecological infrastructure and those services urban planning attempts to provide (Colding, 2011; Colding et al., 2013; Woodruff and BenDor, 2016). Some real-world examples of the use of ecosystem services informing urban planning decision-making can be demonstrated by Ruckelshaus et al. (2015) who evaluated the application of ecosystem services information in different spatial planning contexts, Arkema et al. (2015) who illustrated the use of ecosystem services values and models within coastal planning contexts, Schaefer et al. (2015) who demonstrated examples of incorporating ecosystem services into land-use planning, and Li et al. (2015) who presented an ecosystem services protection and human development planning policy.

Alternatively, scouring the urban planning literature for instances where ecosystem disservices are integrated into decision-making, or at the very least discussed, results in no examples being found. Despite the growing awareness of the advantages of aligning ecosystem services (and to a lesser extent ecosystem disservices) to urban planning and decision-making, their integration remains slow (Woodruff and BenDor, 2016). Kaczorowska et al. (2015) suggest reasons for this slow integration may be due to a number of challenges causing a gap between science and policy. These include: 1) difficulties among practitioners to process uncertainties present in scientific publications, 2) there is a lack of ecological data and analysis needed to validate regional planning and policy at a local level, 3) even when expert studies exist, there is a lack of scientific tools to situate the complexity of interacting systems to relevant contexts and scales, 4) there is a lag time between knowledge appropriation and its effect on policy making, public awareness and action by decision makers, and scientific knowledge is considered just one of many perspectives, and 5) differing values, views and paradigms may be present between stakeholders and decision makers thus influencing approaches to urban ecosystem services.

2.3.2. The role of ecosystem services and disservices in urban environmental management

The application of ecosystem services in environmental management, especially in the context of urban ecosystem-based management, seeks to optimise the provision and consumption of various ecosystem services in a way that they become sustainable (de Groot et al., 2010; Rova and Pranovi, 2017). In the face of growing urbanisation trends, as well as growing awareness of the value of natural capital by the public and private sectors, including the general public, effective management of urban ecosystems and their goods and services is becoming increasingly essential. Prior to the year 2000, environmental management discourse was focused on quality protection, prevention of damage and clean-up of the environment. Subsequent to 2000, environmental management underwent a paradigm shift, focusing on the sustainable use of ecosystem services and natural capital (Breure, 2014). This shift was a direct result of world population growth and the resulting demand of natural resources.

Given the dynamic and complex nature of socio-ecological systems like urban ecosystems, management of these systems face a number of challenges. Because of the obviously connected nature within, and between, parts of ecosystems, management actions on any one component will influence the others in potentially negative or unpredictable ways. Management focused on a single ecosystem service that fails to capture the complexity of the system may produce undesirable effects and changes as a result of trade-off situations between ecosystem services where the provision of one service could possibly inhibit the provision of another (Meacham et al., 2016; Rova and Pranovi, 2017). There is growing evidence that indicates that ecosystem management which removes inherent variations between constituent ecosystem parts, homogenises their spatial patterns and processes, and optimises the extraction of a few ecosystem services in favour of others enhances the vulnerability of ecosystems as a whole (Gunderson et al., 2016). It is therefore very important to practice integrative management methods that recognise the interrelated nature of ecosystems and their processes, functions and resulting services to ensure more effective and beneficial decision-making with respect to sustainable use of urban ecosystem services (Garcia et al., 2016).

As de Groot et al. (2010) discuss, a number of key challenges and questions remain unresolved in the management of ecosystem services in urban environments, and which, if left unaddressed, hinder the full integration of the ecosystem services concept to management objectives and effectiveness. These can broadly be covered in five main issues:

a) Understanding and quantifying how ecosystems provide services: Issues relating to the typology of ecosystem services found in a specific ecosystem and how these are measured, mapped and visualised;

b) Valuing ecosystem services: Issues relating to the complexity of valuing ecosystem services, the conflicts that arise between the different value types (economic, ecological, socio-cultural or psycho-spiritual) and their importance within the context of decision-making, and the effectiveness of methods used to measure different value types;

c) Use of ecosystem services in trade-off analysis and decision-making: Issues relating to cost-benefit analyses of ecosystem services and their values to different stakeholders and decision-makers in the context of limited resources and having to choose which services to focus on over others, how trade-off situations can be minimised when taking into consideration multiple ecosystem services of urban ecological infrastructure;

d) Use of ecosystem services in planning and management: Issues relating to incorporating the resilience of ecosystem functions and thresholds for service use into planning and management agendas and practices;

e) Financing the sustainable use of ecosystem services: Issues relating to the adequacy of current financing methods for investing in urban ecosystem services management in the context of limited economic resources.

In similar vein to urban planning theory, the concept of ecosystem disservices features scarcely in the urban environmental management literature. It is counterproductive for urban environmental management to frame ecosystem functions as purely beneficial without adequately acknowledging the variety of detriments ecosystems inevitably produce considering many management objectives aim to optimise ecosystem service provisioning and consumption while minimising necessary trade-offs (a part of which should include the trade-offs and offsets between ecosystem services and disservices). Lyytimäki and Sipilä (2009) stress how the lack of attention to ecosystem disservices may seriously hamper environmental management in general and urban green management in particular. Not only is knowledge on which ecosystem disservices are perceived as harmful to human well-being essential simply because more people are living in cities, recognising disservices allows for improved identification and characterisation of key environmental nuisances and the people most likely to suffer from them, which improves the strategies adopted to deal with and manage these problems (Lyytimäki and Sipilä, 2009). Integrated assessment of both ecosystem services and disservices is thus fundamental to the success of urban ecosystem management.

2.3.3. The role of ecosystem services and disservices in urban governance

The concept of governance, which refers to the decision-making processes by which rules are set-out and enforced, and by which the provision and use of public goods and services are decided upon by a range of stakeholders and societal actors along with the state, is currently a widely-used notion in urban environmental concerns and policy making (Mann et al., 2015). Urban ecosystems are understood as integrated systems of human societies interacting with, and linked to, multiple political, economic, social, cultural, institutional and technological structures. It is therefore necessary to understand the inextricable relationship between humans and nature in order to better analyse the interactions between urban governance systems and ecosystem services and disservices. Improved recognition and understanding of urban ecosystem services and disservices, their value or cost (both economic and other), their spatial characteristics, and human interactions with them, is very much needed in order for ecosystem services and disservices to move beyond being merely assessment tools, but rather becoming effective instruments to guide urban policy, planning and governance (Troy and Wilson, 2006).

Farhad et al. (2015) discuss how urban governance configurations, in terms of informal and formal institutions and rules, define how humans interact and experience nature, including possible interactions that result in changes in the provisioning of ecosystem services and disservices. From a policy perspective, incorporating the ecosystems services approach is aimed at achieving two key goals, which constitute the core of governance agendas associated to urban ecosystem services: 1) to help address conflicts between economic development and environmental conservation, and 2) to influence the decisions made by stakeholders of ecosystems and their resource base, so that they align their practices with the interests of the beneficiaries of ecosystem services (Muradian and Rival, 2012). Such policies aim to redress the perception that humans and nature are separate, to help solve the tension that exists between economic advancement and the conservation of natural ecosystems, and to help create new partnerships between civil society, local residents, corporate entities and government authorities that mobilise additional problem-solving abilities.

The ecosystem services approach is now extensively embedded in a number of social and political strategies and processes (both globally and locally) and there is the expectation that this concept, as a holistic approach to natured-based solutions, ought to constitute a basis for policy design and be integrated in governance structures at all levels (Primmer et al., 2015). Yet, a majority of the research pertaining to ecosystem services focuses on producing knowledge on ecosystems and their value to humans while important issues such as policy implementation and decision-making, and governance thereof, remains largely ignored. The assumption that rules and decisions will eventually change as new knowledge about ecosystem services is produced, significantly impedes the sustainable use and conservation of ecosystem services because this assumption does not take into account the complex interactions within, and across different governance structures and levels (and other stakeholders) that may have direct implications for the implementation of actual policies that are created (Nie, 2003; Primmer et al., 2015). Furthermore, the adoption of new scientific knowledge and frameworks into policy is not easy – existing structures of policy processes, dominant discourse, and entrenched policy practices for designing and adapting policies may create unfavourable contexts for new methods or practices to be considered (Frantzeskaki and Tilie, 2014).

Mann et al. (2015) discuss some theoretical case-studies from the academic literature that illustrate instances where urban governance and ecosystem services are linked explicitly. Outcomes from their analyses show that, from the research that is available on this topic, most decision-makers in charge of policy and management of ecosystem services focus strongly on biophysical and economic aspects, with less attention paid to socio-cultural dimensions, and governance systems reflect this bias. This focus lead to challenges regarding implementation, acceptance and compliance of policies from various actors or stakeholders based on contrasting values, views and interests in ecosystem services. There is also often a lack of acknowledgement with respect to the political dimensions of governance, both within and between different governance institutions and levels, which challenge policy design and implementation. Conclusions are therefore that future research needs to address issues on how ecosystem services are governed across a multi-level of governance systems, how policies relating to ecosystem services are designed then implemented (from scientific assessment to policy diagnostics), which, and how, stakeholders are involved in these processes and what arguments or support are used in decision-making. As with urban planning and environmental management, ecosystem disservices are all but absent from urban governance research leaving an obvious gap in the literature, and should also be explicitly addressed in future studies.

2.4. Research on urban ecosystem services and disservices

Although a number of comprehensive qualitative and quantitative reviews have examined ecosystem services on a global scale (for e.g. Costanza et al., 1997; Seppelt et al., 2011; Cardinale et al., 2012; Hernández-Morcilla et al., 2013), relatively few have focused on studies that assess urban ecosystem services, with less than 10% of all ecosystem services publications investigating ecosystem services in urban areas (Alavipanah et al., 2017). Even more so this can be said about the comparably low amount of research pertaining to ecosystem disservices in urban environments in the wider ecosystems literature (Figure 2.1). After the dissemination of the ecosystem services approach following the Millennium Ecosystem Assessment (MA, 2005), acknowledgment of the ecosystem disservices concept grew with the beginning stages of its recognition in the ecosystems approach occurring (Zhang et al., 2007; Lyytimäki et al., 2008; Dunn, 2010b; von Döhren and Haase, 2015). Considering over half of the world's population lives in cities, it is critical that more research endeavours to better understand the complexities of the provision and consumption of both ecosystem services and disservices in urban contexts.

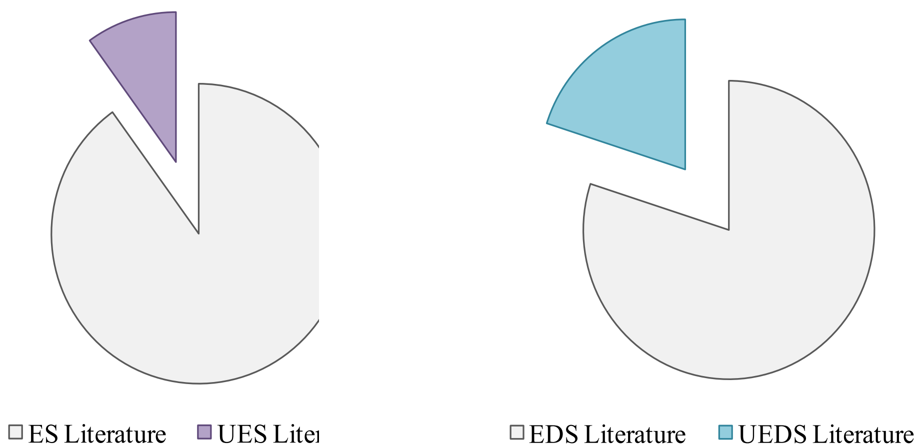


Figure 2.1. Proportions of urban ecosystem services [UES] (<10%) and urban ecosystem disservices [UEDS] (<20%) research relative to their respective wider scientific literature base. Source: Figure elaborated by author from Alavipanah et al. (2017) for ecosystem services and von Döhren and Haase (2015) for ecosystem disservices.

This review section is structured in the following way: synthesis of the literature is principally grouped into two subsections – one for urban ecosystem services and another for urban ecosystem disservices. Within each of these sub-sections, literature is analysed according to four thematic topics:

1) Categories of ecosystem services or disservices elaborated by reviewed papers following the framework used in this study (Table 2.1) - that is, *provisioning, regulating, habitat/support* and *cultural* for ecosystem services and *ecological-, economic-, health-, psychological-* and *general impacting* for ecosystem disservices. (Table 2.1. is an own elaboration by the author and a first step of systematisation of a singular framework of categories for both ecosystem services which have previously been formally categorised, and disservices which have not).

2) Types of ecological infrastructure assessed in the literature.

3) Research perspectives in ecosystem services and disservices studies. This evaluates which perspectives the research was undertaken from.

4) Methodologies used in the literature were analysed.

Literature included in this review were selected according to set criteria: a) The source focused on urban areas, b) The source focused clearly on ecosystem services or disservices, c) The source was credible and relevant in the academic literature in terms of its bibliographical reference and citation in other work, and the date is current enough for the source to be considered contemporary.

Once a general evaluation of existing literature has been discussed and critically analysed, urban ecosystem services and disservices work done in Germany and South Africa is examined, followed by past work on ecosystem services and disservices from urban community gardens.

2.4.1. Urban ecosystem services research

2.4.1.1. Categories of ecosystem services in the literature

Studies on all four categories of urban ecosystem services used in this research were found in the literature. A majority of the work reviewed related to regulating services (Haase et al., 2014; Luederitz et al., 2015; Ziter, 2016) with an emphasis on local climate regulation (Shashua-Bara and Hoffmanab, 2000; Dobbs et al., 2014; Norton et al., 2015), local air quality regulation (Escobedo and Nowak, 2009; Escobedo et al., 2011; Baró et al., 2014; O'Sullivan et al., 2017) and carbon sequestration/storage services (Tratalos et al., 2007; Liu and Li, 2012; Martin et al.,

Table 2.1. Ecosystem services and disservices category frameworks used as the basis for categorisation in this study. Source: Table elaborated by author using TEEB (2011) for ecosystem services and von Döhren and Haase (2015) for ecosystem disservices.

Ecosystem Services		Ecosystem Disservices	
Provisioning Services Services that describe the material or energy outputs from ecosystems.	- food - raw materials - fresh water - medicinal resources	***Ecological Impacts*** Disservices that negatively affect ecosystem structure, processes and/or services that they consequently provide.	- emission of volatile organic compounds by vegetation resulting in degradation of air quality - displacement of native species by invasive or introduced species
Regulating Services Services that ecosystems provide by regulating the quality of air and soil, or providing flood and disease control, etc.	- local climate & air quality regulation - carbon sequestration & storage - moderations of extreme events - waste-water treatment - erosion prevention and maintenance of soil fertility - pollination - biological control	***Economic Impacts*** Disservices that negatively affect economic structures and/or processes.	- damage to infrastructure by nature (plant growth, microbial activity, corrosion, animal damage to structures, extreme events, etc.) - maintenance costs associated with urban vegetation/nature: removal of unwanted species (weeds, invasive species, animals housing in inappropriate places); planting and maintaining vegetation creates substantial costs. - opportunity costs incurred with maintenance costs over other important expenses such as construction costs.
Habitat/Supporting Services Services that underpin all other services. Ecosystems provide living spaces for plants and animals, and also maintain a diversity of plants and animals.	- habitat for species - maintenance of genetic diversity	***Health Impacts*** Disservices that negatively affect human health, an important aspect of quality of life.	- allergies/respiratory problems caused by spread of pollen - vector-spread disease by animals or urban water bodies - wild or semi-wild animals in urban green spaces can cause anxiety over fear of attack, safety, or inconvenience
		Psychological Impacts Disserves that cause negative feelings or discomfort to affected people, another aspect of human quality of life.	- certain smells, sounds, or behaviours from plants and animals may be considered a nuisance or cause annoyance - aesthetic and hygiene impacts due to animal excrement - aesthetic unpleasantness due to vegetative litter from dense/overgrown vegetation, brown fields, wastelands - psychological feelings of insecurity / fear associated with overgrown or dark urban green spaces - vegetation can block views
Cultural Services Services that include the non-material benefits people obtain from contact with ecosystems. This includes aesthetic, spiritual and psychological benefits.	- recreation & mental and physical health - tourism - aesthetic appreciation and inspiration for culture, art, design - spiritual experience and sense of place	***General Impacts on Human Well-Being*** Disservices which are assumed to negatively affect human well-being, not fitting into any of the other categories.	- obstruction of transportation caused by large urban green or blue spaces causing mobility issues - traffic safety issues for cars/trams/buses/trains relating to vegetative debris/litter on the roads surrounding urban green spaces - decrease in water quantity / quality associated with amount of water used for vegetation growth - presence of conserved or protected species can restrict the uses of an area, hindering benefit of those seeking to enjoy nature

2012; Kim et al., 2015). Studies on provisioning and cultural services, although not nearly as frequent as regulating, were relatively well represented. Research on provisioning services had a high focus on food production (Andersson et al., 2007; Barthel et al., 2010; Lauf et al., 2014) and fresh water provisioning (Kroll et al., 2012; O'Farrell et al., 2012; Haase, 2015), while research on cultural ecosystem services emphasised recreation and mental and physical health (Bertram and Rehdanz, 2015; Langemeyer et al., 2015) and spiritual experience and sense of place (Chiesura, 2004; Dou et al., 2017). Habitat/supporting services were the least studied category, with relatively few papers focused on habitat for species (Clergeau et al., 1998; Angold et al., 2006; Radford and James, 2013) and maintenance of genetic diversity (Chapin III et al., 2000; Dobbs et al., 2014).

Overall, a wide variety of urban ecosystem services are represented in the literature although an apparent bias exists. Much emphasis has been placed on regulating services relative to the other categories, with many studies focused on carbon sequestration/storage and local air quality and climate regulation. In contrast, other services in this category such as erosion prevention and maintenance of soil fertility, moderation of extreme events (O'Farrell et al., 2012) and biological control (Yadav et al., 2012) were underrepresented. While an overall inter-category bias exists with respect to regulating services, there are also intra-category biases within each ecosystem service group. Provisioning services works concentrate on food production and fresh water provisioning, with fewer studies discussing raw materials (Dobbs et al., 2014; Lauf et al., 2014), while cultural services focused on recreation, physical and mental health and spiritual experiences compared to aesthetic appreciation (Gopal and Nagendra, 2014) and tourism (O'Farrell et al., 2012). As Haase et al. (2014) discuss, the conceptual underpinnings of indicators remain underdeveloped, and their uses in assessing and analysing ecosystem services are constantly evolving to improve quality and credibility of the data they collect. Consequences of having biases toward certain ecosystem services may result in certain indicators being disproportionally developed and their quality and credibility improved compared to others that will lag behind. Large amounts of data on prominent services will therefore become available, while others' data availability will stall and useful information will be lost. This viewpoint is reiterated by La Rosa et al. (2016) who argue that cultural ecosystem service studies lag behind other categories because of their under-developed indicators and lack of data availability. In sum, most studies centre on regulating and provisioning services with less attention paid to supporting or cultural services – a result that is perhaps the outcome of difficulties associated with characterising and measuring these ecosystem services (Satz et al., 2013).

2.4.1.2. Types of ecological infrastructure in ecosystem services research

Patterns of bias are also evident in the types of ecological infrastructure analysed in studies. While many different types of urban green spaces were studied in the literature, research focused on the bigger and more tangible urban green and blue spaces like forests, parks, lakes, and wetlands, usually at a city scale or larger. For example, Escobedo and Nowak (2009) and Escobedo et al. (2011) conducted studies in Santiago, Chile estimating the amount of air pollution removed by the city's urban forests. Similarly, Chiesura (2004) assessed the role of parks in Amsterdam, The Netherlands, in delivering ecosystem services to those that use them, and Bertram and Rehdanz (2015) evaluated which ecosystem services parks in Berlin, Salzburg, Rotterdam and Stockholm provided the respective cities. Haase (2015) discussed the theoretical types of ecosystem services that come from urban water resources such as seas, lakes, rivers and canals, while Sun et al. (2012) calculated the cooling effects of urban wetlands in Beijing, China, to comment on their effects for local climate regulation. Few studies were done in the smaller 'forgotten' green areas, for example, Angold et al. (2006) measured the floral biodiversity of derelict brownfields in Birmingham, UK, and Andersson et al. (2007) and Barthel et al. (2010) both conducted assessments of provisioning ecosystem services in allotment gardens in Stockholm, Sweden.

2.4.1.3. Research perspectives in ecosystem services literature

An important aspect of contextualising urban ecosystem services studies lies in understanding which perspective research has been undertaken from. Four major research perspectives have been identified in the literature in similar vein to Hubacek and Kronenberg (2013) and Luederitz et al. (2015):

1) Economic: Research that focuses on the economic valuation of ecosystem services in cities using a variety of economic tools and methods. Examples of such studies were conducted by Hougner et al. (2006) who calculated the economic value of seed dispersal services in Stockholm National Urban Park, Sweden using replacement cost techniques, Chen and Jim (2012) who calculated the value of ecotourism in urban parks in Hong Kong using willingness-to-pay methods, and Sutton and Anderson (2016) who

estimated the value of ecosystem services produced by Central Park, New York, using market-value pricing.

2) Ecological: Research that is focused on from an environmental sciences standpoint. The environmental sciences cover a wide range of subjects, and such research includes, amongst others: relationships between ecosystem components, functioning and services; pressures on ecosystems from urbanisation and population growth; soil, air and water quality; biodiversity and conservation, etc. Examples of works with ecological perspectives were carried out by Manes et al. (2016), who quantified the removal of particulate matter (PM_{10}) and Ozone (O_3) by urban forests in ten Italian cities from an urban air quality outlook, and O'Dea et al. (2017) who explored the impacts of aquatic acidification (from anthropogenic emissions such as Sulphur (S) and Nitrogen (N)) on ecosystem services in San Diego, USA, from an air and water quality standpoint.
3) Social: Research that explores social values, perceptions, behaviours and norms relating to urban ecosystem services. This includes the social production of ecosystem services in cities and how these are perceived, valued and distributed differently in cities. Kaźmierczak (2012) investigated the how urban parks are being used to combat declining social ties in Manchester, UK, by supporting social cohesion and inter-personal communication and interaction. Berbés-Blázquez et al. (2016) explored in a theoretical think-piece how institutional and governance systems in cities manifest issues such as power relations, governance effectiveness, inequity, poverty and exploitation, all of which influence and shape the ability of ecosystems to provide services that support and encourage human well-being.
4) Planning and Governance: Research that deals with planning, governance and management aspects of ecosystem services in cities. These include any organisational structures and systems, policy tools, planning requirements and issues, and management approaches that are relevant to urban ecosystem services. Gómez-Baggethun and Barton (2013) and Hansen et al. (2015) both show how the uptake and integration of the ecosystem services framework into urban planning practices is slow, but has become more active in the last few years as society becomes increasingly aware of the benefits provided to cities by ecosystems. From a governance outlook, Muradian and Rival (2012) highlight the challenges of governing urban ecosystem services using market-based policies and approaches, and Primmer and Furman (2012) argue that for

ecosystem service governance to be effective, it needs to move away from being sectoral to holistic and integrated.

Although it was not uncommon for studies to present their arguments from multiple perspectives, most literature had one central perspective that guided the research. In addition, while four broad perspectives have been identified for the purpose of this study, it is acknowledged that a variety of research perspectives in urban ecosystem services literature is much wider than presented here, and will continue to grow. Moreover, economic, ecological, social and planning and governance perspectives relating to ecosystem services research will continue to evolve and transform. This is because views on the values (economic, social or other) of ecosystem services vary significantly over time and by stakeholder group. Furthermore, the availability and distribution of ecosystem services is not uniform across space in cities and are influenced by external socio-economic and political factors and circumstances (Hubacek and Kronenberg, 2013). Planning and governance perspectives will also change as ecosystem services discourse and paradigms shift from top-down sectoral practices to being more integrated, holistic and bottom-up in planning, management and governance. It is therefore necessary to recognise which perspective research is done from in order to understand how that research contributes to wider subject fields and literature bases.

2.4.1.4. Methodology used in ecosystem services research

A large toolbox of methods, techniques and approaches exist in ecosystem services research. It speaks to the strength, variety and comprehensive nature of ecosystem services assessments that a wide range of different tools are available for researchers to use to achieve their study objectives. Broadly, five categories of methodologies are drawn from the literature:

1) Measuring: Studies that use methods, tools or techniques to measure ecosystem services. These types of projects primarily use indicators as proxies to measure, either quantitatively or qualitatively, ecosystem services of interest. Examples of studies that show the process of using indicators to measure a number of different ecosystem services can be found in Whitford et al. (2001), Tratalos et al. (2007) and Dobbs et al. (2014).
2) Models: Research where conceptual, mathematical or computer models have been used or developed to capture broad patterns, relationships or associations between ecosystem services in a landscape. Some models have predictive capabilities and are valuable tools for decision-making regarding future scenarios, while others have the ability to model

past characteristics of a phenomena that help researchers to understand current realities. Lauf et al. (2014), Schreyer et al. (2014) and Antognelli and Vizzari (2016) are examples where authors have used models in urban ecosystem services research.

3) Mapping: Research that uses computer software, usually a GIS, to map characteristics or points of interest pertaining to ecosystem services. Maps are powerful tools for visualising large amounts of data in simplified ways to help planning and decision-making. Examples of works where ecosystem service mapping has been used include Burkhard et al. (2011), Larondelle et al. (2014) and Karabulut et al. (2016).
4) Frameworks: Research where new theoretical frameworks or structures are developed to enhance the understanding of urban ecosystem services. These frameworks grow the overall knowledge base of ecosystem services and improve the conceptual underpinnings of the assumptions and methods research is based on. Examples on the development of new theoretical frameworks in urban ecosystem service research include Dobbs et al. (2011), Alam et al. (2016) and Albert et al. (2016a, 2016b).
5) Interviews and Questionnaires: Studies that collect data through questionnaires or in interviews, usually concerning opinions, perceptions or attitudes related to ecosystem services. Usually, such data is subjective and thus qualitative in nature. Hofmann et al. (2012) and Riechers et al. (2016) are examples of studies where ecosystem services data were collected using interviews and questionnaires.

The types of methods used in a study are a result of research objectives, the data that is available to the researcher and the type of data that needs to be collected by the researcher (von Döhren and Haase, 2015). In most studies, multiple methods are used together to complete the research objectives, however one-method studies were found. For example, Dobbs et al. (2014) used both indicator analysis and GIS data to map multiple ecosystem services and disservices provided by urban forests in Melbourne, Australia, and linked these to landscape structure and socio-demographics. In contrast, Riechers et al. (2016) used only interviews to collect information on peoples' perceptions on cultural ecosystem services in green spaces across Berlin, Germany. While a multi-method approach to research has the main benefit of data triangulation (Davis et al., 2011), the decision of which and how many methods are used should fundamentally be based on research objectives to avoid unnecessary time and data redundancies. Methodology and its limitations are linked to data quality and robustness, and new ideas and information about urban ecosystem services should be created with new and improved methods and techniques. Methods of assessment and data collection, just as with definitions, are central to the ecosystem services concept's success in supporting decision-making in sustainable urban planning and environmental management. Considering this point, it is surprising, and perhaps a great oversight, that so few critical reviews exist of the methodologies used in defining and assessing ecosystem services like that done by Haines-Young and Potschin (2009). Granted the most common method in assessments uses indicators, much of the methodological-critique has been placed on their development, quality, relevance and applicability to ecosystem services across temporal and spatial scales (Layke, 2009; Haase et al., 2014). Nevertheless, it is important that thorough reviews and continuous improvements of other method categories are done to ensure any limitations are addressed and overcome.

2.4.2. Urban ecosystem disservices research

2.4.2.1. Categories of ecosystem disservices in the literature

Papers on all five categories of urban ecosystem disservices used in this research were found in the literature. Studies largely dealt with ecological impacting disservices, where issues like the release of volatile organic compounds by urban forests resulted in a degradation of air quality (Dobbs et al., 2011; Escobedo et al., 2011; Gómez-Baggethun and Barton, 2013) and the propagation of invasive species due to increased urban green and open spaces that had the potential to displace native communities (Azmy et al., 2016; Gaertner et al., 2016) were investigated. Economic impacting disservices were also well represented, where detriments such as the damage to properties and infrastructure by urban nature (Dobbs et al., 2014; Vogt et al., 2017) and the maintenance and repair costs associated with this (Roy et al., 2012; Cariñanos et al., 2017) were focused on. Studies on health impacting disservices that negatively affect human well-being related to allergy or respiratory problems caused by the spread of pollen from urban trees (D'amato, 2000; Cariñanos et al., 2016; Manzano et al., 2017) and the conflicts between human-wildlife interactions in cities that may cause fear of attacks and safety concerns (Barua et al., 2013; Soulsbury and White, 2016). Psychological impacting disservices and general impacting disservice were the least studied categories with relatively few papers in the literature. Psychological impacting disservices research focused on those detriments that caused discomfort or anxiety such as dark, isolated and overgrown spaces in urban parks and woodlands at night (Jorgensen and Anthopoulou, 2007; Hofmann et al., 2012) and aesthetic unpleasantness associated with dense, unmanaged or destroyed urban vegetation (Lyytimäki and Sipilä, 2009; Lyytimäki, 2014; Conway and Yip, 2016), while general impacting disservices like obstructions to transport and mobility networks cause by urban vegetation (Aminzadeh and Khansefid, 2010) was mentioned.

While the importance of urban ecological infrastructure to ecosystem services delivery is familiar, these green spaces also have direct influence on ecosystem disservices provisioning and the resulting consequences to human-nature relationships and attitudes in cities. It is important that potential detriments such as pollen related allergy potentials, conflicts between humans and wildlife, and the economic costs of maintaining urban vegetation and repairing its damage to buildings and infrastructure be investigated explicitly so that they can be better managed and trade-offs to human well-being minimised. It is also important to regard the scale at which studies are undertaken in order to better understand the extent of the potential impacts of ecosystem disservices in cities. Though many of the publications highlighted above did not contain any consistent information regarding scale of their studies, some papers did illustrate spatial scales at the city (e.g. Dobbs et al., 2014; Gaertner et al., 2016) and site-specific levels (Azmy et al., 2016). Although most studies investigated ecological, economic and health impacting disservices, it is too early to definitively point out any research bias patterns as the ecosystem disservices concept, and especially assessments of them in urban contexts, are too new and underdeveloped. The low number of papers published on urban ecosystem disservices shows that the concept has yet to be widely integrated into urban human-nature concerns as has happened with the ecosystem services approach. It is therefore a key task for future research to address this integration deficit and show that ecosystem services and disservices are not, and cannot be, mutually exclusive concepts with respect to sustainable urban planning and management.

2.4.2.2. Types of ecological infrastructure in ecosystem disservices research

Most articles reviewed for this project did not specify which types of ecological infrastructure delivered ecosystem disservices in their study, and those that did used very broad and generalised categories. Such unrefined groupings included urban forests (Escobedo et al., 2011), urban green spaces (Azmy et al., 2016), urban vegetation (D’amato, 2000), urban trees (Manzano et al., 2017; Vogt et al., 2017), urban parks/woodlands (Jorgensen and Anthopoulou, 2007; Hofmann et al, 2012) and generalised urban areas (Soulsbury and White, 2016; Cariñanos et al., 2017) as study units. Although these categories are crude, such groupings suggest ongoing processes of ecosystem disservices identification, categorisations and refinement while the concept grows through its infancy. Villa et al. (2014) and von Döhren and

Haase (2015) further argue that possible reasons for such broad groupings in the units of study in ecosystem disservices literature relate to the concept's developing nature, as it is not yet fully understood the limits of from where these disservices are produced and received. That is to say, urban ecosystem disservices can be produced and received by urban environments, and can be received by cities after being produced elsewhere outside urban limits (von Döhren and Haase, 2015). As more work goes into understanding which ecological infrastructure types produce certain types of ecosystem disservices, and importantly, the scale at which these disservices are felt and experienced, more modification and improvement of ecological infrastructure categories investigated in urban ecosystem disservices research will occur.

2.4.2.3. Research perspectives in ecosystem disservices literature

Studies reviewed in the literature show five dominant research perspectives from which the work was undertaken:

1) Ecological: Research that was done from an environmental sciences view-point. Such research includes, amongst others: relationships between ecosystem functioning and the delivery of disservices; impacts to human health from urban nature; displacement of native by invasive species, etc. Examples of such studies include Cariñanos et al. (2016) who quantified the amount of pollen particulate matter in Granada, Spain, in order to identify the most problematic source tree species, D'amato (2000) who investigated at the links between air quality, plant-derived respiratory allergy potential and human health in Naples, Italy, and Azmy et al. (2016) who analysed the effects of urban green space on the abundance and species composition of four pest hornet populations in Nagoya city, Japan, that are killing and outcompeting native honey bee species.
2) Social: Research that explores social values, perceptions, and attitudes towards urban ecosystem disservices. Jorgensen and Anthopoulou (2007) conducted research that explored the ways in which age affects urban residents' attitudes, perceptions and fears concerning ecosystem disservices associated with urban woodlands in Sheffield UK, while Barua et al. (2013) theoretically examined the impacts of human-wildlife interactions on human livelihoods and well-being according to socio-economic status.
3) Planning: Papers that focus on urban form and related planning issues, such as identifying and classifying disservices for urban planning, creating disservices databases as planning tools, etc. Examples of works from planning perspectives were

carried out by Gómez-Baggethun and Barton (2013), who theoretically identified and classified ecosystem disservices in urban areas to inform planning activities, Dobbs et al. (2014) quantified ecosystem disservices from urban forests in Melbourne, Australia, to provide insights to local policy makers to plan for a more sustainable city, and Vogt et al. (2017) who created a database that city planners can use as a tool to select which trees to use in order to minimise their disservices and costs to people and municipalities in temperate regions.

4) Management: Research that focuses on aspects of environmental management of urban ecological infrastructure for the benefit of human livelihoods and well-being. Conway and Yip (2016) carried out a study in Toronto, Canada, that examined residents' experiences related to tree disservices due to heavy ice and snow fall in order to develop successful management strategies and better understand socio-ecological interactions of people with urban trees, and Gaertner et al. (2016) provided a management framework for better handling invasive species in green and open spaces in Cape Town, South Africa.
5) Theoretical: Research where the theoretical negative drawbacks, costs of, and attitudes and perceptions towards ecosystem disservices are investigated in a hypothetical or academic manner. Examples of studies from theoretical perspectives include Lyytimäki and Sipilä (2009) who theoretically discussed the concept of ecosystem disservices in European cities and how they may potentially influence environmental management, Roy et al. (2012) who reviewed literature on the potential disadvantages of ecosystem disservices in cities across different scales and climate zones, and Lyytimäki (2014) who conducted a study on media representations and public perceptions of ecosystem disservices across cities in Finland, using newspaper articles.

The dominant research perspectives observed in the reviewed literature were from planning and theoretical stances, which suggests that the ecosystem disservices concept and the methods used to measure these are not yet sufficiently developed. Therefore, a central problem for current ecosystem disservices research lies in the lack of physical data and information regarding disservices inventories for most ecological structures in urban environments. This problem is further elaborated by von Döhren and Haase (2015) who argue that the deficiency of systematic data on ecosystem disservices is further exacerbated by the general lack of identification and quantification of the factors (anthropogenic and other) producing ecosystem disservices in cities, and those who are affected by them. Ecosystem disservices assessments are therefore critical to the collection of disservices inventories that are presently deficient in the overall urban ecosystems scientific field, and such deficits need to be addressed if the concept is to be fully integrated with the ecosystem services approach.

2.4.2.4. Methodology used in ecosystem disservices research

The toolbox of methods, techniques and approaches existing in ecosystem disservices research are relatively young in line with the concept's development. Four general groups of methodologies are observable in the literature:

1) Measuring: Research that use methods to measure ecosystem disservices. These types of studies use indicators as proxies to measure, either quantitatively or qualitatively, ecosystem disservices of interest (Dobbs et al., 2011; Gómez-Baggethun and Barton, 2013; Dobbs et al., 2014) or other apparatus in the laboratory or field to quantify data relevant to disservices (Cariñanos et al., 2016; Manzano et al., 2017).
2) Frameworks: Studies where new theoretical frameworks are developed to improve the understanding of urban ecosystem disservices. These frameworks enhance the overall knowledge base of ecosystem disservices and improve the conceptual foundations of the methods used in this field. Examples on the development of new theoretical frameworks in urban ecosystem service research include Escobedo et al. (2011), Barua et al. (2013) and Gaertner et al. (2016).
3) Interviews and Questionnaires: Studies that collect data in interviews or through questionnaires, and usually regard people's perceptions or attitudes related to ecosystem disservices. Such studies were carried out by Jorgensen and Anthopoulou (2007) and Hofmann et al. (2012).
4) Literature Reviews: Research wherein past literature on ecosystem disservices is investigated and used to build new knowledge or further existing ideas. Lyytimäki and Sipilä (2009), Roy et al. (2012), Lyytimäki (2014), Soulsbury and White (2016), Cariñanos et al. (2017) and Vogt et al. (2017) are examples of studies where ecosystem disservices studies employed literature review methods.

Studies in the quantification of ecosystem disservices employed, in the main, indicators as is the standard practise in the ecosystem services approach. Similar to ecosystem services methods, many papers employed more than one method to carry out their research objectives, for example, Vogt et al. (2017) used both literature review and laboratory methods to create a database of preferred trees for urban planting that have minimised disservices, such as maintenance costs and allergy potentials. Similar to methodological aspects discussed in section 2.4.1.4., the decision of which methods are used should primarily be based on research objectives to avoid unnecessary time and data redundancies, and take into account method limitations and how this influences data quality and interpretations thereof. As the ecosystem disservices concept develops and more assessments are done, future research should critically review existing methodologies in terms of quality and relevance of the data they collect and the limitations they address.

2.4.3. Summary of results

Table 2.2 illustrates a concise and traceable summary of the results according to the four sub-sections identified in review of the literature on ecosystem services and disservices:

1) All categories of ecosystem services and disservices are addressed by studies, however notable biases in the literature are evident, with regulating services and ecological impacting disservices having the overwhelming majority of work done in their respective categories.
2) Regarding the types of urban green spaces assessed, ecosystem services studies have well defined categories with bias towards larger ecological infrastructures like forests, parks and woodlands compared to smaller green areas. Ecosystem disservices literature uses broadly-defined and often vague green space categories, which demonstrates the concept's lack of previous studies and continuing developmental nature.
3) Research perspectives have much overlap between ecosystem services and disservices literature. Ecological and economic research perspectives dominate ecosystem services assessments, emphasising the leading paradigms, interests and thinking of current ecosystem services research and researchers. Conversely, ecosystem disservices have the majority of its research from theoretical and planning perspectives, again showing how the concept is still in development and has a current lack of empirical and practical data.
4) Methods used in ecosystem services studies are more advanced that those in ecosystem disservices assessments. Indicator techniques are the main method used for both, while ecosystem services have enhanced quantitative techniques that involve modelling (mathematical, computer and conceptual) and mapping (GIS and other computer software packages). Ecosystem disservices studies employ mostly theoretical and

conceptual methods like using frameworks and compiling literature reviews, and a few studies make use of interviews/questionnaires.

Table 2.2. Summary table of literature review results comparing ecosystem services and disservices literature according to four sub-sections: categories assessed in the literature, types of green spaces evaluated in the studies, dominant research perspectives identified in the literature and methods used in the studies. Source: Table elaborated by author.

	ECOSYSTEM SERVICES	ECOSYSTEM DISSERVICES
CATEGORIES ASSESSED IN THE LITERATURE	*regulating; provisioning; cultural; habitat/supporting.	*ecological impacting; economic impacting; health impacting; psychological impacting; general impacting.
TYPES OF GREEN SPACE ASSESSED IN THE LITERATURE	*urban forests; *urban parks; *woodlands, general urban water sources such as lakes, rivers, streams and wetlands; few studies on derelict areas/brownfields and urban gardens (allotment, home, community).	urban forests; urban green spaces; urban vegetation; urban parks/woodlands; general urban areas.
DOMINANT RESEARCH PERSPECTIVES USED IN THE LITERATURE	*economic; *ecological; social; planning/governance.	ecological; social; *planning; *theoretical; management.
METHODOLOGY TYPES USED IN THE LITERATURE	*measuring techniques (indicators); modelling techniques; mapping techniques; theoretical/conceptual frameworks; interviews/questionnaires.	*measuring techniques (indicators); *literature reviews; theoretical/conceptual frameworks; interviews/questionnaires.

* Denotes those variables where bias was identified in the literature i.e. the focus and/or majority of the work pertained to that variable.

2.5. Research on urban ecosystem services and disservices: Germany and South Africa

2.5.1. Germany

In general, environmental research in Germany relates to a wide variety of biodiversity and conservation concerns, and a lot of data and information regarding these topics is available in the scientific literature (Albert et al., 2016b). Since the dissemination of the Millennium Ecosystem Assessment in 2005 (MA, 2005) and more recently the European Biodiversity Strategy in 2011 (European Commission, 2011), an increase in research interests in ecosystem services in Germany has occurred because of its potential to integrate social, economic and ecological aspects of landscapes, including urban landscapes (Larondelle and Haase, 2012). However, as Bastian et al. (2012) state, compared to their relative importance (by virtue of the majority of people living in cities) urban ecosystem services are rarely discussed in the German literature and their theoretical foundation is less specified than those areas considered more ‘natural’ like rural regions with forests, wetlands, and agricultural space – a trend that is similarly evident in global ecosystem research agendas. This research bias is perhaps a result of Target 2, Action 5 of the European Biodiversity Strategy, which outlines the need for member states to map and assess the state of ecosystem services in their national territories, to evaluate the economic worth of these services and to promote the integration of these values into national accounting and reporting systems at EU and national level by 2020 (Albert et al., 2016b). A number of important studies pertaining to urban ecosystem services have nevertheless been carried out. These studies have predominantly been grouped according to the methodologies they have used - theoretical foundations and conceptual frameworks (for e.g. Bastian et al., 2012) and the modelling and mapping of ecosystem services at the city and landscape level (for e.g. Burkhard et al., 2009, 2011; Kroll et al., 2012; Lauf et al., 2014). A glaring deficit in urban ecosystems research in Germany is evident with almost no practical studies having been done with regards to disservices, with the exception of the extensive literature review by von Döhren and Haase (2015).

In terms of the theoretical basis of urban ecosystem services theory, Bastian et al. (2012) carried out research that conceptualised the Ecosystem Properties, Potentials and Services (EPPS) framework, which has the purpose of better linking the potential performance of ecosystems and the services it provides to current planning and management practices and government schemes. This framework is based on 3 main pillars – analysis of properties and processes of ecosystems, potentials of ecosystems and landscapes, and resulting services and their values from ecosystems – all of which interact with one another and influence the potential outcome of an ecosystem to provide ecosystem goods and services. This conceptual framework was applied as a methodological approach to a park in the city of Leipzig, showing how the EPPS framework could illustrate climate regulation services. Climate regulation according to the EPPS framework demonstrates how the ecosystem process of radiation reflectance and evapotranspiration by leaves on trees bears the ecosystem potential to lower air temperature in the shadow of the respective trees. This potential then converts into an ecosystem service, as was calculated in temperature difference measurements taken in the park by several data loggers. The authors note that this framework based on ecosystem processes and potentials is able to improve the implementation of the ecosystem services approach into planning processes as it has the ability to weight alternative land-use potentials and benefits against each other. This can lead to more informed landscape planning and better governance schemes for conserving ecosystems, especially in dense urban areas where the competition for space between land-uses is a major challenge.

The quantification and mapping of ecosystem services provisioning has been done by a number of authors. Burkhard et al. (2009, 2011) conducted such studies in the urban region of Halle-

Leipzig, using land-cover data collected from the European CORINE project to model and map the capacities of various types of land cover in the Leipzig area to provision the ecosystem services categories as stated in the Millennium Ecosystem Assessment (MA, 2005). The outputs of these assessments were landscape maps showing the provisioning of various ecosystem services in this urban region. Moreover, further results showed that patterns of human activities and land-use changes over time in this area have significantly influenced land cover types' capacities to generate ecosystem services. Kroll et al. (2012) carried out a similar study in the Halle-Leipzig region, assessing the supply and demand of ecosystem services along an urban-rural gradient. Using land use-maps, the European CORINE land cover dataset and other historical environmental data provided by local authorities, ecosystem demand and supply in the region were mapped for the years 1990, 2000 and 2007. Results showed that over this time period, a higher demand/supply ratio for services such as food and water provisioning occurred in the urban areas compared to more rural outskirts, whereas a higher demand/supply for energy and raw material services were observed in the more rural areas compared to the urban areas. The authors conclude that ecosystem demand and supply maps are useful tools for urban planners and managers because they help in decision-making processes when faced with the challenges of modifying city landscapes in order to try and achieve a sustainable balance of resource demand and supply.

Lauf et al. (2014) carried out research that simulated and modelled future scenarios of land-use changes and the affects this has on the provisioning of ecosystem services, using Berlin as a case-study city. The study focused on future growth and shrinkage scenarios, using land-use scenario modelling methods in order to assess and map the impacts to urban ecosystem services. Results indicated the scenario of urban expansion had degrading consequences to the overall provisioning of ecosystem services, whereas urban shrinkage showed positive correlation to ecosystem services generation - this was mostly concerned with model parameters relating to increased land consumption of urban green space and soil sealing during urban growth. Under conditions of urban shrinkage, services such as climate regulation, net carbon storage and biophysical regulation were shown to increase while conditions of urban growth illustrated a decrease in services such as energy provisioning, food provisioning and recreational space. The authors concluded that under both conditions, urban brownfields and garden spaces provided excellent opportunities for the development of new green areas with superior ecosystem services qualities. Lastly, it was discussed how land-use change scenario maps are important tools for local planners and urban environmental managers as they allow comparative assessments of potential realities and impacts to environmental quality and human-well-being.

Riechers et al. (2016) deviated from the status quo in German ecosystem services research by analysing the perceptions of cultural ecosystem services associated with urban green space in Berlin, showing how these services are understood and which services are emphasised. Forty-one interviews were conducted from individuals sampled from the Berlin Senate Administration for City Development and Environment, the Berlin Forestry Commission, and other experts and representatives from local organisations concerned with cultural ecosystem services. Sixteen types of cultural ecosystem services were identified, the most frequently stated being values for recreation and tourism (30%), values for nature awareness (12%), aesthetic values (12%), values for a sense of place and cultural identity (10%), social cohesion (9%) and spiritual and religious values (6%). The authors conclude that urban green spaces hold a wide variety of benefits to local residents. They further argue that it is necessary to try and understand all cultural ecosystems services in a city as emphasis or trade-offs of one over the other can lead to conflicts between residents and planners/managers, and moreover misinform decision-making which may lead to biased policy outcomes. Lastly, focusing on cultural ecosystem services related to urban green can foster public participation and develop a public that is well informed and more involved in sustaining urban nature.

2.5.2. South Africa

It is clear from the scientific literature that there is a general lack of focus on ecosystem services in urban areas in South Africa, and research papers have shown a focus towards ecosystem services in rural and peri-urban areas of the country (for e.g. Le Maitre et al., 2007; Van Wilgen et al., 2008; Egoh et al., 2008, 2011; O'Farrell et al., 2011; Cilliers et al., 2013). Cilliers et al. (2013) suggest that urban ecological studies are not yet considered as an important area of research in most African countries because of the numerous socio-economic challenges these cities face. As a result, very few assessments have been conducted in South Africa relating to the urban ecosystem services, and those that do mainly deal with the mapping and economic valuation of these services at the city scale. The South African literature is thus reviewed according to two main research perspectives – planning and socio-economic.

From a planning perspective, O'Farrell et al. (2012) carried out a spatial assessment that mapped the ecosystem services generated within metropolitan limits of the city of Cape Town. The city, recognised as a developing urban space within a global biodiversity hotspot, has numerous competing land-uses between residential, commercial and conservation interests. The study was done with the purpose of identifying which important ecosystem services are provisioned in the city, to simulate how these would change with modifications to different land-use scenarios within the municipal area, and to develop a method that can be used to identify areas where ecosystem services are deteriorating. Urban ecosystem services (groundwater yield, recharge and quality; coastal zone buffering and protection; water infiltration and soil retention; flood mitigation; land capability and agricultural provisioning) were identified by the Biodiversity Management Branch of the city's municipality and used together with land cover maps to map the generation of these services, as well as to simulate how these would change over time based on three different levels of land-use transformations – no transformation, current-levels of transformation and future projected levels of transformations. Results showed largest influences on ecosystem services generation were based on projected levels of land-use transformation, with a 49% reduction in the potential for agricultural goods, and a 32% reduction in both land capability and flood mitigation. Coastal areas also showed a 25% decrease is potential for coastal zone protection and buffering, 27% decrease in groundwater quality, and 20% decrease in groundwater recharge. Ecosystem services provisioning illustrated optimal potential under the no land-use transformation scenario. The authors concluded that maps showing the generation of ecosystem services under future scenarios are powerful tools for city land-use planners and decision-makers, especially as the city faces huge competition and trade-offs between land-use types.

Economic valuations of urban ecosystem services have been done by Schäffler and Swilling (2013) for Johannesburg and de Wit et al. (2012) for Cape Town, respectively. In the study conducted by Schäffler and Swilling (2013), Johannesburg is purported to house the world's largest urban forest constituting 10 million trees - as such, valuation of regulating services, and particularly carbon sequestration and storage, was the primary concern of this research. Methods used a 50 x 50 m^2 study area (representing a common urban tree stand within the city) together with a global carbon price to estimate carbon storage amounts and calculate its economic value. Results showed that the study plot area stored 32.2 metric tonnes of carbon and when extrapolated for the whole of Johannesburg, estimates were 5.3 million metric tonnes valued at US $64,154,910. de Wit et al. (2012) carried out a similar economic valuation study to estimate the total worth of Cape Town's ecosystem services. Methods used a six-step valuation method that applied the various valuation techniques from the literature to ecosystem services case studies collected in the city. Results estimated a total value of approximately US

$140 million for the city's ecosystem services, further broken down into $69 million for tourism services, $32 million for provision and regulating services, $29 million for recreation services, and $9.5 million for aesthetic service capture by the film and media industry. In both papers, authors recognised the importance of ecosystem services protection and maintenance of biodiversity as critical to the sustainability and economy of both Johannesburg and Cape Town. The authors conclude that ecosystem services have largely been ignored in planning and management processes in South African cities. These research papers were produced to try and change the perception of local governments and politicians because of a lack of knowledge and information on the relationship between ecosystem services, biodiversity conservation and human well-being in practical terms. It is suggested that empirical assessments at finer scales within the city could go a long way into bridging this knowledge gap.

2.5.3. Summary of results

Comparison of urban ecosystem services and disservices research conducted in Germany and South Africa is summarised in Table 2.3:

1) German research has a narrower focus on urban environments compared to South Africa, which largely reflects the many socio-economic challenges South African cities face that leaves little research attention on urban ecological interests and priorities.
2) The dominant research perspectives differ between Germany and South Africa: German interests relate to ecological and economic perspectives that mainly involve ecosystem services accounting, mapping and the simulation of ecosystem services under different future scenarios. In South Africa, planning perspectives are the main research interest, followed by some ecosystem service accounting.
3) The scale at which ecosystem services research is conducted is equally broad in both countries – at the city scale or larger. This shows the need for research at smaller scales within urban landscapes regarding ecosystem services and disservices in both countries.
4) In both countries, urban ecosystem disservices work is severely lacking, reinforcing an overall pattern of a major research gap between ecosystem services and disservices.

Table 2.3. Summary table of literature review results comparing Germany and South Africa research relating to urban ecosystem services and disservices. Source: Table elaborated by author.

	GERMANY	SOUTH AFRICA
DOES RESEARCH FOCUS EXPLICITLY ON URBAN ENVIRONMENTS?	Yes, there is some recognition of research related to ecosystem services and disservices in urban landscapes, mainly in line with certain national and EU policy objectives and expectations.	Limited focus on cities as the majority of ecosystem services research pertains to rural and peri-urban areas. Largely a result of the myriad socio-economic challenges facing South African cities, so urban ecological research not at the forefront of research objectives.
WHAT IS THE DOMINANT FOCUS/PERSPECTIVE OF THE RESEARCH?	Ecological and economic perspectives, largely pertaining to ecosystem services accounting, mapping and simulation of future scenarios.	Mainly planning perspectives relating to urban development and economic perspective relating to ecosystem services accounting.
SCALE OF FOCUS?	Research focus at the city scale: for example, studies in Leipzig and Berlin.	Research focus largely at the city scale: for example, studies in Cape Town and Johannesburg.
ECOSYSTEM DISSERVICES WORK?	Severely lacking in the overall body of ecosystems literature from the country.	Severely lacking in the overall body of ecosystems literature from the country.

2.6. Research on ecosystem services and disservices from urban gardens with an emphasis on community gardens

Review of the literature shows that few studies have dealt with ecosystem services assessments in urban gardens. Research where assessments have been done, three main garden types can be noted: allotment, home and community.

2.6.1. Allotment gardens

Allotment gardens have been shown all through history to be key urban green spaces that have the ability to contribute to the resilience of a city, particularly in providing long-term food security in times of crises (Barthel and Isendahl, 2013). Ecosystem services assessments in these spaces have been completed by Andersson et al. (2007), Barthel et al. (2010), Breuste and Artmann (2014) and Speak et al. (2015).

Andersson et al. (2007) conducted a study in allotment complexes, cemeteries and parks in Stockholm, Sweden, with the purpose of examining the social-ecological implications of local management practices on the generation of ecosystem services from these three green space types. Results showed that different management practices affected the abundance of indicator species, and thus the provisioning of ecosystem services. This was especially clear in the case of allotment gardens where informal management practices resulted in a higher abundance of birds and bumble bees. Moreover, the authors found that allotment managers had a deeper ecological knowledge base and were more motivated to properly manage nature and its processes when compared to managers of parks and cemeteries, suggesting this was a result of the close relationship built between gardener and garden and the ensuing sense of place this created.

Barthel et al. (2010) carried out a similar study, looking at the ecosystem services provided by allotment gardens in Stockholm, Sweden and the influence of management practices on these. Allotment gardens were surveyed and found to generate services such as food provisioning, seed dispersal and pollination, and pest regulation in the broader urban landscape. Results showed that allotment gardens function as communities of practice, where ecological knowledge and behaviours are retained and transmitted by imitation, oral communication, and collective habits of gardeners and other closely involved institutions and collaborative networks. The authors concluded that urban gardens, such as allotment gardens, play a pivotal role in generating ecosystem services in cities and that the knowledge, behaviours and experiences of stewards in these spaces have the potential to counteract any possible future declines of critical ecosystem services in a city landscape.

Breuste and Artmann (2014) carried out a study analysing the ways in which urban allotment gardens contribute to ecosystem services, using Salzburg in Austria as a case study city. Allotment gardens are an important feature in European urban landscapes, providing a range of ecosystem services, utilities, social-cultural meanings and aesthetic values. Results showed that recreation and recovery, connectivity to nature, gardening as a hobby, stress relief and self-sufficiency of food production were the main benefits perceived by gardeners. A majority of allotment gardeners stated that they learn about nature through gardening, and that gardens are their main place to experience nature and wildlife in the city. Conclusions drawn were that while, in the past, allotment gardens had a main function of traditional food production; this is no longer the case. The reduction of space for food provisioning to facilitate other ecosystem services like habitat for biodiversity, contact to nature and physical and mental recreation activities was highlighted as a notable trend in Salzburg allotment gardens.

Speak et al. (2015) conducted an assessment of ecosystem services generated by allotment gardens in Manchester (UK) and Poznań (Poland), with a focus on biodiversity. The assessment was carried out as the authors argued that there is a need to quantify the range of ecosystem services specifically provided by allotment gardens so that their value as an urban land-use can be fully recognised. Results revealed that Poznań allotment complexes had higher overall species richness than Manchester, yet Manchester had higher overall species richness per hectare than Poznań. In terms of ecosystem services generated, all gardens in Manchester provisioned food while only one-third grew produce in Poznań, Garden complexes in Poznań were also found to have more regulating services such as local climate regulation and fresh water provisioning. Collectively, cultural services experienced by gardeners in both cities included social cohesion, education about nature and physical and mental health benefits. The authors concluded that allotment gardens are shown to provide a wide range of ecosystem services in urban areas, and that there is a need for more formal recognition of these benefits in local government policies and management strategies.

2.6.2. Home gardens

Calvet-Mir et al. (2012, 2016) carried out a study that identified and characterised which ecosystem services are generated by home gardens in Vall Fosca, Spain. Moreover, the study aimed to conduct a valuation of the social importance of those identified ecosystem services. The study showed a wide range of ecosystem services experienced in home gardens: food and raw material provisioning, plants grown for medicinal and ornamental benefits, pollination services, soil formation and maintenance, aesthetic services, spaces for recreational activities, relaxation and psychological rejuvenation, spiritual connection with nature, places of environmental education and awareness, and the fostering of social relations and networks. In terms of social importance, cultural ecosystem services were given the highest value by gardeners. The authors conclude that home gardens are overlooked in the broader ecosystem services literature, despite being a pervasive green space in cities and taking up a large portion of urban fabric when added up. The argue that future research should focus more on the potential of these green space types for building resilience to social and environmental challenges faced in urban areas.

Clarke et al. (2014) conducted research in Beijing (China) that examined how biodiversity patterns and the provisioning of ecosystem services changes in home gardens across socio-economic status and an urban-rural gradient. The main ecosystem services experienced were the provisioning of food and medicinal plants, species diversity and other cultural services related to aesthetic values, spiritual and health experiences. Gardens used for food and medicinal provisioning services were highest in peri-urban and rural regions, while gardens in suburban regions mainly had aesthetic and health benefits to residents. The authors conclude that biodiversity in home gardens changes along socio-economic and urban-rural gradient, as do ecosystem services provided by these spaces, where a shift from cultural to provisioning benefits occurs with decreased gardener income in areas farthest away from the city centre.

2.6.3. Community gardens

Camps-Calvet et al. (2016) carried out an assessment of ecosystem services provided by urban allotment and community gardens in Barcelona, Spain. The aim of the study was to identify and characterise which ecosystem services were generated in these urban garden types, and analyse the demographic and socio-economic profile of gardeners and the importance they attribute to the different services provided. Thirteen allotment gardens, 13 community gardens and one other collective garden were selected throughout the city for the study. Twenty ecosystem services were characterised, the most commonly experienced being food supply, maintenance of soil fertility, social cohesion and integration, environmental learning and education, entertainment and leisure, maintenance of cultural heritage, relaxation and stress reduction, and aesthetic beauty. In terms of the relative valuation of ecosystem services by gardeners, cultural were given the highest importance followed by habitat/supporting, regulating and provisioning respectively. The authors conclude that urban gardens are important sources for ecosystem services in cities and have positive impacts on the health and well-being of their users. They argue that increasing the number of collective garden spaces in cities can be an effective nature-based solution for urban policies aimed at enhancing human well-being, social integration and healthy lifestyle behaviours.

Clarke and Jenerette (2015) conducted research that investigated the drivers plant biodiversity and ecosystem service production in community gardens across Los Angeles County, California. The purpose of this assessment was to quantify the biodiversity of community gardens in LA and to uncover the important economic, social and biophysical factors that influence ecosystem services production. Results showed that over a 3-year period, a total of 707 managed species were recorded, 63% of which were classified as ornamental, 32% as edible and 5% as medicinal. These categories were based on whether the species generated provisioning (food), aesthetic or cultural ecosystem services. Furthermore, it was shown that, in LA, species presence, uses and subsequent ecosystem services production is related to socio-economic factors like income and cultural preferences. Gardens situated in impoverished areas with lower income gardeners and reduced access to resources produced more food services through edible species and less ornamentals, while high ornamental species numbers were recorded in more affluent areas where economic resources were high and basic livelihoods secure, thus gardens had more aesthetic and cultural ecosystem services. Furthermore, gardener ethnicity was also shown to influence which species were grown, particularly as this related to edible species. The authors conclude that such assessments are critical to provide comprehensive information for urban planners on the extent to which community gardens provide important ecosystem services in a large city such as Los Angeles. Furthermore, such studies help to link societal and environmental desires for ecosystem services provisioning and sustainable resource use in complex urban landscapes. Lastly, it is argued that community gardens are a good model for understanding human-ecosystem interactions with respect to the biodiversity and the drivers that influence the production of ecosystem services.

Cabral et al. (2017) performed a study in Leipzig, Germany where the authors assessed the effects of urban garden types and management intensity on biodiversity and ecosystem services through comparing allotment and community gardens along a gradient of urbanity. For this assessment, six allotment estates (two urban, two semi-urban, two suburban) and six adjacent community gardens were assessed to identify and quantify specific provisioning, regulating and supporting ecosystem services those green spaces provided. In terms of species richness, allotment gardens were found to harbour 290 species (150 edible and 140 spontaneous) across 0.75 ha and community gardens 255 species (98 edible and 157 spontaneous) across 2.3 ha, suggesting both garden types had a high capacity to provide food and biodiversity ecosystem services. For regulating services, community gardens exhibited a higher percentage area of permeable soil surfaces when compared to allotments, thus having direct impact on services such as water infiltration and soil water retention. Moreover, trees in allotments showed relevant capacity for local climate regulation through carbon storage and localised shading/cooling effects. The authors conclude that allotment and community gardens provide a number of important biodiversity and ecosystem services to urban environments. Their hope is that the information of such studies helps to better inform city planners of the values of these spaces in the face of ever increasing urban pressures and conflicts, particularly as these relate to sustainable urban development, ecosystem functioning and human well-being.

Cilliers et al. (2017) completed a comprehensive database literature search and review of ecosystem services from gardens (food, community, botanical, home and clinic gardens and other) in Sub-Saharan Africa with the intention to determine the current status of research in this area and to group garden ecosystem services according to provisioning, regulating, supporting and cultural categories. The objectives were to investigate from prior studies which ecosystem services are provisioned by gardens in Sub-Saharan Africa and the challenges involved in optimising these. While this review did not explicitly use 'urban' as a search keyword, a total of 75 papers were found with a number of them being in urban areas. Some key literature pertaining to ecosystem services studies conducted in community gardens included the following:

Ruysenaar (2013) explored the role of community gardens in food security in poor urban areas in the Gauteng Province of South Africa. Besides the provisioning of vital food services, these community gardens delivered benefits of social empowerment, increased self-esteem (especially for women), environmental education and strengthening social interaction and community ties. Similarly, Tembo and Louw (2013) carried out a study that looked at the role of two community gardens in Cape Town, South Africa, in provisioning food services in alleviating poverty and hunger for surrounding urban poor communities. In addition, these community gardens were found to improve health, reduce vulnerability to food insecurity, strengthen social relations and generate some income for gardeners and nearby communities.

Overall, it was concluded that gardens form an important part of green infrastructure in Sub-Saharan Africa, especially as this area has large-scale poverty concerns, nutrition deficiencies and a general lack of access to resources (Cilliers et al., 2017). Moreover, gardens were found to have significant potential to enhance human well-being and reduce vulnerability to present and future socio-economic challenges. In particular, as it relates to this thesis, community gardens were found to be key in spaces for creating and transmitting social and ecological knowledge, skills development, social learning and cultural exchange, as well places of physical interaction, participation and sharing of ideas and gardening practices (Cilliers et al., 2017).

2.6.4. Synthesis

In terms of garden types examined in the ecosystem services literature, most research was done with regards to allotment complexes common to European cities, with relatively few studies pertaining to home and community gardens. Research on ecosystem services provided by urban gardens shows a definite European (Andersson et al., 2007; Barthel et al., 2010; Breuste and Artmann, 2014; Speak et al., 2015; Calvet-Mir et al., 2012, 2016) and North American (Clarke and Jenerette, 2015) bias compared to developing parts of the world. Moreover, a major gap is apparent in urban ecosystems research as no previous urban garden studies have considered ecosystem disservices. Taking into account expected population growth estimates and urbanisation projections, conflicts and space trade-offs between land-use types in cities is only going to become more challenging. Community gardens are thus uniquely poised to offer cities, where space is limited, a multitude of ecological, social, cultural and psychological ecosystem services beyond simply food production when compared to other urban ecological infrastructure. Furthermore, the numerous benefits people achieve through interactions with community gardens and other people within these spaces could be critical to changing community mindsets and behaviours that would foster more involved communities with a sense of responsibility to the environment – attributes that are so essential to Great Transition thinking and sustainable development goals. It is absolutely essential however, that research acknowledges both the benefits and negative impacts of urban ecosystems to human comfort and well-being – not doing so will have unfavourable consequences for urban planning and environmental management.

2.7. Conclusions

This chapter provides a synthesis and review of the state of research on urban ecosystem services and disservices. Apparent from the literature, there is the need to consider assessments of ecosystem services and disservices at smaller scales, especially in understanding how the presence of ecosystem services and disservices, and their importance/detriment and relevance, to people or cities, varies considerably across scales (Haase et al., 2014). Furthermore, as population increases and urbanisation expands, space in cities becomes increasingly limited for larger green areas like forests or parks – peoples' interactions with nature in cities may too become limited. Smaller green spaces in cities and the benefits they potentially provide therefore need to be explicitly explored so that their value to people and their well-being can be recognised. In addition, as more land gets consumed for urban fabric, sub-urban agricultural space for growing food is challenged. This thesis aims to address the gap of urban community gardens in ecosystem services and disservices assessments (as a justification for research), which are gaining importance by virtue of the fact that not only do these spaces have the potential to address food security issues, but they also offer a number of opportunities for interaction with nature and social networks and movements in a relatively small amount of space (Guitart et al., 2012). A majority of the literature concerning ecosystem services from urban gardens looks at allotment gardens. Community gardens are not as readily studied and therefore present a unique research opportunity, especially considering ecosystem disservices from these spaces have yet to be investigated. This work also attempts at levelling the bias towards ecosystem assessments of larger urban green spaces that was identified in the literature.

The concept of ecosystem services is finding increased integration and use in urban planning, management and governance theory and practice, while ecosystem disservices inclusion severely lags behind. From the literature, it is clear that the concept of ecosystem services is more widely incorporated and applied than ecosystem disservices in these three fields. With this in mind, the strength of new ecosystem services and disservices research lies in the fact that the results gained from assessments provide valuable information to cities to use to improve decision-making across all aspects of sustainable urban development - planning, management and governance. Outcomes obtained in this study will provide important pieces of new data and information for urban ecosystem services and disservices inventories (that are currently at deficit relative to the overall body of literature), and which will strengthen and improve the basis from which any subsequent work will emanate.

Chapter Three

Methods

3.1. Introduction

The overall purpose of this study is to identify and inventory both the ecosystem services and disservices that are generated in urban community gardens using Berlin and Cape Town as case-study cities. There is a need to quantify and qualify the array of ecosystem services and disservices provided by community gardens so that their value as an urban land-use can be fully recognised and legitimised in cities, where space is often the most valued resource.

The objectives specific to this research formulated in Chapter One are restated here for clarity:

1. Calculate the quantitative share of urban community gardens in Berlin and Cape Town respectively.
2. Identify suitable sampling locations of community gardens in Berlin and Cape Town respectively, from which to assess existing ecosystems services and disservices.
3. Identify and assess which ecosystems services and disservices are provided by the chosen sampling community gardens in Berlin and Cape Town respectively.
4. Demonstrate the relevance and contribution of community gardens to sustainable urban development and the Great Transition.

Methods used to answer the research aim and objectives are presented and described in this chapter. Case study analysis is the predominant research approach used, employing multiple case study cities under different sets of circumstances to enhance the theoretical assumption that multiplicity improves the credibility and suitability of any generalisations of results and conclusions obtained (Houghton et al., 2013). The case study approach is also a means to giving a theoretical based overview of a particular phenomenon or interest, and allows research to go into detail in the same study at the same time. Mixed-method research design is used in each case, namely GIS methods using the on-screen digitising process to estimate the quantitative share of community gardens in each city, indicator analysis used to collect quantitative data and a questionnaire used to gather qualitative data in field assessments of ecosystem services and disservices. Thereafter, quantitative and qualitative data is synthesised in order to obtain results and draw conclusions, which are summarised in Burkhard-type matrices (Figure 3.1).

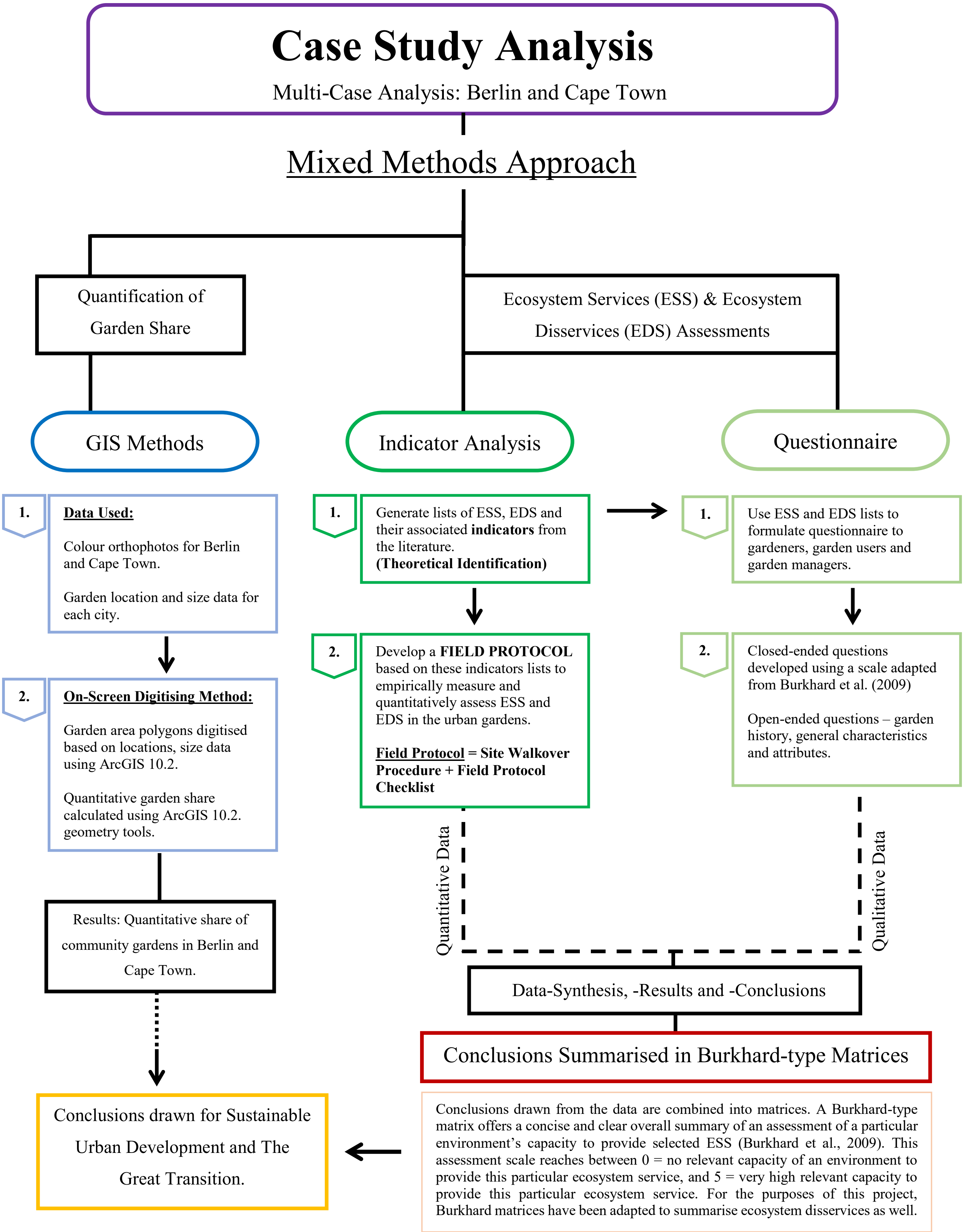


Figure 3.1. Schematic breakdown of mixed methods used in this research – GIS Techniques using the on-screen digitising method, indicator analysis and a questionnaire. Source: Figure elaborated by author.

3.2. Case study analysis

Case study analysis is a research approach that systematically enquires into, and attempts to explain and understand, a phenomenon or set of related phenomena of interest (Yin, 2014). Case study research calls for selecting a few examples of the phenomenon of interest and then intensively investigating those example 'cases'. Through examination, comparison, and analysis of a selected number of cases, the researcher learns about significant characteristics or features of the phenomenon as a whole and how it differs under a variety of circumstances – the case study method therefore allows in-depth investigations of contemporary phenomena within detailed and specific contexts (Zainal, 2007).

The approach to case study research in this thesis is comprised of three main steps: case study design, case study selection, and case study analysis.

3.2.1. Case study design

Case studies are designed to offset the intrinsic limits of this method with respect to the validity and credibility of using data collected in case examples for more generalised extrapolations. Evidence collected from single case study scenarios is questioned regarding its applicability to broader generalisations on a particular phenomenon. However, this data can be solidified and made more rigorous by being embedded in multiple empirical realities, and this is the cornerstone of extrapolating data to inform generalisations of phenomena at wider scales (Houghton et al., 2013). As such, the case study method used in this thesis is designed according to the multiple-cases embedded approach (Yin, 2014), where several cases embedded into different contexts are considered in order to facilitate cross-case comparisons and thus to increase the potential for phenomena generalisations. Berlin and Cape Town offer two very different and distinct settings, and data gathered within each of these unique contexts offers a broad and holistic approach to elucidating the generation of urban ecosystem services and disservices from community gardens in general. Case-level evidence collected from Berlin and Cape Town will also be a fundamental basis for further quantitative and qualitative research and studies in this field as little research currently exists.

3.2.2. Case study selection

Berlin and Cape Town are chosen as case study cities that represent two very unique contexts in terms of environmental conditions, socio-economic and political realities and cultural backgrounds. Moreover, these two cities are selected based on having no previous assessments done relating to urban ecosystem services and disservices from community gardens. The community gardens selected within each city are according to a logical and reasoned research design. In an attempt to avoid bias and investigate as holistically as possible, community gardens are chosen to reflect diverse sizes, different socio-economic circumstances and thus assumed different user groups. The final element taken into consideration is the number of community gardens chosen within each city. In this regard, the literature does not establish any explicit threshold to produce solid results. As Sandelowski (2000) highlights, research that requires human-based interaction or data collection can be difficult to control in terms of sticking to research design and standard practices. This is especially salient when requiring human input regarding participation, opinions and permissions. Given the nature of this problem, and the unpredictability of permissions allowing garden access, a relevant and suitable sample size regarding the number of community gardens assessed is necessarily left an undefined number and limited to those willing to participate.

3.2.3. Case study methods

The investigation of case studies is conducted by means of a mixed-method approach, using both quantitative and qualitative analysis. Research design based on mixed-method techniques has been shown to expand the scope of, and deepen insights from, studies; particularly with respect to the complexities of human-nature phenomena that mandates more complex research designs and an acknowledgement of compatibility between positivism and interpretivism research philosophies (Sandelowski, 2000). Quantitative methods include a field protocol designed from literature-derived indicators (indicator analysis), which are used to empirically measure and quantify ecosystem services and disservices within chosen community gardens. In addition, a qualitative questionnaire structured according to an adapted Burkhard ranking scale (Burkhard et al., 2009) is further based on these literature-derived indicator lists, for completion by community -gardeners, -garden users and -garden managers. Data gathered from case studies therefore not only involves quantitative metrics following empirical measurements in community gardens, but is also supplemented by the qualitative dimensions of people's perceptions and experiences of benefits and detriments within those gardens – this concept of the triangulation principle, where different data sources are used for the same phenomena, consequently increases the validity of research outcomes (Eisenhardt, 1989).

3.3. Quantification of community garden share

3.3.1. GIS methods

Digitisation refers to the process of digitally 'tracing' points, lines or polygons in a geographically correct way (that is, with x and y co-ordinates) from scanned maps or imagery commonly using a GIS software package (Haddock, 1998). On-screen digitising refers to an interactive method of digitisation whereby a user focuses on the computer screen and in the GIS software user interface, and uses the mouse to manually trace features to create a new map layer from a digital map image (Haddock, 1998). The advantage of using on-screen digitising is that, provided the source imagery is taken at a high enough resolution, it allows for a higher level of accuracy as the operator can use the zoom facility down to a pixel-by-pixel solution (Liu and Masson, 2009). A limitation to the digitising component of aerial photography is that any imagery with poor pixel resolution or monochromatic/grey-scale colouring will make it difficult to discern, identify and trace features of interest and influence data accuracy and precision.

Georeferenced colour aerial photographs were obtained for Berlin (Senatsverwaltung für Stadtentwicklung und Wohnen, 2015c) and Cape Town (City of Cape Town, 2016b) and used within ArcGIS software (ArcGIS 10.2) to calculate community garden areas and their urban share. The images are dated August 2015 (Summer) with a spatial resolution of 0.2 x 0.2 m for Berlin, and January 2016 (Summer) with a spatial resolution of 0.08 x 0.08 m for Cape Town (Table 3.1). As the aerial photographs in both cities were taken in Summer devoid of cloud cover at a high spatial resolution and in colour, this facilitated a straightforward and accurate visual task in digitising the garden polygons to a reliable degree. Polygons for all community gardens in Berlin and Cape Town were mapped and drawn in ArcGIS 10.2 in the pixel solution 1:400 using the aerial imagery for each city as the base layers together with garden location and size data acquired from The Foundation Anstiftung (2016) and the Department of Agriculture (S Martin 2016, personal communication, 29 September 2016) for Berlin and Cape Town respectively (Figures 3.2 – 3.3). Once the garden polygons had been drawn within the software and added as a new map layer, ArcGIS 10.2 geometry tools were then used to calculate garden areas (m^2) for individual gardens and the overall urban area share (m^2 and %) of community gardens in each city.

Table 3.1. Characteristics of aerial photographs used in quantification of community garden areas in Berlin and Cape Town. Source: Table elaborated by author.

	Berlin	**Cape Town**
Date of Image	August 2015	January 2016
Spatial Resolution (Pixel Size)	0.2 x 0.2 m	0.08 x 0.08 m
Spatial Reference (Co-ordinate System)	Gauss-Krueger Zone 4 (unit in meters)	WGS 1984 Transverse Mercator (unit in meters)
Supplied by	Senatsverwaltung für Stadtentwicklung und Wohnen	City of Cape Town Municipality

3.4. Ecosystem services and disservices assessments

3.4.1. Indicator analysis

The mainstreaming of ecosystem services and disservices into policies and practices, in order to ensure sustainable use and maintenance of services and to minimise detriments and trade-offs, is fundamental to human well-being in urban environments. According to Cowling et al. (2003) the quantification of ecosystem services is one such important step towards successful actions to safeguard them. However, many ecosystem services and disservices cannot be directly quantified thus making the use of indicators indispensable in ecosystem assessments. An indicator is defined as a metric based on verifiable data that acts as a proxy to convey information about a particular phenomenon (Haase et al., 2014). Indicators allow researchers to measure, monitor and analyse the quantities, conditions, characteristics and changes of ecosystem-structure, -functions, -services and -disservices (Dobbs et al., 2011). The use of indicators in ecosystem assessments is now a widely used method as it reduces the complexity of phenomena, enables the simplification of data collection and interpretations, and allows for better communication between experts, decision-makers and the wider public sector (Dobbs et al., 2011, Crossman et al., 2013). Moreover, indicators help track and communicate how ecosystems support the economic, physical and socio-cultural well-being of people, as well as the proper maintenance and functioning of ecosystems themselves (Haase et al, 2014). As a best-case scenario, scientific evidence acquired through ecosystem services and disservices indicators have the potential to inform public and private sector decision-makers on matters of identifying and prioritising urban environmental management agendas, tracking progress towards those targets, and effectively communicating the importance and value of ecosystems in an urban context (Haase et al., 2014).

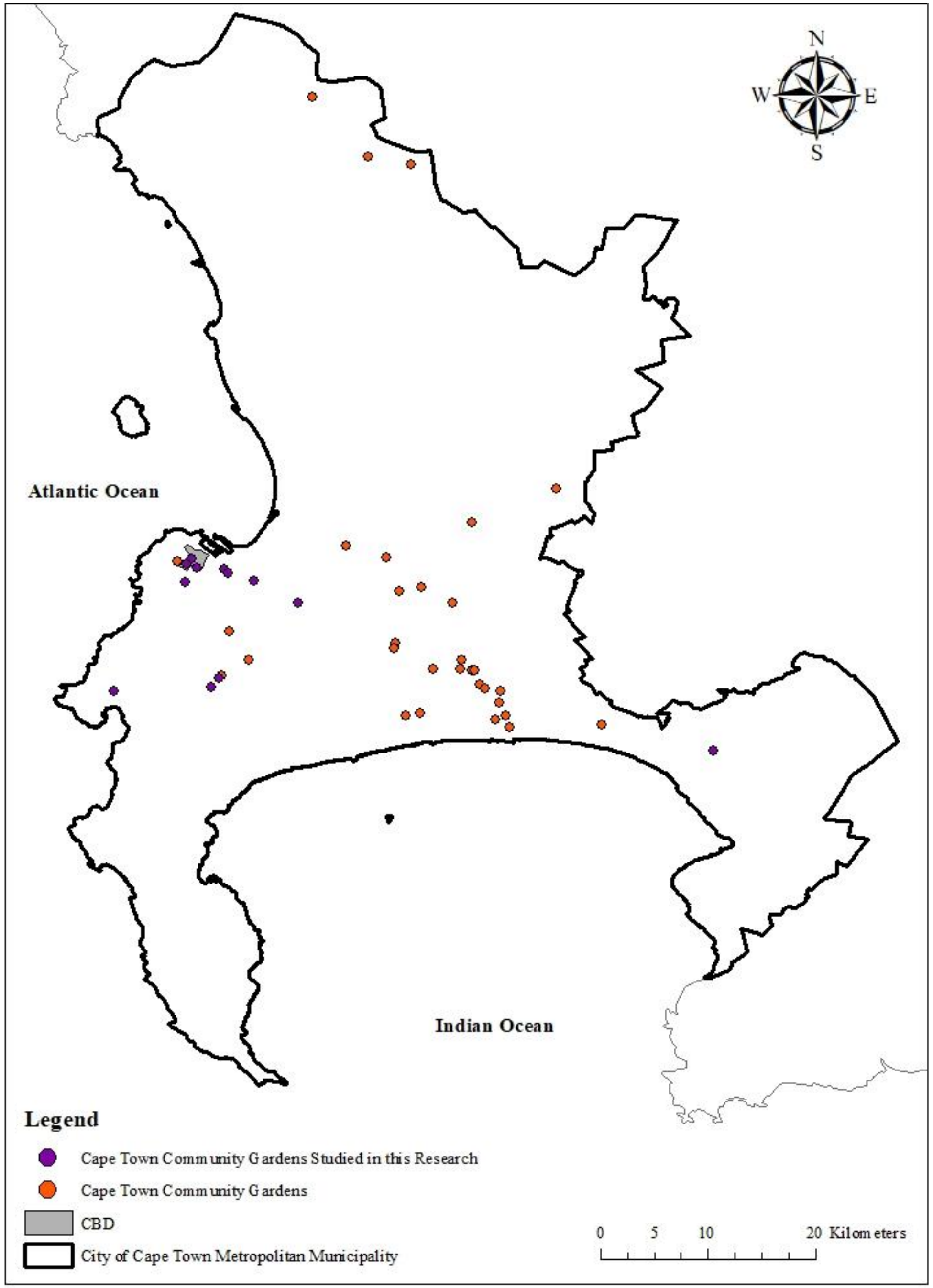


Figure 3.2. Locations of community gardens counted within the City of Cape Town Municipality. Source: Map elaborated by author.

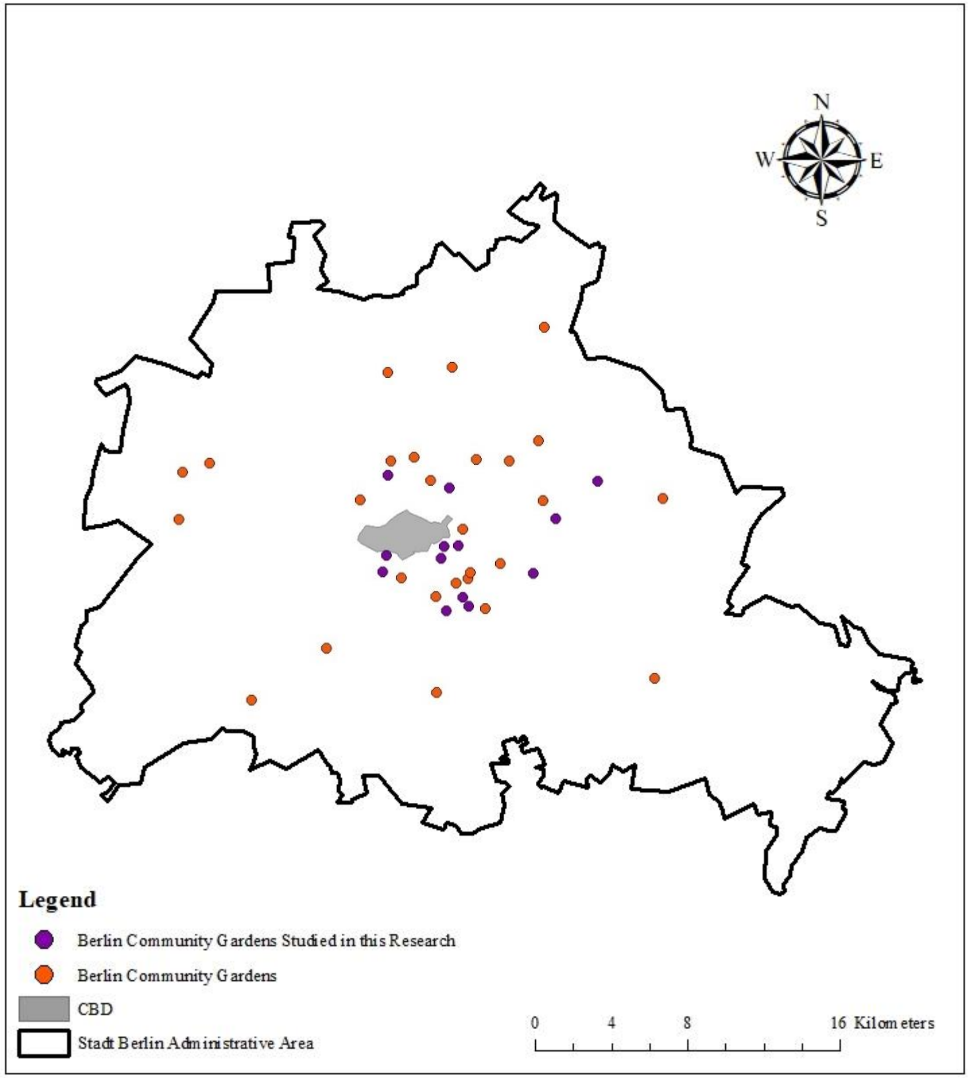


Figure 3.3. Locations of community gardens counted within Stadt Berlin. Source: Map elaborated by author.

Although indicators are a valuable tool that facilitates the simplification of the high complexity in human-environment systems into manageable information, they are not without shortfalls. As Layke (2009), Lyytimäki and Sipilä (2009) and Crossman et al. (2013) illustrate, there are a number of limitations associated to the use of indicators for ecosystem services and disservices measurements: 1) The inconsistency or redundancy of indicators used to measure ecosystem services and disservices creates uncertainty, thus creating challenges for the inclusion of these into resource accounting, environmental management and urban policy decision-making; 2) The capacity of indicators to convey information about ecosystem services and disservices to support policy-makers may be low overall due to uncertainty between how indicators are linked to services and disservices; 3) The indicators available for most ecosystem services and disservices are used to reduce the complexity of phenomena and therefore often miss the diversity and complexity of the benefits or detriments they provide, particularly as this varies across spatial and temporal scales; 4) Data availability and quality are often incomplete to support the use of these indicators for policy decision-making; and 5) Indicators for cultural ecosystem services and almost all ecosystem disservices lag behind other ecosystem services categories, and many are difficult to quantify because of their subjective nature. Because of the pervasive use of indicators in ecosystem assessments, continual research into testing and further developing improved ecosystem services and disservices indicators cannot be over-emphasised (Layke, 2009).

The basis of this research is the identification of ecosystem services and disservices provided by community gardens in urban environments. To this end, lists of urban ecosystem services and disservices and their associated indicators are developed from the literature. The list for urban ecosystem services is adapted primarily using formal categories highlighted in TEEB (2011) that are grouped into four types: *provisioning, regulating, habitat/support and cultural services*, and include services and indicators drawn from multiple sources (Table 3.2). The list for urban ecosystem disservices is adapted using informal groups elucidated in von Döhren and Haase (2015) that broadly categorise according to their impacts on human well-being: *ecological impacting, economic impacting, health impacting, psychological impacting and general impacting disservices*, and also include disservices and indicators from multiple sources (Table 3.3). Formation of these tables is an important analytical step of the research as they set out which indicators are chosen and validates that choice with an academic source, shows the data that is needed in the process of data collection, and importantly, thereafter explains the mechanisms and rationale behind how each indicator relates either directly or through proxy to their respective ecosystem service or disservices (see Tables A1 and A2 in

Appendix A for comprehensive lists of ecosystem services and disservices and their full explanations as Tables 3.2 - 3.3 are abbreviated for in-text integration).

There are a variety of indicators used by different authors to measure ecosystem services and disservices that are available in the literature. Oftentimes, there are multiple indicators for the same service or disservice and it becomes necessary to choose which are used. The nature and complexity of which indicators are chosen in this research are limited by a number of project-specific variables: 1) Availability and/or access to data or other information resources; 2) Availability and/or access to specialised field and laboratory equipment; 3) Availability and/or access to workers or field assistants who can aid the research project; 4) Availability and/or access to funding and what that can facilitate; and 5) Time.

According to Hernández-Morcillo et al. (2013), to ensure quality, those indicators selected should adhere to **SMART** principles - that is, they should be **s**pecific, **m**easurable, **a**chievable, **r**elevant and **t**ime-bound. Indicators used is this study are based on these principles:

Specific: All indicators chosen are clearly defined to relate to a specific ecosystem service or disservice.

Measurable: All indicators are chosen on their ability to be measured either quantitatively or qualitatively.

Achievable: With limited resources, equipment and personnel available for field work, all indicators chosen are able to be measured and achieved. (This included limited access to data and resources, limited availability of field and/or laboratory equipment, and the author carrying out all field measurements and data collection alone).

Relevant: All indicators chosen are literature based and relevant to their specific ecosystem service or disservice, either directly or through proxy. That is, all indicators measure the service or disservice they set out to measure.

Time-bound: The labour-intensive nature of doing field work coupled with the huge quantity of data acquired from ecosystem assessments means that all indicators chosen are able to be measured within reasonable time-boundaries by the author.

Table 3.2. List of ecosystem services, their indicators (including references), indicator measurements and data needed for data collection. Source: Table elaborated by author. (See Table A1 in Appendix A for comprehensive ecosystem services indicators list).

Provisioning Services

Ecosystem Service	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Food: Crops	**Land cover** [Speak et al. (2015); Cabral et al. (2017)]	1. Crop richness (species number) 2. Crop area/total area (%)	1. Species number of crop types grown in each community garden 2. Cultivated area of each community garden (m^2 or %) and the total area of each community garden (m^2)
Food: Livestock	**Livestock number** [Egoh et al. (2012)]	1. Livestock richness (species number) 2. Number of livestock (no. of individuals / ha)	1. Species number of food producing livestock present in each community garden 2. Total number of food producing livestock in each community garden (number of individuals) and the total area of each community garden (m^2)
Raw Materials: Wood/Timber	**Fuel yield** [Egoh et al. (2012)]	1. Kilograms (kg / ha) 2. Wood materials area / total area (%)	1. Amount of raw materials in each community gardens (kg) 2. Area of raw materials (m^2 or %) and the total area of each community garden (m^2)
Fresh Water Supply	**Number and capacity of fresh water resources** [Egoh et al. (2012); Speak et al. (2015)]	1. Number of fresh water sources and water collection tanks (no. of sources and tanks / ha) 2. Total capacity of water collection tanks (l)	1. Total number of fresh water sources and water collection tanks in each community garden and the total area of each community garden (m^2) 2. Capacity (l) of water tanks in each community garden.
Medicinal Resources	**Land cover** [Clarke and Jenerette (2015)]	1. Medicinal species richness (species number)	1. Species number of medicinal plants grown in each community garden

Regulating Services

Ecosystem Service	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Local Climate Regulation	**Land cover** [Egoh et al. (2012)] **Shaded area** [Bastian et al. (2012); Dobbs et al. (2014)] **CO_2 storage and sequestration by trees** [Rowntree and Nowak (1991); Whitford et al. (2001); Tratalos et al. (2007); Escobedo et al. (2011); Dobbs et al. (2014)]	1. Vegetated area / total area (%) 2. Digitised area under canopy (m^2 or %) 3. Total carbon storage (tonnes C / ha) Annual carbon sequestration (tonnes C / ha / yr)	1. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2) 2. Digitised shaded area of each community garden (m^2 or %) and the total area of each community garden (m^2) 3. Digitised tree canopy area of each community garden (m^2 or %) and the total area of each community garden (m^2)
Local Air Quality Regulation	**Land cover** [Egoh et al. (2012); Speak et al. (2015)]	1. Tree density (Trees / ha) 2. Vegetated area / total area (%)	1. Number of trees in each community garden and the total area of each community garden (m^2) 2. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2)
Moderation of Extreme Events: Rain and Wind Storms, Flood Prevention	**Land cover** [Gómez-Baggethun and Barton (2013)]	1. Tree density (Trees / ha) 2. Vegetated area / total area (%)	1. Number of trees in each community garden and the total area of each community garden (m^2) 2. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2)
Water Flow Regulation and Runoff Mitigation	**Land cover** [Gómez-Baggethun and Barton (2013); Speak et al. (2015); DIN (2016); Cabral et al (2017)]	1. Sealed surface area / total area (%) 2. Surface impermeability scores (0 - 1)	1. Sealed surface area of each community garden (m^2 or %) and the total area of each community garden (m^2) 2. Types of artificial surfaces in the garden and associated DIN (2016) scores relating to artificial surfaces' impermeability levels.
Erosion Prevention and Maintenance of Soil Stability	**Land cover** [Egoh et al. (2012); Gómez-Baggethun and Barton (2013); Speak et al. (2015); Albert et al. (2016b)]	1. Vegetated area / total area (%) 2. Sealed surface area / total area (%)	1. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2) 2. Sealed surface area of each community garden (m^2 or %) and the total area of each community garden (m^2)

Habitat/Supporting Services

Ecosystem Service	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Maintenance of Genetic Diversity	**Species Diversity** [Dobbs et al. (2014); Speak et al. (2015)]	1. Shannon Diversity Index (H) 2. Species richness (plants, trees, animals)	1. Number of species and their relative abundance (proportion) in each community garden 2. The number of different species in each community garden

Cultural Services

Ecosystem Service	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Recreation and Mental and Physical Health	**Land use** [Escobedo et al. (2011); Dobbs et al. (2014); Albert et al. (2016b); La Rosa et al. (2016)]	1. Recreation functions of community garden spaces	1. Recreational functions of garden spaces observed in community gardens and recreational functions obtained by questionnaire respondents on their personal interactions/experiences with community gardens.
Tourism	**Visitor numbers** [Egoh et al. (2012); La Rosa et al. (2016)]	1. Number of visitors per month	1. Total number of visitors per month for each community garden and the potentials of tourism in community gardens as perceived by questionnaire respondents on their personal interactions/experiences with community gardens.
Aesthetic Appreciation	**N/A.** [Egoh et al. (2012); Hernández-Morcillo et al. (2013); La Rosa et al. (2016)]		1. Aesthetic appreciation as perceived by questionnaire respondents on their personal opinions regarding their interactions/experiences with community gardens.
Spiritual Experience and Sense of Place	**N/A.** [Hernández-Morcillo et al. (2013); La Rosa et al. (2016)]		1. Spiritual and sense of place experiences as perceived by questionnaire respondents on their personal opinions regarding their interactions/experiences with community gardens.

Table 3.3. List of ecosystem disservices, their indicators (including references), indicator measurements and data needed for data collection. Source: Table elaborated by author. (See Table A2 in Appendix A for comprehensive ecosystem disservices indicators list).

Ecological Impacting Disservices

Ecosystem Disservice	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Displacement of Native by Invasive Species	**Invasive species richness** [Escobedo et al. (2011); von Döhren and Haase (2015)]	1. Invasive species richness (species number)	1. Species number of alien invasives and neophytes in each community garden

Economic Impacting Disservices

Ecosystem Disservice	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Damage to Infrastructure by Urban Nature	**Amount of affected infrastructure** [Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013); von Döhren and Haase (2015)]	1. Amount of infrastructure damaged by nature (m^2)	1. Total amount of infrastructure damaged by nature in each community garden and damage as experienced as perceived by questionnaire respondents on their personal opinions regarding their interactions/experiences with community gardens.
Maintenance and Repair Costs associated with Urban Nature	**Cost of maintenance and repairs** [Lyytimäki et al. (2008); Escobedo et al. (2011); von Döhren and Haase (2015)]	1. Financial costs of maintenance, repairs, energy (€)	1. Total monthly costs experienced in each community garden related to maintenance, repairs and energy.

Health Impacting Disservices

Ecosystem Disservice	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Allergy/Respiratory Problems Caused by the Spread of Pollen	**Allergenic potentials of species** [Gómez-Baggethun and Barton (2013); Dobbs et al. (2014); Ogren (2015)]	1. Species OPALS values	1. Plant and tree species allergenic potenitals classified according to OPALS (Ogren Plant Allergy Scale)
Fear and Anxiety Caused by Wild or Semi-Wild Animals	**Presence of unwanted species** [Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013)]	1. Observed presence of unwanted species (species number)	1. Number of unwanted species in each community garden

Psychological Impacting Disservices

Ecosystem Disservice	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Unwanted Smells, Sounds or Behaviours from People, Plants or Animals	**Presence of unwanted smells, sounds or behaviours** [Lyytimäki et al. (2008); von Döhren and Haase (2015)]	1. Observed presence of unwanted smells, sounds or behaviours	1. Observed presence of unwanted smells, sounds or behaviours from people, plants or animals in each community garden
Aesthetic and Hygiene Impacts due to Animal Excrement	**Presence of animal excrement** [Lyytimäki et al. (2008)]	1. Observed presence of animal excrement	1. Observed presence of animal excrement in each community garden
Aesthetic Unpleasantness due to Overgrown Vegetation	**Land cover** [Lyytimäki et al. (2008); von Döhren and Haase (2015)]	1. Observed aesthetic unpleasantness	1. Observed aesthetic unpleasantness in each community garden
Feelings of Insecurity Associated with Overgrown/Dark Green Spaces	**Area of non-illumination** [Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013); von Döhren and Haase (2015)]	1. Area of non-illumination (m^2)	1. Total area of non-illumination in each community garden
Vegetation Can Block Views	**Land cover** [Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013); von Döhren and Haase (2015)]	1. Tall trees close to buildings (distance, number, size)	1. Number of trees and their distance to adjacent buildings/infrastructure in each community garden

General Impacting Disservices

Ecosystem Disservice	Indicator (incl. references)	Indicator Measurements (Units)	Data Needed
Restricted Use of a Green Space	**Area of private / restricted access** [Lyytimäki et al. (2008); von Döhren and Haase (2015)]	1. Area of private / restricted access (m^2)	1. Total area of private / restricted access in each community garden

3.4.2. Field protocol

As proxies for ecosystem services and disservices, these indicator lists are used to develop a field protocol to empirically quantify ecosystem services and disservices generated in selected community gardens. The field protocol is conducted through a specifically designed *site walkover procedure* using a designated *field protocol checklist* of garden features, characteristics and indicators to measure and collect ecosystem services and disservices field data.

Selection criteria in choosing which community gardens are assessed in each city are limited to the following variables:

1) *Location*: Community gardens are chosen according to their close proximity to the urban centre (CBD) where it is assumed that city infrastructure and the built environment is at its densest and most artificial, and thus competition for space and land-use conflict is at its highest. The purpose of choosing this criterion is to show how assessments, such as is attempted in this thesis, are necessary to demonstrate that community gardens are valid, legitimate and important as a land-use in cities where the competition for space is great and conflict for land-use of significant economic benefit is high.
2) *Garden Size*: A range of relatively large and small community gardens are chosen to avoid size bias.
3) *Garden Access/Permission*: The limiting factor of the number, and of which, community gardens are visited in Berlin and Cape Town is garden access granted by the garden institutions that were approached. Given the unpredictable nature of research and data collection requiring human involvement, a relevant and suitable sample size of community gardens assessed is necessarily undefined and left down to those gardens willing to give permission to garden access.

While 55 community gardens in total (Berlin = 30, Cape Town = 25) were contacted with a request to conduct the research, 26 gardens responded and allowed access – 13 in Berlin and 13 in Cape Town. This constituted a low response rate (47%), reiterating that garden access/permissions were the limiting factor to this research.

Field work was conducted in January and February 2017 in Cape Town and July and August 2017 in Berlin and to coincide with the summer months in the respective hemispheres to allow for optimal vegetation growth and inflorescence to aid identification tasks.

3.4.2.1. Site walkover procedure and field protocol checklist

In all 26 community gardens visited, the following site walkover procedure was carried out using a field protocol checklist as the sheet used for data collection (see Appendix B for full procedure and checklist used):

1. An initial site description was performed where the amount of vegetated area of the garden was estimated using the Londo (1976) scale, the amount and type of impermeable surfaces in the garden measured and scored according to DIN 1986-100: 2016-09 standards, the surrounding land-use of the garden noted according to Stewart and Oke (2012) and any other additional characteristics such as overgrown vegetation or damaged infrastructure that were noticeable were measured and recorded.

2. Crop inventories grown in the gardens were compiled, noting the type of vegetable or herb grown and measuring the total area of the garden occupied by cultivated land.

3. The number and type of livestock present in each garden was recorded. It was also noted if any wild animals were present in the garden and how many occurred, and gardeners were further asked what wild animals they came across during their time in the garden.

4. The number and type of fresh water sources in the garden, if any, were recorded. This did not include municipal supplied tapped water, although it was noted if the garden had access to tapped water. Furthermore, the number of rainwater collection tanks and their capacity were documented.

5. Vegetation surveys were carried out in all community gardens for all plants not considered crops, and their abundances estimated according to the Londo (1976) scale.

6. Trees were counted and identified, and their height estimated for later organisation into three height categories: 0.0 – 4.9m (small), 5.0 - 9.9m (medium), 10+ m (large).

7. The number and type of recreational, physical or mental health facilities present in the garden were identified, counted and described.

3.4.3. Questionnaire

A questionnaire is an instrument that has the primary function of collecting data from individuals by asking a list of questions to try and solve a problem (Siniscalco and Auriat, 2005). Questionnaires are a tool that provides a fast and efficient means of gathering information with regards to respondents' opinions, perceptions and attitudes about particular phenomena or experiences of interest, and data collected using this research approach is inherently subjective. The design of questionnaires, and thus the types of questions used, is dependent on research objectives and whether the researcher wants to collect exploratory information that is qualitative in nature or standardised information that is quantitative in nature (FAO, 1997). Question types can include an open-format which allows respondents to answer in their own words or closed-format (choice categories, scale/ranking or multiple-choice questions) that are set along rigorous and finite responses.

Questionnaires must be carefully designed to yield useful, valid and relevant information with respect to research aims and objectives. Necessary considerations to take into account when formulating an effective questionnaire are highlighted by Burgess (2001): 1) What is the aim of the questionnaire and what is the problem that needs to be solved; 2) Decide on what to measure based on research objectives and thus the types of questions used and data collected; 3) Make sure to use simple language that can be understood by the people who answer the questionnaire (people who may be unfamiliar with the topic, have various levels of education, etc.); 4) Ensuring the questionnaire isn't too long so that people won't get distracted, become uninterested or bored and therefore result in unreliable data; 5) Who is the targeted group of people to address questions to and what is a representative number of respondents; 6) Choose the appropriate collection procedure for the questionnaire; and 7) Decide on the methods that will be used to analyse the data collected in the questionnaire - does the data require statistical analysis or qualitative interpretation?

The questionnaire method has a number of advantages to the process of research: questionnaires are cost efficient, practical and are not a time consuming technique of data collection; questionnaires are relatively simple to construct and distribute; questionnaires have the potential to have large scalability, meaning a large amount of data can possibly be gathered from a wide group of people; questionnaires are an impersonal method of data collection and respondents often feel less pressure or bias due to no face-to-face interaction with an interviewer; respondents have a greater amount of time to respond when compared to interviews, and as such it can be argued that questionnaires allow for deeper thought by respondents compared to ‘first-instinct’ replies in time-limited interviews (NOAA, 2015). Notwithstanding these advantages, questionnaires also have a number of important limitations that need to be taken into consideration. While the impersonal approach of questionnaires can be considered advantageous with respect to bias and influence, not clarifying and explaining the questions to respondents may lead to confusion or differences in understanding and interpretation of the questions, thereby increasing the subjectivity of the answers. Moreover, respondent dishonesty, mood, feelings and attitudes can all potentially influence conscientious responses to questions, thus influencing the validity of the data collected. Data inaccuracies and validity from partial and incomplete data might also be a problem with respect to instances where questions are misunderstood or not relevant and therefore completely skipped (NOAA, 2015). Lastly, researchers have little control over the response rate to questionnaires, which makes it difficult to determine a representative number of respondents and then achieve that number (Sandelowski, 2000). Non-response errors manipulate whether the data that is collected by questionnaires is truly representative of the intended population sample, and therefore influence the data’s validity.

For this study, a formal questionnaire is developed where each respondent is exposed to the same questions and the same system of coding responses (Siniscalco and Auriat, 2005). With the lists of urban ecosystem services and disservices, closed-ended questions are developed using an adapted Burkhard-scale ranking system between 0-5, where 0 = disagree, 1 = very low agreement, 2 = low agreement, 3 = medium agreement, 4 = high agreement and 5= very high agreement (Figure 3.4, see Appendix C for full questionnaire), and used for the purpose of elucidating community –gardeners’, -garden users’ and -garden managers’ perceptions on the services and disservices they feel they experience in community gardens. The reason for using this scaling is to ensure direct relation to the Burkhard et al. (2009) scale, as Burkhard-type matrices for ecosystem services and disservices provisioned by urban community gardens are to be a direct output of this study. This adapted scale collects ordinal data and as Bishop and Herron (2015) discuss, the main issues surrounding ordinal responses involves the appropriate statistical treatment of these data. If the data are ordinal, then usually non-parametric statistics are considered the most suitable for analysis. Parametric statistics are generally perceived more statistically powerful than, and assigned a higher status over, non-parametric statistics, typically due to people’s biases created by the relative simplicity of non-parametric tests (Bishop and Herron, 2015). However, as Knapp (1990) argues, this is not the case despite these biased perceptions, as the most important goal of research is to produce results that are relevant and valid to advancing a particular field of study; valid statistical conclusions require appropriate statistical analyses and researchers should supersede any external pressures to use tests not appropriate or necessary to their data. Further open-ended questions were asked in the questionnaire regarding general garden background information and characteristics.

Relevant and suitable sample size regarding research that necessitates data collection from people is difficult to calculate and adhere to by virtue of the range of human interests, attitudes, moods and behaviours (Sandelowski, 2000). This is especially relevant when requiring human input regarding participation and permissions in attempting to collect data. As such, sample size for questionnaire respondents is unavoidably left at an undefined number, limited to those whom were willing to participate and happened to have interest in the research. Paper-based questionnaires were circulated within the 26 community gardens visited, asking respondents to determine the benefits and detriments they experience from their interactions with, and in, community gardens. A total of 46 respondents were willing to participate in the questionnaire - 22 participants in Berlin and 24 participants in Cape Town.

1. Benefits Produced by Urban Gardens						
	Disagree	Very Low Agreement	Low Agreement	Medium Agreement	High Agreement	Very High Agreement
Questions	No	Yes				
	0	1	2	3	4	5
Provisioning Services						
Food crops (such as vegetables, fruits, herbs) are grown in the garden …						
Regulating Services						
I find the local temperature of the garden area to be cooler than compared to other non-green areas of the city …						
Cultural Services						
When I am in the garden, I feel a sense of being in touch with nature and a sense of belonging …						

2. Detriments Produced by Urban Gardens						
	Disagree	Very Low Agreement	Low Agreement	Medium Agreement	High Agreement	Very High Agreement
Questions	No	Yes				
	0	1	2	3	4	5
Ecological Impacts						
In my experience, invasive (alien) plant or animal species cause problems in the garden (for e.g. weed species) …						
Economic Impacts						
Infrastructure in the garden is often damaged by nature (for e.g. damage from plant growth or roots, corrosion from weather, animal damage to structures, or extreme weather events, etc.) …						
Health Impacts						
I have allergies which are made worse by certain plants in the garden …						

Figure 3.4. Sample of questionnaire developed for this research project. Visible are a select few questions with the closed-ended question structure based on a scale adapted from Burkhard et al. (2009). Source: Figure elaborated by author.

3.5. Data-synthesis, -results and -conclusions

3.5.1. Quantitative data

Field data were collected during site walkover procedures with field protocol checklists by the author. Due to the nature of field work regarding short-hand notes and the quick recording of data, a typed excel spreadsheet of each checklist was created after each site visit to overcome any illegible writing and to avoid forgetting any information gathered during the site visit. All field data was therefore sorted and coded into excel according to the respective ecosystem services and disservices indicators this information represented, and analysis of all ecosystem services and disservices information was carried out on an individual indicator basis – that is, the manner and degree of quantitative analysis depended on the indicator measured (Figure 3.5). Some indicators were measured directly in the field while other indicators required further calculations post data collection in the field.

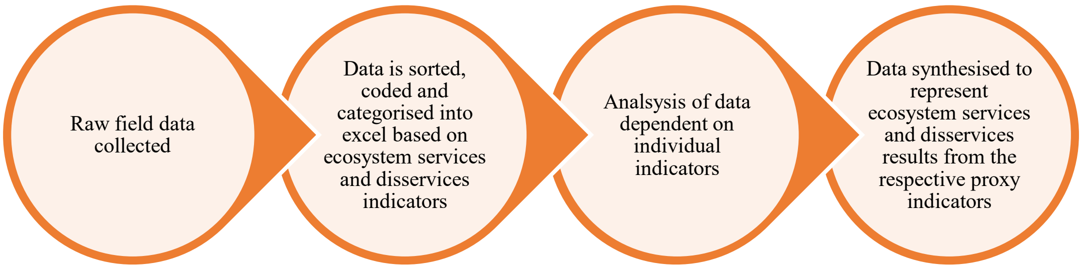


Figure 3.5. Schematic showing the process undertaken to from field data collection to data analysis for quantitative data collected during site walkover procedures using the field protocol checklist. Source: Figure elaborated by author.

3.5.2. Qualitative data

Paper based questionnaires were disseminated in community gardens during site walkover procedures to anyone in the garden who was willing to participate. All answered questionnaires were collected and thereafter coded and input into Statistical Package for the Social Sciences (SPSS v.23) and descriptive statistics were run on the data (Figure 3.6).

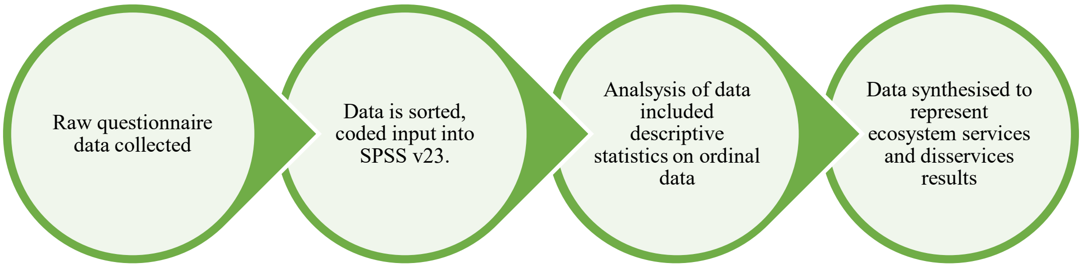


Figure 3.6. Schematic showing the process undertaken to from data collection to data analysis for qualitative data collected using the questionnaire. Source: Figure elaborated by author.

3.5.3. Burkhard-type matrices

Ecosystem assessments generate large volumes of data depending on the number and type of ecosystem services and/or disservices that are being investigated. In addition, questionnaires are tools which can produce large amounts of data conditional to their purpose and how they are structured. As a full spectrum of ecosystem services and disservices are assessed in this study, a large amount of data is assembled, and consequently, the amount of results and conclusions drawn are abundant – these are difficult to show in a simple way without getting lost beneath an overbearing amount of data and results. A Burkhard-type matrix represents a clear, succinct and simple tool that graphically summarises large amounts of results and conclusions with respect to ecosystem services and disservices assessments of a particular environment or land-use type (Burkhard et al., 2009). This can be especially advantageous when attempting to share concise and simplified information to policy makers and planners regarding community gardens in cities and the services and disservices they provide. Burkhard-type matrices are interpreted using the listed ecosystem services and disservices measured in community gardens in Berlin and Cape Town and are scored according to an assessment scale between 0 – 5, where 0 = no relevant capacity of the community gardens to provide this particular ecosystem service / disservice, 1 = low relevant capacity, 2 = relevant capacity, 3 = medium relevant capacity, 4 = high relevant capacity and 5 = very high relevant capacity to provide a particular ecosystem service / disservice (Figure 3.7). Using the approach of Burkhard et al. (2009) and Speak et al. (2015), Burkhard matrices are compiled to graphically display the results and final matrix values for ecosystem services and disservices are scored based on both the quantitative and qualitative data obtained during field work, personal judgement, and previous matrix values based on expert knowledge (Burkhard et al., 2009).

Ecosystem Services	Cape Town	Berlin
Provisioning Services		
Crops		
Livestock		
Wood Fuel		
Timber		
Fresh Water Supply		
Medicinal Resources		
Regulating Services		
Local Climate Regulation		
Air Quality Regulation		
Moderation of Extreme Events		
Water Flow Regulation and Runoff Mitigation		
Erosion Prevention and Maintenance of Soil Fertility		
Noise Reduction		
Habitat/Supporting Services		
Habitat for Species		
Maintenance of Genetic Diversity		
Cultural Services		
Recreation and Mental and Physical Health		
Tourism		
Aesthetic Appreciation and Inspiration for Culture, Art, Design		
Spiritual Experiences and Sense of Place		

Ecosystem Disservices	Cape Town	Berlin
Ecological Impacts		
Displacement of native by invasive species		
Economic Impacts		
Damage to infrastructure by nature		
Garden costs associated with maintenance, repair and energy use		
Health Impacts		
Allergies /respiratory problems caused by spread of pollen		
Wild or semi-wild animals causing anxiety over safety/fear of attack		
Psychological Impacts		
Unwanted smells, sounds or behaviours from plants and animals		
Aesthetic and hygiene impacts due to animal excrement		
Aesthetic unpleasantness due to overgrown, unkept vegetation		
Feelings of insecurity/fear associated with dark garden spaces		
Vegetation blocking views		
General Impactson Human Well-Being		
Restricted use of certain parts of the garden		

No relevant capacity	Low relevant capacity	Relevant capacity	Medium relevant capacity	High relevant capacity	Very high relevant capacity
0	1	2	3	4	5

Figure 3.7. Example structure of a Burkhard-type matrix and its scale. Upon final results, values between 0 – 5 and their corresponding colour are input into the matrix based on the degree to which community gardens in Cape Town and Berlin deliver a particular ecosystem service or disservice. This matrix provides an effective tool for summing up large amounts of data into an easily readable and simple graphic Source: Figure elaborated from Burkhard et al. (2009) by author.

3.6. Data reliability

Reliability refers to the degree of consistency with which a data measures the variable/opinion it was designed to evaluate (Polit and Hungler, 1993). Reliability can be ensured by minimising the sources of measurement error such as data collector bias inconsistency. In this study, data collector bias was reduced by the author being the only person to conduct field surveys and administer the questionnaires to willing participants, thus standardising the conditions in which data was measured and gathered, and how questionnaires were disseminated. Seeking out respondents who are willing to participate in a questionnaire can be challenging, particularly if this requires a large amount of their time or other types of investments by them. As such, every effort was made to make sure the physical and psychological environment in which the questionnaire was completed was as comfortable as possible by promoting privacy and confidentiality, good general rapport and comfort, friendliness between researcher and respondents and objective questionnaire explanations and support.

3.7. Data validity

Validity refers to the degree to which a data measures what it intended to measure and looks at the extent to which the data represents the factors under study (Polit and Hungler, 1993). To achieve content validity, the field protocol and questionnaire included a variety of indicators and questions based on literature-derived ecosystem services and disservices to ensure a comprehensive and representative range of possible ecosystem services and disservices were accounted for. Data triangulation of a mixed-method approach in collecting both quantitative and qualitative information helped to ensure increased validity of any results obtained. All site walkover procedures were carried out by the author and, questionnaires that were completed were handed to each participant personally by, and completed in the presence of, the author. Furthermore, the questionnaire was designed in as simple language as possible for clarity and understanding, and as short and succinct as possible to avoid participant boredom and skewing of results. In instances where the participant was willing to participate but had illiteracy issues, questionnaires were completed on their behalf by the author with their permission.

3.8. Ethical considerations

Scientific rigour of field work procedures, integrity, honesty and diligence of research were the foundation of all data collected and during the analysis of results. In addition, at all times during the process of research concerned with human-based interaction, the rights and concerns of participants should be recognised and protected. Ethical considerations in this study recognised all respondents had the rights self-determination, anonymity and confidentiality, and informed consent. Self-determination and informed consent were presented to all community gardens through an initial request for permission to conduct research on their property and the logistical requirements of the research. Questionnaire participants were informed of background information of the author, the purpose and objectives of the questionnaire and explaining that they had the right to voluntarily accept or decline to participate and could withdraw at any stage of the questionnaire without fear of redress or penalty. Participants were requested not to write their names or any identifiable information on the questionnaire to ensure anonymity, and confidentiality was assured by informing them that their answers would only be seen by the author and not shared with any external third party in a way that could, publicly or otherwise, identify them.

3.9. Conclusions

Methodologies used in data collection for ecosystem assessments have implicit complexities that entail reliability and appropriateness of indicators used, human-related challenges involving participation and permissions, the extensive time periods it takes to complete these procedures in the field, and handling and managing large amounts of data that are collected. Methods employed in this research are grounded in a multi-case study approach that uses mixed methods of both quantitative (indicator analysis) and qualitative (questionnaire) data collection. The methods used in the study are considered reliable and appropriate as ecosystems research fits both quantitative and qualitative enquiry, scientific rigour is promoted through data triangulation from using mixed method techniques, and chosen methods are consistent with those used in the reviewed literature.

Chapter Four

Case Study Cities

4.1. Introduction

This chapter presents the geographical, environmental, socio-economic, and institutional characteristics of Berlin and Cape Town that are relevant for this study. Community gardens are a result of complex social, economic and political situations and circumstances, and so, the intention of this chapter is to contextualise these different aspects in both cities so as to illustrate the diversity of settings in which this research was carried out. The purpose of choosing Berlin and Cape Town as two completely dissimilar settings in which to carry out the assessment is because data gathered within each of these unique settings has potential for context specific meaning and enhanced generalised meaning of results. Furthermore, these two cities are selected based on having no previous assessments done relating to urban ecosystem services and disservices from community gardens, so it is new work in both cities.

4.2. Case study: Berlin

4.2.1. Geographical location and demographic set-up

The city of Berlin is the capital of, and largest city in, Germany, with an estimated population of 3.6 million inhabitants. Representing one of the 16 federal states of Germany, the city of Berlin covers an area of approximately 892 km^2 and has a population density of 3948 inhabitants per square kilometre (Amt für Statistik Berlin-Brandenburg, 2015a). Located in north-eastern Germany, the city is surrounded by the state of Brandenburg and is at the centre of the greater Berlin-Brandenburg Metropolitan Region, which has roughly 5.9 million people (Berlin-Brandenburg.de, 2016). Berlin is positioned at latitude 52° 31' N and longitude 13° 24' E in continental Europe, and has an average elevation of 43 metres above sea level (Figure 4.1).

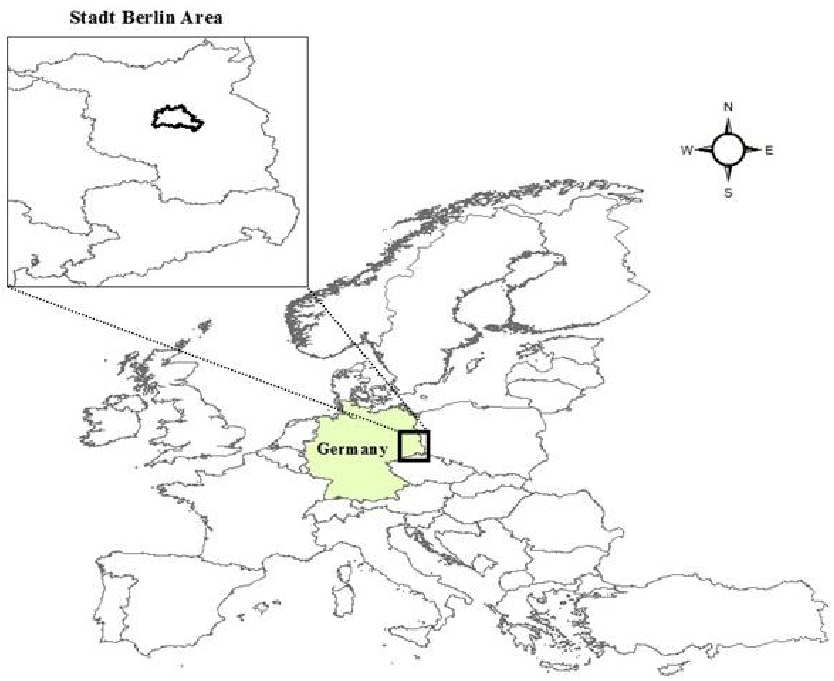


Figure 4.1. Geographical location of the city of Berlin (Stadt Berlin) in the context of Germany and continental Europe. Source: Map elaborated by author from data acquired from ESRI (2014) and GADM (2016).

4.2.2. Landscape and climate

The city's macroclimatic character is classified as humid continental (Dfb) according to the Köppen-Geiger climate classification system, influenced by mild continental climate due to its inland position. This is typified by marked seasonal differences in temperature, with hot and humid summers and very cold winters. Annual average maximum and minimum temperatures are estimated at a high of 24 °C (June – August) and a low of -2 °C (December – February), and average annual precipitation at 570 mm (Amt für Statistik Berlin-Brandenburg, 2015). According to Lauf et al. (2015), Berlin's urban climate, however, is significantly modified by urban heat island effects as temperature increases were found towards the city centre and areas of built environment (high sealing rates) due to heat emitting from artificial surfaces, including and especially at night, long after insolation has ceased. Moreover, urban-induced heat stresses were found to be disproportionately located throughout Berlin, mainly as a result of unevenly distributed urban green spaces in the city, and predominantly influence people of lesser socio-economic status like immigrants - this raises important environmental justice concerns for the city (Kabisch and Haase, 2014; Lauf et al., 2015). In terms of urban landscape attributes relevant to urban gardening, soils, vegetation and groundwater levels are important environmental features to consider, but are also highly modified in large cities like Berlin over very small scales, so general statements about the region are not useful beyond setting an overall context. At large, the following is found in Berlin:

1. ***Soils***: As typified in urban areas, Berlin's soil geochemistry is highly influenced by anthropogenic activity and predominantly sealed within the city, with the inner urban regions and surrounding built up areas showing soils enriched with heavy metal contaminants like Cadmium, Lead, Copper, Chromium, Mercury and Zinc, amongst others, that are largely attributed to additives in building materials, ameliorants for urban vegetation and green spaces, and sewage effluent (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2017a). Urban topsoils largely consist of medium and fine sands and medium loamy sands (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2017a)
2. ***Vegetation***: Urban vegetation in Berlin is characterised by a majority of planted vegetation (i.e. cultivated by human hands) that includes agricultural plants, street and urban trees, and other woody plantations like shrubs and ornamental plants that can withstand climatic conditions (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2017b). Other spontaneous vegetation does exist where vegetation has settled in open and accessible soils by natural progression of dispersal and colonisation processes. Original vegetation has only been able to persist in land used for forest purposes and in bodies of water (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2017b).
3. ***Groundwater***: Groundwater levels are imperative for the city of Berlin as all water for the public water supply is obtained from groundwater reserves. Generally, the city has a fairly shallow groundwater table and surplus water availability, as there are several aquifers in the surrounds of the city (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2017c). Although a positive aspect for urban gardening, this also means urban groundwater is more vulnerable to pollution and contamination in percolation and infiltration processes.

4.2.3. Administrative structure and governance

Berlin is subdivided into 12 boroughs, each of which contains a number of smaller localities (Figure 4.2). The executive government of Berlin is the Senate with senators responsible for their respective departments. The first mayor holds the city's highest office and is also the premier of the federal state of Berlin. Each borough is governed by a borough council consisting of a borough mayor and five councillors. These boroughs are not independent municipalities however, and have limited powers subordinate to the Senate (Kramer, 2013). Administrative structures relevant for this study lie at the borough level as it is between borough authorities, local land owners and gardeners who manage and enter into 'contracts of interim use' of a piece of land for community gardening purposes (Berlin.de, 2017).

Boroughs

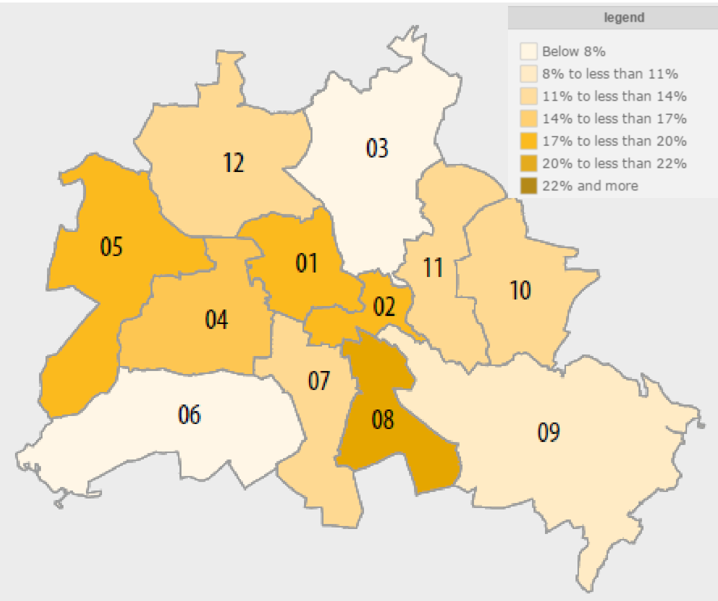
- Charlottenburg-Wilmersdorf
- Friedrichshain-Kreuzberg
- Lichtenberg
- Marzahn-Hellersdorf
- Mitte
- Neukölln
- Pankow
- Reinickendorf
- Spandau
- Steglitz-Zehlendorf
- Tempelhof-Schöneberg
- Treptow-Köpenick

Figure 4.2. Stadt Berlin boroughs (Bezirke) and localities (Ortsteile). Source: Berlin Maps 360 (2016).
http://berlinmap360.com/carte/pdf/en/berlin-districts-map.pdf

4.2.4. Socio-economic contextualisation

Berlin is a culturally diverse city, having a large foreign national population of approximately 17% (598 261) of the total population (as of December 2016, the most up to date available figure) and consisting of immigrants mainly from Turkey, Poland, Italy, Lebanon, Serbia, Russia, China and Vietnam (Amt für Statistik Berlin-Brandenburg, 2016). As a result of past separate developments during the cold war period, Berlin has undergone a lot of economic restructuring since reunification which has led to considerable unemployment and uneven socio-economic distributions throughout the city - like many metropolitan areas, Berlin has an unequal distribution of wealth throughout the urban fabric (Figure 4.3) (Kramer, 2013). Localities that face major challenges mainly occur within the city centre (Moabit and Wedding in Mitte, Kreuzberg-Nordost and Neukölln-Nord) and the wider areas of Spandau-Mitte and Nord Marzahn/Hellersdorf. These regions face socio-economic problems associated with deprived neighbourhoods such as high unemployment, lower education levels and high early school leaving rates, high crime rates and large migrant populations with high migration rates (Kramer, 2013). As of March 2017, the unemployment rate in Berlin was 9.8%, slightly higher than the national average of 6.7% for Germany (European Commission, 2016; Amt für Statistik

Berlin-Brandenburg, 2017a). The majority of the labour market in Berlin is highly skills-orientated and a large proportion of the population are educated. This leads to the exclusion of vulnerable groups (such as migrants, disabled, unemployed, school drop-outs and elderly) which leads to social challenges concentrating in the more problematic areas of the city. Average monthly household income for Berlin in 2016 was estimated at €2791 (Amt für Statistik Berlin-Brandenburg, 2017b) and an average of 14.1% of the population were considered to be living below the poverty line (Amt für Statistik Berlin-Brandenburg, 2015). Socio-spatial segregation in Berlin concerning average household incomes and average poverty rates reveal the western suburbs are more at risk that eastern suburbs, thus Berlin exhibits divided socio-spatial remnants of its old *Western* and *Eastern* parts (Figure 4.3).



Boroughs	Poverty Rate (%)
01 Mitte	18.5
02 Friedrichshain-Kreuzberg	18.5
03 Pankow	6.9
04 Charlottenburg-Wilmersdorf	14.8
05 Spandau	18.6
06 Steglitz-Zehlendorf	7.8
07 Tempelhof-Schöneberg	12.5
08 Neukölln	21.5
09 Treptow-Köpenick	9.9
10 Marzahn-Hellersdorf	13.9
11 Lichtenberg	13.7
12 Reinickendorf	13.1
Average (Berlin)	**14.1**

Figure 4.3. Socio-spatial distribution of residents at risk of poverty in Berlin in 2015. Poverty rate refers to the percentage of the local population of each borough whose per capita income is lower than the poverty threshold. Source: Amt für Statistik Berlin-Brandenburg (2015). https://www.statistik-berlin-brandenburg.de/instantatlas/interaktivekarten/sozialbericht/atlas.html

4.2.5. Urban green

In Berlin, 13.1% (117 km^2) of the city is covered by urban green spaces which are made up of playground and recreational areas (including parks and smaller green areas) (53 km^2), allotment gardens (30 km^2), green areas surrounding roads (14 km^2), cemeteries (11 km^2) and sport facilities/swimming pools (9 km^2) (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2015a; Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2015b). The culture and practice of urban gardening is well established in Berlin and Germany, and has flourished since the 19th century (Groening, 1996). While a number of different urban garden types exist in Berlin (for e.g. roof gardens, community gardens, allotment gardens, guerrilla gardens), allotment gardening is by far the most wide-spread and practiced throughout the city followed by community gardening. As Kabisch and Haase (2014) show, urban green space in Berlin is unevenly distributed across the city and therefore disproportionately available to a subset of urban residents. This unequal distribution is especially the case in the dense and highly populated inner city where competition for space and between land-uses is high. Considering the unequal distribution of green space in the city together with socio-economic contextualisation of Berlin is important for urban gardening from the aspect of where community gardens are located/distributed throughout the city, the socio-economic realities of those neighbourhoods and thus the type of user or gardener that interacts with a community garden and what benefits or detriments they perceive to get from that space.

Not only are urban gardens used as a space to grow food, but local governments and city residents recognise these as important spaces for the improvement of environmental justice through regulating microclimate and air quality, adding to aesthetic appreciation of nature, environmental education and spaces where social connections are built and community interactions are enhanced (Berlin.de, 2017). As Berlin has a dense and highly populated inner city that is only expected to expand with increased urbanisation and migration trends, in addition to a general tendency of having poorer populations within the city centre as shown in Figure 4.3, the small space requirements together with their myriad potential benefits offers good reasons to expand community gardening within the city compared to other green space types.

4.2.6. Urban gardening regulations

In general, urban gardening in Berlin is not highly regulated. While allotment gardens are a formally recognised, planned and regulated land-use within the city, all other forms of urban gardening, including community gardens, have no legal framework in Berlin and Germany. The basic process of 'control' for community gardens (and others) is an 'interim use' contract between local borough authorities, the landowner and gardeners who enter into an agreement with respect to the type and duration of gardening activities that are allowed on that piece of land (Berlin.de, 2017). The Federal Ministry for the Environment, Nature Conservation, Construction and Reactor Safety (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2015) have drafted a document of guiding principles to help municipalities, landowners and residents with the set-up and management of community gardens in neighbourhoods. Specifically, the purpose of this guide is to assess the value of urban community gardens as places of gardening, and community meeting and integration which contribute to social and neighbourhood development. It aims to give guidance, suggestions and recommendations to municipalities and other relevant actors on best conditions for implementation and maintenance of community garden projects that seek to be important open green areas, as productive places for food security as well as spaces with great social-spatial, integrative effects particularly in disadvantaged neighbourhoods. Recommendations of the document also address the following issues: area and space utilisation optimisation; organisation, interaction and cooperation of actors and stakeholders with municipalities; garden installation and operation best practice; planning involving municipalities and residents; and garden support. To sum up, urban gardening (allotment gardens excluded) in Berlin is not strictly controlled. This however, is not necessarily a negative thing as the creativity and free-spirited dynamic nature of community gardens derive their unique and evolving character from the absence of strict regulations, and such rigid structures would likely not be welcome by most community gardens and the people within them. This is also advantages as it allows for easy proliferation of community gardens without strict red-tape and bureaucracy compared to other green space types.

4.3. Case study: Cape Town

4.3.1. Geographical location and demographic set-up

The city of Cape Town is a coastal-situated urban area in South Africa, and is the second most populous city in the country with an estimated population of 4.0 million inhabitants (City of Cape Town, 2016a). Representing the legislative capital of the country and housing the seat of Parliament of South Africa, the City of Cape Town Metropolitan Area covers approximately 2461 km^2 and has a population density of 1530 inhabitants per square kilometre (Stats SA, 2011). Located in the south-west of the country, the city is the primary urban centre of the Western Cape province, one of the nine official provinces of the Republic of South Africa. The metropolitan area is bordered by the Atlantic Ocean to its West and the Indian Ocean to its South. The city of Cape Town is positioned at latitude 33° 55’ S and longitude 18° 25’ E in Sub-Saharan Africa, and has an average elevation of 22 metres above sea level (Figure 4.4).

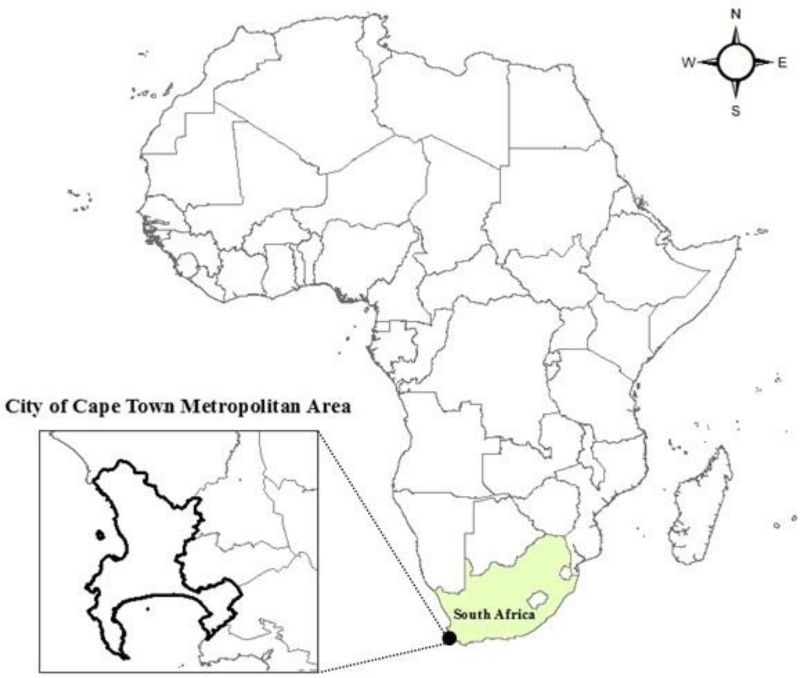


Figure 4.4. Geographical location of the city of Cape Town Metropolitan Area in the context of South Africa and continental Africa. Source: Map elaborated by author from data acquired from ESRI (2014) and GADM (2016).

4.3.2. Landscape and climate

Cape Town is located at the south-western most point of South Africa and is surrounded by complex and diverse landscape. The city is embedded in the foothills of the mountainous Cape Peninsula which runs southwards for over 50 km, and is further surrounded by the Atlantic Ocean to its West and Indian Ocean to its South (Western Cape Government, 2013). The tip of the Cape Peninsula is the meeting point of the two oceans, with the cold Benguela current running up the West coast and the warm Agulhas current along the South coast. The interaction between these two currents, in addition to the geographic location of Cape Town in the mid-latitudes results in a macroclimate classified as Mediterranean dry-summer subtropical (Csb) according to the Köppen-Geiger climate classification system. The Mediterranean climate of the city is typified by mild wet winters and dry hot summers. Annual average maximum and minimum temperatures are estimated at a high of 27 °C (January – March) and a low of 7 °C (June – August), and average annual precipitation at 475 mm (Conradie, 2012). As with most large cities, Cape Town's urban microclimate does exhibit some temperature modifications associated with heat island effects, but these are not very pronounced because of strong south-easterly winds that blow across the city, especially in the summer months, and brings with them dry cooler air and some positive effects on air quality and pollution scattering (Kruger et al., 2010). The urban landscape attributes relevant to urban gardening (soils, vegetation and groundwater levels) are also highly modified in Cape Town over very small scales much like Berlin, so general statements about the region are provided only to give broad context.

1. ***Soils***: Much of the city is situated on a large geomorphological coastal plain of marine sandy topsoils that are acidic and calcareous in nature, with some areas of the inner city having granite derived clay and loam soils (University of the Western Cape, 2017). Cape Town topsoils also show some heavy metal contamination with elements such Cadmium, Copper, Iron, Nickel, Lead and Zinc from urban pollutants such as effluent, landfill sites and degradation of building materials (Ayeni et al., 2010).
2. ***Vegetation***: Majority of the urban vegetation within the city is planted green that is cultivated and managed by humans, however Cape Town does have areas of remnant indigenous vegetation communities within the city. This is because the City of Cape Town houses the Cape Floristic Kingdom, one of the six floristic kingdoms of the world, which is a well-known biodiversity hotspot and an UNESCO World Heritage Site. As such, conservation initiatives are prominent throughout the city (including the urban fabric) and comprise large amounts of urban-adjacent land being protected by national parks and conservation areas, as well as marine protected areas in the surrounding oceans (South African National Parks, 2017). Large portions of the suburban and peri urban outskirts of Cape Town have extensive urban agriculture activities, so agricultural produce is also a common urban vegetation type in some areas. Urban development, agricultural expansion and afforestation in the metropolitan area have greatly pressured and threatened indigenous floral biodiversity, and human-nature conflicts are often at the forefront of development strategies (Cowling et al., 2003).
3. ***Groundwater***: 98% of Cape Town's public water supply comes from surface water (water collected from dams and rivers in catchment areas surrounding the city) and 2% is supplied from groundwater (City of Cape Town, 2017d). Under normal conditions, there are several aquifers in and around the city that supplement groundwater levels in the city, however, Cape Town is currently experiencing severe drought conditions and is in the midst of an unprecedented water crisis which has resulted in large drops in dam levels and water table depths (City of Cape Town, 2017d). With respect to urban gardening, this water crisis places extreme water availability and usage limitations on gardening activities.

4.3.3. Administrative structure and governance

Cape Town is partitioned into 24 sub-council areas, each of which is made up of between three and six wards (Figure 4.5). Each sub-council elects a chairperson as the highest authority of that area, and every ward within each sub-council chooses a ward councillor to sit on the city council along with the chairperson. The city is thus governed by a city council of 231 members that chooses the executive mayor as its head, whom in turn elects a mayoral committee of 11 members that are responsible for their respective departments. Furthermore, a non-politically affiliated city manager is appointed as the head of Cape Town's daily administrative responsibilities, and who in turn appoints in each sub-council a non-political manager to run each sub-council's day-to-day administration. Sub-councils are not independent entities of city governance and therefore have limited power subordinate to the city council and executive mayor as the highest authority (City of Cape Town, 2017a). Administrative structures relevant for this study lie at municipal level, as it is the Recreation and Parks Department of the city who facilitate access to land and/or other controls for urban gardening to respective gardeners and landowners (City of Cape Town, 2013).

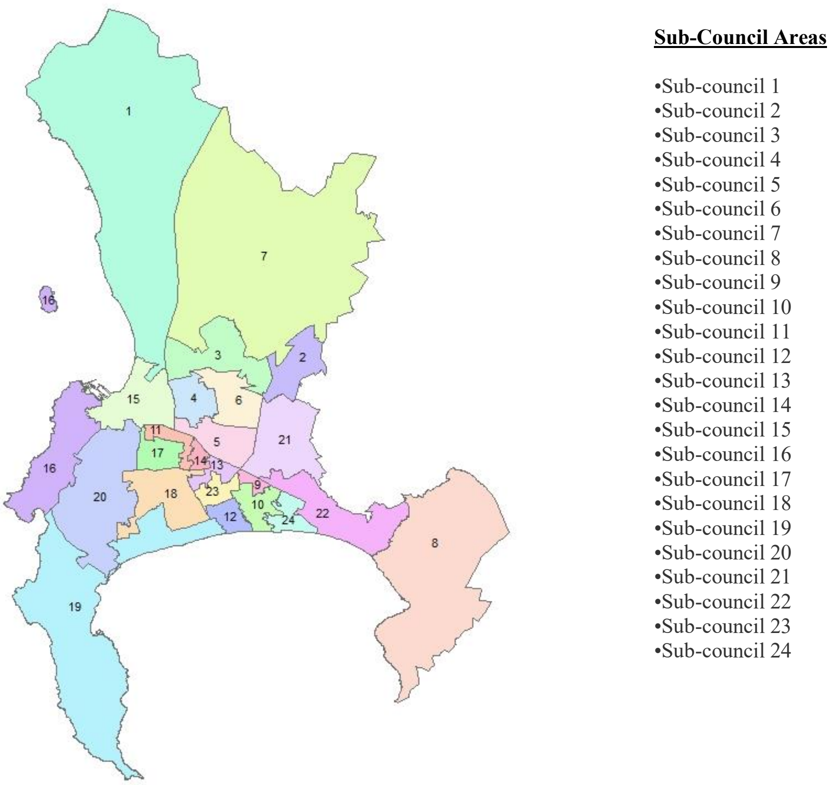


Figure 4.5. City of Cape Town sub-council area designations. Source: Map elaborated by author from data acquired from City of Cape Town (2016b).

4.3.4. Socio-economic contextualisation

Due to South Africa's political history under the Apartheid government, Cape Town's spatial planning, urban fabric and socio-economic status of certain areas still exhibit remnants of a past regime where the city was divided into suburbs and neighbourhoods where different races were discriminated against, separated and required to live by law (Temple et al., 2006). Today, Cape Town is a diverse city that reflects a myriad of races, cultures, ethnics groups, languages, socio-economic classes and education levels that make up the South African nation. Yet, despite democratisation of the country in 1994, the city still experiences several socio-economic challenges, particularly in historically marginalised communities and areas such as the Cape Flats in the eastern suburbs and widespread homelessness in the city centre; there is still considerable inequality in terms of wealth, employment and education level distribution throughout the city between races. Cape Town has a foreign national population of around 5% (206 359 people) and mainly consisting of immigrants from other African countries, while the majority of migrant workers in the city come from other provinces in South Africa (Stats SA, 2011) – 2011 is the most up to date figure available as in South Africa, census is only done every 10 years. In 2016, the unemployment rate in Cape Town was 21.1%, and was lower than the national average of 27.7% for South Africa. Moreover, 25.9% of households in the city were living below the poverty line compared to 45.5% on a national level (City of Cape Town, 2016a). Average monthly household income in Cape Town was approximated to be R18824 (€1298 per month, where 1 Euro = 14.50 South African Rand), which is higher than the national average of R11387 (€795) per month (Stats SA, 2017). It is important to note that Cape Town is unlike most other South African cities in that its built infrastructure, transport networks, and basic service access, provisioning and delivery are at the levels of developed countries – it is a developed city in a developing country. This is reiterated in the city's higher performances in terms of less people living below the poverty line, lower unemployment rates and higher average monthly income amounts compared to corresponding national levels. Nevertheless, Cape Town has to deal with many developing country social ills such as high crime rates and serious health challenges like high HIV/Aids and Tuberculosis rates that are pervasive throughout South Africa.

4.3.5. Urban green

In the City of Cape Town Metropolitan Area, 9% (217 km^2) is covered by urban conservation areas and 1% (27 km^2) is occupied by open urban green space (City of Cape Town, 2016b). Urban green spaces are further comprised of district parks (2.45 km^2), community parks, including sports and recreation fields (17.9 km^2), special biodiversity pathways (1.14 km^2) and cemeteries (5.26 km^2) (Cape Town Green Map, 2017). The rest of the area of the metropolitan is occupied by mountain ranges and other physical landscape features. Most of the agricultural areas are in the suburban outskirts of the city to the North and East, while urban green spaces, green corridors and urban conservation areas are scattered throughout the city. As Willemse (2017) shows, urban green space in Cape Town is unequally distributed across the city, occurring mainly in richer neighbourhoods and has resulted in environmental justice concerns in poorer communities.

Urban gardening (including community gardens), although a growing trend, is still a relatively uncommon practise and land-use in urban South Africa. Urban gardens have largely been designated to suburban and peri urban areas where races were historically forced to live and were discriminated against, and where socio-economic inequalities and severe poverty remain today due to that legacy. As such, most community gardens in the country have the main purpose of being tools used for poverty alleviation, health benefits, and most importantly, food and livelihood security in poorer communities and areas (Chinsamy and Koitsiwe, 2016). Informal community-based food gardens are therefore the main type of urban gardening that takes place within Cape Town, and is often seen as supporting urban agricultural efforts in the city to reduce food insecurity (Western Cape Government, 2013). Unfortunately, as space is often the scarcest and most valuable resource in cities, community gardens within the city are uncommon and seen as a temporary land-use to be later repurposed for development or economic profit. Their benefit, value and legitimacy as a permanent urban space are yet to be investigated and recognised.

4.3.6. Urban gardening regulations

There are no formal or legally binding regulations governing the creation, use and management of urban space as community gardens in Cape Town and South Africa. Municipal policies relevant (indirectly) to urban gardening in Cape Town do exist, and although not legally binding, strongly encourage and guide local government development processes and influence private and public behaviours and actions in using urban space as community-driven food gardens in the city. The *Food Gardens Policy in Support of Poverty Alleviation and Reduction* (City of Cape Town, 2013) is a document created with the aim of addressing the plight of people who are poor, vulnerable or marginalised through establishing sustainable food gardens in urban spaces which act to aid food insecurity and alleviate poverty. The strategic intent of this policy is, inter alia; to redress the injustices of the past Apartheid regime effectively;

support the vulnerable through enhancing access to infrastructure and resources; promote and foster social integration; mobilise resources (social, natural, cultural, economic and other) for social development; and aims to build healthy, accessible, inclusive and sustainable communities in the city. This policy is governed by the requirements set out in the *Urban Agricultural Policy* for Cape Town (City of Cape Town, 2007) which is the overarching framework that guides the growing of agricultural products in the city.

It is evident that urban gardening in Cape Town has a major focus on food production for food security and poverty reduction. If more widely adopted, inherent qualities of community gardening such as community building and social integration, common-resource management and communal governance, environmental education and sustainable behaviours and practises can help to address many of the socio-economic and environmental ills, in addition to primary food security, that are trying to be overcome in Cape Town. An assessment of the ecosystem services and disservices from community gardens in the city is therefore the first important step in making their value to people openly known.

4.4. Conclusions

Value of community gardens is gained from these spaces being recognised as an important land-use with potential to abate environmental injustices in marginalised areas and address localised socio-economic challenges. It is therefore imperative to assess ecosystem services and disservices from community gardens in a variety of contexts so that their value is made explicit to solving these problems. The cities of Berlin and Cape Town exhibit very different geographical, environmental, socio-economic, political and institutional settings in which community gardens occur, and which are made clear here. These characteristics and their differences are important in contextualising the community garden movement in each country with respect to their availability, their purpose and, as it relates to this research, the local physical environment and social settings that enable certain site-specific ecosystem services and disservices to be produced and experienced. Moreover, data gathered in these two unique settings can greatly enhance the transferability of common findings to broader contexts, which ultimately contributes to the wider field of ecosystem services and disservices research.

Chapter Five

Results

5.1. Introduction

This chapter describes the results that were produced to address the research aim and objectives. The quantitative share of urban community gardens in Berlin and Cape Town was calculated through GIS techniques. Thereafter, a specifically designed field protocol was conducted in 26 community gardens to measure quantitative field data using indicators that act as proxies for ecosystem services and disservice in these urban green spaces. In addition, a questionnaire was circulated to 46 respondents who were asked questions based on the perceived benefits and detriments they experience in urban community gardens. Once results were obtained, Burkhard-type matrices for ecosystem services and disservices in both cities were compiled to sum-up these large amounts of data. All figures and tables in this chapter are elaborated by the author.

5.2. Community garden share

As of 1 July 2016, a total of 59 community gardens in ***Berlin*** (The Foundation Anstiftung, 2016) and 43 community gardens in ***Cape Town*** (Department of Agriculture, 2016) were counted. Total community garden area in ***Berlin*** was calculated at 0.145 km^2 and occupied 0,016% of the city. Total community garden area in ***Cape Town*** was calculated at 0.066 km^2 and occupied 0,003% of the city. These garden shares are assumed as the minimum possible values as some garden areas were not obtainable by either visual estimation using the aerial photographs or the acquired size and location data. As such it was only possible to complete the quantification of community garden share in ***Berlin*** to 95% (56 of 59 gardens were quantified) and in ***Cape Town*** to 88% (38 of 43 gardens were quantified). The total quantitative share of community gardens in Berlin and Cape Town are shown in Table 5.1.

Table 5.1. Total quantitative share of community gardens in Berlin and Cape Town.

	Municipal Area (km^2)	Community Garden Area (km^2)	City Area Covered by Community Gardens (%)	Number of Community Gardens	Number of Gardens Quantified in Digitisation Process	Number of Gardens Quantified (%)
Berlin	892	0.144856	0.016239	*59	56/59	95
Cape Town	2461	0.066492	0.002702	*43	38/43	88

*minimum number

Community garden descriptive characteristics are shown for the city as a whole (Table 5.2). Re-iterated in square meters, ***Berlin*** had a total community garden area of 144856 m^2 and ***Cape Town*** a total area of 66492 m^2. Average community garden areas were calculated at 2587 m^2 and 1662 m^2 respectively, with ***Berlin*** exhibiting the higher average garden size. It was evident from the range of community garden areas that a wide variety of garden sizes were present in both cities.

Table 5.2. Community garden descriptive characteristics for Berlin and Cape Town.

	Total Community Garden Area (m^2)	**Range of Community Garden Area (m^2)**	**Average Community Garden Area (m^2)**
Berlin	144856	60 - 13000	2587
Cape Town	66492	56 - 16780	1662

The 26 community gardens evaluated in this study are shown in Figures 5.1 (***Cape Town***) and 5.2 (***Berlin***), and gardens are listed according to the order in which they were assessed in the field, from first to last. A total garden area of 22710 m^2 (2.271 ha) was assessed in ***Cape Town*** which constitutes 34% of the total community garden share in the city (Table 5.3). In ***Berlin***, a total garden area of 32575 m^2 (3.258 ha) was assessed, or 22% of the total community garden share in the city (Table 5.4). Average sizes of the community gardens investigated were 1747 m^2 in ***Cape Town*** and 2506 m^2 in ***Berlin***.

Calculation of urban quantitative shares gains importance because one significant advantage of community gardens is their relatively small size compared to other larger ecological infrastructure like parks or forests that take up a greater amount of urban area. In cities, where population numbers are ever increasing and therefore space and land-use competition are extremely high, the space efficiency of small green areas like community gardens together with recognition of the numerous benefits they provide to the city and its residents gives them comparative advantage in potential planning decision-making. In both cities, the total share of urban area occupied by community gardens amounted to less than 0.02% (Table 5.1) which is an almost negligible percentage and illustrates that community gardens do not take up a lot of space in ***Berlin*** and ***Cape Town***. Carrying out ecosystem services and disservices assessments from community gardens in these two cities can be used together with this quantification data to provide valuable information to local municipalities that legitimise the use of urban land for community garden areas because of their low space requirements and ability to provide many

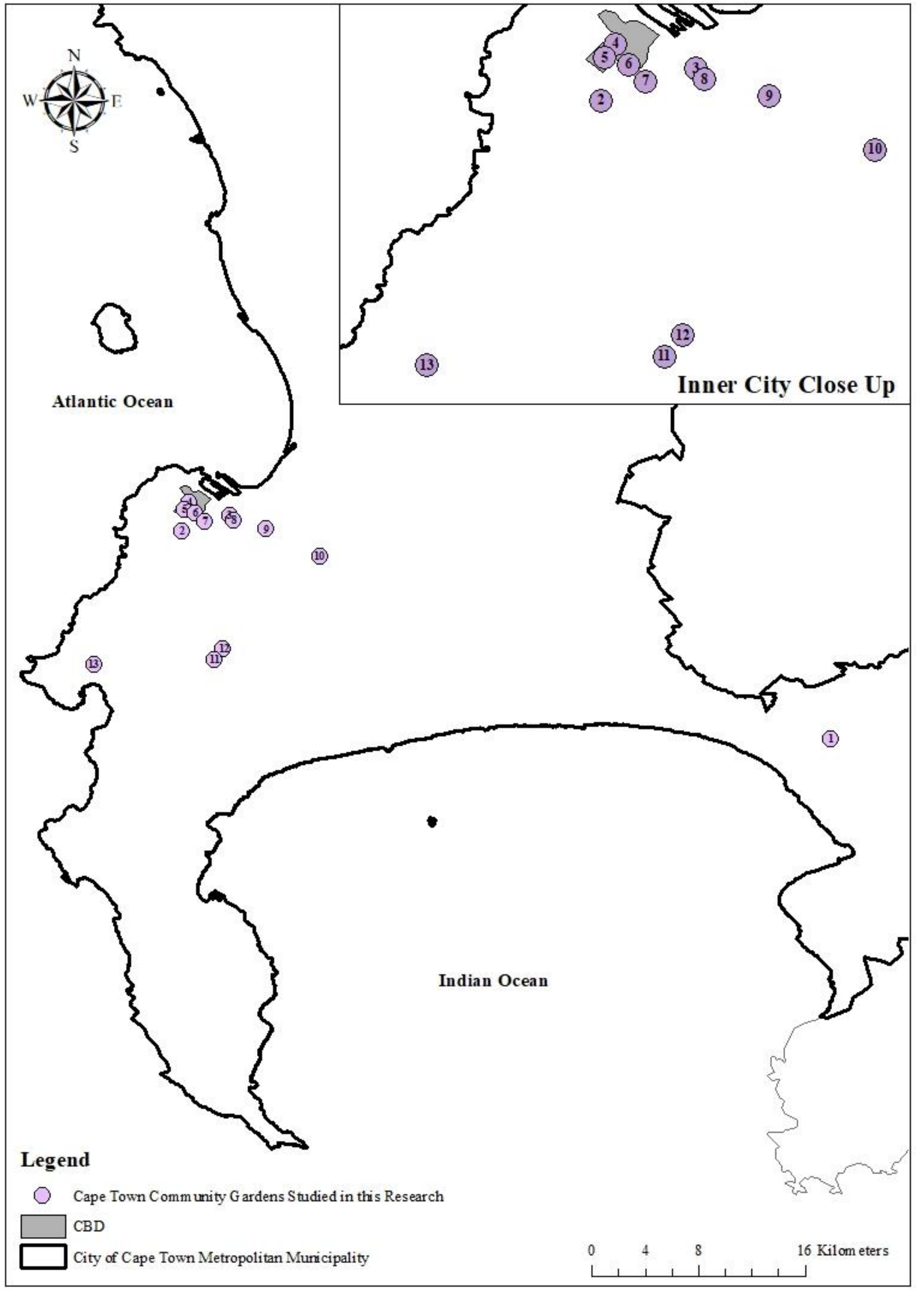


Figure 5.1. Location of those community gardens assessed in Cape Town. Numbers correspond to the order in which the gardens were assessed, from first to last, and are linked to Table 5.3.

Table 5.3. Individual community gardens assessed for ecosystem services and disservices in Cape Town. Visible are the garden names, garden name abbreviations used in the results and garden sizes. Numbers in the first column correspond to their respective locations in Figure 5.1.

Garden Number	***Garden Name***	***Abbreviation***	***Area (m^2)***
1	Somerset West Village Garden	SWVCG	1910
2	Oranjezicht City Farm	OZCF	3025
3	Al-Noor Orphanage Garden	ANOCG	190
4	Central Methodist Community Garden	CMCCG	57
5	VOC Vegetable Garden	VOCVG	1410
6	Khulisa Streetscapes Community Garden A	KSCG_A	520
7	Khulisa Streetscapes Community Garden B	KSCG_B	2215
8	Woodstock Peace Garden	WPG	2925
9	Observatory Junior School Garden	OJSG	342
10	Christine Revel Childrens Home Garden	CRCHG	56
11	Soil for Life	SFL	4650
12	Constantia Village Organic Food Garden	CVOFG	185
13	Kronendal Flower Garden	KFG	5225
Totals		**Number of Gardens**	**13**
		Total Area (m^2)	**22710**
		Average Area (m^2)	**1747**
		Percentage Share of Total Community Garden Area in the City	**34%**

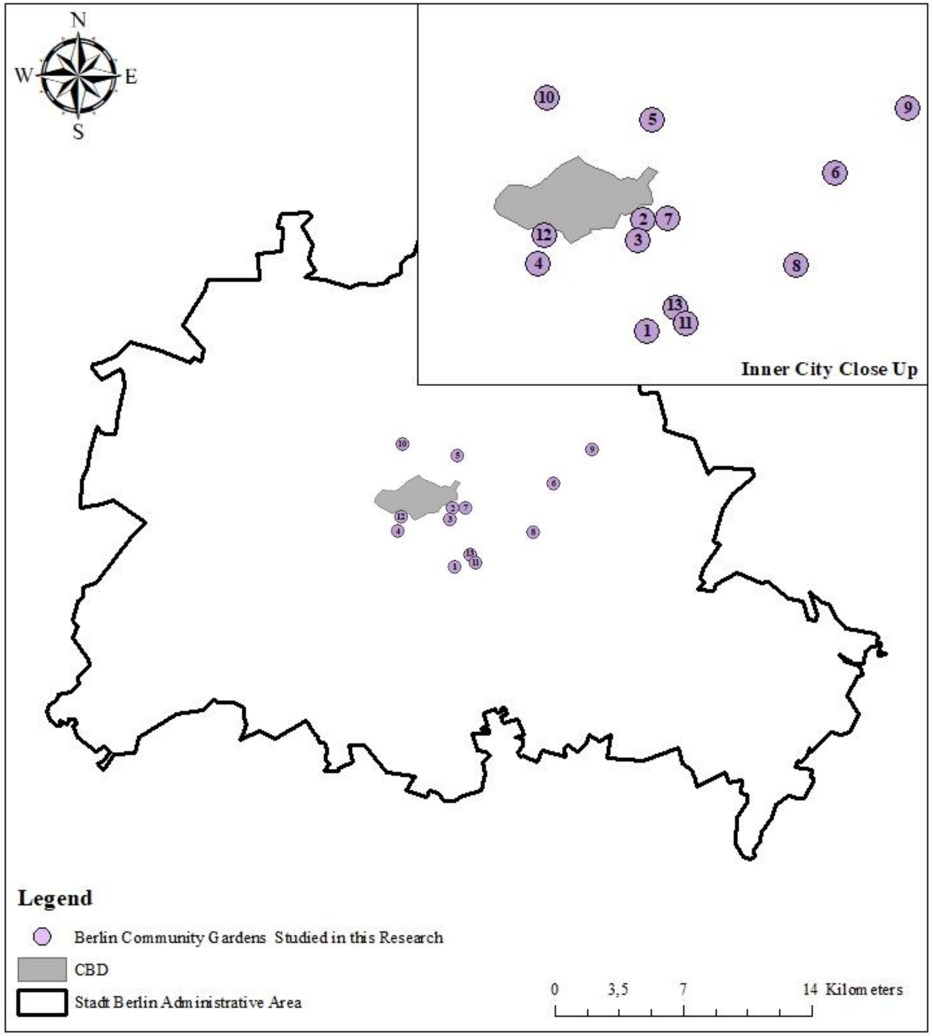


Figure 5.2. Location of those community gardens assessed in Berlin. Numbers correspond to the order in which the gardens were assessed, from first to last, and are linked to Table 5.4.

Table 5.4. Individual community gardens assessed for ecosystem services and disservices in Berlin. Visible are the garden names, garden name abbreviations used in the results and garden sizes. Numbers in the first column correspond to their respective locations in Figure 5.2.

Garden Number	*Garden Name*	*Abbreviation*	*Area (m^2)*
1	Gemeinschaftsgarten Allmende-Kontor	GAK	8000
2	Berolina Generationengarten	BGG	395
3	Prinzessinnengarten	PRG	5500
4	Pallaseum Gemeinschaftsgarten	PLG	750
5	Kiezgarten Schliemannstraße	KSS	1410
6	Lichtenberger Stadtgarten	LSG	1150
7	Gemeinschaftsgarten Spreeacker	SKR	300
8	Kiezgarten Fischerstraße	KFS	8000
9	Spiel/Feld Marzahn	SFM	660
10	Interkultureller Gemeinschaftsgarten Himmelbeet	IGH	1700
11	Gemeinschaftsgarten Prachttomate	GPT	1450
12	Interkultureller Garten City im Familiengarten	GCF	700
13	Klunkergarten	KLG	3670
Totals		**Number of Gardens**	**13**
		Total Area (m^2)	**32575**
		Average Area (m^2)	**2506**
		Percentage Share of Total Community Garden Area in the City	**22%**

benefits to the city and local people, and may further aid in the prioritisation of community gardens over other green space types in future urban planning and development projects.

5.3. Ecosystem services assessments

Results of field protocols performed in ***Berlin*** and ***Cape Town*** community gardens are shown in Chapters 5.3.1 – 5.3.4 which are grouped according to ecosystem services categories.

5.3.1. Provisioning services

Provisioning services inferred from indicators in this research include: *food* (crops and livestock), *raw materials* (wood and timber), *fresh water supply*, and *medicinal resources*.

5.3.1.1. Food

5.3.1.1.1. Crops

Crop yield (tons per hectare) is a common indicator relating to crop provisioning services – this measure was not possible as many gardens in both cities did no accounting for the amount of produce they grew, so a reliable yield could not be obtained from field surveys or questionnaires. The proxy indicator used to make inferences about food services was therefore **landcover** from which *crop richness* was recorded, where crop richness is defined as the total number of crop types grown in each community garden. In addition, the area of cultivated land (*crop area*) was calculated as a percentage of the total garden area for individual community gardens (Cabral et al, 2017).

<u>*Crop richness*</u>

Full lists of *crop richness* for individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D1- D2 in Appendix D. The overall crop richness for ***Cape Town*** community gardens was 54 with an average of 15 crops types grown per garden. The overall crop richness for ***Berlin*** community gardens was 108 with an average of 26 crops types grown per garden.
Although many similar *crop types* were grown in each city, prominent differences in the variety and amount were apparent. In ***Cape Town***, spinach, tomatoes, peppers and beetroot were some of the most commonly grown vegetables (Figure 5.3) while berries (black- and redcurrants, strawberries, raspberries, blueberries), lettuce, rocket and beetroot were popular in ***Berlin*** gardens (Figure 5.4). ***Berlin*** gardens also had a larger variety of unusual crop types such as kohlrabi, exotic potato and tomato varieties, goji berries and goose berries. ***Berlin*** community

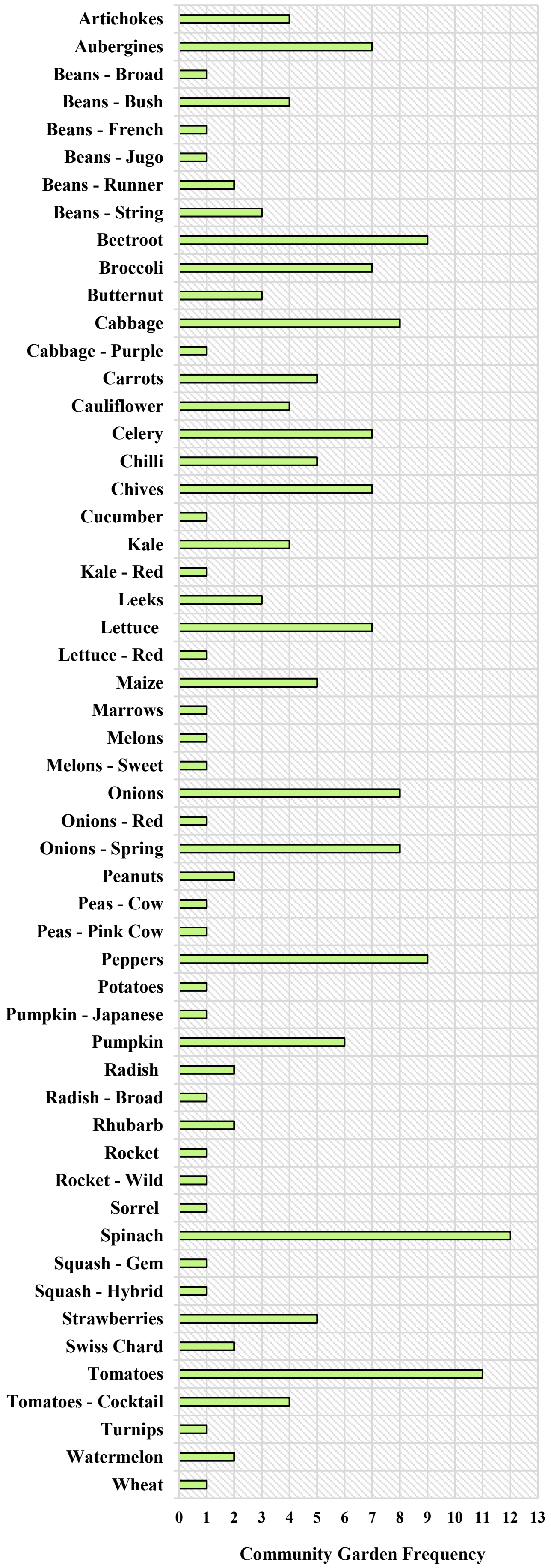


Figure 5.3. The frequency (x-axis) and type of crop grown (y-axis) in Cape Town community gardens. Overall crop richness was 54 crop types.

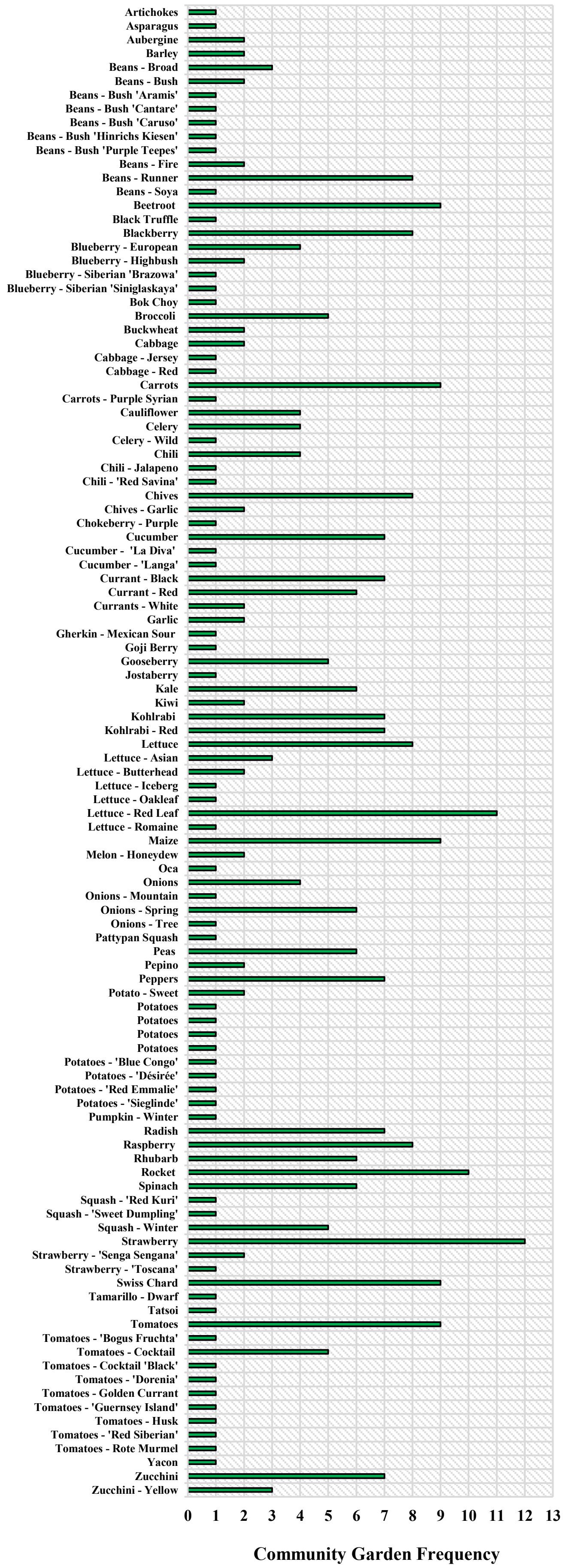


Figure 5.4. The frequency (x-axis) and type of crops grown (y-axis) in Berlin community gardens. Overall crop richness was 108 crop types.

gardens thus had a higher variety and average number of crop types grown per garden compared to ***Cape Town*** (Figure 5.5).

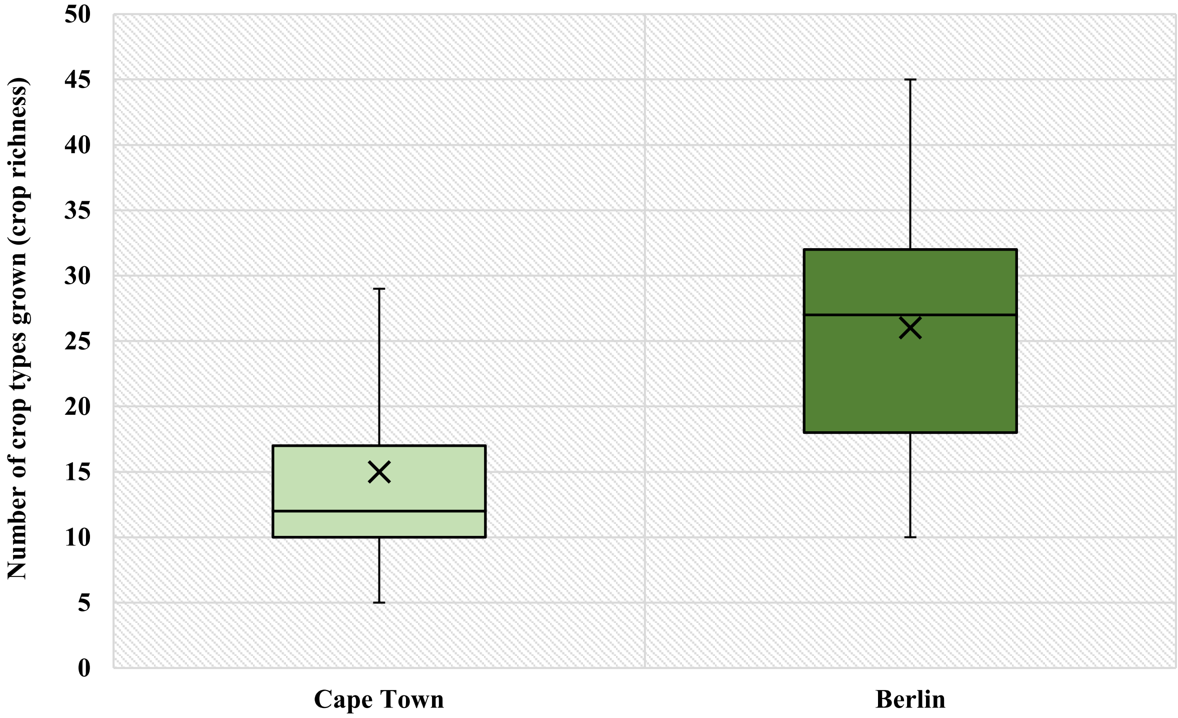


Figure 5.5. Crop richness comparison for community gardens in Cape Town and Berlin (x denotes the mean).

<u>*Crop area*</u>

Full lists of *crop area* measured in individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D3 - D4 in Appendix D. In ***Cape Town***, 8119 m^2 of cultivated land was measured from a total garden area of 22710 m^2, which corresponded to 36% of the total area being allocated to land for food provisioning. Correspondingly, in ***Berlin***, 12098 m^2 of cultivated land was measured from a total garden area of 32575 m^2, which represented 37% of the total area assessed being allocated to land for food provisioning, therefore, in both cities, over ⅓ of community garden space supplied food provisioning services. Comparison of crop area measurements shows that, while overall percentages of cultivated land are similar in both cities, ***Cape Town*** gardens had higher variations in the areas of cultivated land relative to total garden areas (Figure 5.6). Moreover, ***Cape Town*** gardens had a higher average percentage of cultivated land (57%) compared to ***Berlin*** (40%) (Figure 5.6) suggesting a primary purpose of many ***Cape Town*** community gardens related to food ecosystem services, a primary need, and thus reflected the lower socio-economic context of ***Cape Town*** as detailed in Chapter Four.

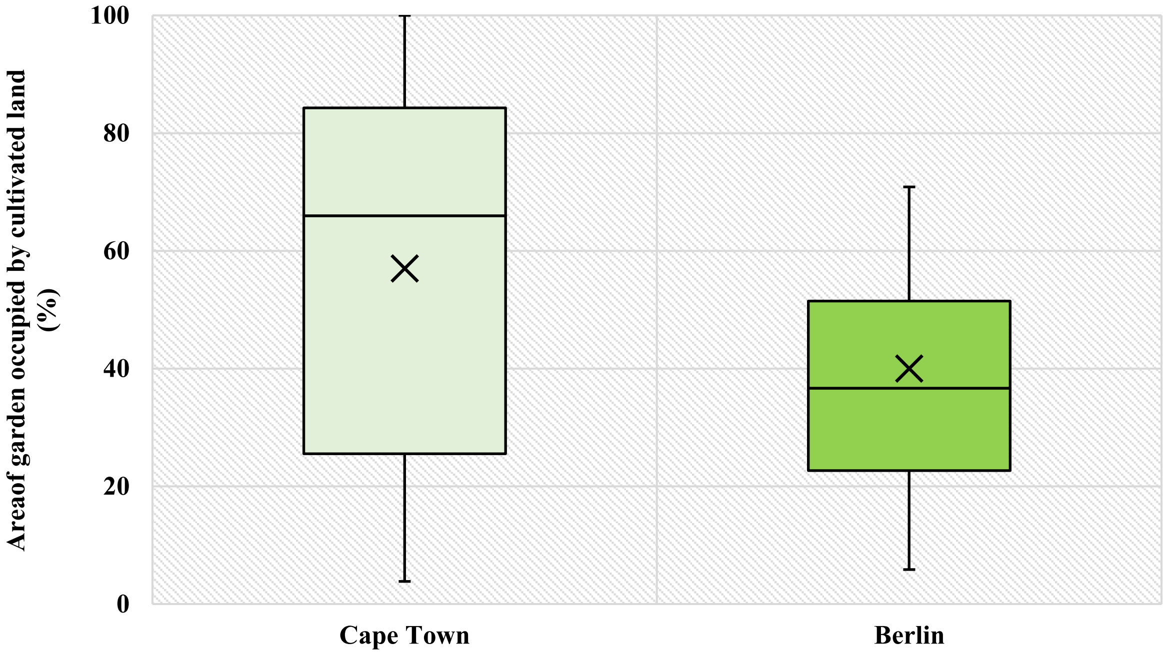


Figure 5.6. Area of cultivated land (%) in community gardens in Cape Town and Berlin (x denotes the mean).

Qualitative results obtained from the questionnaire showed that garden users perceived community gardens to have a high capacity to provide food services. When asked about food crops grown in the garden (Q.1), 83% of respondents in ***Cape Town*** and 96% in ***Berlin*** answered with high and very high agreement that food cultivation was a major land-use in the community garden.

In terms of perceived direct benefit experienced from these food services (for e.g. through direct consumption) (Q.2), respondents in ***Cape Town*** answered with 4% in high agreement and 42% in very high agreement, while 25% were in medium agreement (Figure 5.7). In ***Berlin***, 27% of the respondents highly agreed and 36% very highly agreed that they benefit directly garden food resources, while 27% were in medium agreement (Figure 5.7). Interestingly in ***Cape Town***, where many gardens had a primary purpose of food production, 29% of respondents felt they did not benefit directly from these food services in any way. This is perhaps a result of the differences in respondent type between the two cities, where over 50% of those who answered the questionnaire in ***Cape Town*** identified as either a garden manager or visitor with no measure of extended stay or interaction in the garden, while 91% of the respondents in ***Berlin*** were either a garden manager or gardener who would regularly work in the gardens.

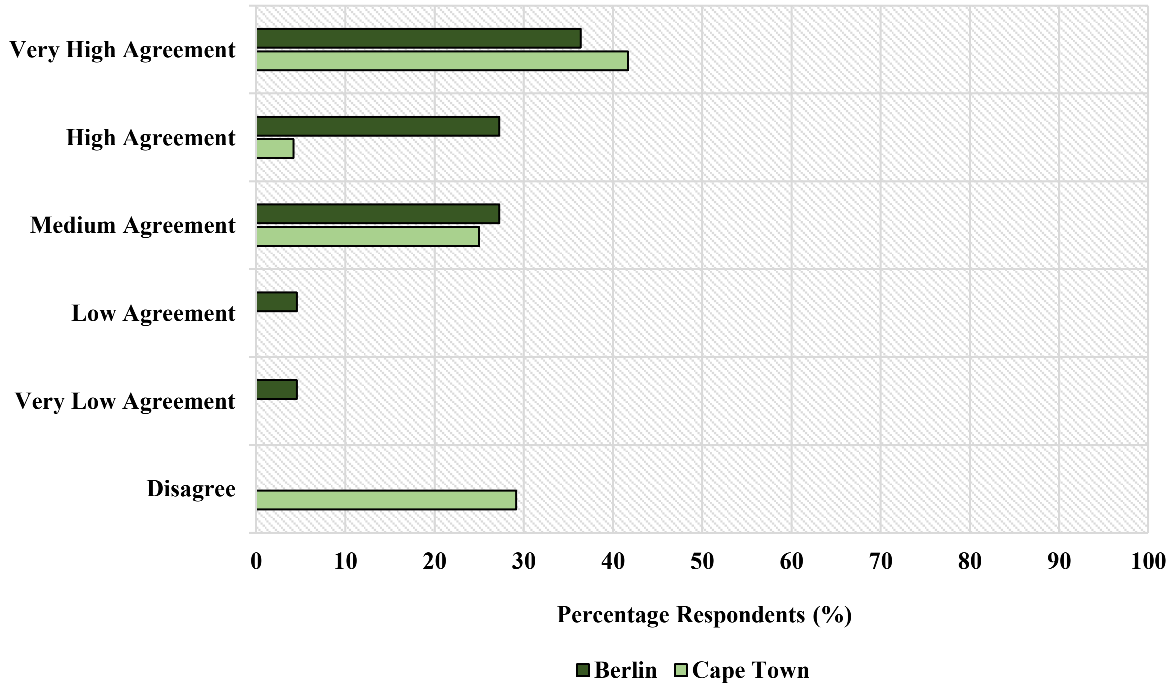


Figure 5.7. Questionnaire responses when asked whether respondents directly benefit from crops grown in community gardens.

5.3.1.1.2. Livestock

The proxy indicator used to make inferences about food from livestock was **total livestock number**, where the total number of livestock per community garden area was recorded (Egoh et al., 2012).

Full lists of *total livestock numbers* measured in individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D5 - D6 in Appendix D. A total livestock number of 53 individuals was measured for ***Cape Town*** community gardens, occurring in three gardens only. Of the 53 livestock individuals counted, 30 were chickens, 10 were rabbits, 10 were ducks and 3 were guinea pigs (Figure 5.8), thus a livestock richness of four types was observed. As different animals have different functions, uses and by-products for consumption, only those livestock that provide any sort of by-product or are used as food counts as food ecosystem services that come from livestock. Of the four types of livestock counted, only chickens and ducks were used to produce food items, either through direct consumption of the animal or for by-products like eggs (rabbits and guinea pigs were used for companionship and enjoyment and so are unrelated to food ecosystem services). Therefore, 75% of the total livestock number produced food ecosystem services for ***Cape Town*** community gardens in a total 2.271 ha, which translates to 40/2.271 = 17.6 ≈ 18 individuals of food producing livestock per hectare of community garden. In ***Berlin***, bee colonies were the only livestock type present and a total of 16 bee colonies were counted (Figure 5.9). Of the 16 bee colonies recorded, 88% provisioned food by-product services (honey) in a total garden area of 3.258 ha, which translates to 14/3.258 = 4.3 ≈ 4 honey producing bee colonies per hectare of community garden.

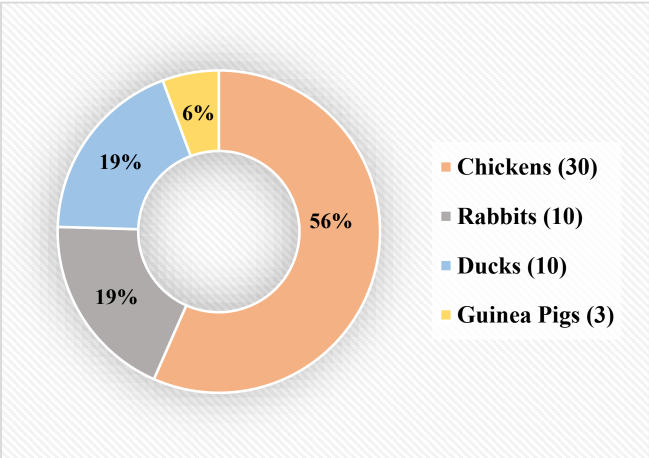


Figure 5.8. Proportional breakdown of total livestock number (53) for community gardens in Cape Town. A livestock richness of 4 types was observed.

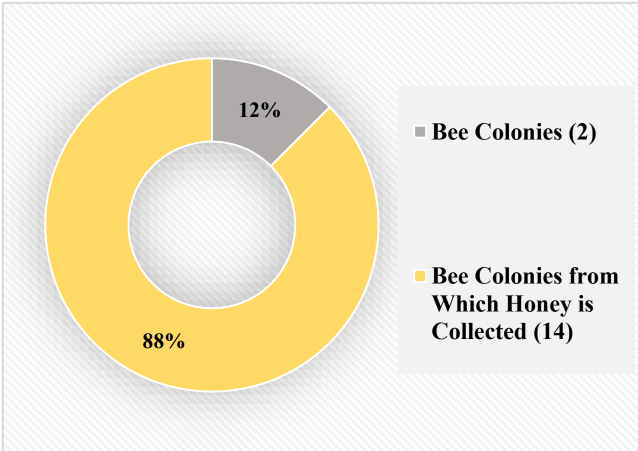


Figure 5.9. Proportional breakdown of total livestock number (16) for community gardens in Berlin. A livestock richness of 1 type was observed.

Opinions gathered from the questionnaire showed that garden users perceived community gardens to have a low capacity to provide food services from livestock. When asked about domestic livestock presence in the garden (Q.4), 83% of respondents in ***Cape Town*** and 96% in ***Berlin*** disagreed that any livestock was present in the garden. In terms of the perceived direct benefit from the livestock that was present (Q.5), and overwhelming majority of respondents in both ***Cape Town*** (92%) and ***Berlin*** (100%) felt they received no benefit at all (Figure 5.10). The perceptions from ***Berlin*** participants are interesting as it shows these respondents did not consider bee colonies to be a part 'livestock' but rather natural fauna of the garden ecosystem.

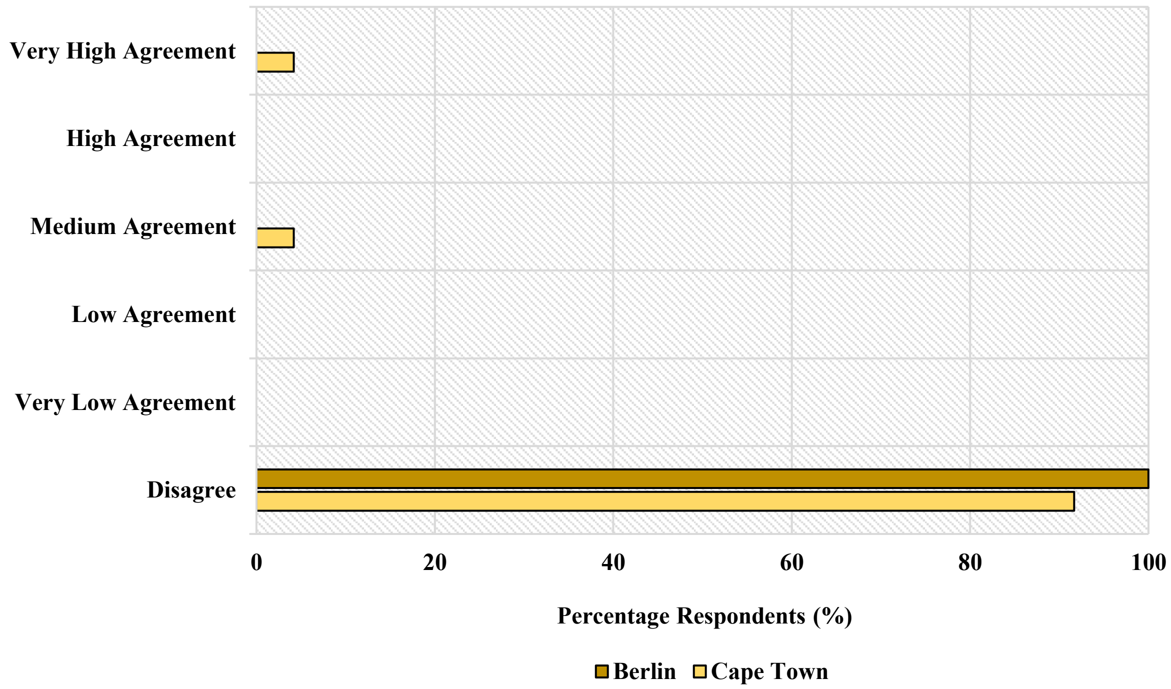


Figure 5.10. Questionnaire responses when asked whether respondents directly benefit from livestock (for e.g. through direct consumption of the animal or its by-products) in community gardens.

5.3.1.2. Raw materials

Wood and timber yield (tons per hectare) are common indicators relating to raw material provisioning services and used in this study (Egoh et al., 2012).

During field surveys in ***Cape Town*** and ***Berlin***, no wood or timber collections or stocks were visible in any of the community gardens assessed. Comparatively, questionnaire respondents were asked whether the garden provided any raw materials such as wood or timber (Q.6) and from which they derived benefit (Q.7). Responses echoed a perceived low capacity for community gardens in both cities to provide raw materials as 100% of the respondents in ***Cape Town*** and 77% in ***Berlin*** felt no such raw materials were found in community gardens (Figure 5.11). Only 5% of the questionnaire participants in ***Berlin*** were in very high agreement and 5% in high agreement that community gardens provided them with raw materials which they could use and benefit from.

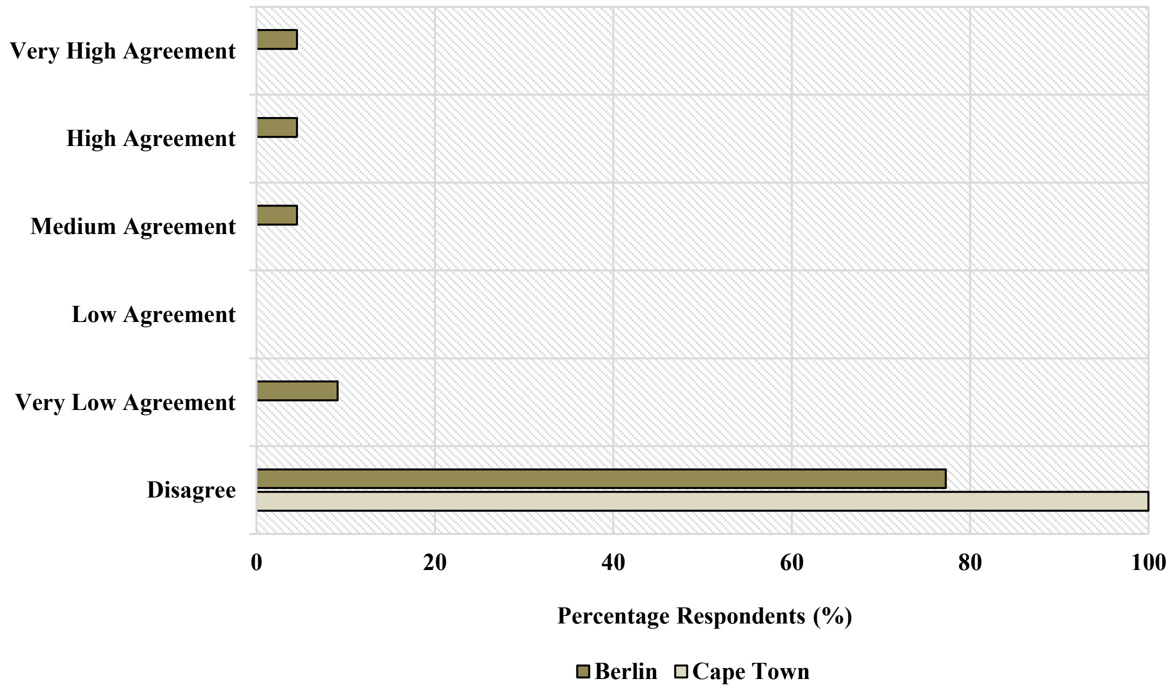


Figure 5.11. Questionnaire responses when asked whether community gardens provided any raw materials such as wood or timber from which respondents derived benefit.

5.3.1.3. Fresh water supply

The indicator used to make inferences about fresh water supply was **total water resources capacity**, where the total capacity of fresh water resources (litres) per community garden area was calculated and used as a proxy to illustrate potential capacity for fresh water supply. In addition, the **number of fresh water resources** and **number of water collection tanks** per garden area were counted (Egoh et al., 2012; Speak et al., 2015). Also shown is the water usage per month (kl) to assess whether the provisioning of fresh water in the community gardens was able to meet individual needs.

Full lists of *fresh water resources* in individual ***Cape Town*** gardens are shown in Table D7 in Appendix D. It must be noted that all gardens had access to fresh water from municipal taps, however tapped water use was severely limited because of restrictions enforced by the municipality due to extreme drought (City of Cape Town, 2017b). Three gardens in **Cape Town** had on-site fresh water sources other than tapped municipal water – Khulisa Streetscape Community Garden B (mountain spring), Woodstock Peace Garden (borehole) and Kronendal Flower Garden (borehole). Six gardens actively collected rainwater through installed tank

apparatus, however eight gardens had water collection tanks as two gardens stored water pumped from their fresh water sources. This resulted in 62% of community gardens in ***Cape Town*** having water collection tanks with a total capacity of 101500 litres when full. A total of 17 water collection tanks were counted across the whole community garden area of 2.271 ha, which translates to 8 water tanks per hectare and an average tank capacity of 7808 litres.
Figure 5.12 shows a comparison of tank total fresh water capacity and average monthly water usage for community gardens in ***Cape Town***. Assuming all rainfall connected to tanks is collected and based on the exclusion of tapped fresh water services supplied by the municipality because of drought-induced water restrictions, six of the 13 community gardens used more water than their tanks had capacity to provide thus showing a greater reliance on municipal supplied water to maintain their gardening needs (SWVCG, OZCF, CMCCG, KSCG_A, KSCG_B, CRCHG). Five gardens had enough fresh water provisioned by their tank capacity to ensure their demand per month was met (ANOCG, WPG, OJSG, SFL, KFG). Two gardens did not have available data on garden water usage (VOCVG and CVOFG) - please refer to Table 5.3 for ***Cape Town*** community garden abbreviations used throughout the results section.

Full lists of *fresh water resources* in individual ***Berlin*** gardens are shown in Table D8 in Appendix D. All gardens had access to municipal tapped water and only one garden had an on-site fresh water source other than tapped municipal water – Kiezgarten Fischerstraße (well). Ten gardens (77%) collected water in tanks with a total fresh water capacity of 27420 litres when full. A total of 42 water collection tanks were counted across the whole community garden area of 3.258 ha, which translates to 13 water tanks per hectare and an average tank capacity of 2109 litres. Figure 5.13 shows a comparison of tank total fresh water capacity and average monthly water usage for community gardens in ***Berlin***. Alternative to ***Cape Town***, all ***Berlin*** gardens had a heavy reliance on tapped water and rainfall, and almost all did not monitor their water usage because of the abundant availability of municipal water and adequate rainfall. All gardens felt that tapped water and rainfall were more than sufficient to meet their water needs each month, and accordingly, based on tapped water and rainfall availability, all community gardens in ***Berlin*** had a high capacity for the provisioning of fresh water ecosystem services. Based on the exclusion of tapped fresh water services supplied by the municipality and assuming all rainfall connected to tanks is collected, two community gardens in Berlin had enough fresh water provisioned by their tank capacity to ensure their demand per month was met (LSG, KLG) while the other 11 gardens had an unknown capacity to provide fresh water ecosystem services to meet their needs due to unavailable data - please refer to Table 5.4 for ***Berlin*** community garden abbreviations used throughout the results section.

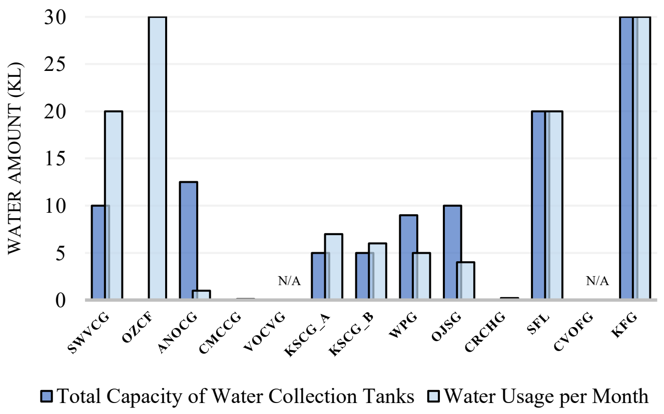


Figure 5.12. Comparison of tank total fresh water capacity (kl) and average monthly water usage (kl) for community gardens in Cape Town. Average monthly water usage data were not available for VOC Vegetable Garden and Constantia Village Organic Food Garden.

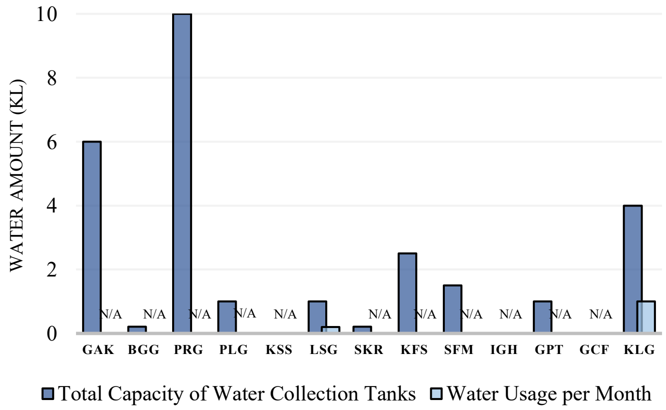


Figure 5.13. Comparison of tank total fresh water capacity (kl) and average monthly water usage (kl) for community gardens in Berlin. Average monthly water usage data were not available for almost all community gardens except Lichtenberger Stadtgarten and Klunkergarten.

Comparison of fresh water resource data shows marked differences in the availability of municipal water in each city. While all gardens in both cities had access to tapped water, the use of this was severely limited in ***Cape Town*** due municipal restrictions because of drought conditions in the city, whereas this was abundant and readily available in ***Berlin***. Moreover, because of the drought, while ***Cape Town*** had fewer water collection tanks, they were generally of bigger capacity than those in ***Berlin***, and ***Cape Town*** gardens had rigorous water usage accounting because of the extended dry period. This was contrary to ***Berlin*** where the monitoring of the amount of water used was of little concern to gardens (Tables D7 – D8 Appendix D). An interesting outcome is that 77% of ***Berlin*** community gardens collected rainfall and water in tanks compared to 62% in ***Cape Town*** which is surprising considering the huge difference in water availability in both cities.

Opinions gathered from the questionnaire regarding the perceived provisioning of fresh water in community gardens were split. When asked about fresh water resource presence in the garden (Q.8), a majority of respondents in both cities (75% in ***Cape Town*** and 50% in ***Berlin***) disagreed that any fresh water resources (other than municipal tap water) were present in the garden, while 17% of respondents in ***Cape Town*** and 18% in ***Berlin*** very highly agreed that there were fresh water resources available (Figure 5.14). These findings are in line with the quantitative data as a total of four fresh water resources others that tapped water were recorded across all gardens in ***Cape Town*** and ***Berlin***. This advocates that in the absence of municipal provided fresh water, the capacity for community gardens in both cities to provide fresh water is low.

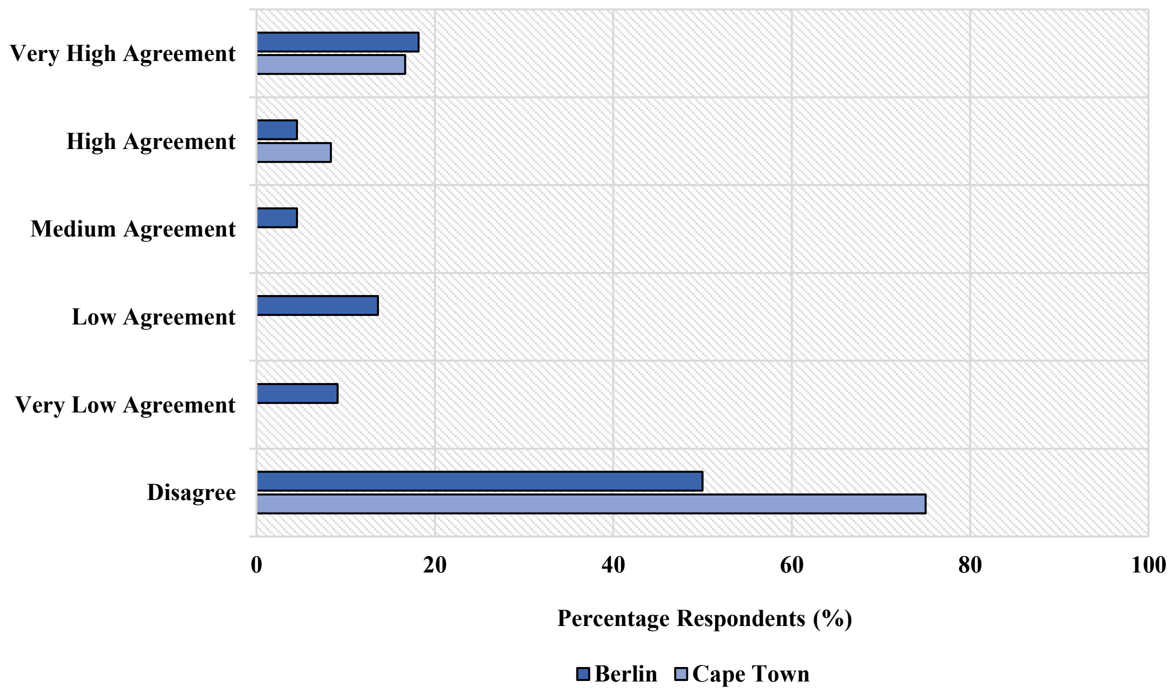


Figure 5.14. Questionnaire responses when asked whether any fresh water resources (for e.g. ponds, lakes, reservoirs) were present in community gardens.

5.3.1.4. Medicinal resources

The indicator used to make inferences about medicinal resources was **medicinal species richness** was used as a proxy to illustrate the community gardens capacity for provisioning this ecosystem service (Clarke and Jenerette, 2015).

Full lists of species with medicinal properties are shown in Tables D20 for ***Cape Town*** and D23 for ***Berlin*** in Appendix D (shown as those species highlighted in green in species lists). In ***Cape Town*** gardens, a total of 156 vascular plant species were recorded with 52 species having medicinal properties (33%) (Figure 5.15). In ***Berlin***, a total of 320 vascular plant species were recorded with 57 species having medicinal properties (18%) (Figure 5.16).

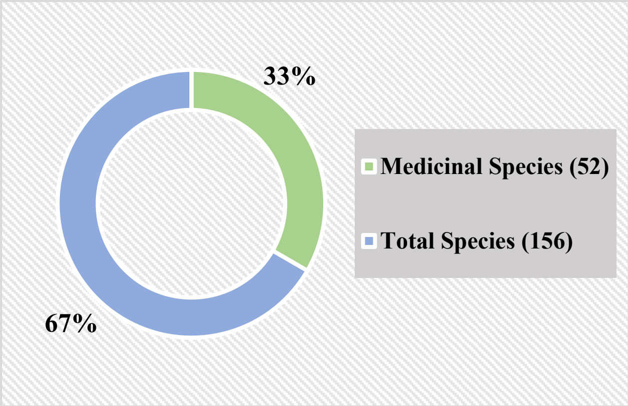


Figure 5.15. Medicinal species as a percentage of total vascular plants species number for Cape Town community gardens.

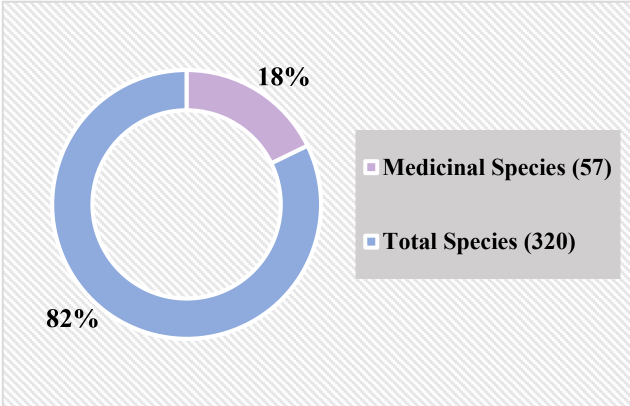


Figure 5.16. Medicinal species as a percentage of total vascular plants species number for Berlin community gardens.

While a number of species in both cities had medicinal attributes, almost none were grown explicitly for this quality. The majority of these were grown for the purposes of education and used as a tool to illustrate the historical and traditional medical uses they had rather than for direct use. In ***Cape Town***, this was especially the case in the VOC vegetable garden, Observatory Junior School garden and Soil for Life garden where a high number of medicinal species are observed. In ***Berlin***, Prinzessinnengarten and Interkultureller Gemeinschaftsgarten Himmelbeet had a number of in-garden educational activities on medicinal plants.

Questionnaire responses on medicinal plants in the gardens were markedly different between ***Cape Town*** and ***Berlin*** participants. When asked about whether certain crops or plants grown in the garden had any additional uses (e.g. medicinal uses) (Q.3), opinions were split. In ***Cape Town***, a majority of respondents disagreed (54%) or were in low (4%) or very low (12%) agreement (Figure 5.17). However, in ***Berlin*** many participants perceived additional medicinal benefits to plants as 41% were in very high agreement and 27% in high agreement (Figure 5.17). This is an interesting result considering a higher percentage of plant species with medicinal properties was recorded in ***Cape Town*** than compared to ***Berlin*** (Figures 5.15 – 5.16). This suggests that although educational activities around plant medicinal uses were a focus in both cities rather than direct use, ***Berlin*** gardeners had more knowledge of, and/or experience with those plants from which medicinal benefit could be derived.

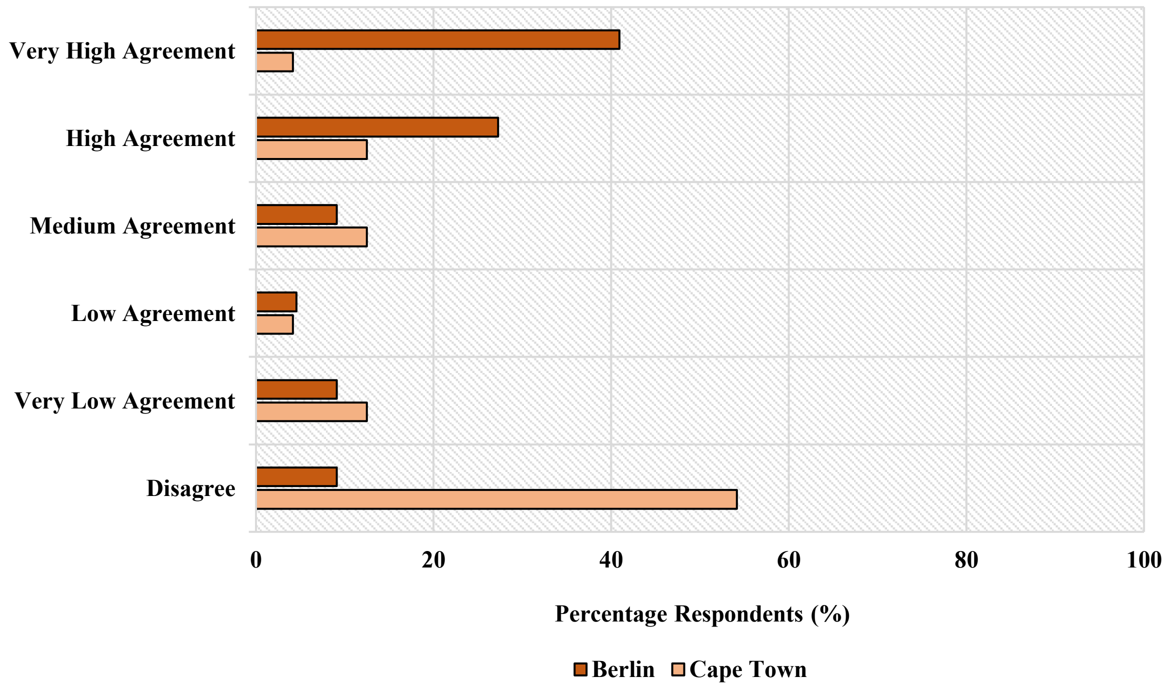


Figure 5.17. Questionnaire responses when asked if certain crops in the garden had additional uses such as being used for medicine.

5.3.2. Regulating services

Regulating services inferred from indicators in this research include: *local climate regulation*, *local air quality regulation*, *moderation of extreme events*, *water flow regulation and runoff mitigation* and *erosion prevention and maintenance of soil fertility*.

5.3.2.1. Local climate regulation

The indicators used to make inferences about local climate regulation were: tree canopy area where tree canopy areas were digitised using aerial photos and calculated as a percentage of the total garden area (%) to be used in carbon sequestration and storage calculations (Rowntree and Nowak, 1991). These percentages are used to infer **shaded area** under tree canopy (%) to illustrate the community gardens capacity for regulating/maintaining local climates by cooling (Bastian et al., 2012; Dobbs et al., 2014). In addition, **landcover** was used as a proxy to calculate the vegetated area of the garden to show the gardens' capacities for energy/heat absorption and evaporative cooling from transpiration (Egoh et al., 2012).

Shading by trees

Full lists of *digitised tree canopy cover* estimated for individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D12 - D13 in Appendix D. In ***Cape Town***, total shaded area occurring underneath tree canopies was estimated at 5343 m^2, which corresponded to 24% of the total garden area (22710 m^2) assessed. In ***Berlin***, total shaded area was estimated at 8926 m^2 (27%) of the total garden area assessed (32575 m^2). Comparison of the data collected shows that, on average, ***Cape Town*** had less percentages of shaded areas within community gardens with the ability to cool localised temperatures than in ***Berlin*** gardens (Figure 5.18). Moreover, ***Berlin*** gardens had a higher overall percentage area of shaded area by tree canopy (31%) compared to ***Cape Town*** (16%).

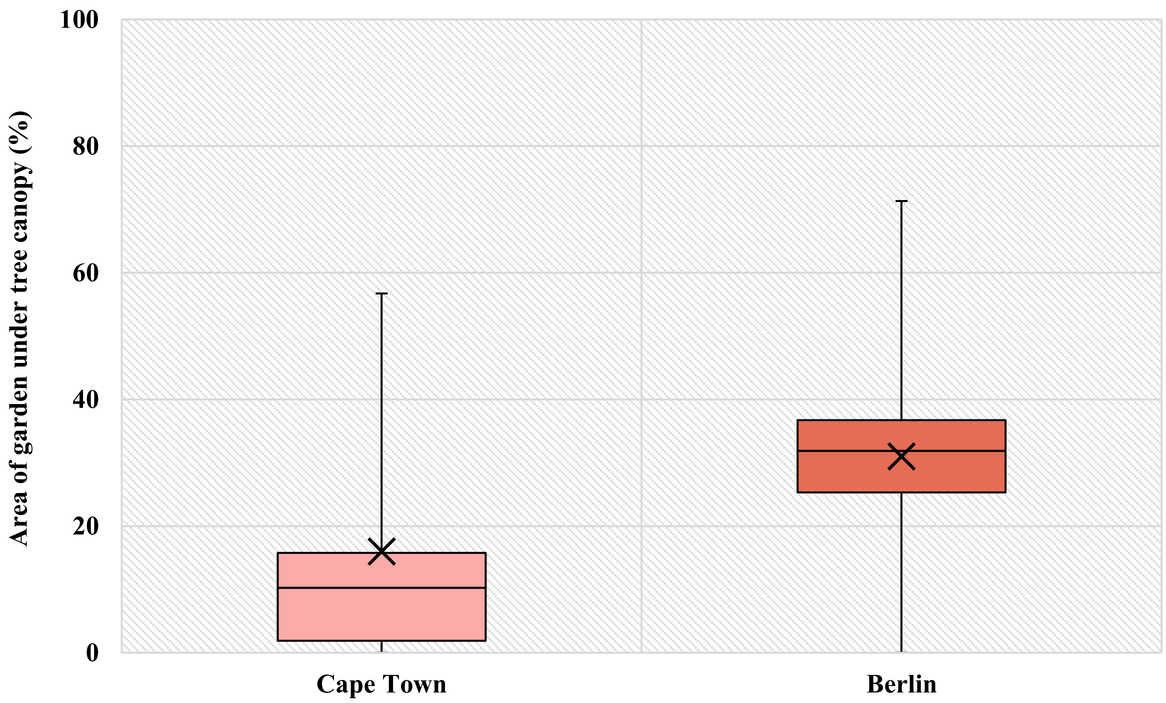


Figure 5.18. Shaded area under tree canopy (%) in community gardens in Cape Town and Berlin (x denotes the mean).

Carbon sequestration and storage by trees

Equations derived by Rowntree and Nowak (1991) were used to estimate total carbon storage and annual carbon sequestration from urban trees using percentage tree cover that is digitised from aerial photos. This method provides generalised and conservative estimates of carbon stored and sequestered per unit area of tree crown in the absence of equivalent empirical tree data in a particular location (Rowntree and Nowak, 1991; Whitford et al., 2001).

Eqn 1. Total Carbon Storage (tons Carbon per hectare) = [1.063 x % digitised tree cover]
Eqn 2. Annual Carbon Sequestration (tons Carbon per hectare per year) = [8.275 x 10^{-3} x % digitised tree cover]

These equations resulted from Rowntree and Nowak's (1991) study on carbon storage and sequestration dynamics of urban trees across metropolitan Chicago. They have been successfully applied elsewhere in number of urban areas in the UK (Whitford et al., 2001; Tratalos et al., 2007) and Australia (Dobbs et al., 2014).
Full lists of digitised tree cover, total carbon stored (t C) and total carbon sequestered (t C per year) estimated for individual community gardens in Cape Town and Berlin are shown in Tables D12 - D13 in Appendix D.

Total percentage tree cover digitised for all ***Cape Town*** community gardens was 24 % (Table 5.5).
Total Carbon Storage (t C ha^{-1}) = [1.063 x 24] = 25 t C ha^{-1} for community gardens in Cape Town.
Annual Carbon Sequestration (t C ha^{-1} yr^{-1}) = [8.275 x 10^{-3} x 24] = 0.195 t C ha^{-1} yr^{-1} for community gardens in Cape Town.

Total percentage tree cover digitised for all ***Berlin*** community gardens was measured at 27% (Table 5.5).
Total Carbon Storage (t C ha^{-1}) = [1.063 x 27] = 29 t C ha^{-1} for community gardens in Berlin.
Annual Carbon Sequestration (t C ha^{-1} yr^{-1}) = [8.275 x 10^{-3} x 27] = 0.227 t C ha^{-1} yr^{-1} for community gardens in Berlin.

Based on Rowntree-Nowak equations (Table 5.5), *total carbon storage* was estimated at 25 tons per hectare in ***Cape Town*** gardens and 29 tons per hectare in ***Berlin***. *Annual carbon sequestered* was estimated at 0.195 tons per hectare per year in ***Cape Town*** and 0.227 tons per hectare per year in ***Berlin***.

Table 5.5. Carbon storage (t C ha^{-1}) and annual carbon sequestration (t C ha^{-1} yr^{-1}) estimates for Cape Town and Berlin community gardens as calculated by Rowntree and Nowak (1991) equations.

	Proportion of garden area under tree canopy (%)	Carbon storage (t C ha^{-1})	Carbon sequestered (t C ha^{-1} yr^{-1})
Cape Town	24	25,01	0,1947
Berlin	27	29,13	0,2267

Carbon storage and sequestration estimates for individual gardens show a number of outliers in each city (Figures 5.19 – 5.20). In ***Cape Town***, Khulisa Streetscape Community Garden B and Soil for Life had high tree canopy percentages of 57% and 48% respectively (Table D12 – Appendix D). In ***Berlin***, Prinzessinnengarten and Gemeinschaftsgarten Spreeacker had high tree canopy percentages of 71% and 69% respectively (Table D13 – Appendix D). These inordinately high percentages influenced the overall average estimates of total carbon storage and sequestration significantly. Excluding these outliers, total carbon storage is re-estimated at 12 tons per hectare in ***Cape Town*** and 19 tons per hectare in ***Berlin***, and annual carbon sequestered at 0.099 tons per hectare per year in ***Cape Town*** and 0.149 tons per hectare per year in ***Berlin***.

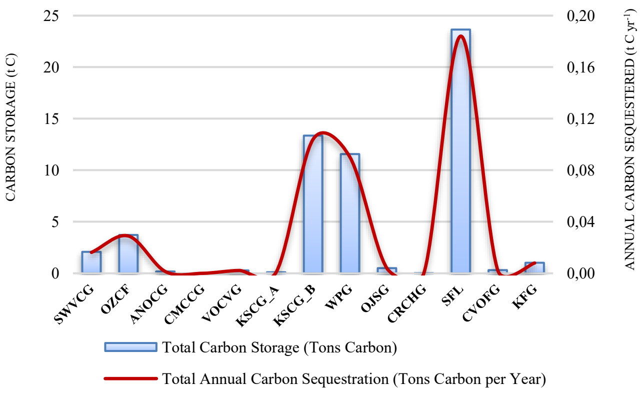


Figure 5.19. Estimated carbon storage (t C) and annual carbon sequestration (t C yr^{-1}) for Cape Town community gardens.

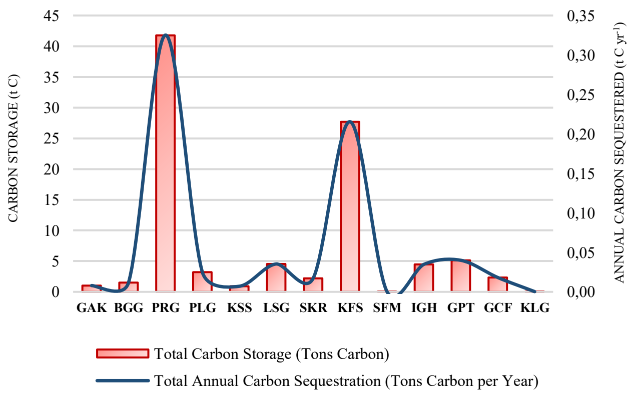


Figure 5.20. Estimated carbon storage (t C) and annual carbon sequestration (t C yr^{-1}) for Berlin community gardens.

Vegetated area

Full lists of vegetated area measured in individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D14 - D15 in Appendix D. Total *vegetated area* occurring in ***Cape Town*** community gardens was measured at 20179 m^2 of the total garden area 22710 m^2 (89%) and in ***Berlin***, 25171 m^2 of the total garden area of 32575 m^2 (77%). Vegetated surfaces cover a high percentage of community gardens in both cities (average garden area covered by vegetated surfaces is 87% in ***Cape Town*** and 79% in ***Berlin***) (Figure 5.21) and therefore these spaces have a high capacity for energy absorption and evaporative cooling from transpiration (evapotranspiration). Vegetated surfaces influence the local climate of neighbourhoods compared to surrounding urban artificial surfaces and groundcover that would otherwise cause local heat island effects. This is especially salient when taking into account the commercial land-use and artificial landcover types of the immediate surrounding environment of these community gardens.

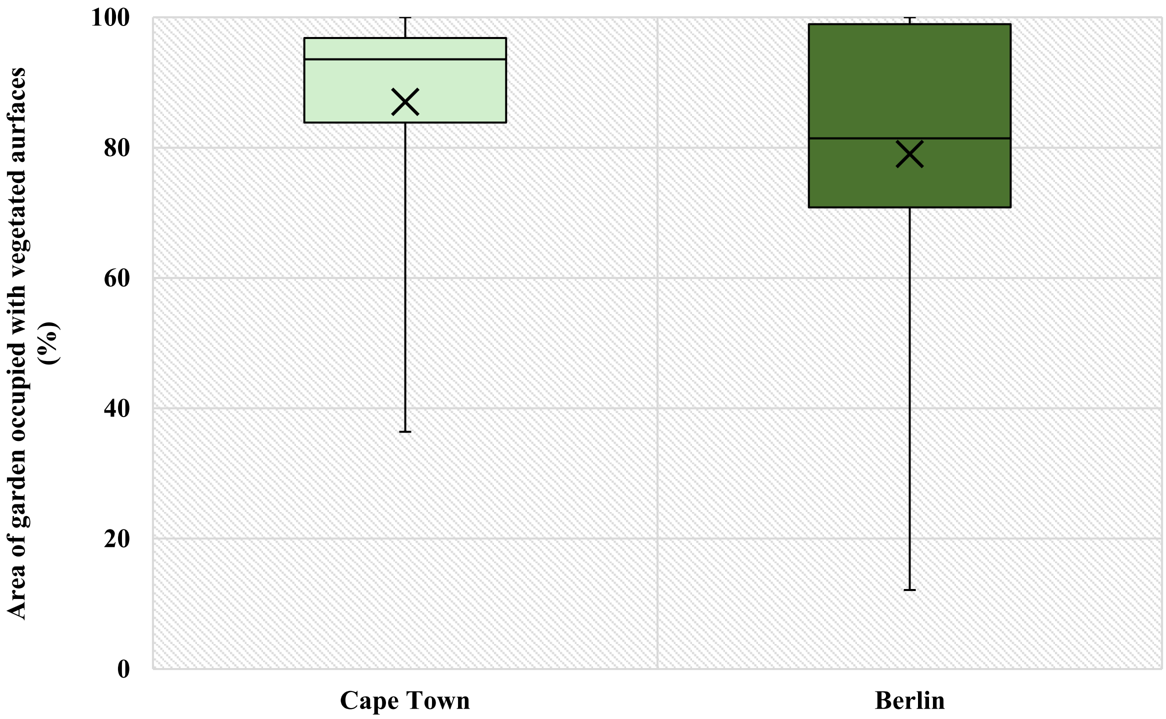


Figure 5.21. Area of vegetated surfaces (%) in community gardens in Cape Town and Berlin (x denotes the mean).

Qualitative results collected from the questionnaire suggest that people in both cities perceive community gardens to some influence on regulating local temperatures. Respondents were asked whether they found the local temperature of the garden to be cooler compared to other non-green areas in the city (Q.13). In ***Cape Town***, 46% of the respondents very highly agreed and 21% highly agreed, while in ***Berlin***, 18% were in very high agreement, 18% in high agreement and the majority of respondents in medium agreement (41%). Only 4% in ***Cape Town*** and 5% in ***Berlin*** disagreed that cooler temperatures were experienced in the community garden areas (Figure 5.22). Overall, those people interacting with community gardens in both cities felt that a distinguishable temperature difference between the garden area and surrounding artificial urban surfaces/areas could be felt, thus local climate regulation services were perceived to be present.

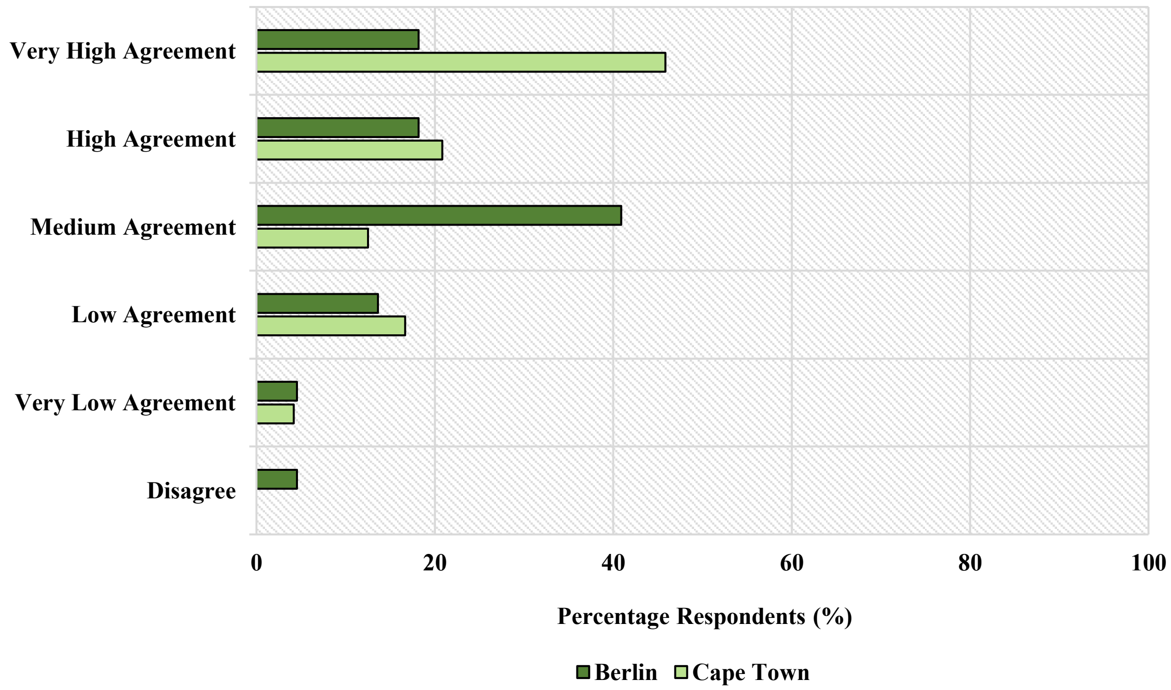


Figure 5.22. Questionnaire responses when asked whether respondents found the local temperatures in community gardens to be cooler than other non-green areas in the city.

5.3.2.2. Local air quality regulation

The indicator **tree density,** where the tree density was calculated per total garden area in each city, was used as a proxy to illustrate community gardens' capacities for regulating local air quality (Egoh et al., 2012; Speak et al., 2015). This is because trees sequester carbon dioxide (CO_2) and other gaseous air pollutants and, through the process of photosynthesis release oxygen back into the atmosphere.

Full lists of tree numbers counted in community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D16 - D17 in Appendix D and are categorised according to height classes. In ***Cape***

Town, a total of 219 trees were counted over a total garden area of 2.271 ha, with a tree density of 96 trees per ha (Table 5.6). In ***Berlin***, a total of 125 trees were counted over a total garden area of 3.258 ha, with a tree density of 38 trees per ha (Table 5.6). At first glance, it appears that ***Cape Town*** has a much higher tree density than ***Berlin***, but this is misleading and it is necessary to split trees into height groups in order to look at patterns more thoroughly. Moreover, it is necessary to establish whether trees are deciduous or evergreen as this has direct impact on trees losing leaves and thus their effect on local air quality regulation.

Table 5.6. Tree densities for Cape Town and Berlin community gardens.

	Number of trees	**Total garden area (ha)**	**Tree density (trees per ha)**
Cape Town	219	2,271	96
Berlin	125	3,258	38

A number of interesting patterns are shown in Figures 5.23 and 5.24. First, ***Cape Town*** gardens have a majority of trees in the lower height bracket (0.0 – 4.9 m) (56%) compared to ***Berlin***, where most trees are in the largest height bracket (>10 m) (70%). Second, 65% of the tree species recorded in ***Cape Town*** are evergreen and therefore keep their foliage all year, while 98% of the counted trees in ***Berlin*** are deciduous and lose their leaves in winter (Tables D16 - D17 Appendix D). Overall, it was found that ***Cape Town*** gardens had many small trees, both deciduous and evergreen with smaller crown sizes (Figure 5.23), while a large majority of trees in ***Berlin*** were greater than 10 meters high and deciduous with larger crown sizes (Figure 5.24).

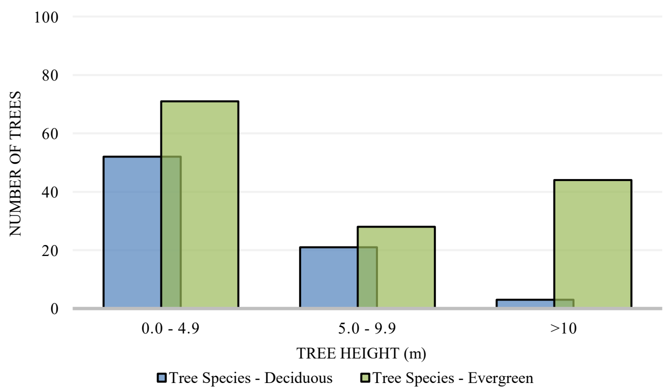


Figure 5.23. Number of deciduous and evergreen trees counted in Cape Town community gardens organised according to size classes.

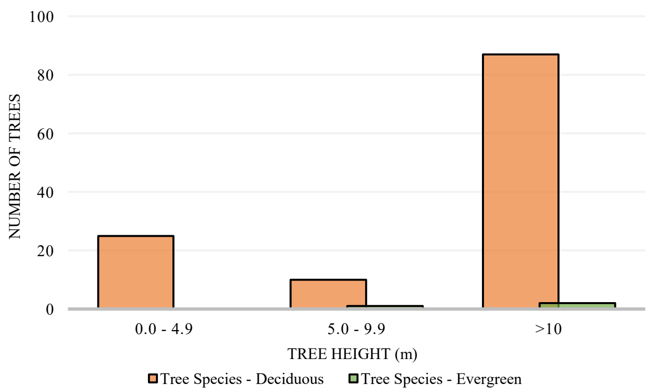


Figure 5.24. Number of deciduous and evergreen trees counted in Berlin community gardens organised according to size classes.

Glick et al. (2016) show measured tree densities (trees per hectare) from major global biomes. From their study, all environments averaging below 200 trees per hectare are standard densities expected in desert or semi-desert areas. Temperate and tropical grasslands are shown to average 300 trees per hectare and a variety of forest types with around more than 800 trees per hectare. With tree density values of 96 and 38 trees per hectare for ***Cape Town*** and ***Berlin*** respectively, and based on the assumptions that the bigger the tree the larger the tree canopy volume for gaseous pollutant extraction, it can be said that the trees in community gardens in these cities likely contribute in a low capacity to overall local air quality regulation in each city.

Questionnaire respondents were asked whether they found the air in community garden areas to be cleaner than other non-green areas in the city (Q.14). In ***Cape Town***, 46% of respondents very highly agreed, 25% highly agreed and 17% were in medium agreement. In ***Berlin*** gardens, 18% of respondents were in very high agreement, 41% in high agreement, 18% in medium agreement. Only 4% in ***Cape Town*** disagreed that cleaner air was experienced in the community garden areas (Figure 5.25). Generally, those people interacting with community gardens in both cities therefore perceived experiencing a degree of local air quality regulation services in these spaces

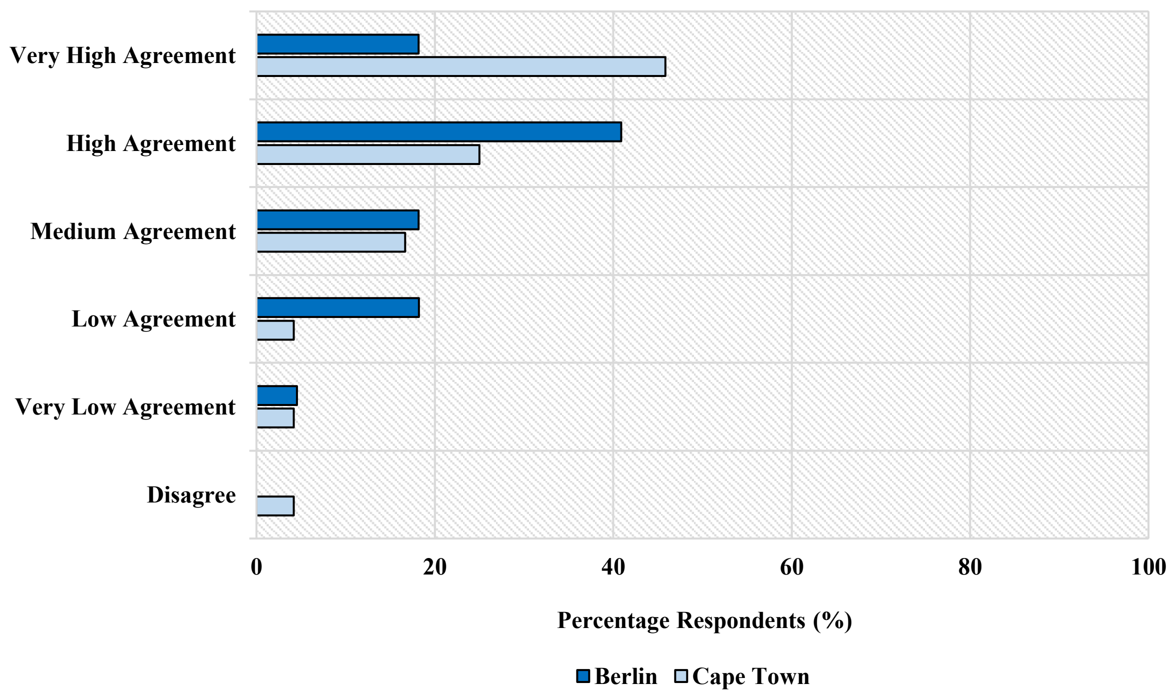


Figure 5.25. Questionnaire responses when asked whether respondents found the air in community gardens to be cleaner than other non-green areas in the city.

5.3.2.3. Moderation of extreme events: rain and wind storms, flood prevention

The indicator used to make inferences about moderation of extreme events was **tree density** where the number of trees was measured per individual garden area and used as a proxy to illustrate the community gardens capacity rainfall and wind interception (Gómez-Baggethun and Barton, 2013). This is because tree canopies intercept extreme events like storms and moderate the energy of intense rainfall or wind. This is particularly true for larger trees with big canopy cover and so it is important to consider tree size in this regard. In addition, the vegetated area of the garden can be used as a proxy to show the gardens capacity for attenuating flood runoff in extreme storm or flood events (shown already in section 5.3.2.1. Local climate regulation).

Full lists of *tree numbers* counted in individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D18 - D19 in Appendix D and illustrate the number of trees per height category grouped into small (0.0 - 4.9 m), medium (5.0 - 9.9 m) and large (>10 m). Based on the assumption that the larger the tree the bigger the canopy volume and thus the higher rainfall interception potential, in ***Cape Town*** gardens, trees categorised as small with low rainfall and wind interception capacity had a density of 54 trees per hectare, trees with medium interception capacity had a density of 21 trees per hectare and trees with high rainfall interception capacity had a density of 22 trees per hectare (Table D18– Appendix D). In ***Berlin*** gardens, trees categorised as small with low rainfall and wind interception capacity had a density of 8 trees per hectare, trees with medium interception capacity had a density of 3 trees per hectare and trees with high rainfall interception capacity had a density of 27 trees per hectare (Table D19 – Appendix D). ***Cape Town*** community gardens therefore mainly had small trees with a modest capacity for rainfall interception and moderation wind energy (Figures 5.26) while ***Berlin*** gardens housed, in general, larger trees more adept to the moderation of such weather extremes (Figure 5.27). Furthermore, Figure 5.21 shows that ***Cape Town*** and ***Berlin*** community gardens had a high percentage of the total garden area covered by vegetated surfaces. Therefore, community garden spaces in both cities have capacity for water infiltration and moderating flood water attenuation in extreme events compared to artificial surfaces surrounding the garden areas in each city.

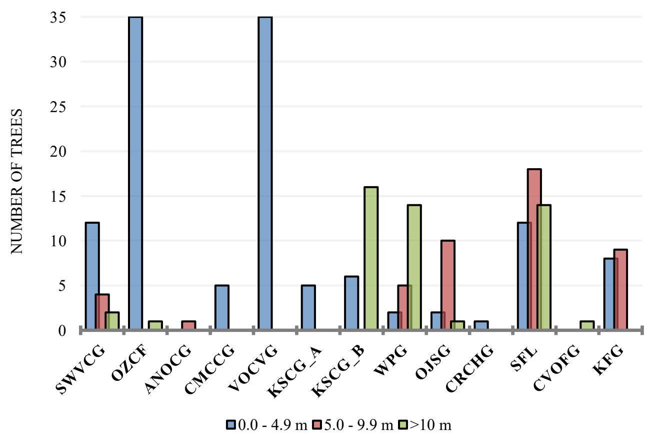


Figure 5.26. Number of trees per height category counted in Cape Town community gardens.

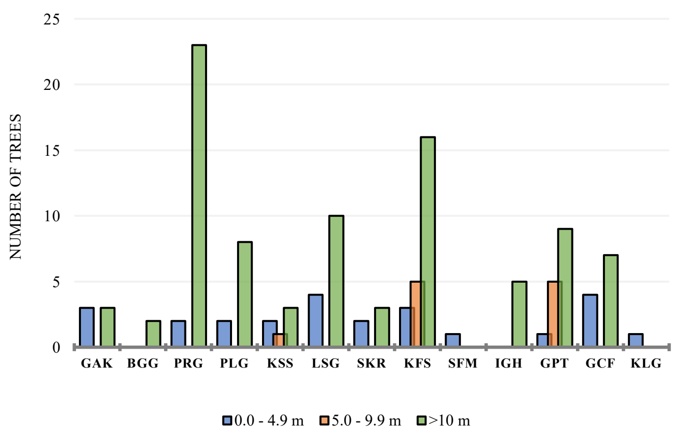


Figure 5.27. Number of trees per height category counted in Berlin community gardens.

Questionnaire responses regarding perceived benefits of garden spaces against extreme weather events showed no apparent pattern between ***Cape Town*** and ***Berlin*** participants. Respondents were asked whether they considered the garden and its vegetation to act as a buffer or protection against the impacts of extreme events like storms, flooding or strong winds (Q.15). In ***Cape Town***, opinions varied as 33% of respondents in very high agreement and 21% in high agreement, while 21% were in low agreement and 13% in very low agreement (Figure 5.28). In ***Berlin***, most participants were in low (27%) and medium (41%) agreement (Figure 5.28). This is an interesting result considering ***Berlin*** gardens generally had larger sized trees, and thus greater buffer protections against extreme events, than those in ***Cape Town***. Possible explanations for these differences of opinions include:

1. ***Cape Town*** gardens have, on average, higher percentages of vegetated surfaces compared to ***Berlin*** gardens (Figure 5.21), so questionnaire respondents in ***Cape Town*** could perceive community gardens to be more effective at water run-off attenuation and flood prevention when it does rain than ***Berlin*** respondents found in their experiences.
2. Alternatively, as ***Cape Town*** is currently suffering from extreme drought, severe weather events of intense rainfall and flooding are not frequently experienced in the city. This could foster the false perception of respondents in ***Cape Town*** that the gardens are effective at moderating intense rainfall and flood water run-off because in their experience, they have not experienced or witnessed such extreme events in the garden (i.e. garden users have falsely perceived the absence of extreme weather-related detriments are due to garden attributes rather than climate-related drought conditions).

3. Over the summer months, intense summer storms were frequently experienced in ***Berlin*** that resulted in flooding in parts of the city, including some of the gardens where field work was conducted (this was directly observed by the author). The close time period between these storms and respondents answering the questionnaire could have influenced their perceptions on the effectiveness of community gardens in dealing with strong winds, rainfall intensity and flood water attenuation.

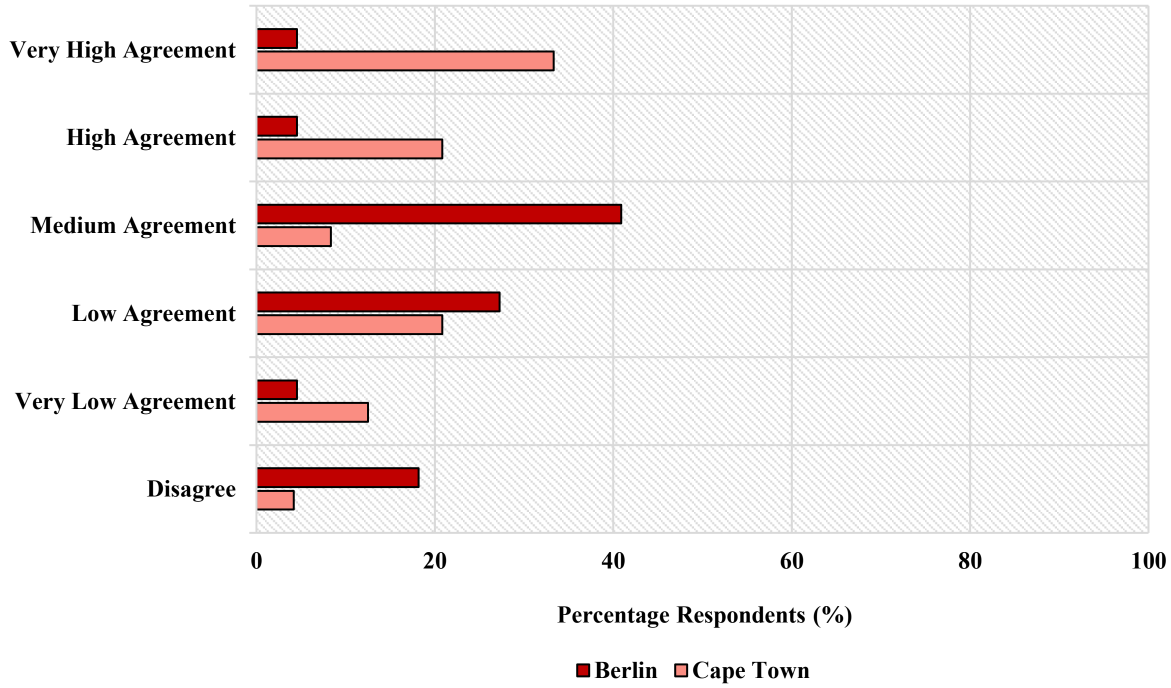


Figure 5.28. Questionnaire responses when asked whether respondents considered the garden and its vegetation to act as a buffer and protection against impacts of extreme events such as storms, flooding or wind.

5.3.2.4. Water flow regulation and runoff mitigation

The indicator used to make inferences about water flow regulation and runoff mitigation was **impermeable landcover**, where the area of sealed surfaces compared to the total garden area (%) was used as a proxy to illustrate the community gardens capacity for water infiltration into the ground and runoff mitigation (Speak et al., 2015; Cabral et al., 2017). In addition, it is recognised that not all sealed surfaces are completely impervious, so those surfaces categorised as sealed were scored according to a decimal scale of run-off coefficients for artificial surfaces as set out by the German Institute for Standardization (DIN, 2016) who classify German building standards (DIN 1986-100: 2016-09) for drainage systems in buildings and on land.

DIN 1986-100: 2016-09 uses a decimal scale measure between 0 and 1 of run-off coefficients of built-up area ground cover types, where 0 represents 100% infiltration and 1 represents 0% infiltration (Table D9 – Appendix). This scale is used to infer a decrease in groundwater recharge in built-up areas based on surface types. All impermeable ground cover types recorded in each garden were given DIN values and these were averaged for one value per garden.

Full lists of *impermeable surface area* measured in individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D10 - D11 in Appendix D. In ***Cape Town*** gardens, a total sealed area of 2531 m^2 from 22710 m^2 (11%) was measured, with artificial surfaces tending to have overall high average DIN coefficients denoting high run-off capacities (Figure 5.29). In ***Berlin***, a total sealed area of 7404 m^2 from 32575 m^2 (23%) was measured, and similar to ***Cape Town*** gardens, these surfaces generally had high DIN coefficients and thus low infiltration capacities (Figure 5.30). ***Berlin*** gardens had the most buildings, paved (asphalt) and bricked walkways and concreted areas used for recreational and entertainment activities, while ***Cape Town*** gardens had fewer buildings, mostly mulched or bare-sand walkways and designated entertainment or recreational areas in the garden were rare.

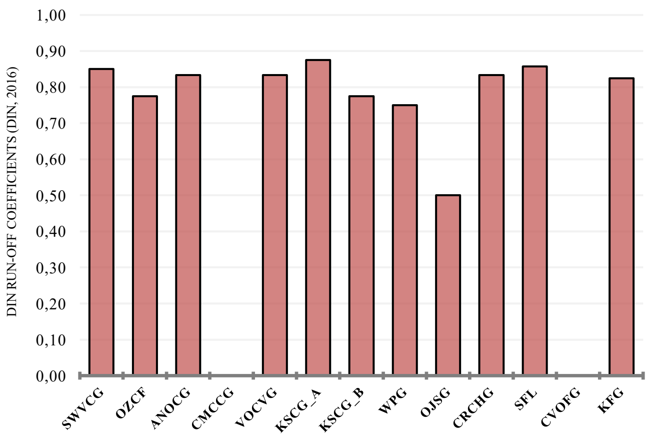


Figure 5.29. Average DIN (2016) run-off coefficients for all artificial surfaces observed in community gardens in Cape Town. A score of 0 denotes the surface is completely permeable (and infiltration is 100%) while a score of 1 denotes the surface is complete impermeable (and infiltration is 0%).

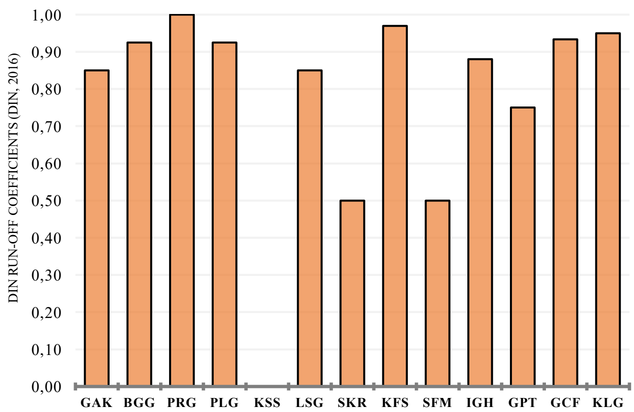


Figure 5.30. Average DIN (2016) run-off coefficients for all artificial surfaces observed in community gardens in Berlin. A score of 0 denotes the surface is completely permeable (and infiltration is 100%) while a score of 1 denotes the surface is complete impermeable (and infiltration is 0%).

Comparison of ***Berlin*** and ***Cape Town*** gardens shows that overall proportions of sealed surfaces are low, with ***Berlin*** gardens having higher variations and average (21%) proportions of sealed surfaces in community gardens compared to ***Cape Town*** (13%) (Figure 5.31). Although both cities had impervious surfaces that on average tended towards being strongly sealed and thus having high potential for surface run-off in those areas, the low percentages of sealed surface areas in gardens of both cities is unlikely to negatively influence water flow regulation and run-off in a significant manner.

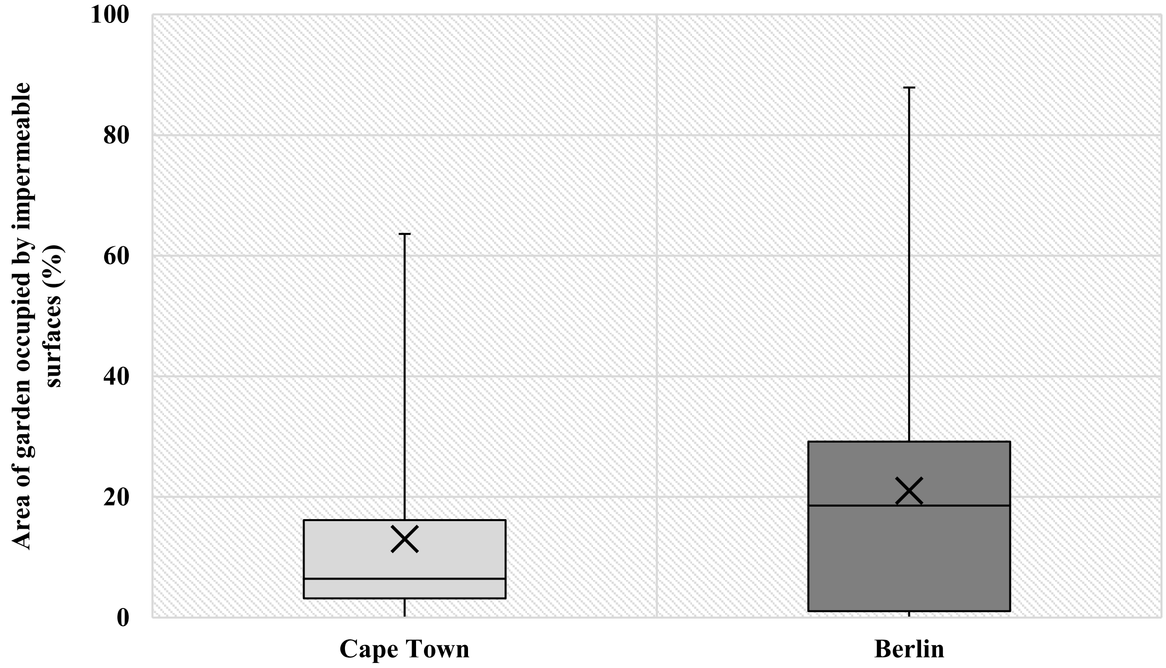


Figure 5.31. Area of sealed surfaces (%) in Cape Town and Berlin community gardens (x denotes the mean).

5.3.2.5. Erosion prevention and maintenance of soil fertility

The indicator used to make inferences about erosion prevention and maintenance of soil fertility was **vegetative cover** where the total vegetative cover (%) was measured per garden area and used as a proxy to illustrate the community gardens capacity for regulating erodibility and soil retention. This is because vegetation and its roots trap and bind soil particles, reducing their susceptibility to erosion and promoting soil stability. In addition, the sealed surface area of the garden (%) can be used as a proxy to show the gardens capacity for water infiltration and thus the gardens capacity for maintaining optimum soil moisture content which promotes plant growth. Together this indicator can be used with information on gardens' composting practices to make inferences on its capacity for maintaining an optimum level of soil fertility (Egoh et al., 2012; Speak et al., 2015).

Figure 5.21 illustrates the area of ***Cape Town*** and ***Berlin*** community gardens that is covered by vegetated surfaces. As a reminder, total vegetated area occurring in ***Cape Town*** community gardens was calculated to be 89% and 77% in ***Berlin*** respectively (Table D14 - D15 – Appendix D).

Figures 5.32 – 5.33 illustrate the areas of ***Cape Town*** and ***Berlin*** community gardens that were covered in sealed surfaces and the source of composting used. All community gardens in both cities used organic composting to ameliorate and improve soil fertility and aid plant growth. In ***Cape Town***, seven of the 13 community gardens assessed (54%) had their own on-site areas where organic compost was self-made in the garden, while the other six (46%) used organic compost that was bought or supplied either from a store or third party (Figure 5.32). In ***Berlin***, all community gardens had on-site areas where composting was made and used to ameliorate soil fertility (Figure 5.33). Additionally, ***Cape Town*** and ***Berlin*** gardens generally had low percentages of their total areas covered with sealed surfaces. Coupling these two variables together, community gardens in both cities employed good practices for regulating soil fertility and stability through pervasive organic composting practises, optimum soil moisture levels because of low sealed surface areas and high areas of vegetated surfaces to bind the soil and prevent erosion.

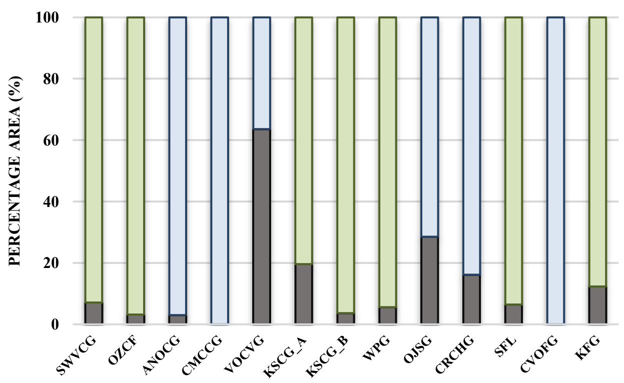


Figure 5.32. Area of impermeable surfaces as a percentage of total garden area (%) for individual community gardens in Cape Town (shown in grey). Gardens illustrated with green gradients are those community gardens that had on-site organic composting areas and used this self-made compost to ameliorate soil fertility. Gardens illustrated with blue gradients are those community gardens that bought organic compost from a store or other source.

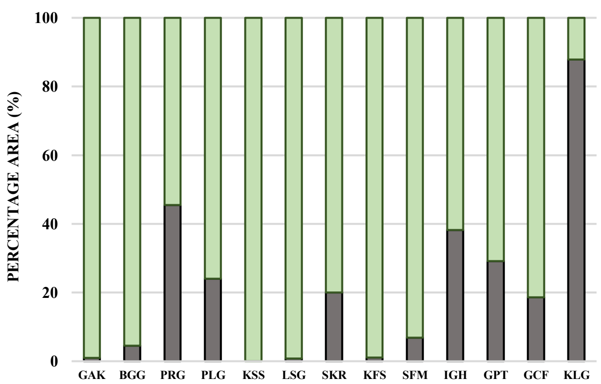


Figure 5.33. Area of impermeable surfaces as a percentage of total garden area (%) for individual community gardens in Berlin (shown in grey). Gardens illustrated with green gradients are those community gardens that had on-site organic composting areas and used this self-made compost to ameliorate soil fertility.

Questionnaire respondents were asked whether they felt the garden and its vegetation prevented erosion and maintained the stability of the soil (Q.16). In ***Cape Town***, opinions were mixed as the majority of participants were in very high agreement (50%) and high agreement (17%), while 21% were in low agreement and 8% disagreed. In ***Berlin*** gardens, opinions were evenly spread, with 27% of respondents in high agreement, 23% in medium agreement and 14% equally spread across each of the low agreement, very low agreement and disagreement categories (Figure 5.34). Results in both cities are mixed and no pattern of opinions is observable at face value. If anything, answers to this question appear person specific and their perceptions of garden benefits to soil stability and against erosion are likely down to their personal knowledge about, and experiences with, such phenomena.

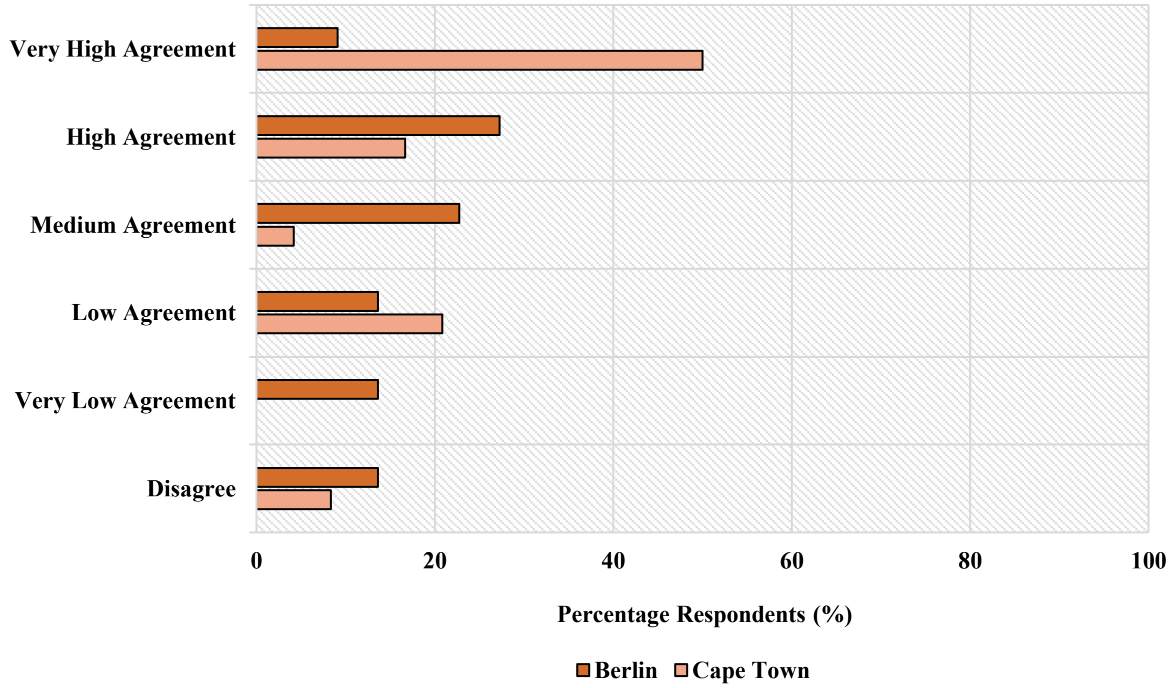


Figure 5.34. Questionnaire responses when asked whether community gardens and their vegetation prevent erosion and maintain soil stability.

5.3.3. Habitat/Supporting services

Habitat/Supporting services inferred from indicators in this research include: *maintenance of genetic diversity*.

5.3.3.1. Maintenance of genetic diversity

Indicators used to make inferences about the maintenance of genetic diversity are **species richness** and **diversity**, where species richness is the total number of different species recorded in community garden areas in both cities, and species diversity is calculated according to the Shannon Diversity Index as a proxy for biodiversity. Both species richness and diversity are important for ecosystem productivity and functioning and consequently, the delivery of ecosystem services (Dobbs et al., 2014; Speak et al., 2015).

<u>Species richness</u>

Full lists of *floral and faunal species* recorded in individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D20 – D25 in Appendix D. In ***Cape Town*** gardens, a total of 156 vascular plants species (spontaneous and ornamental species, excluding edible crops), 35 tree species and 44 faunal species (excluding livestock) were recorded (summarised below in Table 5.7). In ***Berlin***, 320 vascular plants species, 34 tree species and 31 faunal species were recorded (Tables 5.8). Average floral richness per hectare was higher in ***Berlin*** (109 species ha^{-1}) than ***Cape Town*** (84 species ha^{-1}), while average faunal richness per hectare was higher in ***Cape Town*** (19 species ha^{-1}) than ***Berlin*** (10 species ha^{-1}).

Overall patterns of vascular plant species richness were much higher in ***Berlin*** community gardens than in ***Cape Town***, with the average number of vascular plants per garden being significantly higher in Berlin (58) than Cape Town (21) (Figure 5.35) (see Tables D20 and D23 in Appendix D for full lists). Unsurprisingly, ***Berlin*** vascular plants thus belonged to a greater number of families (65) than in ***Cape Town*** (55) (Tables 5.7 – 5.8). In both cities, Asteraceae and Lamiaceae were overwhelmingly the families with the most species occurring (Figure 5.36 – 5.37). Common and well represented species in both cities included companion plants *Calendula officinalis*, *Tagetes spp*, *Lavandula spp*, and a variety of culinary herbs such as *Ocimum basilicum*, *Salvia officinalis*, *Origanum vulgare* and *Mentha spp*. Spontaneous vascular plant species were much more frequently occurring in ***Berlin*** gardens and the low amount of spontaneous flora in ***Cape Town*** gardens is attributable to:

1) The higher intensity of management practices in these ***Cape Town*** gardens compared to ***Berlin*** with respect to weed and spontaneous vegetation removal.
2) The higher proportion of ***Cape Town*** garden areas being used for crop production.
3) The severe drought conditions in ***Cape Town*** which have severely influenced plant growth.

Table 5.7. Floral and Faunal species richness characteristics for community gardens in Cape Town.

Flora		Fauna	
Overall species richness	191	Overall species richness	44
Vascular plant species richness	156	Invertebrate species richness	18
Vascular plant families represented	55	Invertebrate classes represented	1
Tree species richness	35	Vertebrate species richness	26
Tree families represented	21	Vertebrate classes represented	5
Overall species richness per hectare	84	Overall species richness per hectare	19
Average overall species richness (per garden)	15	Average overall species richness (per garden)	3

Table 5.8. Floral and Faunal species richness characteristics for community gardens in Berlin.

Flora		Fauna	
Overall species richness	354	Overall species richness	31
Vascular plant species richness	320	Invertebrate species richness	13
Vascular plant families represented	65	Invertebrate classes represented	3
Tree species richness	34	Vertebrate species richness	18
Tree families represented	13	Vertebrate classes represented	3
Overall species richness per hectare	109	Overall species richness per hectare	10
Average overall species richness (per garden)	27	Average overall species richness (per garden)	2

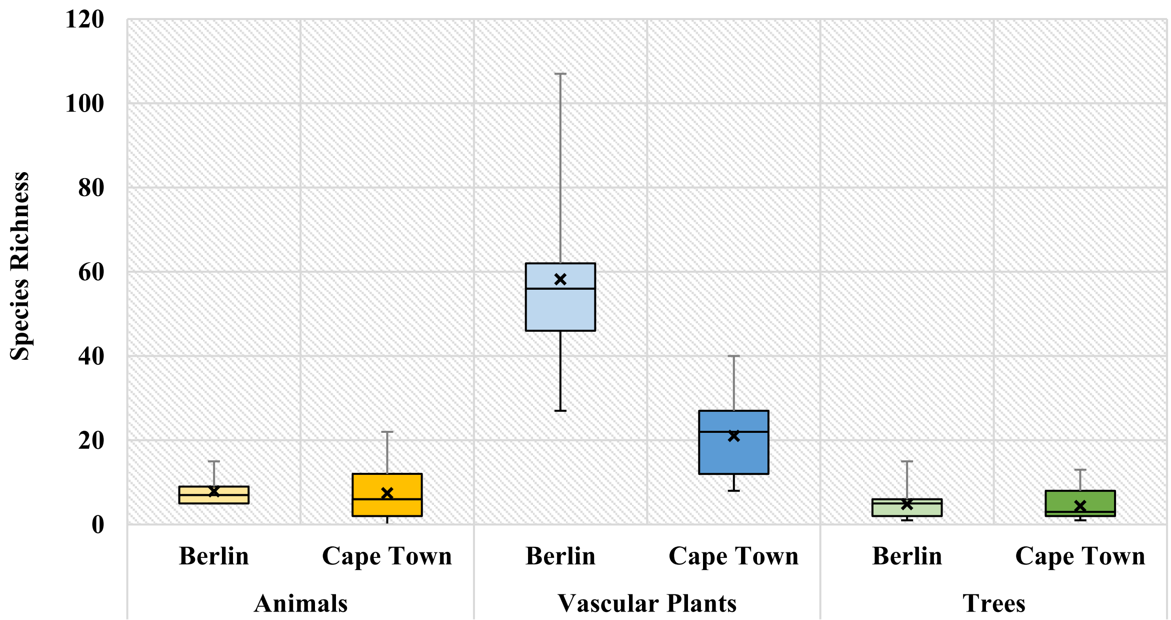


Figure 5.35. Comparison of animal, vascular plant and tree species richness in Cape Town and Berlin community gardens (x denotes the mean).

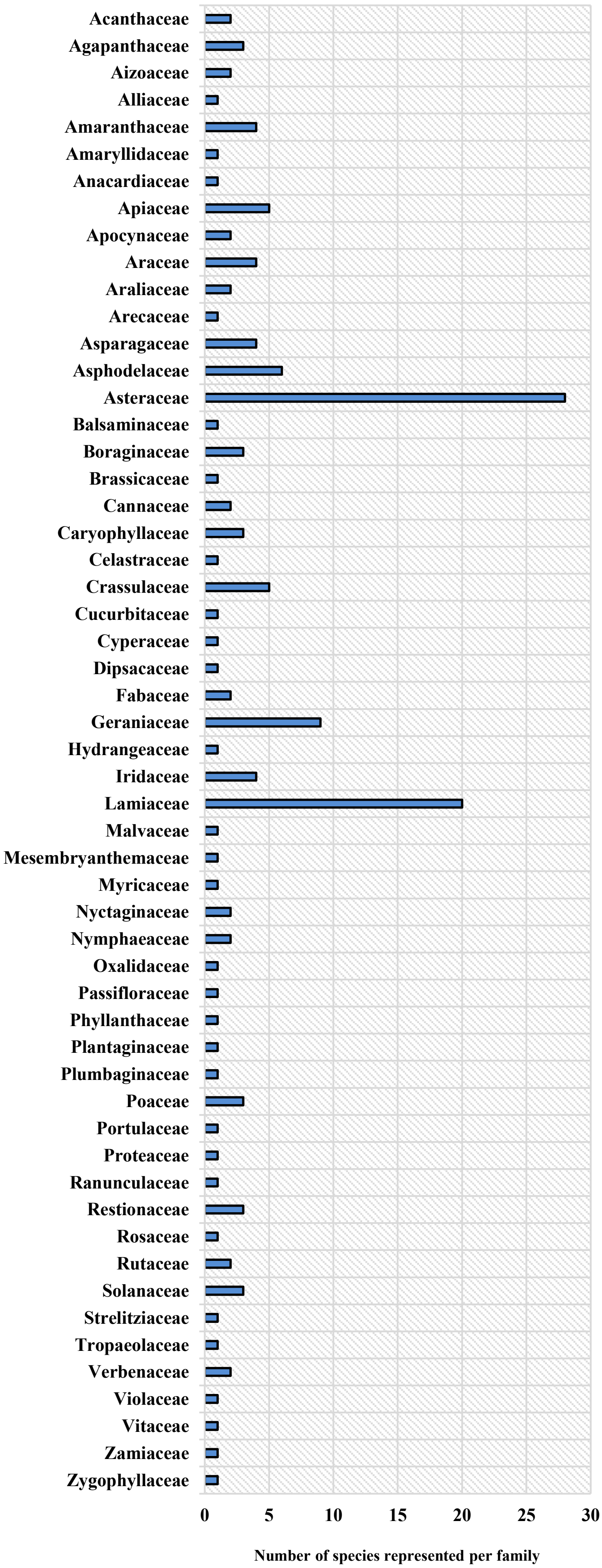


Figure 5.36. Number of species per family recorded for vascular plants in Cape Town community gardens.

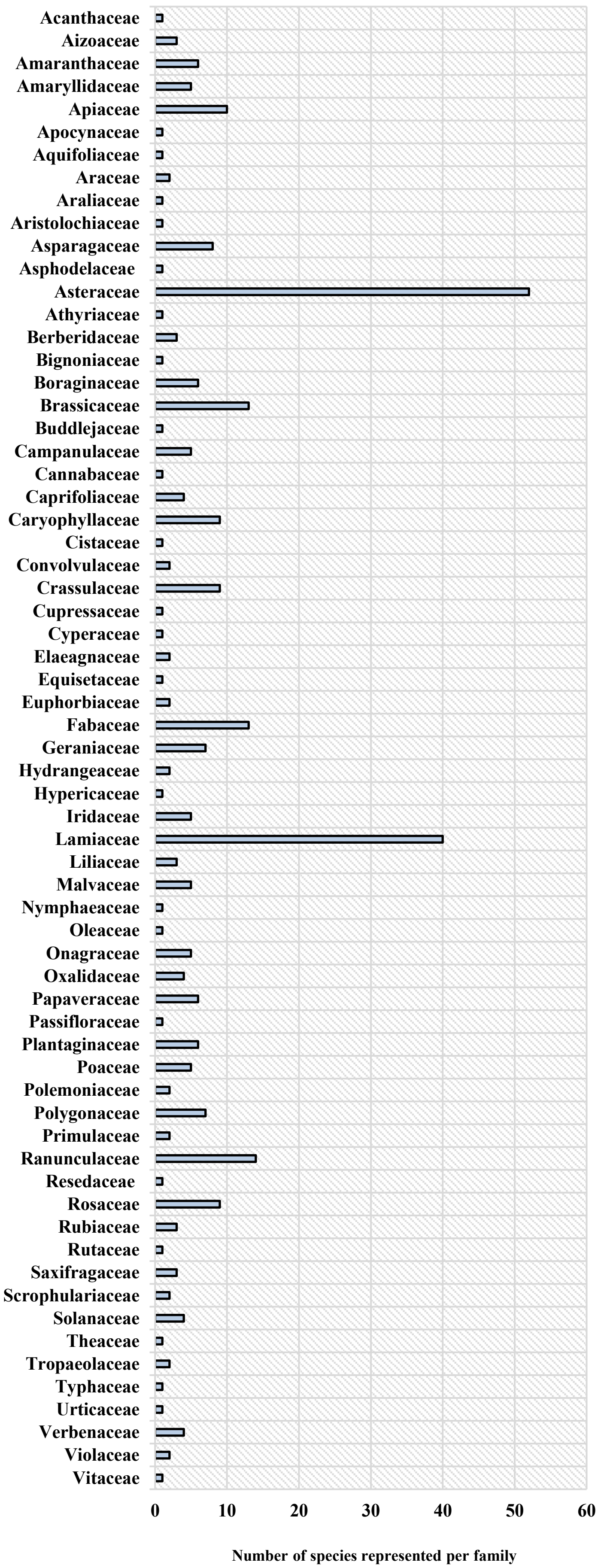


Figure 5.37. Number of species per family recorded for vascular plants in Berlin community gardens.

Overall patterns of tree species richness were similar in ***Cape Town*** and ***Berlin*** community gardens (see Tables D21 and D24 in Appendix D for full lists). Although the average number of trees species per garden were similar in both cities (***Cape Town*** = 5, ***Berlin*** = 4) (Figure 5.35), tree species in ***Cape Town*** belonged to a greater number of families (21) than in ***Berlin*** (13) (Figures 5.38 – 5.39), with the most commonly occurring species being fruits trees (*Malus and Prunus spp*) of the Rosaceae family in both cities.

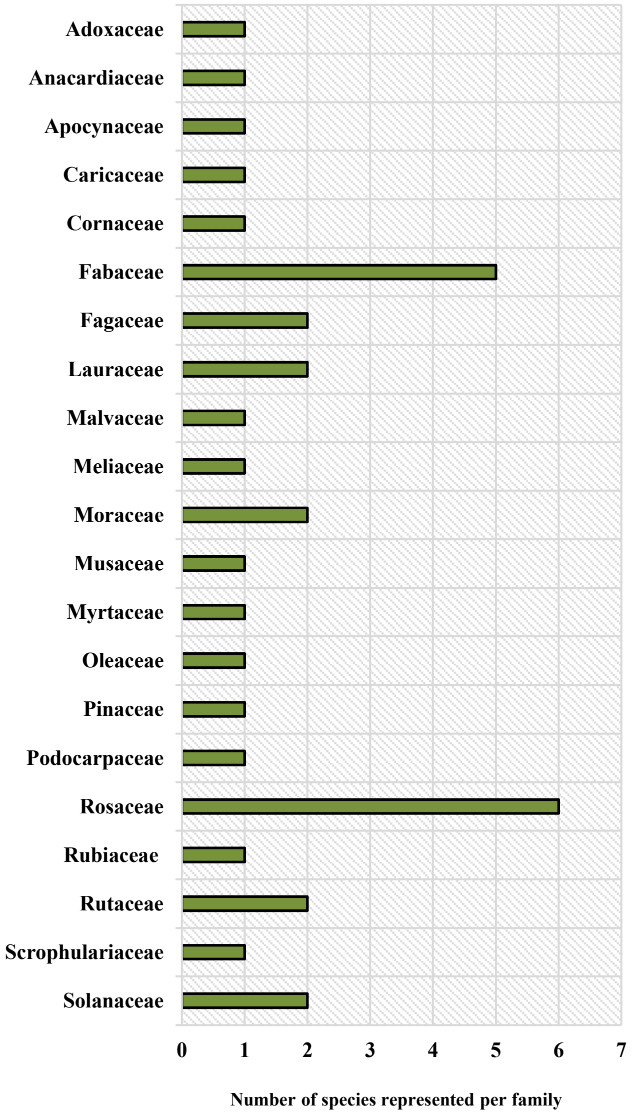


Figure 5.38. Number of species per family recorded for trees in Cape Town community gardens.

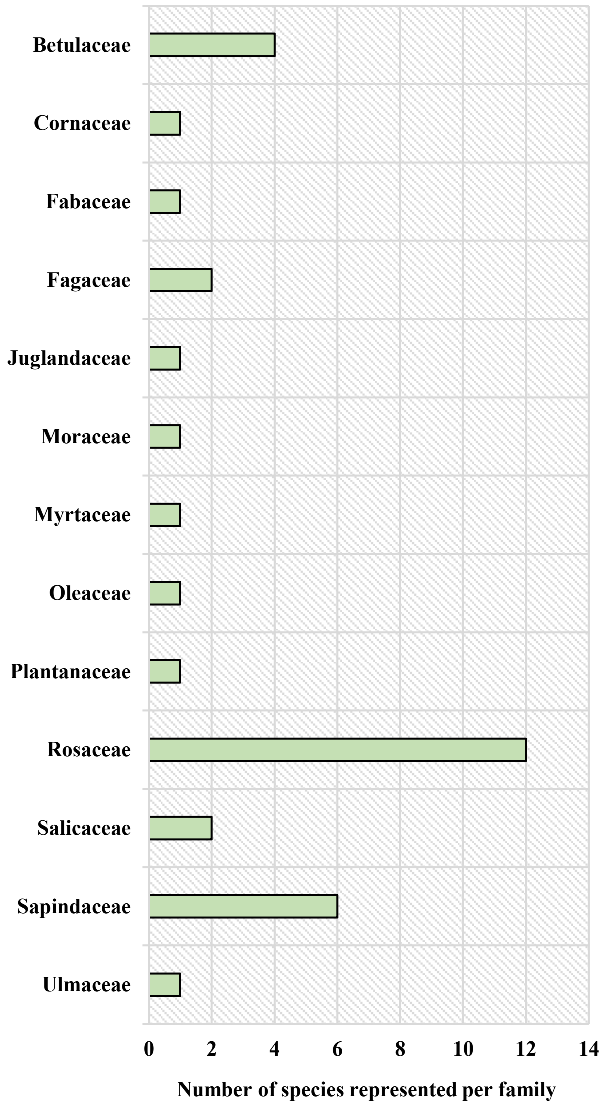


Figure 5.39. Number of species per family recorded for trees in Berlin community gardens.

For fauna, insect species (invertebrate) were well represented in both cities, as were birds and mammal vertebrates (Figures 5.40 – 5.41) (see Tables D22 and D25 in Appendix D for full lists). Common birds occurring in both cities were sparrows (*Passer spp)* and domestic pigeons *(Columba livia domestica)* which both have a global cosmopolitan distribution, while mammals such as grey squirrels *(Sciurus carolinensis)* were observed in ***Cape Town*** and red foxes *(Vulpes vulpes)* in ***Berlin***, respectively.

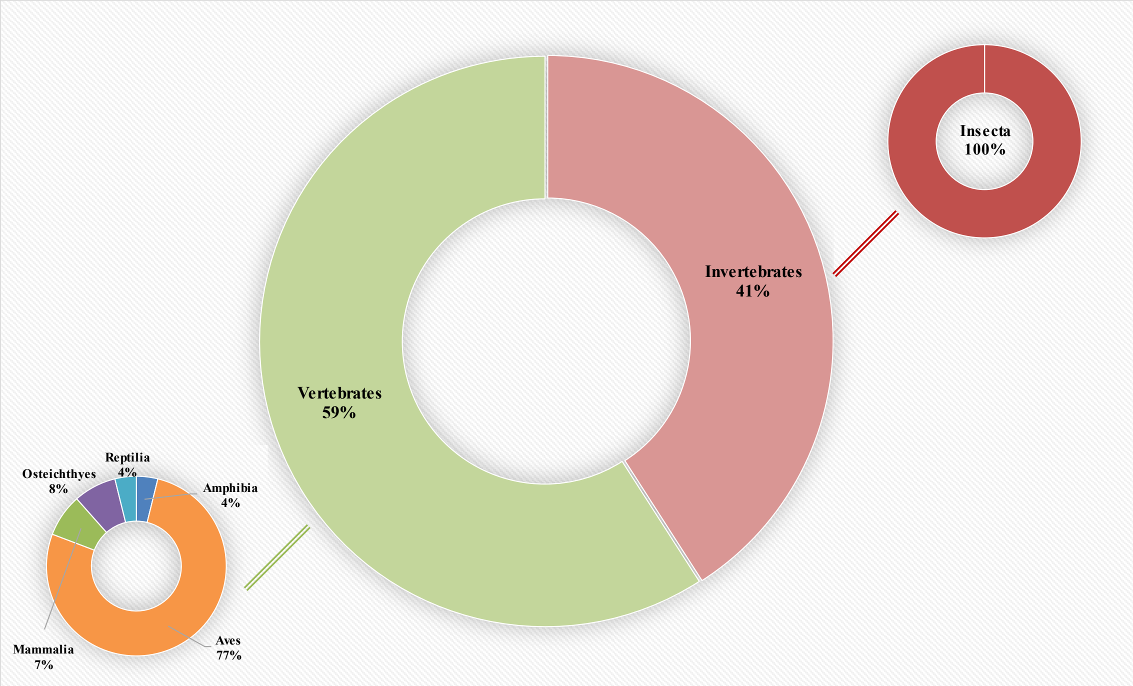


Figure 5.40. Number of species per class or phylum recorded for animals in Cape Town community gardens.

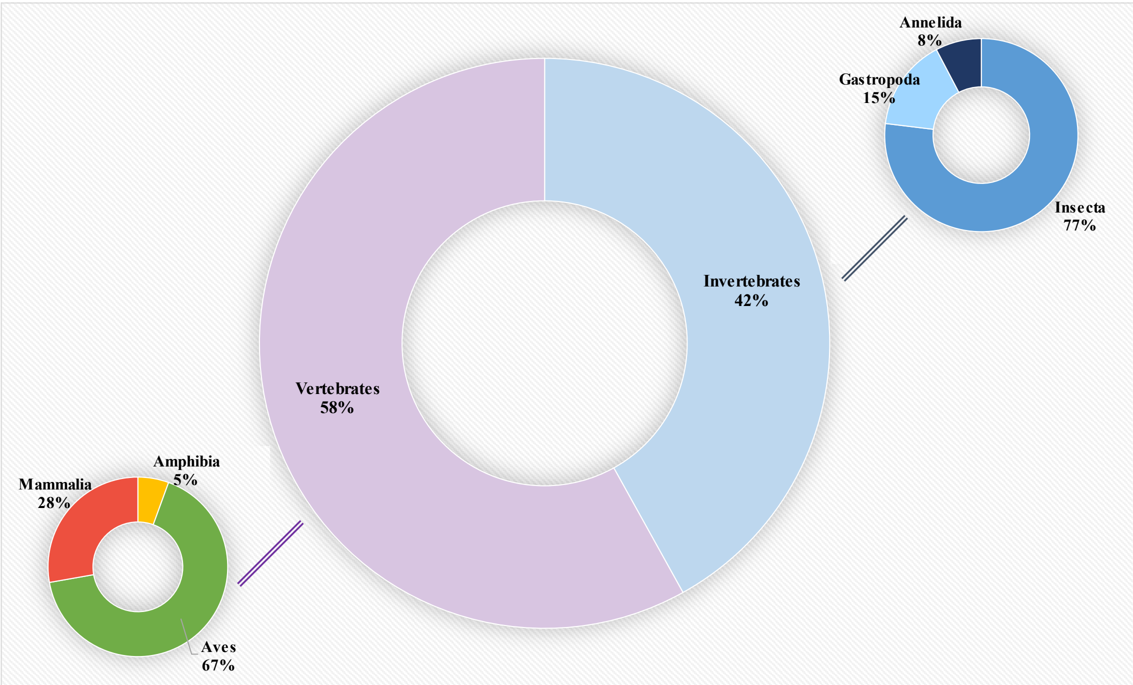


Figure 5.41. Number of species per class or phylum recorded for animals in Berlin community gardens.

Figures 5.42 – 5.43 show log-log plots of species richness against area for ***Cape Town*** and ***Berlin*** community gardens. Species equilibrium theory predicts that the slope of a log-log plots falls between 0.20 and 0.35 (Crowe, 1979). Slopes were calculated at 0.44 (R^2 = 0.436, $p < 0.05$) in ***Cape Town*** and 0.66 (R^2 = 0.663, $p < 0.05$) in ***Berlin***, both of which indicate non-equilibrium and therefore suggest species richness in community gardens in both cities is not a function of area. This is to be expected as all community gardens had purposefully planted vegetation, like ornamentals, that disproportionately increases species richness independent of size.

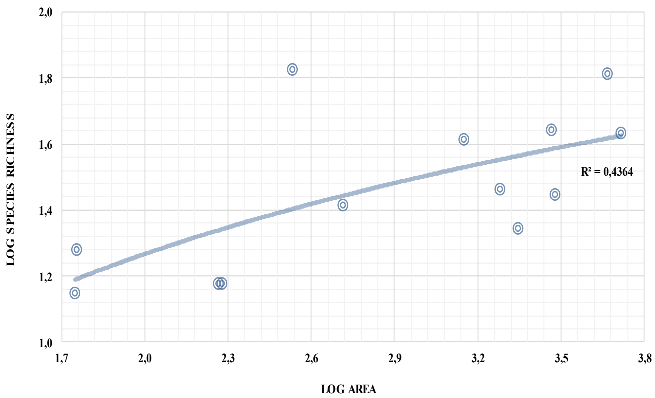


Figure 5.42. Log-log plot of species richness against area for Cape Town community gardens.

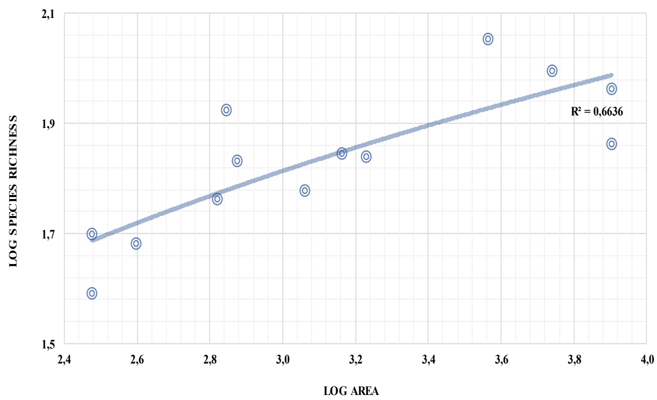


Figure 5.43. Log-log plot of species richness against area for Berlin community gardens.

<u>*Species diversity*</u>

The Shannon Index of species diversity is used as a statistical measure to calculate the diversity of species recorded in ***Cape Town*** and ***Berlin*** community gardens. This measure takes into consideration both species richness and relative abundance in a population, and is defined by:

$$H' = -\sum_{i=1}^{n} pi \ln pi$$

where pi is the relative proportion of species i to the total number of species and $\ln pi$ is the natural logarithm multiplied by this relative proportion (Spellerberg and Fedor, 2003). Evenness is a statistical measure of how proportional abundances are distributed amongst the total species number, and assumes a value between 0 and 1 where 1 represents complete species equitability (i.e. there are no dominant species in a community). Evenness is calculated by H' / H'_{max} where H'_{max} = ln (total species richness).

In ***Cape Town*** community gardens, average H' was calculated as 1,51 for vascular plants, 0,97 for trees and 1,12 for animals (Table 5.9). All evenness scores in ***Cape Town*** gardens are relatively similar (E_{plants} = 0,30, E_{trees} = 0,27, $E_{animals}$ = 0,29) and trending towards uneven (i.e. E_H<0,50) suggesting most communities of plants, trees and animals had dominant species. In ***Berlin*** community gardens, average H' was calculated as 3,35 for vascular plants, 1,18 for trees and 1,67 for animals (Table 5.9). Evenness scores for vascular plants (E_{plants} = 0,58) and animals ($E_{animals}$ = 0,49) trended words being more even than not (i.e. E_H>0,50 suggesting an equitable dominance of species, while tree species in trended towards uneven (E_{trees} = 0,33).

Table 5.9. Average Shannon Diversity Index (H`) and Evenness (E_H) scores for community gardens in Cape Town and Berlin.

	Shannon Diversity Index and Evenness					
	Cape Town			Berlin		
	Average H'	H'_{MAX}	Average E_H	Average H'	H'_{MAX}	Average E_H
Vascular Plants	1,51	5,05	0,30	3,35	5,77	0,58
Trees	0,97	3,56	0,27	1,18	3,53	0,33
Animals	1,12	3,78	0,29	1,67	3,43	0,49

Shannon Diversity values are usually within a range of 0 to 4 in natural or undisturbed environments (Spellerberg and Fedor, 2003). Community gardens are 'quasi-natural' disturbed urban environments with disproportionate high species richness planted on purpose, so outliers to the normal range are expected. Shannon diversity H' values were, on average, higher across all three categories (vascular plants, trees and animals) in ***Berlin*** gardens than ***Cape Town*** (Figure 5.44). Greater variability in tree and animal species diversity between individual gardens were observed in ***Cape Town***, while the highest range of species diversity was observed for vascular plants in ***Berlin*** gardens (Figure 5.44).

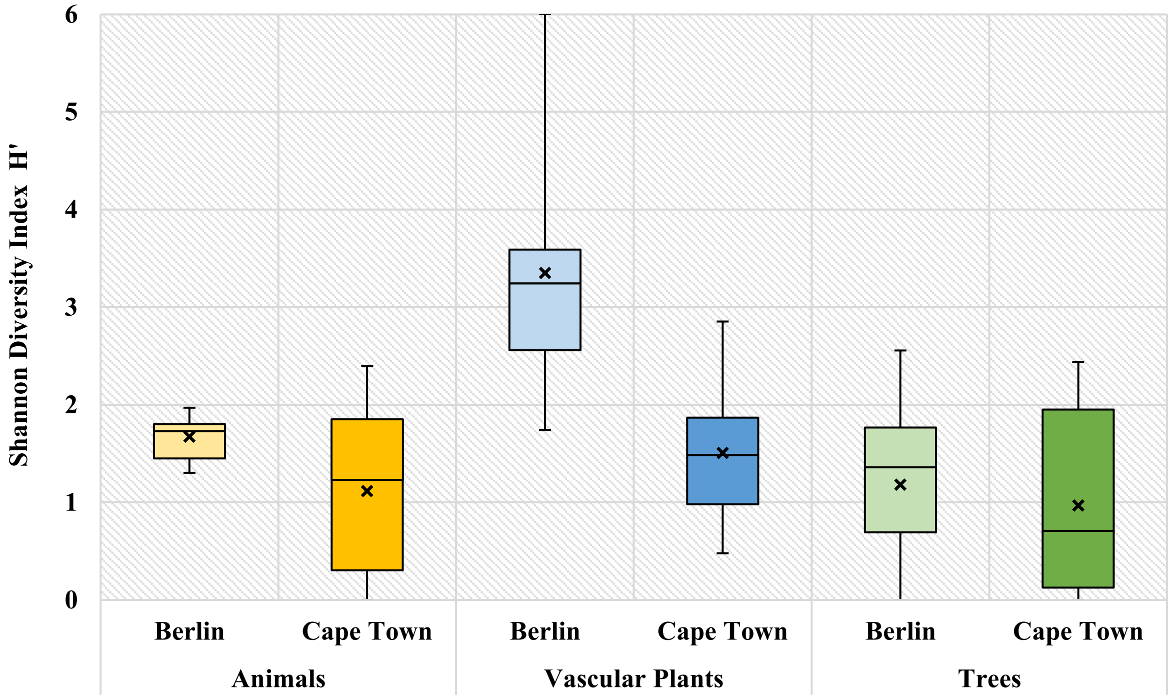


Figure 5.44. Comparison of Shannon Diversity Index (H`) scores for animals, vascular plants and trees in community gardens in Cape Town and Berlin (x denotes the mean).

The richness and diversity of fauna and flora in community gardens in ***Cape Town*** and ***Berlin*** can also be related to habitat ecosystem services. In most habitats, plant communities determine the physical structure of that environment and thus have a significant influence on the presence, distribution and interactions of animal species with their surrounding habitats (Tews et al., 2004). This is because, different habitats provide a variety of niche space and specific environmental resources that can be exploited by an array of plants and animals, therefore increasing species diversity. Based on this simplified concept, the assumption is therefore that high species richness and diversity of plants and animals correlates to a variety of habitats for them to persist in.

The richness and diversity of faunal and floral species in ***Cape Town*** and ***Berlin*** consequently illustrates that a variety of habitats are provisioned within community gardens. In addition, a number of manmade habitats such as bird houses and feeders, beehives, insect hotels, livestock enclosures and water features like fish ponds were present in some of the community gardens in order to attract species (Figure 5.45).

Bird house in Gemeinschaftsgarten Allmende-Kontor

Beehive in Prinzessinnengarten

Chicken enclosure in Soil for Life

Insect hotel in Kiezgarten Fischerstraße

Fish pond in Oranjezicht City Farm

Figure 5.45. Examples of manmade habitats observed in Cape Town and Berlin community gardens. Source: All images taken by author during field work.

5.3.4. Cultural services

Cultural services inferred from indicators in this research include: *recreation and mental and physical health*, *tourism*, *aesthetic appreciation and inspiration for culture, art, design*, and *spiritual experience and sense of place*.

5.3.4.1. Recreation and mental and physical health

The indicator used to make inferences about recreation and mental and physical health was **land-use** where the recreational and health functions of community gardens were recorded per garden area and used as a proxy to illustrate capacity for recreational and health potential (Dobbs et al., 2014; Albert et al., 2016b; La Rosa et al., 2016). This included the number and types of recreational facilities recorded in each community garden area. Cultural ecosystem services are considered the hardest group to "quantify" as it is very difficult to measure people's feelings or opinions on the cultural benefits and services they perceive to experience (La Rosa et al., 2016). That is why, most of the cultural ecosystem services in this thesis use a questionnaire to try and gauge people's perceptions on which cultural services they experience. Recreational and health functions of land-use is defined by the author as any space, facility or apparatus in the garden that can either be used for relaxation, enjoyment, refreshment or restoration beyond the scope of 'work'. Furthermore, any space, facility or apparatus that is perceived to cater to a person's mental and/or physical health or needs was included in this categorisation. The activity of gardening was the main recreational activity in all community gardens and so too its physical and mental benefits by virtue of a community garden's inherent land-use. The following data therefore does not include this inherent recreational and health function.

Full lists of *recreational and health facilities* counted in individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D26 – D27 in Appendix D. In ***Cape Town***, a total of 68 recreational and health spaces, facilities and uses/activities were counted and grouped in nine functional types (Figure 5.46). Benches (71%) used for picnics or quiet time and designated picnic areas (7%) were the dominant facilities and spaces of these community gardens. Furthermore, wooden carved seating (9%) was a common facility in which people could use to enjoy to sit and ´be´ in the garden for relaxation and mental health. Fish ponds and water features (6%) such as canals were present and could be used enjoyment in the gardens, and physical activity apparatus such as jungle gyms (2%), a garden maze (2%) and trampolines (1%) were not abundant, but were present. In ***Berlin***, a total of 209 recreational and health spaces, facilities and uses/activities were counted and grouped in 13 functional types (Figure 5.47). Benches (64%) and wooden seating (22%) were the main facilities in these gardens. Restaurants and bars (2%) were recreational spaces occurring in a few ***Berlin*** gardens, as were physical health facilities such as jungle gyms and a basketball court (2%). ***Cape Town*** and Berlin gardens therefore had a high capacity for recreation and mental and physical health services based on the variety of functions they provide.

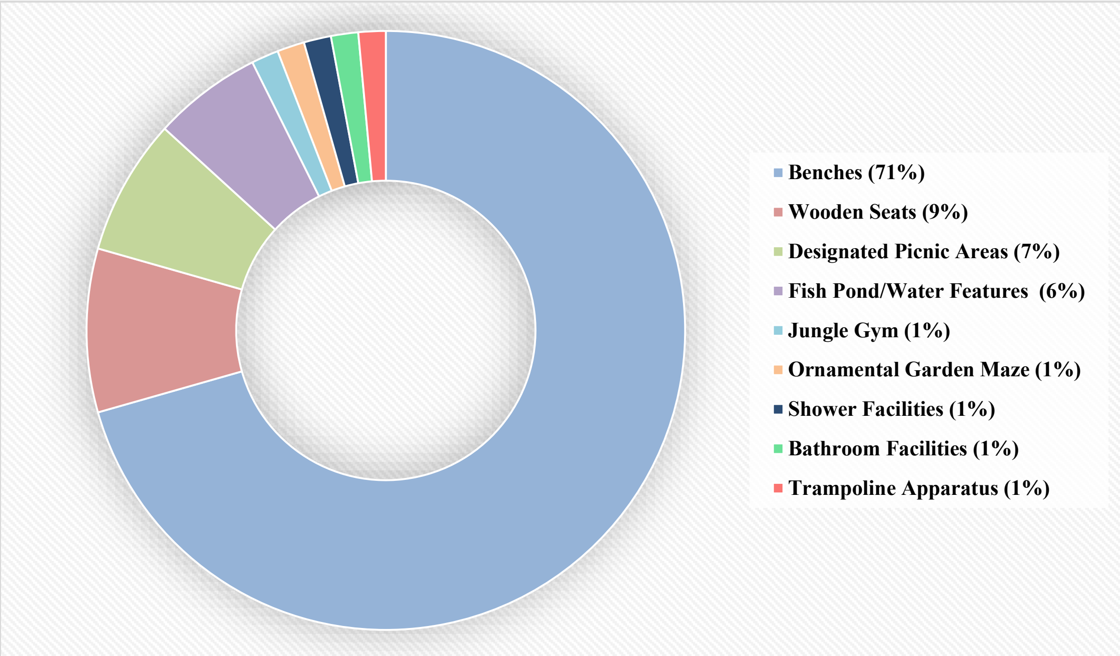


Figure 5.46. Recreational and health uses/facilities observed in Cape Town community gardens.

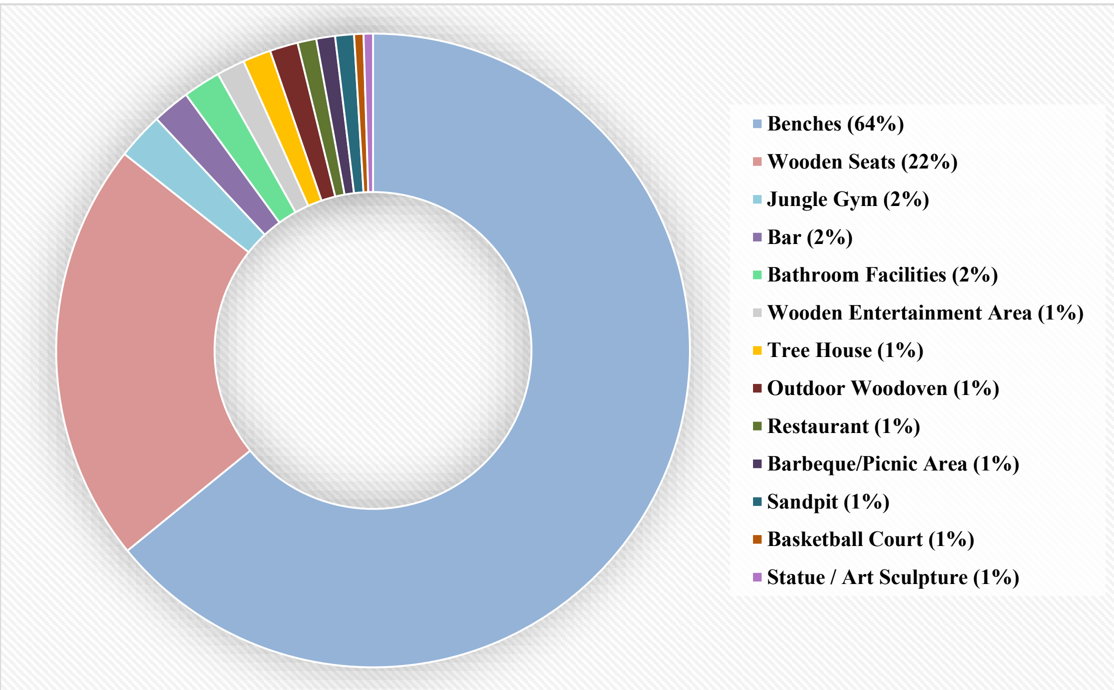


Figure 5.47. Recreational and health uses/facilities observed in Berlin community gardens.

Qualitative results obtained from the questionnaire reiterated that community gardens have a high capacity for recreational and mental and physical health services in both cities. When asked about using the garden for physical exercise and health purposes (Q.19), a total of 75% of respondents in ***Cape Town*** and 64% in ***Berlin*** respectively answered with high and very high agreement. Moreover, respondents were asked if they used the garden for recreational purposes such as picnics, family outings or for social interaction with others (Q.21). Opinions in ***Cape Town*** and ***Berlin*** were very similar in this regard, with 42% of respondents in ***Cape Town*** in very high agreement and 17% in high agreement that they used the garden for these recreation purposes, while 29% were in medium agreement (Figure 5.48). In ***Berlin***, 41% of the respondents very highly agreed and 23% in high agreement, while 27% were in medium agreement (Figure 5.48). Participants in both cities also agreed that community gardens contributed to people's livelihoods in some way (Q.18), either by securing some income, the necessities of life (e.g. food and water) for their health and well-being or fulfilling the cultural requirements of their livelihood needs, and importantly noted that environmental learning and education was a main cultural experience in many of the garden spaces (Q.23). Overall, an overwhelming majority of respondents in both cities perceived that community garden spaces provided them with recreational and mental and physical health services from which they benefitted.

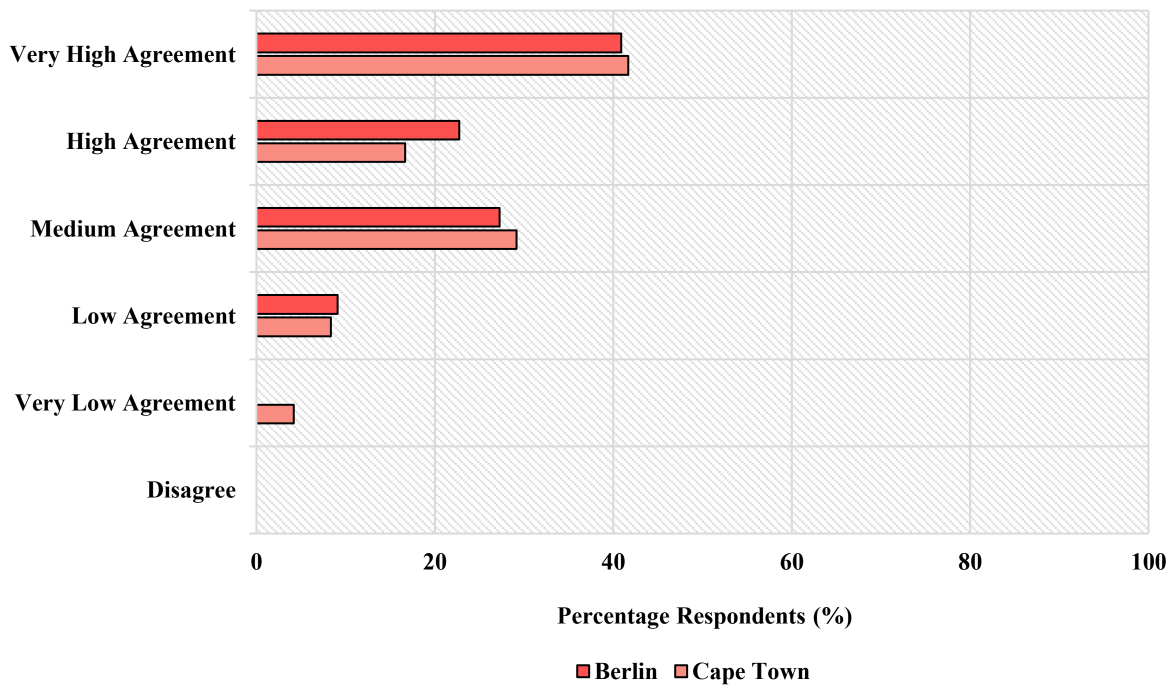


Figure 5.48. Questionnaire responses when asked whether respondents used community garden spaces for recreational purposes.

5.3.4.2. Tourism

The indicator used to make inferences about tourism was **visitor numbers** where the average number of visitors per month was recorded per garden area and used as a proxy to illustrate capacity for tourism services (Egoh et al., 2012; La Rosa et al., 2016).

Tables D28 - D29 in Appendix D show the *average number of visitors* for all community gardens in ***Cape Town*** and ***Berlin***. Gardens in ***Berlin*** had a markedly higher average number of visitors per month (1690) than Cape Town (200) (Figure 5.49). This is because seven of the 13 community gardens in ***Berlin*** were either situated in or next to a park or open green space of some sort. In addition, four gardens had either a bar and/or restaurant facilities which attracted many visitors. In ***Cape Town***, one garden was situated in an open public park, while three gardens were situated next to schools which attracted visitors for environmental education purposes. No gardens had any bar or restaurant facilities. Based on total garden area assessed in both cities, Cape Town (2.271 ha) had 1145 visitors per hectare of community garden space while Berlin (3.258 ha) had 5706 visitors per hectare of garden space. It is evident that being located in or near parks and open green space greatly influences the number of people visiting community gardens.

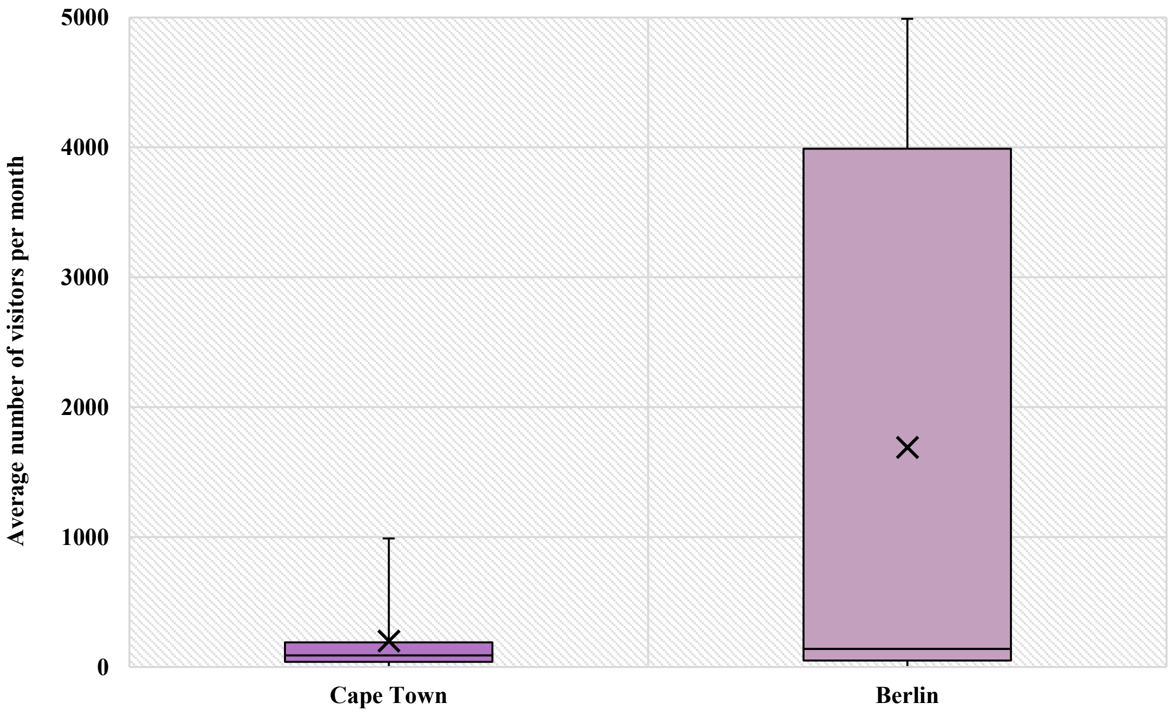


Figure 5.49. Average number of visitors per month to community gardens in Cape Town and Berlin (x denotes the mean).

Interesting opinions came from questionnaire respondents when asked about their willingness to pay for access to the garden (Q.30). Willingness-to-pay can be used as a proxy for tourism ecosystem services (La Rosa et al., 2016) and participants were asked whether, if made necessary, they would pay for access to the garden because of the benefits it provided to them. The split in responses between ***Cape Town*** and ***Berlin*** participants shows interesting facets of the socio-economic realities of who is using community gardens in each city, and how these realities influence how people see, use and value their money. In ***Cape Town***, where the socio-economic status of the average person is low- or lower middle-income, a large majority of respondents (83%) had no willingness to pay for access to the garden and its services if they had to (Figure 5.50). In ***Berlin***, where the middle- and high-income class is stronger, 32% of respondents showed very high willingness, 14% high willingness, although conversely 27% showed no willingness to pay for community garden access if need be (Figure 5.50).

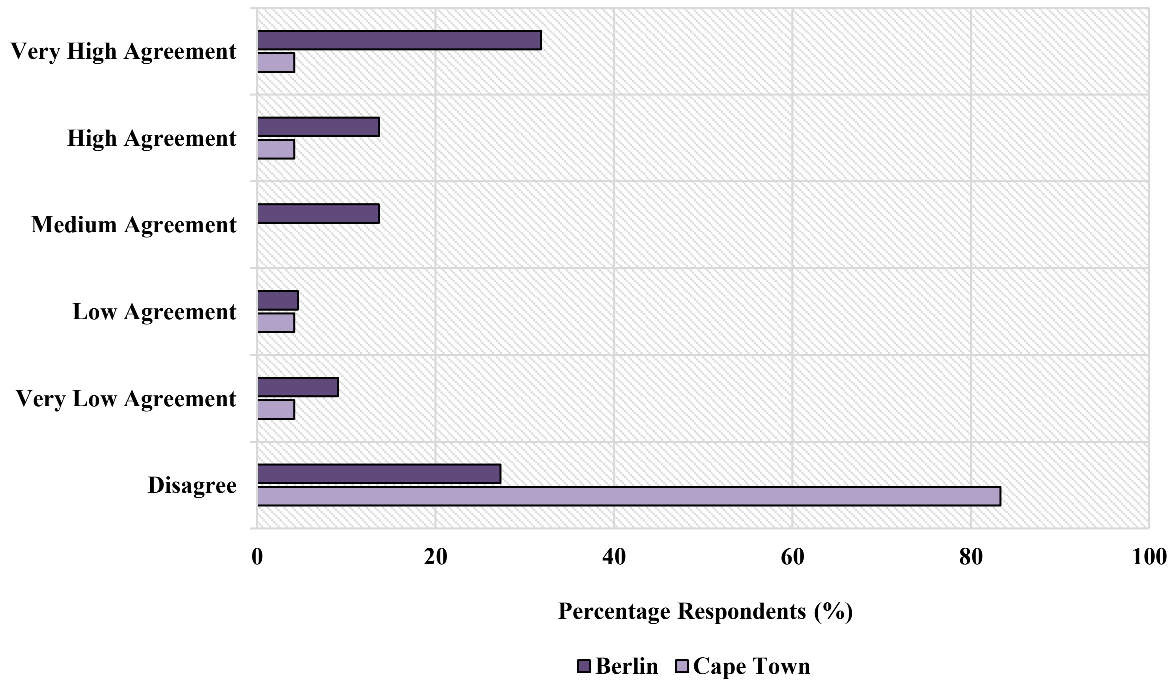


Figure 5.50. Questionnaire responses when respondents were asked whether they would be willing to pay for access to the community garden.

5.3.4.3. Aesthetic appreciation and inspiration for culture, art, design

As aesthetic appreciation is a subjective concept and difficult to measure, questionnaires were disseminated within community gardens to ascertain peoples' perceptions on how they view the aesthetic value and potential of community gardens in the overall urban setting (La Rosa et al., 2016).

First, participants were asked whether they felt that the community garden area enhanced their appreciation of nature and natural landscapes (Q.25). Responses in both cities were similar, with 58% of respondents in ***Cape Town*** and 55% in ***Berlin*** in very high agreement (Figure 5.51).

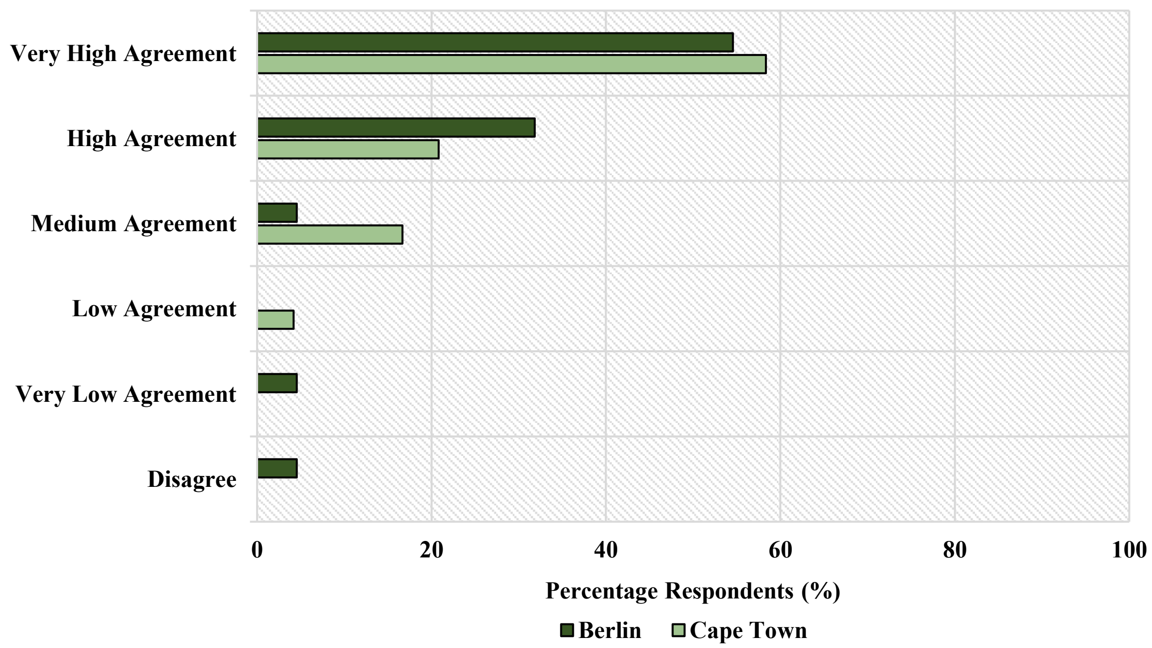


Figure 5.51. Questionnaire responses when asked whether respondents felt community gardens enhanced their appreciation for nature.

Second, participants were asked whether they felt that community gardens improve the overall attractiveness and beauty of the city as a whole (Q.26). Responses were overwhelmingly positive, with 67% of respondents in ***Cape Town*** and 68% in ***Berlin*** in very high agreement (Figure 5.52).

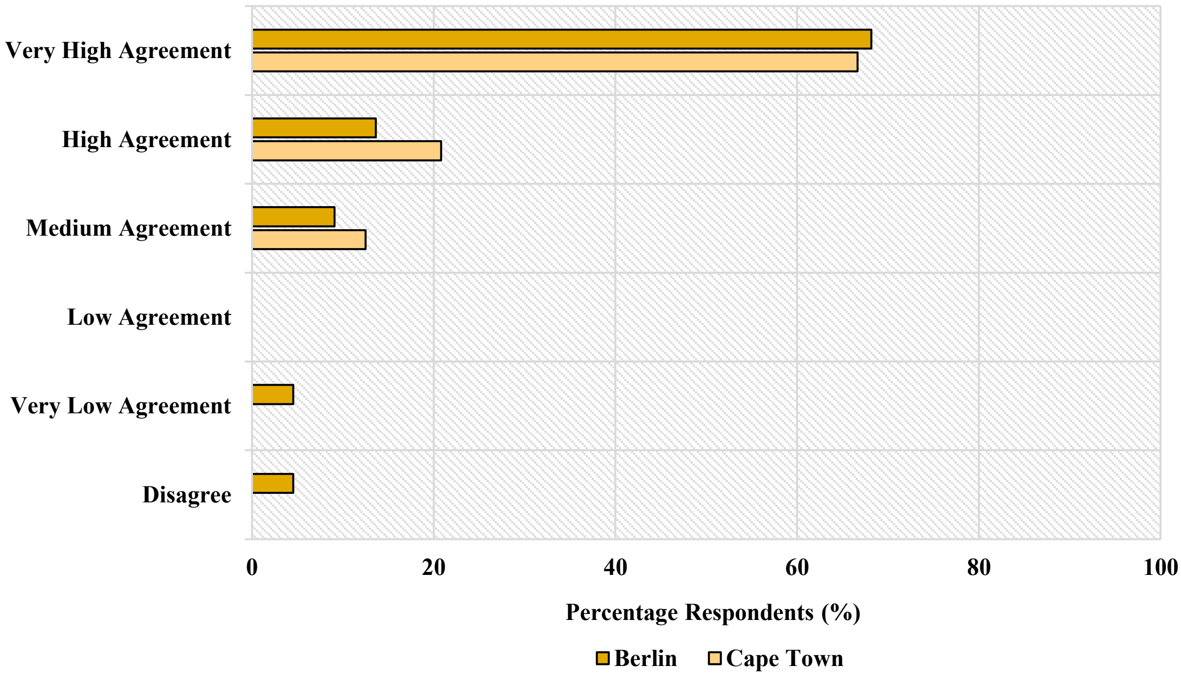


Figure 5.52. Questionnaire responses when asked whether respondents felt community gardens improve the overall attractiveness and beauty of the city.

Third, participants were asked whether they felt that community gardens provided opportunities to contribute to transform the city to be more sustainable and resilient in the face of issues such as climate change (Q.29). In ***Cape Town***, 58% of respondents very highly agreed while in ***Berlin*** 36% were in very high agreement and 36% in high agreement (Figure 5.53).

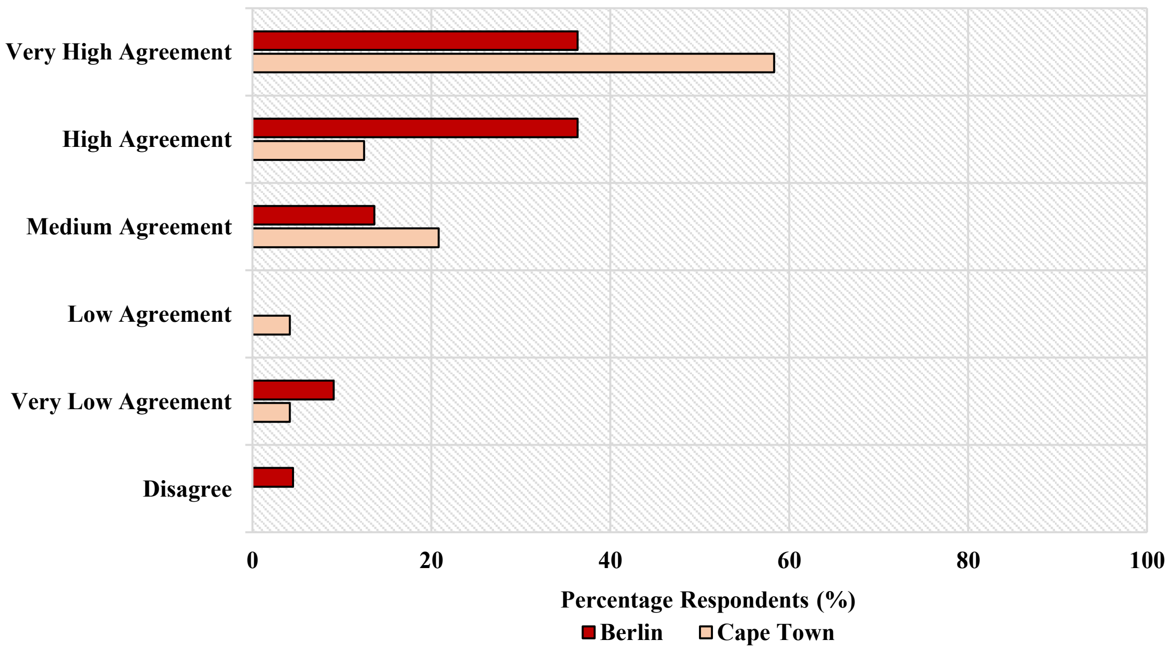


Figure 5.53. Questionnaire responses when asked whether respondents felt community gardens provided opportunity to make the city more sustainable and resilient in the face of issues such as climate change.

Overall, respondents in both ***Cape Town*** and ***Berlin*** therefore perceived that community garden spaces enhanced their appreciation for nature and improved the overall aesthetic value of the urban landscape. Furthermore, participants felt that community gardens had the ability to build the overall sustainability and resilience of urban environments against the impacts of climate and environmental change.

5.3.4.4. Spiritual experience and sense of place

Spiritual experience and sense of place are also subjective concepts and therefore a challenge to measure, so questionnaires were disseminated within community gardens to ascertain peoples' perceptions on how, based on their interactions and use of the garden, these influence their perceived experiences of spiritual and sense of place services (La Rosa et al., 2016).

First, participants were asked whether the garden was used for the social and cultural integration of migrants, jobless or homeless people (Q.20). In ***Cape Town***, a large majority of 71% of the respondents very highly agreed, while in ***Berlin***, 46% of the participants very highly agreed and 27% highly agreed (Figure 5.54). The strong responses in ***Cape Town*** were expected as many gardens were used as food sources and safe places for vulnerable jobless people, many of whom were homeless.

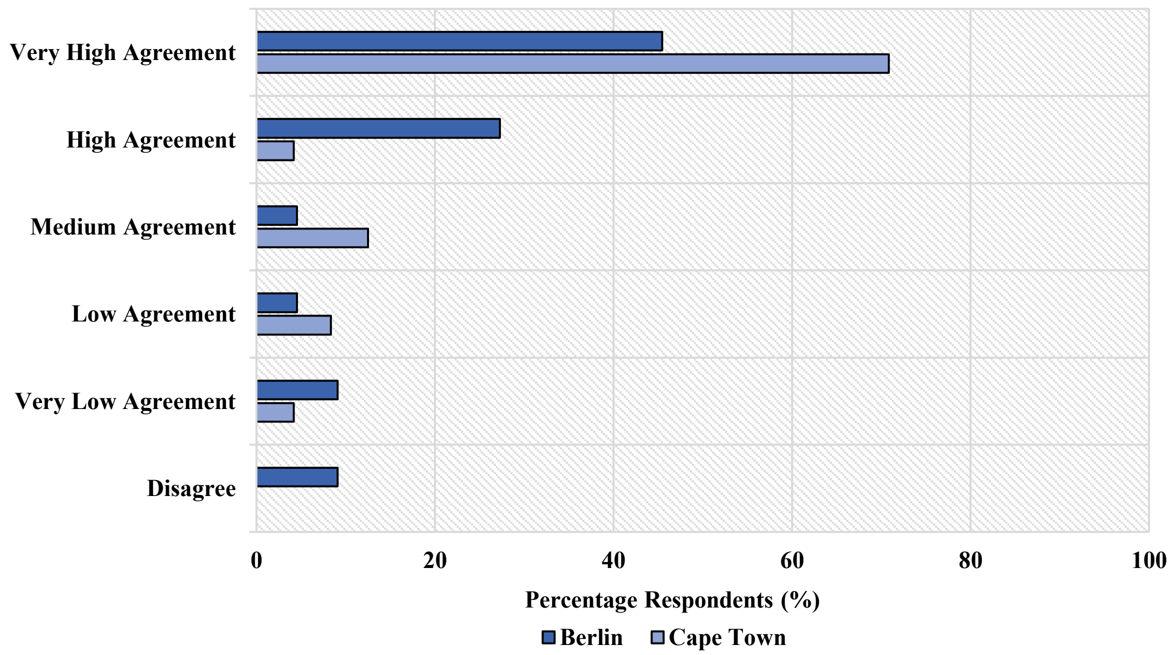


Figure 5.54. Questionnaire responses when asked whether community gardens were used for the social and cultural integration of migrants, jobless or homeless people.

Second, participants were asked if they felt that their interaction with the garden and other people in it helped them feel as part of a group and not isolated from others (Q.22). ***Cape Town*** responses were once again strong with 67% of respondents in very high agreement. ***Berlin*** respondents also felt such benefits from interaction within the community gardens, with 27% in very highly agreed and 41% in high agreement (Figure 5.55).

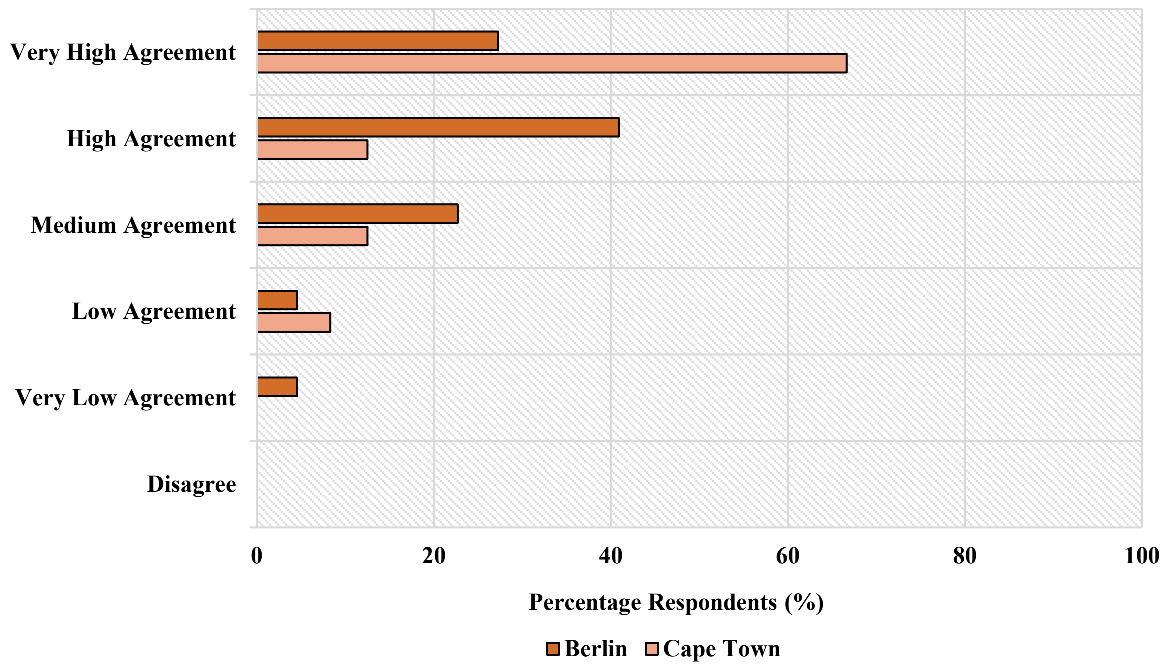


Figure 5.55. Questionnaire responses when asked if participants felt as a part of a group in community gardens.

Third, participants were asked whether they felt benefits such as less stress and increased relaxation in community gardens (Q.27). Responses in both cities were similar and overwhelmingly positive, with 79% of respondents in ***Cape Town*** and 64% in ***Berlin*** in very high agreement (Figure 5.56).

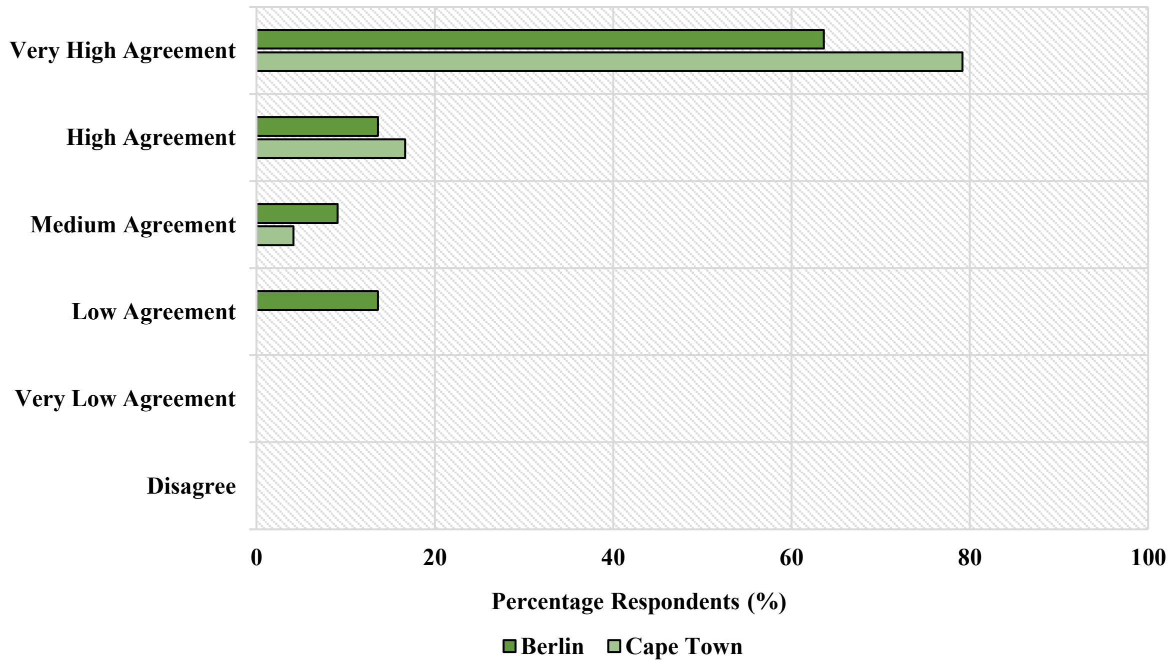


Figure 5.56. Questionnaire responses when asked if participants felt stress relief and increased relaxation in community gardens.

Fourth, participants were asked whether they felt a sense of being in touch with nature and a sense of belonging when they were in the community garden (Q.28). In ***Cape Town***, 67% of respondents were in very high agreement and 21% in high agreement, while in ***Berlin***, 59% of respondents were in very high agreement and 32% in high agreement (Figure 5.57).

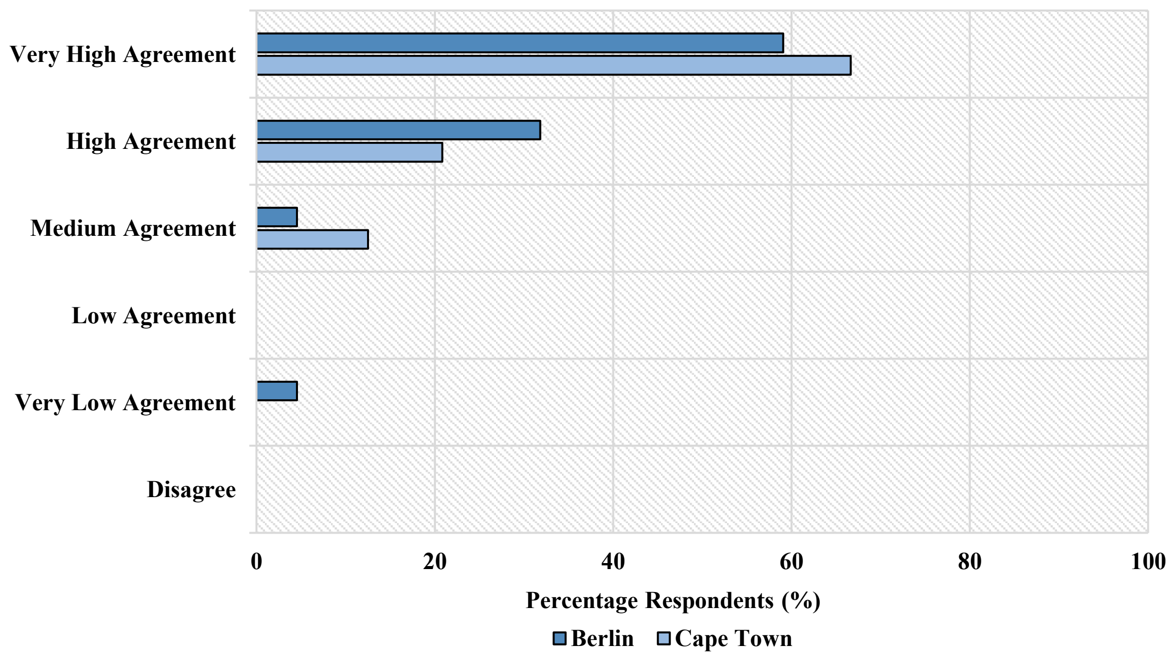


Figure 5.57. Questionnaire responses when asked if participants felt a sense of being in touch with nature and belonging when in the community garden.

From these quantitative results, it is evident that people in both cities felt that community garden spaces provided a number of important spiritual experiences and create a sense of community and belonging for those who interact with them. Because of inherent characteristics of community gardens such as civic building and eco-community building, they are important spaces for the cultural and social integration of migrants or those disenfranchised to become a part of a community and feel a sense of social belonging and not feel so alone. They were also perceived to improve people's duty towards environmental responsibility by creating a sense of being in touch with nature and therefore establishing stewardship to its sustainable use and protection. It was also recognised that these spaces were important places for stress relief and relaxation, spiritual upliftment and quiet time in urban areas where people's lives are often fast-paced and busy.

5.3.5. Discussion of major ecosystem services findings

This study shows that local socio-economic, physical landscape, environmental and climate conditions result in marked differences and patterns in ecosystem services delivery.

Provisioning services

Comparisons of percentage areas of the community gardens occupied with crop area (Figure 5.6) suggest that many of the ***Cape Town*** gardens have the primary purpose of being used for food production and securing basic needs, similar to the results found in the study by Tembo and Louw (2013) for the city. ***Berlin*** gardens also reflect the city's higher overall socio-economic background and general higher educated user-groups as they were increasingly used as nature-based spaces in an urban landscape aimed at enhancing human well-being, social integration and healthy lifestyle behaviours beyond just food production (Camps-Calvet et al., 2016). Concerning food provisioning services, ***Berlin*** gardens in particular show impressive crop richness, and differences in crop varieties between the two cities can be attributed to crop climate requirements, personal gardener crop preferences and/or crop knowledge, as well as garden history and purpose. The diversity of agronomic species is often overlooked in biodiversity concerns, including conservation, but are nevertheless important concerns for food security in many cities around the world (Cabral et al., 2017). Community gardens therefore contribute as important urban green spaces for provisioning food services, enhancing food security and maintaining agrobiodiversity in both cities.

In terms of fresh water provisioning, results show how local climate conditions have a substantial impact on the availability of fresh water services, supporting the scientific consensus that any future stresses imposed on ecosystems from climate change will significantly affect the ability of ecosystems to deliver services (Mooney et al., 2009). While rainwater collection was a common practice is both cities, gardens in ***Cape Town*** generally rely more heavily on rain water harvesting and fresh water sources (like boreholes and the mountain springs recorded in ***Cape Town*** gardens) than those in ***Berlin*** because of water restrictions placed on municipal water usage due to drought in the city. Groundwater sources are not a reliable alternative in ***Cape Town*** as the dry conditions have resulted in substantial drops to the water table across the city (City of Cape Town, 2017d). This has resulted in crop irrigation requirements in ***Cape Town*** community gardens being continually strained and unsustainable because of poor groundwater availability and stringent water usage limitations enforced by the municipality. Comparatively, ***Berlin*** community gardens experience frequent rainfall to fill their tanks, replenish groundwater levels and have easy access to municipal supplied freshwater provisioning services for their garden requirements. Extreme climate events such as drought are thus shown to be a major disruptor of ecosystem structure and functioning.

Regulating services

It is interesting that despite their relatively small size, community gardens in both cities exhibit a capacity for regulating services, at least at a small scale. Local urban climate and air quality regulation begins with urban vegetation, as it acts as both a sink for heat energy and gaseous pollutants such as carbon dioxide and other atmospheric contaminants (Lin et al., 2016). The contribution of community gardens to climate regulation through heat absorption/shading and carbon sequestration and storage is limited and relies on extant vegetation communities and structure within individual gardens, reinforcing the notion that the generation of ecosystem services is down to context-specific factors and is spatially explicit (Andersson et al., 2015). ***Cape Town*** community garden structures were generally open as they had low average percentages of shaded area from trees but high proportions of open vegetated surfaces. Alternatively, ***Berlin*** gardens had both high percentages of shaded area from trees and vegetated surfaces (Figures 5.18 and 5.21). So, although the urban vegetation planted within community gardens in both cities acts to reduce temperatures by combatting local urban heat island effects, their effectiveness in doing so is site-specific. Garden size, garden location and surrounding land-use does influence a community garden's vegetation structure and composition through restrictions placed on tree numbers, sizes and canopy extent within a city centre due to space limitations and surrounding building densities. In ***Cape Town***, many gardens within the city centre were small and could not house large canopied trees because of space limitations relating to dense surrounding buildings. Gardens in both cities that were located outside the CBD in suburbs or surrounded by less dense infrastructure were generally larger and therefore had a greater abundance of taller trees. Furthermore, ***Berlin*** gardens had a higher number of mature and large trees (Figure 5.24) compared to ***Cape Town*** (Figure 5.23), so ***Berlin*** gardens showed a greater contribution to local climate regulation through higher carbon sequestration and storage capacity (Cabral et al., 2017). In terms of conservative estimations of carbon storage that were calculated using Rowntree-Nowak equations, the approximations of 12 and 19 tons per hectare for Cape Town and Berlin gardens, respectively, were in line with estimations gathered by Strohbach and Haase (2012) for urban trees (including domestic and allotment gardens) in Leipzig. Although carbon storage and sequestration capacity are dependent on variables such as tree species and maturity and therefore individual allometric equations are the most accurate method to estimate carbon characteristics, Rowntree-Nowak estimations have been shown by Whitford et al. (2001), Tratalos et al. (2007) and Dobbs et al. (2014) to be a reliable alternative technique in data-limited situations across a wide climate range.

Vegetated surface area amounted to around 85% - 95% in most of the gardens assessed in ***Cape Town*** and 70% - 95% in those surveyed in ***Berlin***, while sealed ground like pathways and garden buildings occupied, in the main, less than 20% in ***Cape Town*** gardens and 30% in ***Berlin***. Community gardens in both cities therefore play an important role in groundwater recharge and water regulation, similar to other urban green spaces in city environments, by enhancing water infiltration through absorbing water runoff and rainfall attenuation because of their large areas of permeable landcover and few impervious areas. High proportions of vegetated surfaces in community gardens also acts to counter urban soil erosion concerns as root systems bind and stabilise the soil structure (Dobbs et al., 2011).

Habitat/Supporting services

Community gardens are havens for significant diversity of plants, birds and insects, and in particular can harbour large numbers of indigenous plant species as was shown in this study - an outcome that was similarly found in the studies by Clarke and Jenerette (2015) and Cabral et al. (2017). In ***Cape Town*** gardens, 87 indigenous species were recorded across all gardens which corresponds to 46% of the total vascular plant richness counted, and in ***Berlin***, 169 indigenous species were recorded (48%). In both cities therefore, almost half of the recorded vascular plant richness was native, showing how these spaces act as small-scale urban biodiversity hotspots. In general, high species richness of fauna and flora relates to the diversity microhabitats and niche space in a system (Tews et al., 2004). High species richness and diversity in community gardens in ***Cape Town*** and ***Berlin*** therefore also offer indirect reflections that vital habitat ecosystem services are delivered in these spaces.

Cultural services

The purpose of community gardens has evolved since their early 19th century function of being an urban food source in times of war, crisis and economic struggle (Scheromm, 2015). Arguments by Guitart et al. (2012) and Ruysenaar (2013) discuss how community gardens are now considered vital socio-recreational spaces for community interaction and integration, environmental education programmes, cultural exchange, and a myriad of recreation and relaxation activities beyond a primary focus on food production. The activity of gardening is seen as a primary source of recreation and relaxation in most of the gardens that were assessed in both cities, and from which people derived enjoyment and a sense of stress relief. There were also many other recreation facilities such as benches, picnic areas and barbeque spots in gardens that people use and enjoy. In addition, community gardens in both cities hosted a number of tourists each month, meaning they were frequented by the general public for the cultural services they provide - either the variety of recreation facilities that are enjoyed by local communities or for activities that promoting good physical and mental health to garden users.

Conclusion

Ecosystem services assessment results suggest that the services and benefits generated by community gardens in ***Cape Town*** and ***Berlin*** is positively disproportionate to their relatively small size, which further legitimises their importance and value as an urban land-use. An inventory assessment, such as the one done in this study, is the first step in providing local city planners and urban environmental managers with explicit and tangible information of this value, and outcomes here are therefore important data sources for local authorities in both ***Cape Town*** and ***Berlin***.

5.4. Ecosystem disservices assessments

Results of field protocols performed in Berlin and Cape Town community gardens are shown in sub-chapters 5.4.1 – 5.4.5 which are grouped according to ecosystem disservices categories.

5.4.1. Ecological impacting disservices

Ecological impacting disservices inferred from indicators in this research include: *displacement of native by invasive species that causes harm*.

5.4.1.1. Displacement of native by invasive species that cause harm

The indicator used to make inferences about the displacement of native by invasive species is **invasive species richness** (Escobedo et al., 2011; von Döhren and Haase, 2015). It is important to note that introduced and invasive species are different; introduced species, although foreign, need not necessarily cause ecological harm – but can. Invasive species are those species which outcompete others for resources and niche space to the other species' detriment. Shares of indigenous, non-indigenous (archaeophyte and neophyte) and invasive species recorded in ***Cape Town*** and ***Berlin*** are summarised in Tables 5.10 – 5.11 (see full Tables D20-D21 for vascular plant invasive species and Tables D23-D24 for tree invasive species in Appendix D - shown by those species highlighted in red). Nomenclature used to classify species are slightly different in each country as South Africa does not use the archaeophyte and neophyte terminology and instead uses a broad 'non-indigenous' term to represent those species introduced to the country irrespective of the date of introduction.

Table 5.10. Floral species richness of indigenous, non-indigenous and invasive species recorded in community gardens in Cape Town.

Overall Species Richness	**191**
Vascular Plants	**156**
Indigenous	73
Non-Indigenous	78
Alien Invasive Species	5
Trees	**35**
Indigenous	14
Non-Indigenous	11
Alien Invasive Species	9

**Invasive species were identified using the National Environmental Management: Biodiversity Act of 2004 Invasive Species List that was updated in July 2016 (Government of South Africa, 2004).*

Table 5.11. Floral species richness of indigenous, non-indigenous (archaeophyte, neophyte) and invasive species recorded in community gardens in Berlin.

Overall Species Richness	**354**
Vascular Plants	**320**
Indigenous	144
Archaeophytes	107
Neophytes	65
Alien Invasive Species	4
Trees	**34**
Indigenous	25
Archaeophytes	4
Neophytes	3
Alien Invasive Species	2

**Invasive species were identified using the Black and Grey lists of invasive species produced by Das Bundesamt für Naturschutz (2013).*

Cape Town community gardens recorded more invasive species (vascular plants and trees) than in ***Berlin*** although the number of invasive species was not high in either city – 7% in ***Cape Town*** and 2% in ***Berlin*** (Figures 5.58 – 5.59). Both gardens showed a majority of non-indigenous (introduced) species because much of the vegetation (beyond crop production) in these gardens were herb varieties, companions plants, and ornamental cultivars or hybrids that were purposefully planted and cause no ecological harm to indigenous species. Purposefully planted varieties were particularly the case in ***Cape Town*** gardens, where drought conditions meant little spontaneous vegetation outside specifically planned companion plants and ornamentals were present.

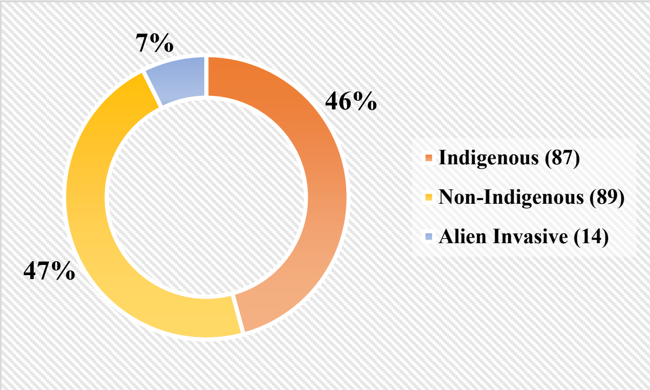


Figure 5.58. Proportional shares of indigenous, non-indigenous and invasive floral species recorded in Cape Town community gardens.

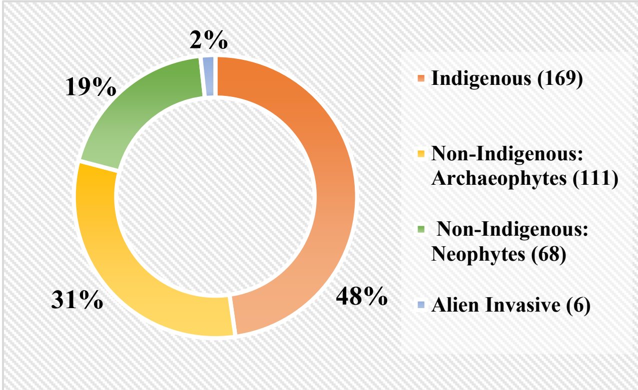


Figure 5.59. Proportional shares of indigenous, non-indigenous (archaeophyte, neophyte) and invasive floral species recorded in Berlin community gardens.

While invasive species numbers were not high in either city, weedy species and some problematic neophytes caused issues for gardeners in ***Cape Town*** and ***Berlin*** respectively. The most common occurring weedy species in ***Cape Town*** were kikuyu grass (*Pennisetum clandestinum*), Patterson's curse (*Echium plantagineum*) and plantain (*Plantago lanceolata*) and in ***Berlin*** St John's Wort (*Hypericum perforatum*), primrose (*Oenothera oakesiana*) and Lucerne (*Medicago spp*) (Tables D20 and D23 – Appendix D). Although clover is not a neophyte in Germany, red clover (*Trifolium pratense*) and white clover (*Trifolium repens*) were very common weedy species in ***Berlin*** gardens. In terms of problematic animals, rats (*Rattus spp*) were a problem in both cities, Egyptian geese (*Alopochen aegyptiaca*) and guinea fowl (*Numida meleagris*) destroyed crops in ***Cape Town*** gardens (Table D22 – Appendix D) and slugs (*Limax maximus*) and snails destroyed crops in ***Berlin*** (Table D25 – Appendix D).

Questionnaire respondents were asked if any invasive plant or animal species caused problems in the garden (Q.33). Opinions were mixed in both cities. In ***Cape Town***, 13% of the respondents were in high agreement, 25% in medium agreement and 38% disagreed, while in ***Berlin***, 36% of respondents were in medium agreement, 23% in low agreement and 27% disagreed (Figure 5.60). Despite and the majority of floral species being non-indigenous, they had been introduced into the garden on purpose and held no ecological detriment to indigenous species. In addition, very few animal species were considered to be problematic in both cities. Insights from the majority of garden users in both cities therefore suggests that the general perception is that of community gardens do not have a high amount of ecological impacting disservices relating to the presence of invasive species in garden areas, but do still have a few problematic species to deal with in gardening activities.

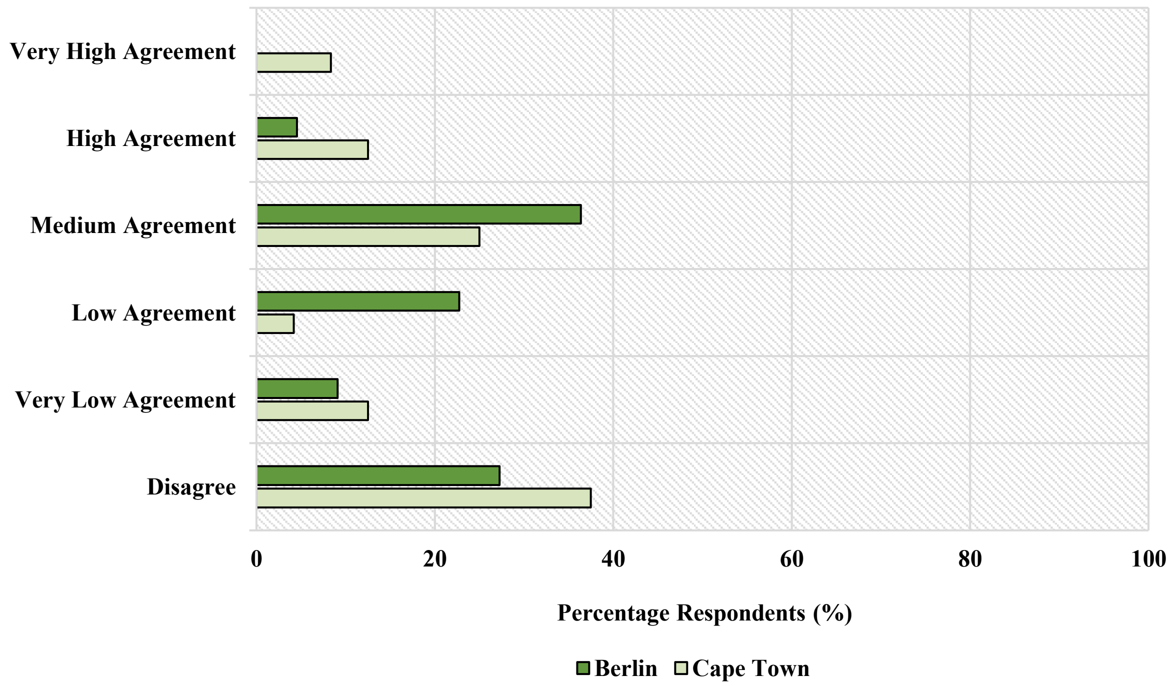


Figure 5.60. Questionnaire responses when asked whether any invasive plant or animals species cause problems in the garden.

5.4.2. Economic impacting disservices

Economic impacting disservices inferred from indicators in this research include: *damage to infrastructure by nature*, and *costs associated with repairs and maintenance of urban vegetation/nature*.

5.4.2.1. Damage to infrastructure by nature

The indicator used to make inferences about the damage to infrastructure by urban nature is **amount of affected infrastructure**, where amount of affected infrastructure (m^2) is the total area of damaged infrastructure observed and measured in the total community garden (Lyytimäki et al., 2008; Gómez-Baggethun and Barton; 2013; von Döhren and Haase, 2015).

Al-Noor orphanage garden in ***Cape Town*** had the only measurable infrastructure damage due to nature in any of the gardens in both cities. This was damage to garden fencing and shade-cloth over vegetable patches because of strong winds, and was measured at 85 m^2 (45% of the total garden area). In total, the amount of damaged infrastructure was negligible in both cities, with community gardens having low capacities for damaging garden infrastructure.

Qualitative results collected from the questionnaire appear to reiterate that community gardens in ***Cape Town*** and ***Berlin*** have a low capacity for damage to infrastructure by nature. Respondents were asked whether infrastructure in the garden was often damaged by nature (Q.34). In ***Cape Town***, a majority of 58% of the respondents disagreed that infrastructure was often damaged, while in ***Berlin*** 41% disagreed and 32% were in very low agreement. In contrast, only 4% of respondents in ***Cape Town*** very highly agreed and 9% in ***Berlin*** were in medium agreement (Figure 5.61). Overall, those people interacting with community gardens in both cities perceive that the damage to infrastructure caused by nature in community gardens was low, and did not experience those disservices often.

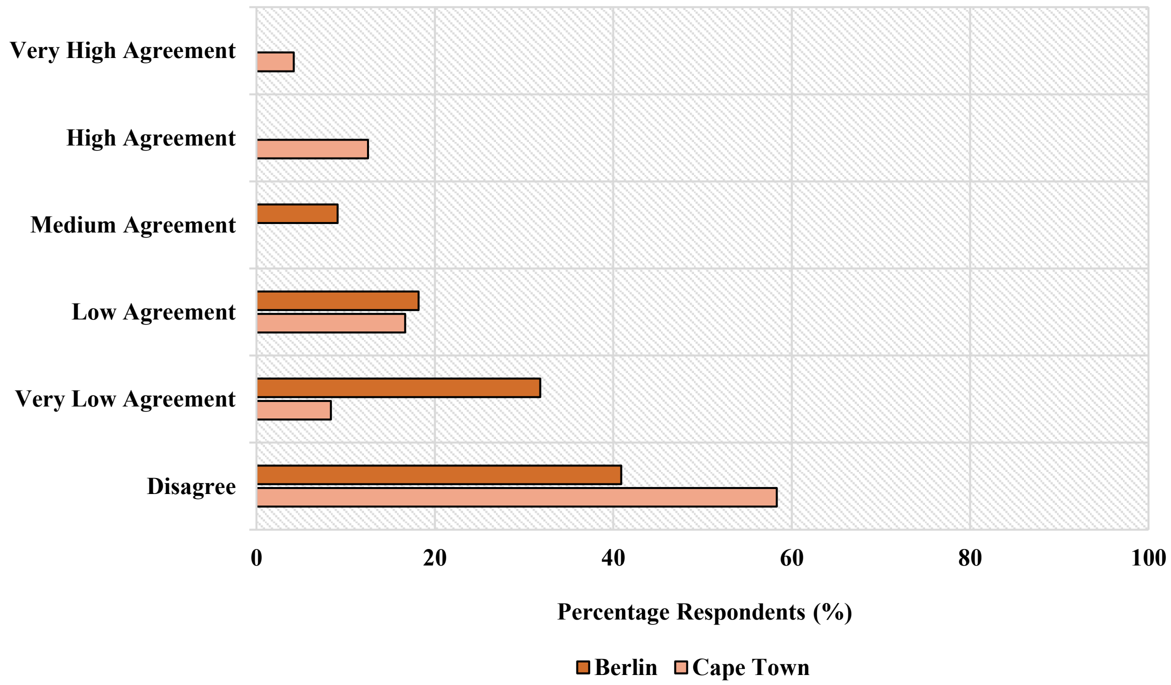


Figure 5.61. Questionnaire responses when asked if infrastructure in the garden is often damaged by nature (for e.g. damage from plant growth or roots, corrosion from weather, animal damage to structures, or extreme weather events, etc.).

5.4.2.2. Costs associated with repairs and maintenance of urban vegetation/nature

The indicator used to make inferences about the costs associated with repairs and maintenance of urban vegetation/nature in the gardens is **financial and energy costs associated with maintenance and repair** where the monetary cost associated with monthly maintenance, repairs and energy requirements were obtained for each community garden (Escobedo et al., 2011; von Döhren and Haase, 2015).

Full lists of *monthly costs of maintenance, repairs and energy* in individual community gardens in Cape Town and Berlin are shown in Tables D30 - D31 in Appendix D. Unfortunately, many gardens in both cities either had no available information on these costs or were unwilling to part with this financial information. From those gardens that did provide data, total monthly costs for maintenance and repairs were higher in ***Berlin*** gardens (€5164) than ***Cape Town*** (€2090), while total monthly energy costs were higher in ***Cape Town*** (€211) than ***Berlin*** (€73). Total overall monthly financial costs (maintenance, repairs and energy) for ***Cape Town*** were therefore €2301 across 2,271 ha of community garden area, which translates to €1013 per hectare. In ***Berlin*** gardens, total overall monthly costs were €5237 across 3,258 ha of community garden area, which amounts to €1607 per hectare. Generally, monthly costs per garden were low in both cities except for a few exceptions - Prinzessinnengarten was a standout outlier in ***Berlin*** (€5000) and Woodstock Peace Garden in ***Cape Town*** – both of which significantly brought up the average (Figure 5.62). Overall, the monthly amount of money spent on maintenance, repairs and energy is low in both cities and therefore the economic impacting disservices from community gardens are low.

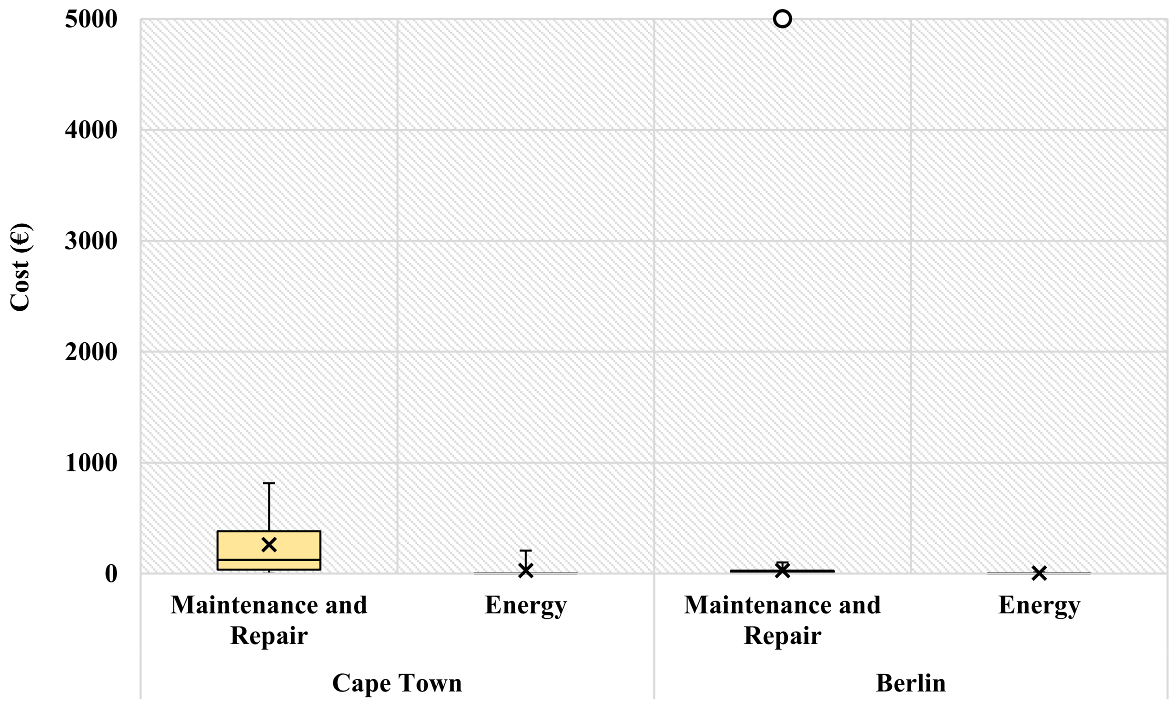


Figure 5.62. Monthly costs in Euros associated with maintenance and repairs, and energy requirements in Cape Town and Berlin community gardens (x denotes the mean).

Questionnaire respondents were asked whether they considered the financial costs associated with maintenance and repair in the garden to be high (Q.35). Both cities had overall similar opinions, with the majority of 63% of respondents in ***Cape Town*** disagreeing, 13% in very low agreement and 8% in low agreement that costs were high. In ***Berlin*** 32% disagreed and a further total of 59% of respondents in very low and low agreement (Figure 5.63). Additionally, respondents were asked if they felt opportunity costs associated with maintenance and repair in the garden (Q.36), and if energy costs for maintenance were high (Q.37). In both cases, the majority of participants disagreed. Overall, people interacting with community gardens in Cape Town and Berlin perceived that the financial costs of maintenance, repair and energy usage were low, and economic impacting disservices were not too high.

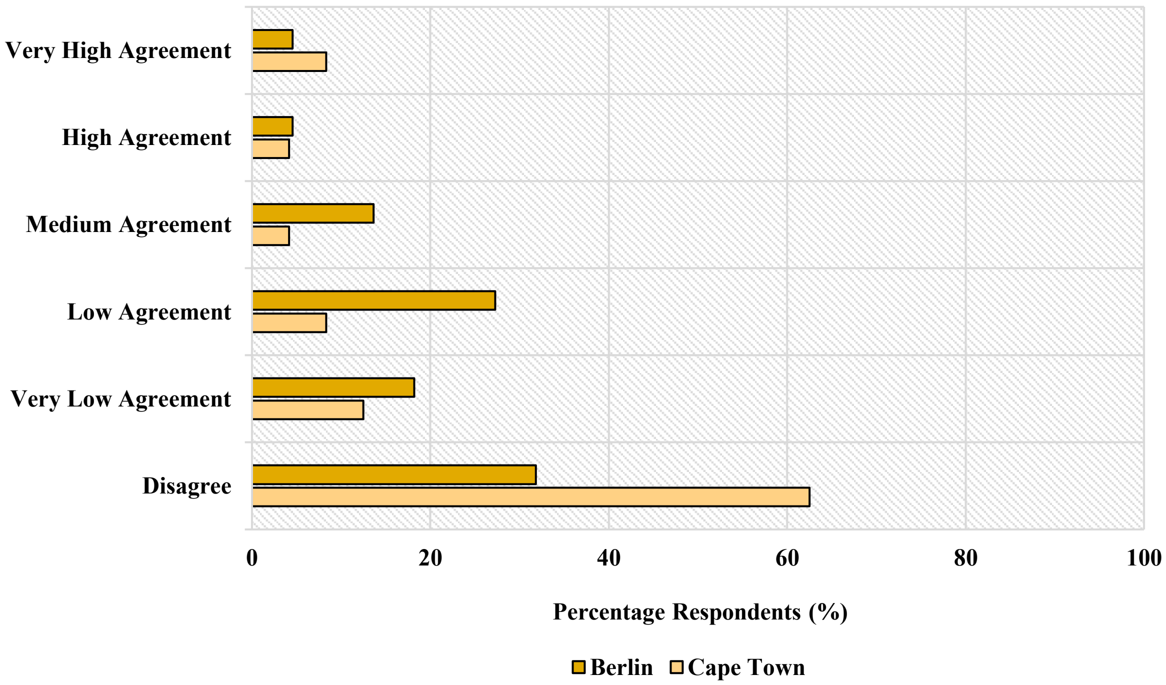


Figure 5.63. Questionnaire responses when asked if respondents felt the costs of maintenance and repair in the garden were high.

5.4.3. Health impacting disservices

Health impacting disservices inferred from indicators in this research include: *allergies/respiratory problems caused by the spread of pollen*, and *wild or semi-wild animals in urban green spaces that cause anxiety over fear of attack, safety or inconvenience*.

5.4.3.1. Allergies/respiratory problems caused by the spread of pollen

The indicator used to make inferences about the allergy problems caused by the spread of pollen in the gardens is **allergenic potentials of problem plants** where OPALS (Ogren Plant Allergy Scale) were calculated for each species recorded in community garden areas (Gómez-Baggethun and Barton, 2013; Dobbs et al., 2014; Ogren, 2015). The OPALS are a scale between 1 – 10 derived by biologist Thomas Ogren rating plant species allergenicity, where 1 is the lowest allergenicity and 10 is the highest (Ogren, 2015). These OPALS were used as a proxy to show community gardens potentials for causing allergies.

According to Ogren (2015), vascular plants or trees ranked with an OPALS 1 – 5 are considered to have fairly low allergenic potential and 6 – 10 high potential. Full lists of vascular plant and tree species and their OPALS for individual community gardens in ***Cape Town*** and ***Berlin*** are shown in Tables D32 - D35 in Appendix D. A number of plant and tree species occurred in each community garden, and thus an average OPALS were calculated per garden.

OPALS for vascular plant species in ***Cape Town*** and ***Berlin*** gardens were low as all gardens averaged below 5 in both cities (Figures 5.64 – 5.65). Specific vascular plant species that had high OPALS, and thus a high capacity for causing allergies, were *Chenopodiastrum murale* (10) occurring in two gardens and *Artemisia afra* (8) in one garden in ***Cape Town***, and *Chenopodium album* (10) occurring in two gardens and *Chenopodium giganteum* (10) in five gardens in ***Berlin***.

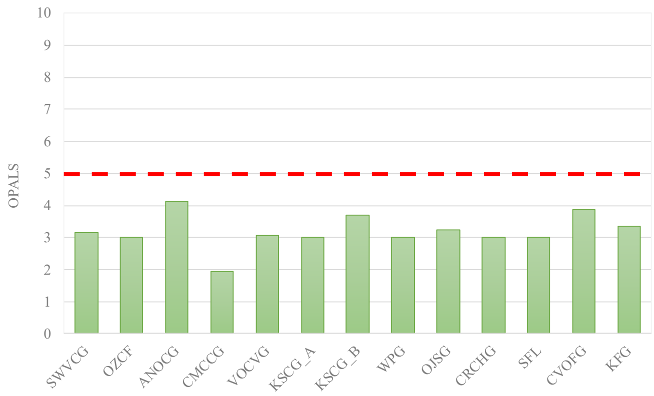


Figure 5.64. Average OPALS for vascular plant species recorded in Cape Town community gardens.

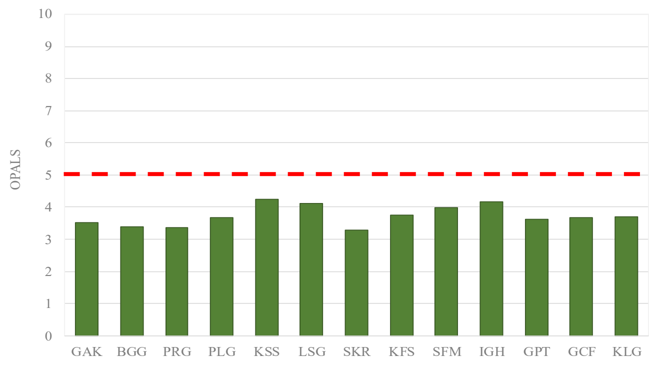


Figure 5.65. Average OPALS for vascular plant species recorded in Berlin community gardens.

OPALS for tree species in ***Cape Town*** were mixed as five gardens averaged above 5 and eight averaged below 5, while ***Berlin*** gardens were generally high scoring with 11 gardens averaging OPALS above 5 (Figures 5.66 – 5.67). Specific tree species that had high OPALS were *Vachellia karoo* (10), *Acacia saligna* (10) and *Podocarpus latifolius* (10) each occurring in one garden in ***Cape Town***, while *Betula pendula* (9) occurred in four gardens and *Juglans regia* (9) in one garden in ***Berlin***. Based on average OPALS, vascular plant species in both cities have overall low allergy potentials and thus little potential capacity for health impacting disservices, while trees, particularly in ***Berlin***, have a high potential capacity for causing all allergy disservices.

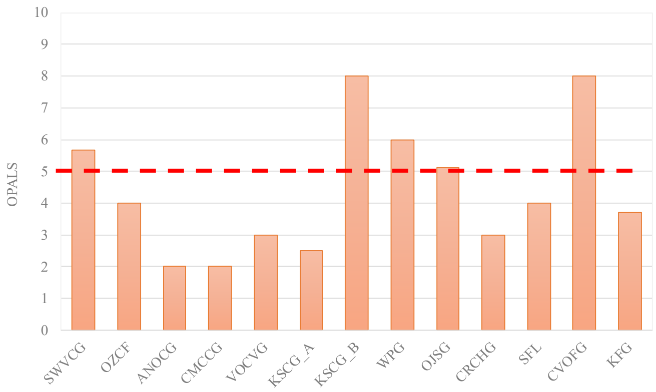


Figure 5.66. Average OPALS for tree species recorded in Cape Town community gardens.

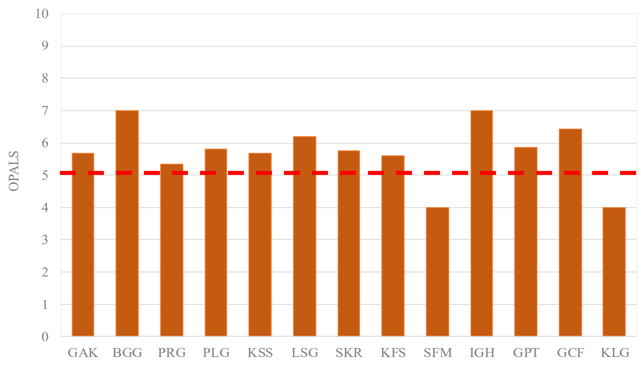


Figure 5.67. Average OPALS for tree species recorded in Berlin community gardens.

Qualitative results collected from the questionnaire suggest that general perceptions from garden users are that community gardens have a low capacity for allergy disservices. Respondents were asked if they suffered from allergies that were exacerbated because of vegetation in the garden (Q.38). For ***Cape Town*** community gardens, no participants were found to experience any allergic or respiratory reactions caused the spread of pollen (100% in disagreement). ***Berlin*** participants were almost as undivided, as 86% of respondents disagreed that they suffered from allergies because of plants in community gardens (Figure 5.68). While opinions in both cities were unanimous that community garden vegetation caused no allergy or respiratory problems, it must be acknowledged that whether one suffers from allergies is down to individual physiology in a person. Opinions could have been significantly different if a subset of questionnaire respondents in both cities had physiological disposition towards allergies. Nevertheless, from an ecosystem disservices point of view, it important to consider species OPALS as these show allergy *potentials* irrespective of whether they are actually experienced or not.

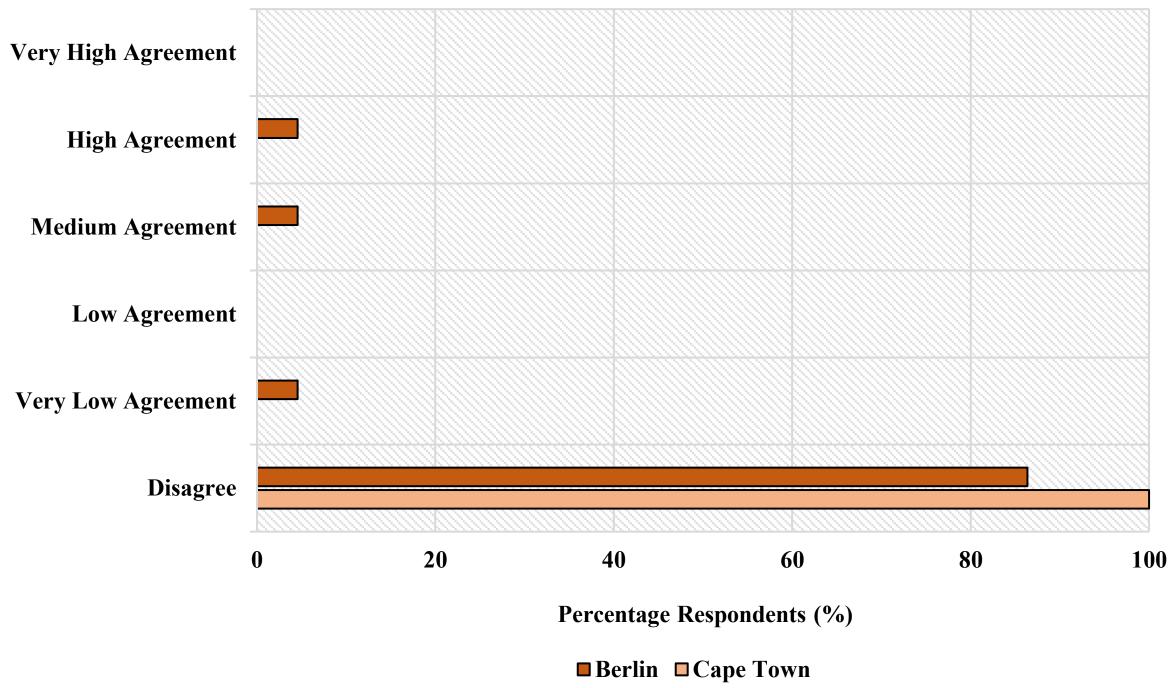


Figure 5.68. Questionnaire responses when asked if respondents experienced allergies that were made worse by plants in the community garden.

5.4.3.2. Wild or semi-wild animals in urban green spaces that cause anxiety over fear of attack, safety or inconvenience.

The indicator used to make inferences about wild or semi-wild animals that cause anxiety over fear of attack, safety or inconvenience is **presence of unwanted species** where participants of the questionnaire were asked to identify those species present in the garden they considered problematic (Lyytimäki et al., 2008; Gómez-Baggethun and Barton, 2013). Since abundances of animal species are hard to measure accurately over time by virtue of the fact that they are constantly mobile, it is difficult to gauge the true abundances of those species in the garden that cause inconvenience in any way. As such, this indicator takes into account their presence only as a proxy for their potential capacity to cause anxiety and inconvenience – defined as those species that either caused physical harm or fear of physical harm to a person, or inconvenience by destroying produce etc. in the garden.

Full lists of *faunal species considered problematic* in ***Cape Town*** and ***Berlin*** gardens are shown in Tables D22 and D25 in Appendix D (species highlighted in red in species lists). In ***Cape Town***, five species were considered an inconvenience mainly due to their destroying of crops

– Aphids (*Aphidae*), various bird species (*Alopochen aegyptiaca*, *Bostrychia hagedash*, *Numida meleagris*) and rats (*Rattus spp*) (Figure 5.69). In ***Berlin***, slugs (*Limax maximus*), snails, and rats (*Rattus norvegicus*) and mice (*Muridae*) inconvenienced gardeners by infesting restaurant and bar areas or eating produce growing in the gardens. In both cities, low percentages (10% - 11%) of the total species richness were considered problematic (Figure 5.70).

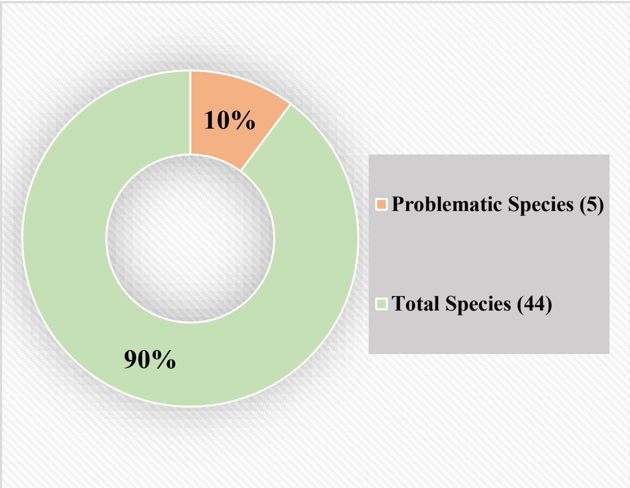


Figure 5.69. Percentage total species richness considered problematic in Cape Town community gardens.

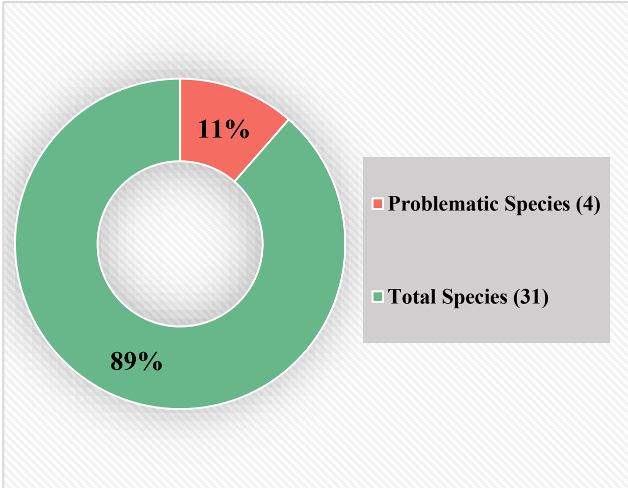


Figure 5.70. Percentage total species richness considered problematic in Berlin community gardens.

Questionnaire respondents were asked whether any wild or semi-wild animals were present in the garden that caused inconvenience or feelings of fear and anxiety for their safety (Q.39). Opinions were alike in both cities as the majority of respondents disagreed that any such animals were present (75% in ***Cape Town*** and 68% in ***Berlin***). In contrast, a low 12% of respondents in Cape Town gardens highly and very highly agreed that such dangers were present (Figure 5.71). Generally, however, people interacting with community gardens in both cities perceived that the threat and inconvenience of wild animals was low.

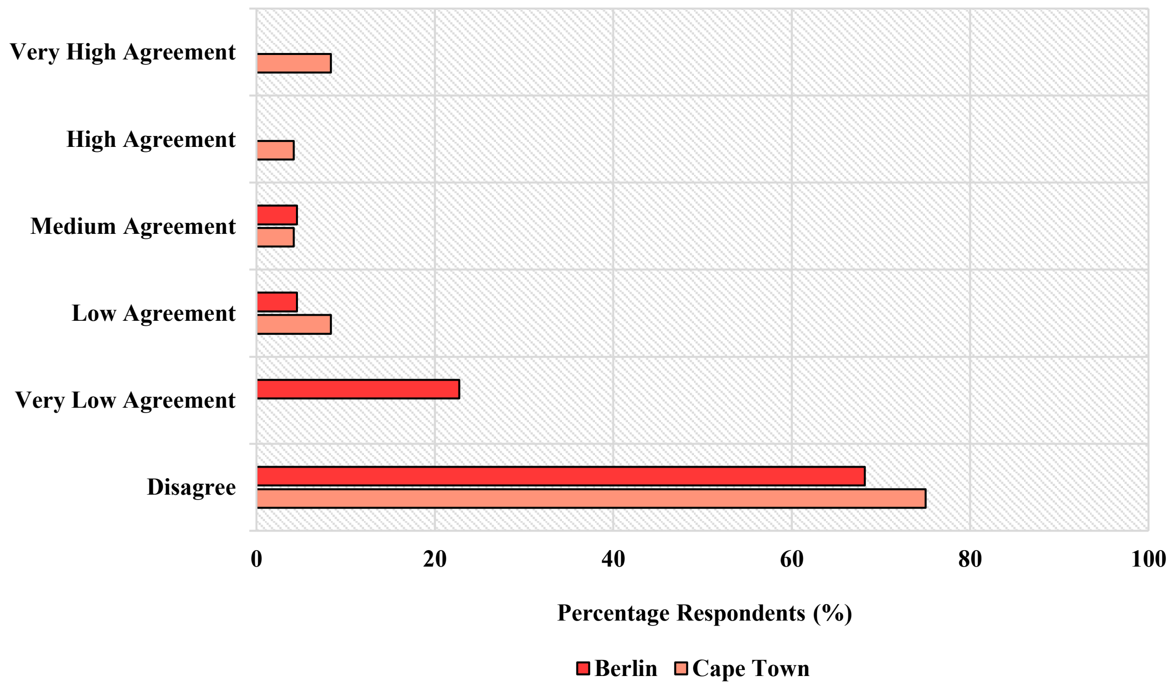


Figure 5.71. Questionnaire responses when participants were asked if certain wild or semi-wild animals present in the garden caused inconvenience or feelings of fear and anxiety for their safety.

5.4.4. Psychological impacting disservices

Psychological impacting disservices inferred from indicators in this research include: *certain smells, sounds or behaviours from people plants and animals may be considered a nuisance or cause annoyance*, *aesthetic and hygiene impact due to animal excrement*, *aesthetic unpleasantness due to vegetative litter from dense/overgrown vegetation, psychological feelings of insecurity / fear associated with overgrown or dark urban green spaces*, and *vegetation blocking views*.

5.4.4.1. Certain smells, sounds or behaviours from people, plants and animals may be considered a nuisance or cause annoyance

The indicator used to make inferences about smells, sounds and behaviours that may be considered a nuisance or inconvenience is **presence of unwanted smells, sounds or behaviours** where participants of the questionnaire were asked whether they experienced any smells, sounds or behaviours present in the garden they considered problematic. During garden visits, it was also noted if any unwanted smells, sounds or behaviours could be identified and observed (von Döhren and Haase, 2015).

No unwanted or foul sounds, smells or behaviours were physically observed during any of the community garden visits in ***Cape Town*** and ***Berlin***. Questionnaire opinions reiterated this finding with almost unanimous results in both cities. First, participants were asked whether any smells or sounds from people, plants or animals in the garden were considered a nuisance or caused discomfort or annoyance (Q.40). An overwhelming majority of respondents in both cities disagreed (100% in ***Cape Town*** and 96% in ***Berlin***) (Figure 5.72).

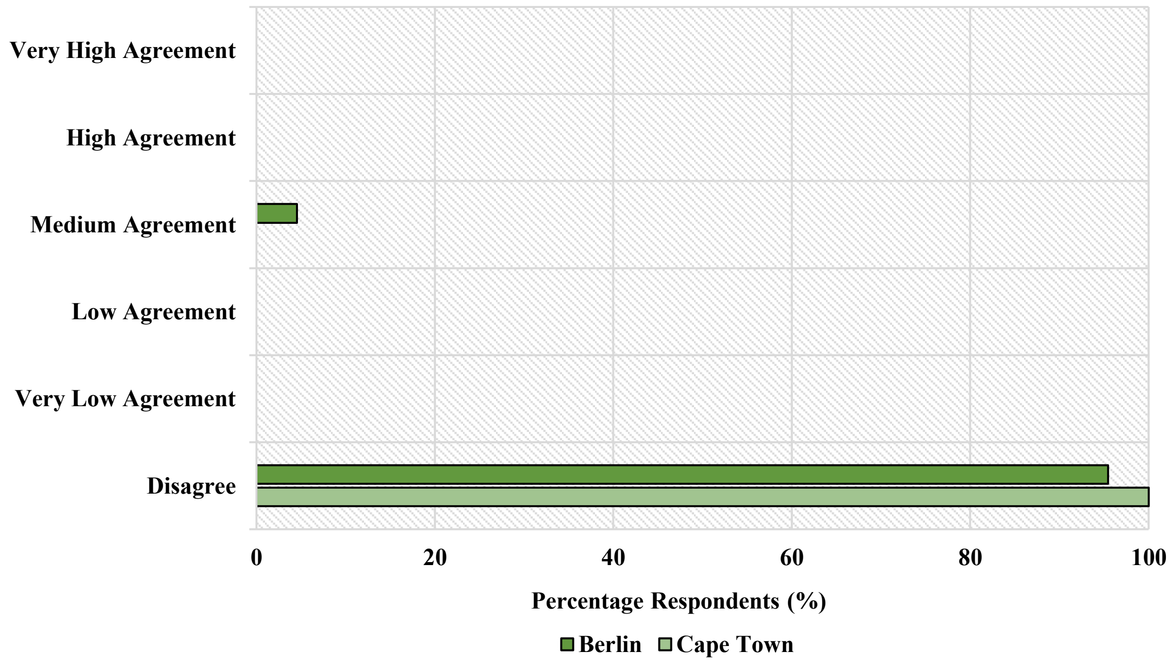


Figure 5.72. Questionnaire responses when asked if any smells or sounds from people, plants or animals in the garden were considered a nuisance or caused discomfort or annoyance.

Second, participants were asked whether any smells or sounds from people neighbouring the garden were considered a nuisance or caused discomfort or annoyance (Q.41). Opinions were again analogous in both cities as a vast majority of participants disagreed that they experienced such discomforts (100% in ***Cape Town*** and 82% in ***Berlin***) (Figure 5.73). Therefore, according to respondent perceptions, few undesirable sounds, smells or behaviours were experienced in both cities and thus the capacity for community gardens in Cape Town and Berlin to deliver such disservices was low.

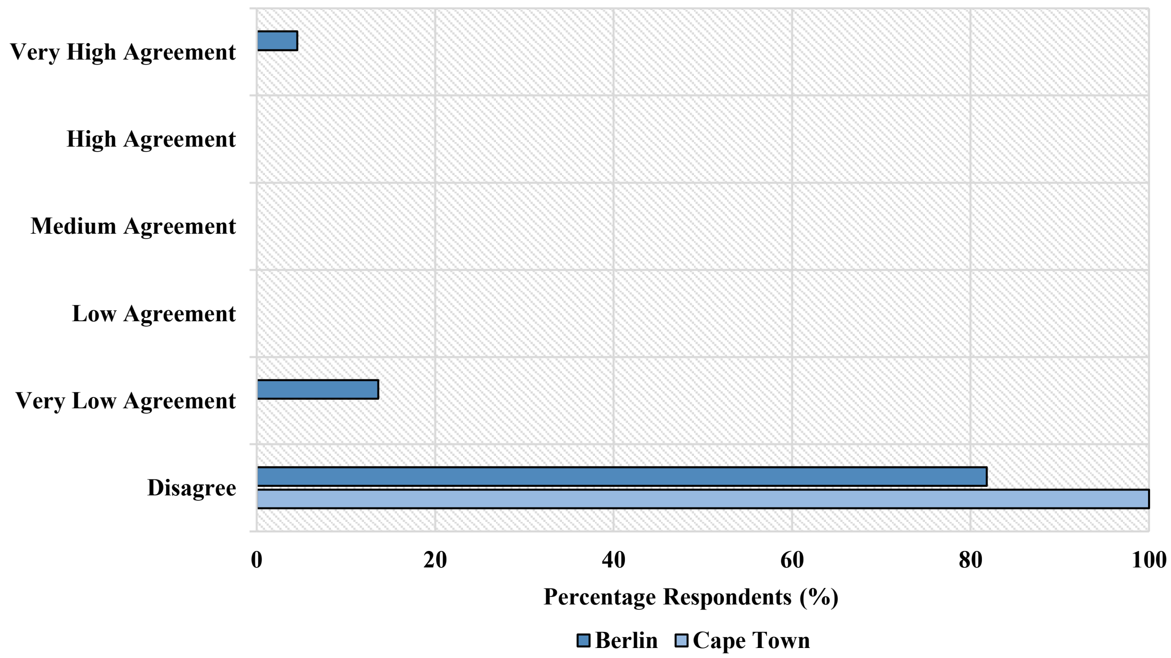


Figure 5.73. Questionnaire responses when asked if any smells or sounds from people neighbouring the garden were considered a nuisance or caused discomfort or annoyance.

5.4.4.2. Aesthetic and hygiene impacts due to animal excrement

The indicator used to make inferences about aesthetic and hygiene impacts due to animal excrement is **presence of animal excrement** where participants of the questionnaire were asked whether they experienced or observed any animal excrement they considered problematic. During garden visits, it was also noted if any animal excrement could be identified and observed (Lyytimäki et al., 2008).

No animal excrement was physically observed during any of the community garden visits in ***Cape Town***, while one garden in ***Berlin*** (Interkultureller Gemeinschaftsgarten Himmelbeet) had observable animal excrement.

Results from questionnaires showed that participants felt animal excrement was not a major problem in the gardens. Most ***Cape Town*** (92%) and ***Berlin*** (73%) respondents disagreed when asked if animal excrement and waste was a problem in the garden (Q.42) (Figure 5.74). Based on participant perceptions, disservices caused by animal excrement in community gardens is low in both cities.

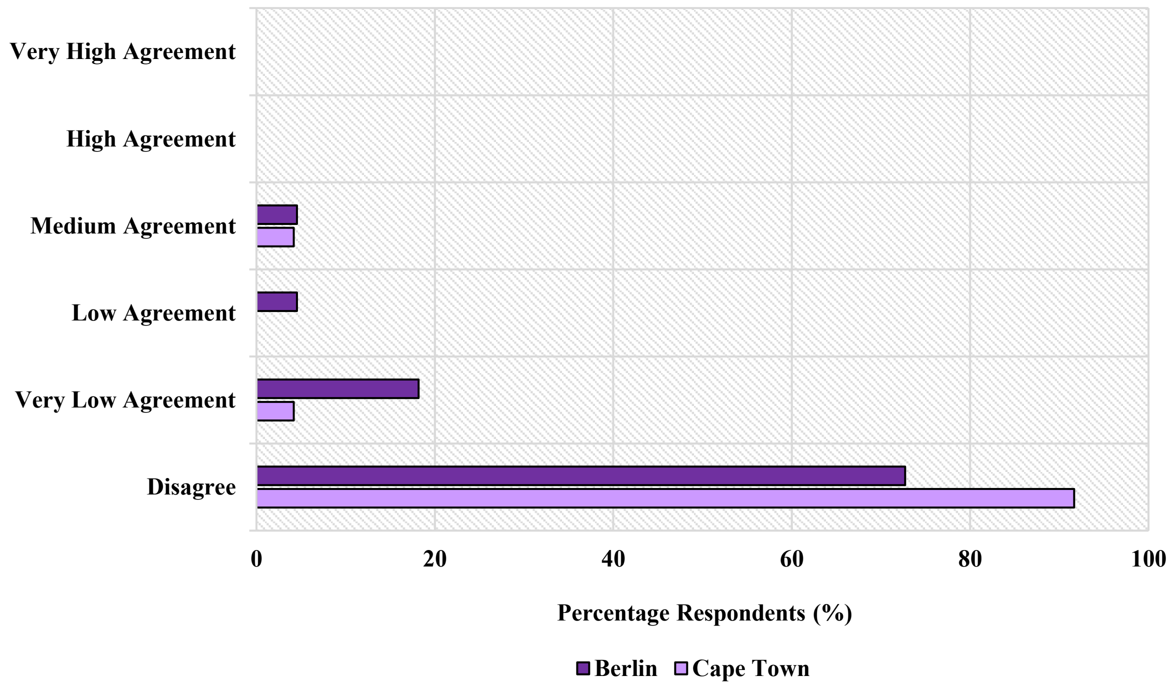


Figure 5.74. Questionnaire responses when participants were asked if animal excrement was a problem in community gardens.

5.4.4.3. Aesthetic unpleasantness due to dense/overgrown vegetation

The indicator used to make inferences about aesthetic unpleasantness due to vegetative litter from dense/overgrown vegetation, brownfields, wastelands is **land cover** where observed aesthetic unpleasantness as a result of the existing landcover was recorded during community garden visits. In addition, participants of the questionnaire were asked whether they experienced or observed any aesthetic unpleasantness from superfluous vegetative litter or overgrown vegetation in the garden (Lyytimäki et al., 2008; von Döhren and Haase, 2015).

'Aesthetic unpleasantness' is a subjective concept and differs between people. What might look untidy to one person can be perceived as wild and preferable to another. It is therefore difficult to quantitatively assess vegetation considered overgrown or unkept. However, a generalised observation from garden visits in both cities is that overall, ***Cape Town*** gardens had more structured and formally-set layouts compared to ***Berlin*** gardens, where many felt more wild and natural in their design.

Questionnaire respondents were asked whether they felt like the community garden they interacted with had a lot of overgrown or poorly maintained vegetation that looked untidy and unpleasant (Q.43). In ***Cape Town***, 67% of participants disagreed that the garden had a lot of overgrown and untidy vegetation and in ***Berlin***, 77% were in very low agreement and disagreement. Contrastingly, 13% of the respondents in ***Cape Town*** highly and very highly agreed that unkept and poorly maintained vegetation was present in the garden that looked untidy (Figure 5.75). So, while answers were mixed for ***Cape Town***, overall opinions in both cities show that people interacting with community gardens perceived aesthetics to be good.

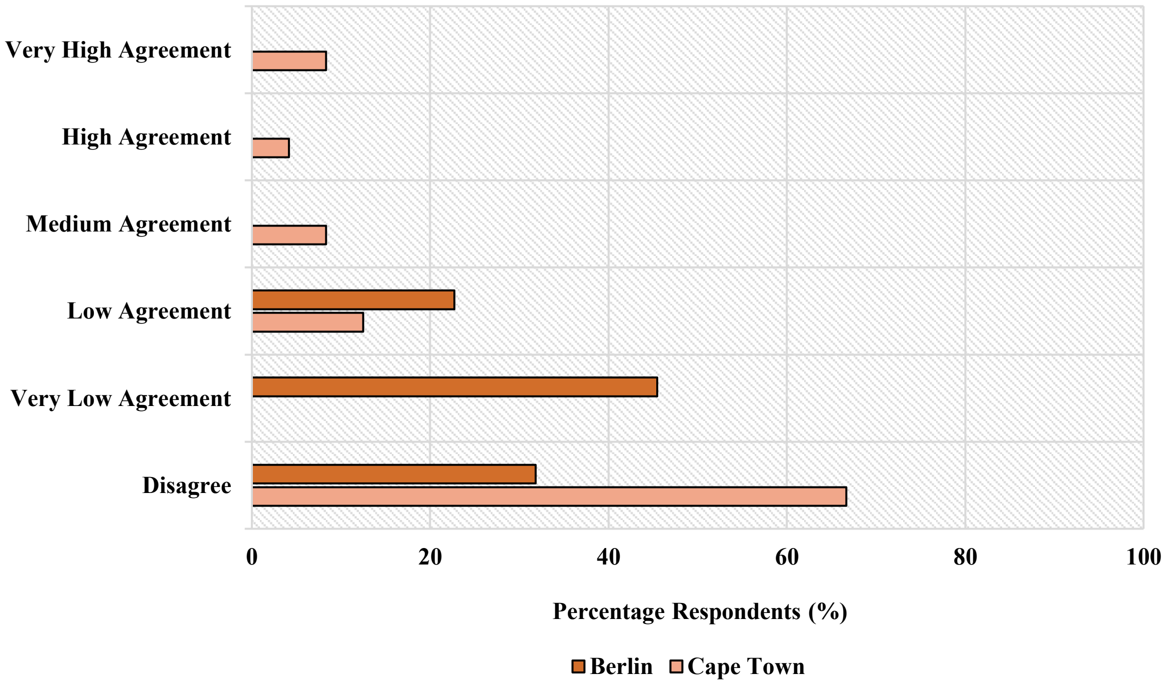


Figure 5.75. Questionnaire responses when participants were asked if community gardens had a lot of overgrown or poorly maintained vegetation that looked untidy and unpleasant.

5.4.4.4. Psychological feelings of insecurity/fear associated with overgrown or dark urban green spaces

The indicator used to make inferences about feelings of insecurity/fear associated with overgrown or dark urban green spaces is **area of non-illumination** where the area of non-illumination of community gardens was measured. In addition, participants of the questionnaire were asked whether they experienced feelings of insecurity or fear due to overgrown or dark spaces in the garden, particularly at night (Lyytimäki et al., 2008; Gómez-Baggethun and Barton, 2013; von Döhren and Haase, 2015).

Every community garden visited in ***Cape Town*** had 100% of the garden non-illuminated – i.e. none of the gardens had any lighting. This is because gardens were closed and locked at night, and entry is forbidden after certain hours – usually overnight. All gardens in ***Berlin*** were dark and not illuminated, except for Prinzessinnengarten that had some lighting in and around the on-site restaurant.

Opinions collected in the questionnaire showed although most gardens had no lighting, very few felt afraid of these dark spaces. When asked about non-illuminated areas in the garden that might cause feelings of insecurity or fear in the dark (Q.45), 100% of the respondents in ***Cape Town*** and 64% in ***Berlin*** respectively stated they felt no such spaces were present (Figure 5.76). ***Cape Town's*** results were expected as no gardens were open at night. In contrast, a few ***Berlin*** gardens were open 24 hours and had no locked fencing around them (for e.g. Kiezgarten Schliemannstraße, Lichtenberger Stadtgarten, Gemeinschaftsgarten Spreeacker) and 5% of respondents were in very high agreement that there were dark spaces which caused them fear and anxiety at night. An overwhelming majority of respondents in both cities, however, perceived no feelings of insecurity or fear.

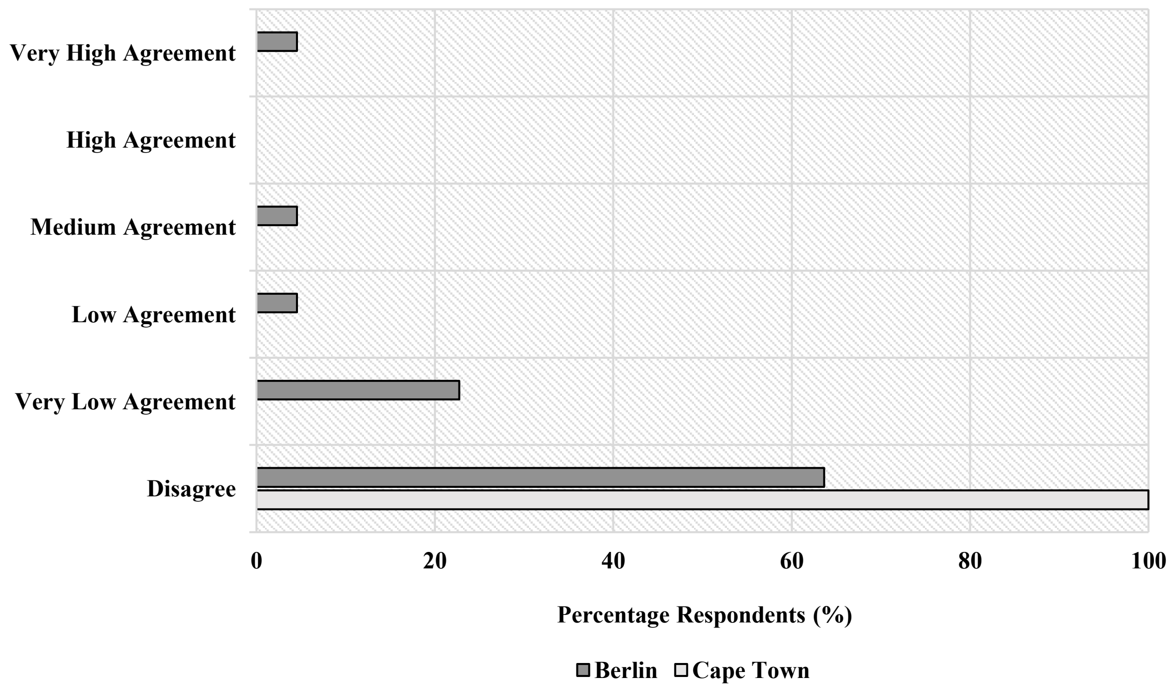


Figure 5.76. Questionnaire responses when asked if non-illuminated areas in community gardens caused respondents to have feelings of insecurity or fear at night.

5.4.4.5. Vegetation blocking views

The indicator used to make inferences about vegetation that blocks views is **land cover** where observed vegetation or tree cover was used as a proxy for obstruction to views to or from the garden (Lyytimäki et al., 2008; Gómez-Baggethun and Barton, 2013; von Döhren and Haase, 2015). View obstruction is a subjective concern as appreciation for certain views change between people, therefore this is a difficult disservice to quantify. As such, those gardens where participants stated they experienced vegetation obstructions to views were focused on. This involved identifying that vegetation considered to obstruct the views to/from the garden, recognizing the possible number and size of the obstructing vegetation and estimating its distance to the garden or its infrastructure.

Cape Town: Six gardens (46%) stated they felt vegetation in or surrounding the garden caused or had the potential to cause obstruction to views and/or transport networks to/from the garden to a significant degree.

Somerset West Village Community Garden: A row of Eucalyptus street trees were within 0.5m of the front of the garden and the road to enter the garden. Gardeners stated that the extensive root system of the trees often had effects of the tarred roads and damaged walkways to the garden.

Oranjezicht City Farm: The garden was situated at an elevated vantage point at the base of Table Mountain, overlooking the ocean and harbour. Gardeners stated that the vegetation of the vacant land in front of the garden obstructed these ocean/harbour views as it was unmaintained.

Woodstock Peace Garden: Gardeners stated that the garden had very dense vegetation in some areas which blocks out all exterior views and creates a very insular environment.

Soil for Life: Trees from a surrounding plantation were found to block out all exterior views of the surrounding mountains.

Khulisa Streetscape Community Garden_B: Garden occurs underneath a pine plantation. Pine is very messy, so immediate vegetation in the garden blocks an overhead walkway and blocks mountain views.

Kronendal Flower Garden: A row of tall Oak trees within 0.5 m from the garden fence blocked mountain views. Trees are in the neighbouring school property.

***Berlin*:** One garden (8%) specified that tall vegetation in or surrounding the garden caused the obstruction of views.

Lichtenberger Stadtgarten: Garden was surrounded by park trees to the one side and rows of street trees on the other. This created a very insular feeling when inside the garden.

Quantitative results obtained in the questionnaire showed that few people felt that garden views were obstructed because of vegetation. Participants were asked whether any tall vegetation in or near the garden obstructs views or transport networks and affects them (Q.44). A majority of respondents in both cities (58% in ***Cape Town*** and 73% in ***Berlin***) disagreed that this was the case. Alternatively, a low 13% of respondents in ***Cape Town*** and 5% in ***Berlin*** respectively felt that tall vegetation did create obstructions (Figure 5.77). People interacting with community gardens in both cities however generally perceived no negative impacts from tall vegetation causing any significant disservices with respect to obstructing views and/or transport networks surrounding the gardens.

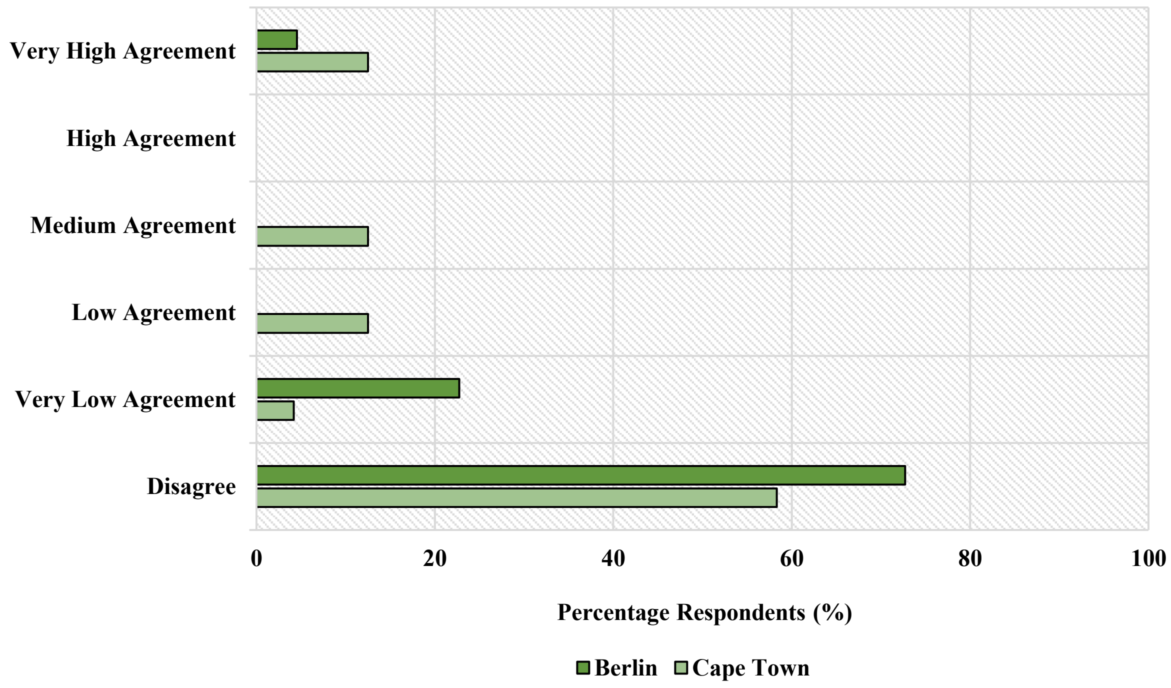


Figure 5.77. Questionnaire responses when participants were asked if tall vegetation blocks views or obstructs transportation networks at or near the garden which affects them.

5.4.5. General impacting disservices on human well-being

General impacting disservices calculated and inferred from indicators in this research include: *presence of conserved or protected species can restrict the uses of an area, hindering benefit of those seeking to enjoy nature (habitat competition with humans)*.

5.4.5.1. Presence of protected species can restrict the uses of an area, hindering benefit of those seeking to enjoy nature

The indicator used to make inferences about conserved area that hinder access and thus enjoyment is **conservation areas** where gardens were checked and observed for areas of private or inaccessible land due to conservation measures or protection measures were recorded (Lyytimäki et al., 2008; von Döhren and Haase, 2015).

No restricted or protected areas were physically observed during any of the community garden visits in ***Cape Town*** and ***Berlin***.

Results from questionnaires showed that almost all participants perceived no disservices relating to restricted or conserved areas in community gardens. An overwhelming majority of respondents in both cities (100% in ***Cape Town*** and 91% in ***Berlin***) disagreed when asked if any restricted areas in the garden hindered the benefits they received (Q.46) (Figure 5.78).

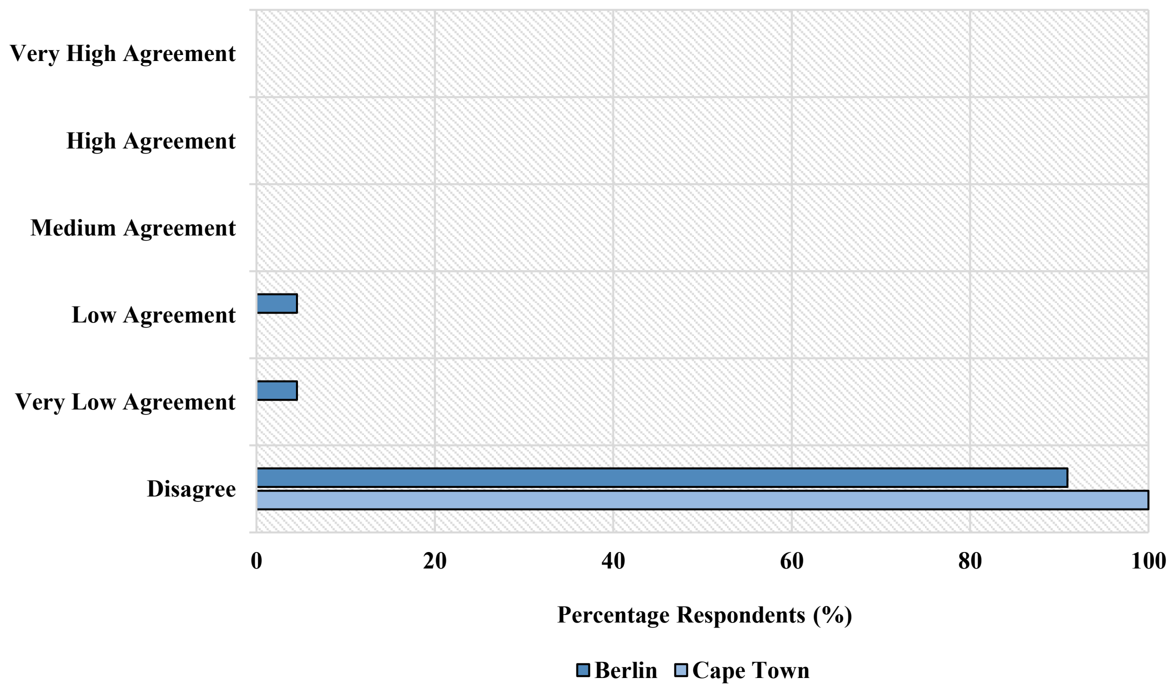


Figure 5.78. Questionnaire responses when participants were asked any restricted or private access areas were present in the garden and which they would like to access.

5.4.6. Discussion of major ecosystem disservices findings

Major findings of assessments carried out suggest that the range of ecosystem disservices generated in community gardens was low in both ***Berlin*** and ***Cape Town***.

Ecological impacting disservices

Cities are found to be hotspots of biological invasions as factors such as land-use, amount of impervious surfaces, distance to the city centre, human population size and building density are shown to relate to the success of non-indigenous species in urban areas (Celesti-Grapow et al., 2006; Kuhman et al., 2010; Gaertner et al., 2017). Urban green is particularly susceptible to invasions from problematic species, that can negatively affect and alter ecosystem structure and functioning upon which urban societies depend (Gaertner et al., 2017). Community gardens assessed in this study, however, appeared to counter this vulnerability with only few alien invasive species being found in both cities.

Low numbers of invasive floral species (14 species, 7%) in ***Cape Town*** community gardens (Figure 5.58) can possibly be explained by three main factors:

1) Stringent maintenance regimes in most gardens meant that frequent weeding and upkeep took place.
2) Severe drought in ***Cape Town*** likely had an influence on the persistence of spontaneous vegetation, as water was highly rationed and used for crops requirements alone.
3) On average, high percentages of garden areas were used to grow food leaving little space for other vegetation to grow.

These three aspects also conceivably explain the large difference in overall vascular plant species richness between ***Cape Town*** and ***Berlin*** community gardens. In ***Berlin***, the low percentage of invasive species (6 species, 2%) (Figure 5.59) accounts to Germany having only 38 invasive vascular plant species (Das Bundesamt für Naturschutz, 2013), but a large variety of neophytes did cause gardeners some problems during maintenance and garden care. This was because ***Berlin*** gardens generally had less stringent management procedures, and were left to grow 'wild' by choice/design which allowed the proliferation of weedy species more frequently than ***Cape Town***.

Economic impacting disservices

Most community gardens in both cities had basic in-garden sheds/buildings with little to no formal on-site infrastructure which meant that damage to any structures by urban nature was minimal. The economic costs associated with maintenance, repair and energy usage were therefore kept low in most gardens which is a positive outcome considering community gardens are generally managed and funded by non-profit associations or community/neighbourhood groups. Economic resources are central to the persistence of community gardens and disservices associated with garden costs have the capacity to decide whether a garden survives, especially if those costs are high. Gardens in ***Cape Town*** that expressed the highest concerns with costs of maintenance were expectedly those with the most intense and stringent maintenance regimes, where money was used for gardening ameliorants like composting. In ***Berlin***, the gardens stating concerns over high maintenance costs were those with restaurant or bar facilities and had to use funds to maintain infrastructure and facilities associated with these. Garden purpose and amount of infrastructure therefore appeared to positively correlate to the economic costs that were incurred in community gardens in both cities.

Health impacting disservices

As many of the gardens in ***Berlin*** and ***Cape Town*** were located close to the city centre, health disservices linked to fear of attack from wild animals were low and an expected outcome, largely due to the absence of any dangerous ones. Such a disservice is likely more common in large urban parks or forests, where the green area is bigger and isolated, and larger animals find it easier to live and hide largely beyond the reach of humans (Villaseñor et al., 2014). Community gardens did however, have to contend with smaller pests that mainly caused inconvenience by eating produce, but not on a large scale.

Potential allergy related disservices caused by the spread of pollen were deemed to be low from extant vascular plant species in both cities, and moderate to high from tree species (Figures 5.64 – 5.67). These results are certainly context specific and cannot be generalised for broader community garden meaning as they are entirely dependent on either, which vascular plant and/or tree species people choose to plant in their gardens, or those existing vascular plant and/or tree species that are already there. Moreover, whether people *actually* experience allergies in dependent on their own physiology, and gardener opinions from the questionnaire could have been entirely altered if different people had answered the questionnaire instead. Nevertheless, results obtained from urban plant and tree allergy assessments are important and can be related to studies like Vogt et al. (2017) who developed the Citree database to aid local municipalities in choosing urban tree species to minimise the disservices delivered by them. If city planners and managers minimise the *potential risk* of allergies from urban vegetation by knowing of and planting species with low OPALS and managing those with high OPALS, the *actual experienced* health disservice is minimised irrespective of individual human physiological vulnerabilities.

Psychological impacting disservices

Psychological impacting disservices registering in a low capacity in ***Berlin*** and ***Cape Town*** mainly pertained to aesthetic unpleasantness, either from animal excrement or unkept vegetation. While ***Cape Town*** gardens were mostly formally structured in terms of garden layout and more intensely maintained compared to ***Berlin*** gardens that were organised to feel 'natural' and 'wild' by design, a majority of users in each context felt the aesthetics of garden spaces were desirable in the urban landscape. This result is interesting as it points out the subjectivity of a concept like 'aesthetic unpleasantness' and how people's perceptions of what looks nice and what doesn't are based on personal preferences. This subjectivity also relates to perceived disservices associated to vegetation that is considered to block views of garden users as a subset of garden users may find tall vegetation to be a hinderance while others may appreciate the insular feeling of garden spaces from the surrounding city landscape.

In addition, community garden users in both cities generally perceived that garden spaces did not have areas that caused them fear or safety concerns in the dark. As a majority of the gardens assessed in both cities were not accessible and locked in the overnight hours, this was expected. This particular disservice is mostly associated with open urban green spaces like parks and forests, as was observed by Jorgensen and Anthopoulou (2007) in their study on urban woodlands, where people felt secluded and unsafe in the dark because of the open spaces in them.

Conclusion

The most salient outcome from results of ecosystem disservices generated in community gardens in Berlin and Cape Town is that there aren't many of them, including perceptions by garden users. This adds value to community gardens as a legitimate urban land-use in both cities as local municipalities are able to identify explicitly that gardens spaces in ***Cape Town*** and ***Berlin*** cities provide various benefits but few detriments, and can plan and manage accordingly in both cities. It is difficult to relate these disservices inventories to existing studies as no previous work on ecosystem disservices from community gardens is presently available - this assessment and its outcomes are currently the first encompassing both concepts and is a critical starting point for any subsequent ecosystem services and disservices research.

5.5. Final assessment of results using Burkhard-type matrices

Large amounts of quantitative and qualitative results are presented in sections 5.3 and 5.4 of this chapter. In order to provide a clear and concise synthesis of these, Burkhard-type matrices are compiled for all ecosystem services and disservices assessed in ***Cape Town*** and ***Berlin*** community gardens as a final assessment. These tables are a useful tool to simplify and graphically summarise large amounts of results relating to ecosystem services and disservices inventories from a particular environment or land-use type (Burkhard et al., 2009).

Final scores used in the matrices are calculated in the following way (see Tables E1 - E4 in Appendix E for full score calculations and their rationale):

1) ***Qualitative scores***: Averages were obtained from SPSS statistics with regards to questions pertaining to certain ecosystem services and disservices, and these average values were taken as a qualitative score. This was a simple task as the questionnaire used a ranking scale similar to that of a Burkhard-type matrix.
2) ***Quantitative data***: Quantitative data, where possible, were converted into values out-of-five to coincide with the Burkard scale used in the matrices. Where data could not be converted, quantitative scores were based on a degree of personal judgement, and previous matrix values from Burkhard et al. (2009) and Speak et al. (2015) for general urban gardens.
3) ***Final scores***: Once single qualitative and quantitative scores had been obtained for each ecosystem service and disservice, these were averaged to attain a final score which is observable in the matrices below (Tables 5.12 and 5.13).

Values in the matrix are used because they represent community gardens' capacities to provide the individual service or disservice assessed on a scale between 0 – 5 (Burkhard et al., 2009), where: 0 = no relevant capacity (i.e. a service or disservice is unlikely to be provided), 1 = low relevant capacity, 2 = relevant capacity, 3 = medium relevant capacity, 4 = high relevant capacity, and 5 = very high relevant capacity (i.e. a service or disservice is very likely to be provided).

5.5.1. Ecosystem services

Ecosystem services generated in community gardens in both cities provide roughly the same type and in similar capacity, although a number of subtle differences are evident (Table 5.12).

Provisioning services are the lowest averaging category of ecosystem services in both cities ($\bar{x} = 2$), but ***Berlin*** gardens are found to have a higher score for crop provisioning based on higher overall crop richness and crop area percentages. Livestock is not a common food source in community gardens of either city, but is measurable in a low capacity. ***Berlin*** gardens have a higher capacity for fresh water provisioning because of readily available tapped water resources from the municipality and frequent rainfall compared to ***Cape Town*** that is experiencing strict municipal water restrictions because of drought, thus garden water requirements are constantly stressed and unsustainable.

Regulating services average the same in Cape Town and Berlin ($\bar{x} = 3$), with generally all ecosystem services being regulated in a comparable capacity. Local climate regulation is adjudged to be medium capacity in both cities due to gardens generally having few trees to provide shade (and thus enhance local temperature control) or to store and sequester carbon in any significant capacity. General low tree densities and small tree sizes recorded in community gardens in both cities also appear to have a clear influence on limiting capacities for air quality regulation and the moderation of extreme weather events like rain or wind storms. Noticeably, water flow regulation and run-off mitigation scored highly in both cities, mainly due to large areas of gardens being occupied by vegetated surfaces and few impervious ones. Erosion prevention services scored higher values in ***Cape Town*** than ***Berlin***, largely attributable to ***Cape Town*** gardens having a higher overall percentage of garden areas occupied by vegetated surfaces to act as binding agents of the soil.

Habitat/supporting services have a higher delivery in ***Berlin*** gardens ($\bar{x} = 4$) than in ***Cape Town*** ($\bar{x} = 3$), largely due to the overwhelmingly higher number of vascular plant richness in ***Berlin*** compared to **Cape Town**. Species diversity values as calculated by the Shannon diversity index show how community gardens function as important spaces for biodiversity in urban landscapes, and can be rich biodiversity hotspots. Using species richness and diversity as indirect indicators of microhabitat availability, ***Cape Town*** and ***Berlin*** community gardens also have a good capacity to provide natural and man-made habitats for species.

Cultural services are high scoring in both cities showing the importance of community garden spaces beyond food production. These areas are shown to be used for peoples' recreational enjoyment in a number of ways, and contribute to users' mental, physical and spiritual health and well-being. Tourism services are experienced in community gardens to a small degree, more so in ***Berlin*** gardens that have facilities like restaurants or bars. Subjectively, community gardens in both cities are highly valued for their aesthetic worth as a green space in urban areas.

Table 5.12. Final assessment of ecosystem services in community gardens in Cape Town and Berlin. Final average scores per ecosystem service are shown in the matrix.

Ecosystem Services	**Cape Town**	**Berlin**
Provisioning Services	$\bar{x} = 2$	$\bar{x} = 2$
Crops	3	4
Livestock	1	1
Wood Fuel	0	0
Timber	0	0
Fresh Water Supply	2	3
Medicinal Resources	1	2
Regulating Services	$\bar{x} = 3$	$\bar{x} = 3$
Local Climate Regulation	3	3
Air Quality Regulation	2	2
Moderation of Extreme Events	2	2
Water Flow Regulation and Runoff Mitigation	4	4
Erosion Prevention and Maintenance of Soil Fertility	4	3
Noise Reduction	3	3
Habitat/Supporting Services	$\bar{x} = 3$	$\bar{x} = 4$
Habitat for Species	3	4
Maintenance of Genetic Diversity	3	4
Cultural Services	$\bar{x} = 3$	$\bar{x} = 4$
Recreation and Mental and Physical Health	3	4
Tourism	2	3
Aesthetic Appreciation and Inspiration for Culture, Art, Design	4	4
Spiritual Experiences and Sense of Place	4	4

Score and colour assessment key

No relevant capacity	**Low relevant capacity**	**Relevant capacity**	**Medium relevant capacity**	**High relevant capacity**	**Very high relevant capacity**
0	**1**	**2**	**3**	**4**	**5**

5.5.2. Ecosystem disservices

A positive outcome of this study is that ecosystem disservices produced by community gardens in both cities are generally low scoring (Table 5.13).

Ecological impacting disservices average $\bar{x} = 1$ in both cities as a low number of the total plant species counted are identified as invasive and a threat to outcompeting and displacing native communities. Neophyte and weedy species do cause a few inconveniences, but only in a low capacity.

Economic impacting disservices are also minimal ($\bar{x} = 1$), with almost no garden infrastructure having been damaged by nature in both cities in either city. Costs associated with maintenance, repair and energy use are the highest impacting disservices, although on average these are relatively low amounts of money per month in both ***Cape Town*** and ***Berlin***. Money availability is a limiting factor in many community gardens, so garden costs are an important disservice to quantify.

Health impacting disservices show low allergenic potential disservices from vascular plants in both cities, and although allergenic potentials from trees were moderate in ***Cape Town*** and high in ***Berlin***, qualitative scores from both cities showed that people in the gardens did not suffer from this potential threat and thus the actual realised disservice is low.

Psychological impacting disservices scored at overall low capacities, with a few instances of perceived aesthetic unpleasantness due to overgrown or dense vegetation being of slight concern in both cities ($\bar{x} = 1$), while vegetation that is considered to block views was a concern in ***Cape Town*** gardens ($\bar{x} = 2$). All other psychological impacting disservices are absent.

General impacting disservices on well-being are absent, with no areas of any garden in either city being off limits or having restricted use.

Table 5.13. Final assessment of ecosystem disservices in community gardens in Cape Town and Berlin. Final average scores per ecosystem service are shown in the matrix.

Ecosystem Disservices	Cape Town	Berlin
Ecological Impacts	$\bar{x} = 1$	$\bar{x} = 1$
Displacement of native by invasive species	1	1
Economic Impacts	$\bar{x} = 1$	$\bar{x} = 1$
Damage to infrastructure by nature	1	0
Garden costs associated with maintenance, repair and energy use	1	2
Health Impacts	$\bar{x} = 1$	$\bar{x} = 1$
Allergies /respiratory problems caused by spread of pollen	1	1
Wild or semi-wild animals causing anxiety over safety/fear of attack	1	1
Psychological Impacts	$\bar{x} = 1$	$\bar{x} = 0$
Unwanted smells, sounds or behaviours from plants and animals	0	0
Aesthetic and hygiene impacts due to animal excrement	0	0
Aesthetic unpleasantness due to overgrown, unkept vegetation	1	1
Feelings of insecurity/fear associated with dark garden spaces	0	0
Vegetation blocking views	2	0
General Impacts on Human Well-Being	$\bar{x} = 0$	$\bar{x} = 0$
Restricted use of certain parts of the garden	0	0

Score and colour assessment key

No relevant capacity	Low relevant capacity	Relevant capacity	Medium relevant capacity	High relevant capacity	Very high relevant capacity
0	**1**	**2**	**3**	**4**	**5**

5.5.3. Synthesis

Findings summarised in Table 5.12 show that, in general, ***Cape Town*** gardens have the highest delivery of cultural services followed by regulating and habitat/supporting services, with provisioning services having the lowest capacity of delivery. In ***Berlin*** gardens, habitat/supporting services present the highest delivery, followed by cultural and regulating services, and similarly, provisioning services are the category with the lowest delivery. These results are interesting in the context of broader urban ecosystem services research where biases towards studies on regulating and provisioning over cultural and habitat/supporting services were found in the literature and discussed in Chapter 2.4.1. As Haase et al. (2014) suggest, this bias occurs because certain ecosystem services, like cultural ecosystem services, and the indicators used to measure them are underdeveloped as they are not well studied and are often difficult to quantify due to issues like subjectivity. The community gardens assessed in this study showed the highest delivery of those very categories that are understudied like cultural and habitat/supporting, therefore results reiterate the need to evolve and improve the indicators and methods used to measure these underdeveloped categories and gather more data on them to address this deficiency of information.

Findings summarised in Table 5.13 demonstrate the overall low capacity of community gardens in both cities to generate ecosystem disservices. In ***Cape Town*** gardens, psychological impacting disservices have the highest delivery followed by economic, health and ecological impacting disservices. In ***Berlin***, economic impacting disservices have the highest capacity of delivery, followed by health and ecological impacting disservices, and psychological impacting disservices the lowest capacity. These findings have no previous context or reference in the literature as of yet, as this disservices inventory is the first of its kind with respect to urban community gardens.

Assessments that take into consideration *both* ecosystem services and disservices delivered are necessary in order to provide holistic and complete data and information to local municipal authorities and other relevant decision makers (Lyytimäki and Sipilä, 2009). Final assessments synthesised in Tables 5.12 and 5.13 show that community gardens provide a net positive benefit to the cities of ***Cape Town*** and ***Berlin***, thus providing legitimacy and impetus to their acceptance as a useful, valuable and valid urban green space and land-use.

5.6. Conclusions

Field assessments conducted in community gardens across ***Berlin*** and ***Cape Town*** reveal that a range of important ecosystem services ecosystem services are generated by these spaces, and that few ecosystem disservices also occur that need to be considered and managed. Outcomes from the questionnaire supported these results as people interacting with community gardens perceived a variety of benefits delivered to them in these areas while experiencing only a few detriments.

Differences of those ecosystem services and disservices generated in each city can largely be attributed to the local socio-economic, physical landscape, environmental and climate conditions of each city. For example, large differences in vascular plant richness between ***Cape Town*** and ***Berlin*** related to personal garden/gardener choices and local environmental and climatic conditions that were stressed in ***Cape Town*** that led to less generation of habitat/supporting services. Differences related to garden costs further show how socio-economic backgrounds in each city, and of garden user groups, influence people's value of money and hence their perception of economic impacting disservices. These examples consequently support idea that the contribution of community gardens to the delivery of urban ecosystem services and disservices is spatially explicit (Andersson et al., 2015).

Having argued that the generation of ecosystem services and disservices is context-specific, issues regarding the transferability of any ecosystem assessment results to a wider general context is raised. Using a multi-case study approach to research can overcome the issue with transferability to an extent, as employing multiple case study cities and gardens within each city under different sets of circumstances (socio-economic, environmental and other) enhances the validity of any generalisations of results and conclusions obtained (Houghton et al., 2013), especially where similarities in results and conclusions exist. For example, both cities showed that cultural ecosystem services were the category with the highest delivery and valued greatly by garden users. This shows the perceived value and benefit of cultural services are experienced similarly across differing socio-economic and cultural contexts, so general conclusions can be drawn (i.e. results are transferable to a degree). Final assessment tables are good resources that easily summarise the similarities and differences in the generation of ecosystem services and disservices between ***Cape Town*** and ***Berlin*** community gardens at a glance. As a number of similarities are evident, it is justifiable that generalisations drawn from the results of this study can be transferred to other contexts with relative validity.

Overall, the net positive benefit of community gardens gives great credence to these spaces becoming a legitimate and formally recognised urban land-use, especially together with the small amount of space they occupy in dense urban environments that frequently contend with land-use conflicts and trade-offs. The inherent purposes, benefits of, and practices in community gardens have been shown to greatly align to the values and purposes of the Great Transition movement by promoting eco-community building, forming sustainability-driven citizen movements, and encouraging a public consciousness that feels a responsibility and duty to the care and protection of the natural world. Community gardens therefore have immense potential for sustainable urban development objectives in ***Cape Town*** and ***Berlin*** by providing green spaces wherein socio-economic, environmental and cultural benefits can be experienced and shared.

Chapter Six

Discussion

6.1. Introduction

This thesis attempts to close a gap in current research by assessing the range of ecosystem services and disservices that are provisioned by urban community gardens so as to highlight their benefits to people and make known any detriments that may be produced. As it currently stands, very few ecosystem service assessments have been conducted in community gardens and no such studies concerning ecosystem disservices exist. However, such assessments are important so that community gardens are recognised as green assets to cities, where their use and benefit is presently underestimated or not explicitly known by local populations, including local municipalities.

The intention in this chapter is to critically discuss and correlate major findings to the four research objectives presented in Chapter One. To contextualise this discussion, a link to theory and literature is required as this places the discussion within the context of the not only community garden research, but also the wider field of ecosystem services and disservices studies. After this discussion, limitations of the study are acknowledged with recommendations for future work to overcome these, and an outlook is provided, wherein the outcomes of this project as they relate to research and practice are highlighted.

6.2. Meeting objectives

Objectives defined to address the primary aim of this research are set out in Chapter One, all of which have been met within the limits of this project. Specified objectives of this research are reiterated here:

1. Calculate the quantitative share of urban community gardens in Berlin and Cape Town respectively.
2. Identify suitable sampling community gardens in Berlin and Cape Town respectively, from which to assess existing ecosystems services and disservices.
3. Identify and assess which ecosystems services and disservices are provided by the chosen sampling community gardens in Berlin and Cape Town respectively.

4. Demonstrate the relevance and contribution of community gardens to sustainable urban development and the Great Transition.

6.2.1. Calculate the quantitative share of urban community gardens in Berlin and Cape Town.

The first objective was to calculate the quantitative share of community gardens in Berlin and Cape Town with the purpose of establishing how much urban area these ecological infrastructure occupies. Aerial photography was obtained for Berlin (Senatsverwaltung für Stadtentwicklung und Wohnen, 2015c) and Cape Town (City of Cape Town, 2016b) and used together with community garden location and size data for each city calculate their urban share.

Migration to urban areas is a continuing global trend and the need for sustainable urban development is an increasingly important issue. The 'compact city', characterised by high density urban form and built environment, has gained global influence as a planning approach for sustainable development in cities to counteract the negative effects of urban expansion and sprawl (Haaland and van den Bosch, 2015). Nevertheless, urban densification is shown to cause issues like competition between land-uses and severe space limitations that negatively impact the availability of urban green space (Jim, 2004; Haaland and van den Bosch, 2015), and in some instances, can cause the removal of it (Brunner and Cozens, 2013). As presented in results in Chapter 5.2, community gardens, because of their compact size and space efficiency, are shown to occupy small amounts of the overall urban landscape. This characteristic makes them extremely suitable to wider integration into 'compact city' planning for sustainable urban development objectives. Comparative advantage of community gardens over other green space types is also gained when taking into consideration the inventory of ecosystem services and disservices that are supplied to people and the city together with their small space requirements. The data gathered on ecosystem services and disservices inventories from community gardens therefore offer key planning, development and management information to local municipalities for sustainable urban development in cities, and provides incentive for their reiterated adoption into urban ecological infrastructure as their value is becomes more widely recognised.

While quantification work in this study was done from the perspective of showing their space efficiency as a comparative asset to other green space types, two interesting research questions for future work arise:

1) To investigate whether the size of community gardens correlates in any way to the volume and/or type of ecosystem services or disservices that are provisioned?

2) To investigate whether very little quantitative share of community gardens is compensated by high qualitative importance of ecosystem services in those spaces. How does quantitative share influence ecosystem disservices?

Such questions raise intriguing avenues for future work and would result in valuable data and information if analysed. Although a range of garden sizes were assessed in both cities in this research, the purpose for this was to avoid size biases and not to comment on how size influences the amount or type of ecosystem services and disservices provisioned - such conclusions would require different field analysis than that which has been done here. Similarly, evaluating if little quantitative share of community gardens in cities is offset by high qualitative importance of ecosystem services in those spaces would necessitate altogether different questions and questionnaire structure to those asked here, as this was not the purpose of the questionnaire disseminated in this research.

6.2.2. Identify suitable sampling community gardens in Berlin and Cape Town from which to assess existing ecosystems services and disservices.

The second objective was to prepare for field assessments by identifying suitable sampling gardens in each city. Selection criteria in choosing which community gardens were assessed were according to three variables:

1. *Location* of gardens with a close proximity to the city centre were selected, as it is here where infrastructure is purported to be at its most dense and land-use conflict at its highest. This aspect was chosen to relate to objective 1 to show the comparative advantage that community gardens have over other green space types in dense cities by encompassing small and compact sizes and a range of ecosystem services (and few disservices) to benefit local neighbourhoods and their residents.
2. *Size* was a garden selection criterion with the purpose of avoiding size bias.
3. *Garden access permission* was the limiting selection criterion of this objective as it resulted in those gardens that were actually evaluated. Given the low response rate of gardens approached (47%), the number of gardens assessed in each city was limited to willingness to participate and interest in the research.

This study shows that the provisioning of ecosystem services and disservices in a particular community garden relies, in part, on the garden's location in the city (see discussion in Chapter 5.3.5.). Such a conclusion is supported by similar practical outcomes from Cabral et al. (2017) who concluded in their study that location influenced the contribution of ecosystem services in an allotment and community gardens in Leipzig. Moreover, Andersson et al. (2015) theoretically support this idea as they discuss how the generation of ecosystem services in urban green space is location-dependent.

6.2.3. Identify and assess which ecosystems services and disservices are provided by the chosen sampling community gardens in Berlin and Cape Town.

The third objective of this research, and arguably the crux of the entire project, was to carry out assessments of community gardens in Berlin and Cape Town in order to establish inventories of the types of ecosystem services and disservices that are provisioned in these urban green spaces. Doing so addresses an existing deficiency in research, particularly for data on ecosystem services and disservice collections from smaller ecological infrastructure in urban environments (von Döhren and Haase, 2015 and Alavipanah et al., 2017). The logistics of community garden assessments involved collecting empirical quantitative data from 26 community gardens across Berlin and Cape Town, and qualitative data from questionnaires.

As Cowling et al. (2003) discuss, the quantification of ecosystem services is one such important step towards making their value explicitly known and therefore implementing successful actions to safeguard them. In addition, simultaneously identifying ecosystem disservices minimises impacts and trade-offs in their mitigation and management. The assembly of new data and information on a particular phenomenon is critical to preserving and improving our knowledge and understanding of that phenomenon, not only in its particular instance, but also the larger research field in which that phenomenon occurs (Turner et al., 2015). Relating this concept to ecosystems research, identifying and assessing which ecosystem services and disservices are generated in community gardens in Cape Town and Berlin therefore acts as a primary data source of these inventories as it has been shown that few previous studies exists with respect to services and disservices from community gardens. This new data not only strengthens the basis of ecosystem services and disservices understanding in each local city context, but upon transferring results to a more general context, it has relevance to the wider scientific fields of urban ecosystem services and disservices as well.

Previous assessments of community gardens have unanimously focused on ecosystem services from these spaces but, as has been argued throughout this study, such assessments will only ever be 'half the story', particularly if human benefit from, and well-being in these spaces are of concern. Results from ecosystem services assessments in this study reiterate the many findings of Clarke and Jenerette (2015), Camps-Calvet et al. (2016), Cabral et al., (2017) and Cilliers et al. (2017) that community gardens are valuable services supplying units to urban areas. As no previous studies have considered ecosystem disservices in community gardens or any other urban garden type, results obtained from ecosystem disservices assessments have no relation to similar studies as of yet. In general, this study found that the amount and intensity of ecosystem disservices provisioned by community garden spaces in Cape Town and Berlin were low enough to insignificantly impact human enjoyment, safety and well-being. Collective identification and assessment of ecosystem services and disservices generated in community gardens therefore confirms to local authorities and planners in both cities that these gardens have overall net positive benefits to quality of life and people's well-being.

6.2.4. Demonstrate the relevance and contribution of community gardens to sustainable urban development and the Great Transition.

Sustainability is a broad concept that mutually links social, economic and environmental ideals and goals (Gibson, 2006). The urban perspective on and concern for sustainability becomes ever more relevant as urbanisation continues to change and influence large portions of the Earth's landscape, including ecosystems (Childers et al., 2015). Many cities already recognise the need to advance urban sustainability by adopting formal sustainable development plans which focus on particular sectors like urban design, infrastructure types, transportation, energy and water (Newman and Jennings, 2012). However, as Childers et al. (2015) show, these urban plans often appear to have a narrow focus on existing urban infrastructures (e.g. transport networks, storm water treatment, water supply systems) and larger green infrastructures (e.g. parks and forests), and are rarely integrated into contemporary urban sustainability approaches at smaller neighbourhood scales. Consequently, there is regularly disconnect between intentions of these plans at a municipal level, and their integration at local neighbourhood level.

The idea of ecosystem services has gained increasing appeal to politicians, policy makers and, to some extent the public, because as a scientific concept, it not only characterises and explains the interdependence between humans and nature, but also ascribes a judgement on the state of natural systems to identify parts of human-nature interactions that need to be changed or improved (Abson et al., 2014). Urban ecosystem services and disservices concepts therefore have great potential to act as boundary objects for urban sustainability – that is, these concepts can link policy makers, different scientific disciplines and the public to collaborate on common sustainable urban development goals (Abson et al., 2014).

Community gardens, as ecosystem services and disservices supplying units, have relevance and contribute to the three pillars of sustainability (social, economic, environmental) in urban development objectives:

Socio-economic: Highlighting the socio-economic dimensions of sustainable urban development, themes of community, health and well-being, food security and poverty reduction are important in cities (Ferris et al., 2001). Community gardens in Cape Town and Berlin are shown in the results of this project to explicitly promote these themes as inherent characteristics of their purpose and use - gardening in, and as a community; gardening for the benefits of health and recreation, and gardening with the purpose of food security and/or poverty reduction. Furthermore, community gardens were shown as spaces where local citizens could socially integrate and build a community based on values of diversity, pluralism and democracy. Community-driven aspects are a fairly unique and advantageous characteristic of community gardens compared to other green space types where users of these spaces utilise them in a somewhat isolated manner (e.g. urban park or forest visitors) and don't experience such levels of social integration with, and upliftment from, others.

Environmental: Environmental dimensions of sustainable urban development contain broad themes such as biodiversity and ecosystem protection, sustainable resource use, environmental justice, waste management and climate change mitigation and adaptation measures. Community gardens are shown in this project to address some of these themes, at least in part at the local neighbourhood scale. Gardens in Cape Town and Berlin exhibited high species richness and acted as spaces of local biodiversity havens, they provided, to some extent, ecosystem protections against extreme weather and erosion, and were perceived to regulate climate and temperatures of the neighbourhood. Moreover, practices used in community gardens encourage people to use natural resources sustainably, promotes healthy lifestyles and teaches people the value of nature to their livelihoods and well-being.

The socio-economic and environmental benefits of community gardens are also relevant to Great Transition paradigms, which emphasise that human values and practices based on eco-communalism, solidarity and connectedness, equality and environmental responsibility are the pathway to a humanistic, community-driven, diverse and environmentally conscious planetary civil society. Community gardens are thus important urban green spaces in which to foster Great Transition morals and principles. Furthermore, community gardens are urban green spaces that can serve to bridge the disconnect between municipal and local level sustainable urban development objectives as they include civic intervention of local authorities with other public agencies that act in partnership with citizen groups (Ferris et al., 2001).

6.3. Limitations of the study

6.3.1 Methods

A number of limitations are present in the methods used in this study:

1) *Case Study Analysis*: This approach has some concern regarding the transferability of any data collected because case-studies are context-specific (Houghton et al., 2013). Multiplicity addresses transferability issues by enhancing the potential for generalisation, especially if similar results are observed between two very different contexts. This study thus tried to overcome the transferability limitation by using a multiple-cases approach (Yin, 2014) with multiple case cities and case gardens selected within each city.

   Future research recommendations pertaining to ecosystem services and disservices assessments are to have a focused collection of a 'target' cases (i.e. 'target' number should refer to the maximum number of research units (e.g. the max. number of community gardens possible that is balanced by the time and effort it takes to collect data in them) that are different enough to enhance the transferability of the results obtained.
2) *Indicator Analysis*: Using indicators to measure certain types of ecosystem services or disservices is difficult because they are either underdeveloped or subjective and thus open to interpretation (Layke, 2009 and Crossman et al., 2013). This is predominantly true for cultural ecosystem services and most ecosystem disservices. Therefore, there are limitations in the use of indicators, their relevance and also their applicability in some cases, and an unfortunate reality is that many ecosystem service and disservice inventories remain incomplete because of their inherently subjective nature. It follows therefore that data gathered using indicators needs to be scrutinised by the researcher on whether it is valid, relevant and applicable to the ecosystem services or disservice it sets out to measure. This study attempted to ensure indicator relevance and quality by

employing the SMART principles suggested by Hernández-Morcillo et al. (2013) in choosing which indicators were used. Future research should continually strive to try new indicators, improve the quality of existing ones and test their relevance at regular time intervals (von Döhren and Haase, 2015).

3) *Questionnaire*: Unfortunately, when a person conducts research that requires human input and energy, like a questionnaire, the researcher has very little control over the number of people that are willing to participate (Sandelowski, 2000). It is therefore difficult to establish what a representative sample of the population is and then achieve that number of participants. Participation is consequently an unavoidable limitation in most qualitative research, and low response rates and non-response errors can manipulate whether the data that is collected by questionnaires is truly representative of the intended population sample, which may influence the data's validity. When concerned with people's views, attitudes or perceptions on a particular phenomenon, it is always better to have more than less, especially as this relates to the representability of conclusions drawn from those opinions. Research should therefore strive to have as many participants as are willing and possible.

6.3.2. Field work

At the outset, it must be recognised that some element of human error will always be present in research pertaining to ecosystem services and disservices assessments due to their inherent time-consuming and labour-intensive nature, whether it be in the process of field data collection or in the analysis of that data to infer results. This potential for error is amplified especially if a single researcher is conducting the study because of limitations in the resources available to help with large amounts of field work that can take an inordinate amount of time to complete. The manner in which field work is conducted is dependent on the resources available to a researcher, such as availability of equipment, access to field personnel to help with data collection, time available for a study and funding. It is important to weigh up all of the above and ensure the researcher takes the most prudent and scientifically rigorous actions in conducting field work with what is available to them despite limitations.

In preparation of field work, a total of 55 community gardens were contacted with a request to conduct research in their gardens, but only positively 26 responded, which is a 47% response rate. Although this percentage is acceptable, permission to garden access was a major limiting factor in this research and is a difficult problem to effectively address.

In carrying out field work, the weather during some site visits made data collection extremely challenging – this was particularly the case in Berlin where intense summer storms were frequent. Data collection during inclement weather can potentially influence the manner and discipline with which field work is carried out thereby impacting the quality of that data. As Cape Town has a Mediterranean climate, most rainfall occurs in winter and no such weather challenges occurred during garden visits in that city.

In conducting questionnaires during garden visits, many respondents in Cape Town were illiterate and this meant a lot more time than planned had to be spent helping people answer the questionnaire. As such, many questionnaires were conducted in almost a semi-formal interview structure between the participant and the researcher, and may have influenced the number of respondents willing to participate because some potential contributors might have been feeling reluctant, shy or inadequate due to their education level. In Berlin, people interacting with, and in, the community gardens seemed much busier, so many potential participants who were approached said they did not have time because of their garden activities, and in some cases admitted they had no interest in partaking. Although the questionnaire was translated into German for the Berlin gardens, there were a few instances of a language barrier between the researcher and person answering the questionnaire. To overcome this, a translator was used to explain the questionnaire requirements to participants in those instances.

6.4. Outlook

6.4.1. Implications for research

What is clear from the research conducted in this study is that the integration of both services and disservices concepts in ecosystems research is not yet fully recognised and implemented. Ecosystem disservices are derived from, and therefore are conceptually related to, the ecosystem services approach (von Döhren and Haase, 2015), yet very few assessments consider and relate both notions together despite this being necessary for nuanced and holistic evaluations. Moreover, the amount of research pertaining to urban ecosystem disservices is severely lacking behind that of ecosystem services, although this gap is slowly being recognised and addressed as seen in the reviewed literature in Chapter Two. A key problem for current ecosystem disservices research lies in the lack of physical data and information regarding disservices inventories for most ecological structures in urban environments, an issue that is discussed by von Döhren and Haase (2015) who claim that the deficiency of systematic data on ecosystem disservices is further exacerbated by the general lack of identification and quantification of the factors (anthropogenic and other) producing ecosystem disservices in cities, and those who are affected by them. Further research regarding ecosystem disservices assessments are therefore critical to the collection of disservices inventories that are presently deficient in the overall urban ecosystems scientific field, and such deficits need to be addressed if the concept is to be fully integrated with the ecosystem services approach.

Research carried out here also carries methodological implications as it illustrates the necessity of comparing quantitative and qualitative methods (and the results obtained therefrom) when studying human-nature phenomena and interactions. Results of this study suggest there may be a large difference between ecosystem services and disservices outcomes deduced from empirical quantitative data and the qualitive data gathered on people's perceptions towards them. Quantitative data may show delivery of a particular service or disservice in an urban environment, but it is just as important to ascertain whether people perceive any benefit or detriment from that service or disservice in reality - i.e. whom does it impact? People's perceptions are influenced by their history and past experiences, socio-economic circumstances, education level, age and health status, and these attributes absolutely influenced how ecosystem service benefits and disservice impacts were perceived by those who answered the questionnaire. For example, for participants in Cape Town who generally had low socio-economic status and many of whom were immigrants, food and social integration and cohesion services provided by community gardens were greatly valued, while Berlin participants valued gardens for their ability to provide access to urban nature for psychological and physical well-being in busy urban environments. Lyytimäki and Sipilä (2009) congruently discuss how factors such as age, culture and socio-economic status influence people's interactions with urban ecosystems and affect their perceived experiences with services and disservices. Acknowledging both quantitative and qualitative values correspondingly helps the management of urban green spaces to ensure that the services and disservices from those areas are interpreted as equitable resources for all user groups - local municipalities, other stakeholders, and users alike.

Ecosystem services and disservices are not static concepts and are constantly changing (Lyytimäki and Sipilä, 2009). Climate change, environmental modification and human processes such as urbanisation not only influence existing ecosystems but also lead to the emergence of new ones which may create novel types of services and disservices in urban environments. While the role of urban green spaces as providers of valuable services essential to mitigating the effects of climate change are increasingly studied (Wolch et al., 2014; Kabisch and van den Bosch, 2017), new knowledge on how the above-mentioned factors influence the provisioning of ecosystem disservices under different scenarios is crucial for future research. This study can thus serve as a critical starting point for future urban ecosystem assessments, especially with respect to ecosystem disservices, that look to evaluate the impacts of projected future situations of warmer temperatures and degrees of urbanisation on the provisioning of ecosystem services and disservices in cities.

6.4.2. Implications for policy and practice

This study has shown community gardens provide a wide range of ecosystem services with few ecosystem disservices in urban areas, and therefore emphasises the need for more formal recognition of these spaces in local government policies and management strategies. The outcomes of this study also help to better inform city planners and managers explicitly of the values of community gardens, particularly as these relate to sustainable urban development objectives, urban ecosystem functioning and its management for human well-being (Albert et al., 2016a; Langemeyer et al., 2016, Nin et al., 2016). The application of ecosystem services and disservices in local environmental management, especially in the context of urban ecosystem-based management, would serve to optimise the provisioning and consumption of various ecosystem services in a way that they become sustainable, while simultaneously minimising the trade-offs from ecosystem disservices to people's safety and well-being (de Groot et al., 2010; Rova and Pranovi, 2017). In both cities, the results and information obtained from this study show tangible and relevant implications for local government policies and practice regarding social and environmental targets and objectives.

Cape Town

For Cape Town, this study supports the sentiments of Cilliers et al. (2017) by showing community gardens are an important part of green infrastructure in the city, especially as parts of this area have large-scale poverty concerns, nutrition deficiencies and a general lack of access to resources. Beyond the basics of food production, community gardens played a vital role in delivering benefits of social empowerment, strengthening social interaction and community ties, and improving the self-esteem of many disenfranchised and vulnerable people.

In terms of practice, outcomes from community gardens assessments in Cape Town can be used to by local authorities to address and achieve existing sustainable urban development objectives in the city.

1. For example, the city's five-year Integrated Development Plan (IDP) 2017-2022 is the principal and overarching strategic framework that informs planning and development in the city. In particular as it relates to community gardens, the IDP looks to develop community and social programmes addressing provisioning and access to green space and recreational facilities, social (re)integration and poverty alleviation. This includes, identifying space for establishing and maintaining food and community gardens (City of Cape Town, 2017c, p. 91-105). Wider adoption of community gardens throughout the city can provide such spaces where these green space availability, social integration and poverty alleviation objectives are realised.
2. Another example of where results from this study can have direct practice implications relate to objectives highlighted in the City of Cape Town's Integrated Metropolitan Environmental Plan (IMEP) 2001-2020 (City of Cape Town, 2001, p. 9-14), which is the primary policy that informs all environmental and conservation planning, management and decision-making in Cape Town. Specific objectives of the plan that community garden assessments done in this study directly apply to include:

    1) Conservation of landforms and soil critical to urban farming and gardening;

    2) Recognising the importance and value of natural and green spaces in the city which provide a range of essential goods and services to people's well-being, in addition to ensuring sustainable land-use practices in those spaces;

    3) Supporting activities and spaces that encourage environmental-justice, -education and -awareness which enhances people's understanding and appreciation of the environment, and promotes sustainable lifestyles, environmental rights and use of natural resources; and

    4) Supporting community driven environmental projects and environmental structures or spaces in communities that can be autonomously governed.

Berlin

Partaking in urban experiences with nature without having to move or go far is challenged by the current trend to build more compact cities (Lyytimäki and Sipilä, 2009). Berlin follows this densification trend, and many residents seek to interact with nature in their neighbourhoods despite opportunities with urban green becoming increasingly restricted as the city is built-up.

1. An example of how results of this research can contribute to practice in Berlin's local context is seen in looking at the Berlin Strategy | Urban Development Concept 2030 (Senatsverwaltung für Stadtentwicklung und Wohnen, 2015d). This strategy focuses on Berlin's development initiatives and goals to the year 2030, concentrating on specific transformation areas and targeted directions in achieving sustainable development.
   Of relevance to community garden assessments, the strategy proposes socio-economic developments that reinforce neighbourhood diversity, including those that strengthen social cohesion and community building, those that create spaces for social integration and neighbourhood growth, and those that preserve and develop local green spaces as meeting places for recreation and local climate compensation areas. Community gardens can offer local neighbourhoods such spaces.
   The strategy also proposes environmental developments for more urban green spaces that improve urban sustainable practices and encourage healthy lifestyles for Berlin residents. Such developments might include spaces that safeguard urban natural resources and improve the ecological qualities of the city by protecting resources like soil (and minimising soil sealing), biodiversity, climate and air. Benefits delivered by community gardens in Berlin therefore have direct relation to these socio-economic and environmental objectives of the Berlin Strategy, and consequently offer key nature-based solutions for urban policies aiming to enhancing human well-being in local neighbourhoods of the city.

6.5. Conclusions

Ecosystem assessments contribute to understanding the dynamics between ecosystem functioning and human well-being. Research objectives set out to address the aim of inventorying community garden ecosystem services and disservices have been met within the scope and limitations of this study. Limitations of research are often beyond that which a researcher can control and place restrictions on a study's findings and their interpretation. Good research design can however help to mitigate the influence of these limitations to an extent.

Ecosystem assessments completed in this study are shown to be relevant to practice as valuable information resources for local practitioners in both cities for addressing socio-economic and environmental targets in sustainable urban development related policies. Furthermore, this study shows implications for research as a reliable starting point for future urban ecosystem services and disservices studies in community gardens, which can use this assessment to reference and supplement their work with. This study and its findings therefore serves as a baseline contribution of collective assessment of ecosystem services and disservices from community gardens for both the local and wider ecosystems field contexts.

Chapter Seven

Conclusions

7.1. Summary of thesis

Recap of thesis outline

Chapter One provides a general introduction into the background of cities, population growth and their impacts ecosystems. The chapter also sets out definitions and categorisations of ecosystem services and disservices, and provides introductions into sustainable development and the Great Transition.

Chapter Two reviews the literature to ascertain the current state of the art for ecosystem services and disservices in urban environments. The importance, role and function of community gardens as providers of necessary ecosystem services is shown, and past literature on urban ecosystem services and disservices according is discussed.

Chapter Three shows the methods that are used in community garden assessments in each city. Using an over-arching case-study approach, both quantitative (indicator analysis) and qualitative (questionnaires) mixed-methods were used in order to collect data in Berlin and Cape Town gardens.

Chapter Four discusses the environmental, socio-economic, administrative contexts of Berlin and Cape Town as the chosen case study cities used in the research.

Chapter Five describes the results that were obtained from data collection and its analysis. Large amounts of data were obtained for both ecosystem services and disservices from both cities, so results are synthesised into final assessment Burkhard-type matrices.

Chapter Six includes a critical discussion of major finding of this thesis as they correlate to the research objectives. Limitations of the study are shown, largely pertaining to methods used and the field work aspects of data collection. A thesis outlook is given, showing implications and contributions of the study to research and practice.

7.2. General conclusions

Recapitulation of purpose and findings

This research is conducted with the purpose of inventorying the types of ecosystem services and disservices that are provisioned by urban community gardens.

Outcomes shows that community gardens in Berlin and Cape Town provide ecosystem services to both local areas of each city and also the people who interact with them, while delivering a few ecosystem disservices as well. Major findings of this research are consistent with previous research outcomes that show community gardens in urban areas are valuable contributors to human well-being (Clarke and Jenerette, 2015; Camps-Calvet et al., 2016; Cabral et al., 2017; Cilliers et al., 2017). Significant differences between the two cities in terms of their ecosystem services and disservices provisioning, and how these are perceived relied, to some extent, on small-scale factors like a garden's physical location in the city and choices made by individual gardeners within the garden such as crop choice and management intensity, and also larger-scale influences of broader socio-economic and cultural contexts in each city, and most notably larger scale climate and environmental factors.

By addressing current gaps that are identified in the fields of ecosystem services and disservices, contributions of this research to knowledge comprise the following:

- A novel inventory of both ecosystem services ***and*** disservices generated in community gardens. Such an empirical inventory does not yet exist in the ecosystems field, and even less so, from work conducted in community gardens in a developing country.
- A study that integrates ecosystem services and disservices concepts. This is a major current shortfall in ecosystems research, as has been shown in reviewed literature where disservices concepts, methods and research perspectives are significantly underdeveloped and under researched compared to services.
- An information resource for local authorities and decision makers in Cape Town and Berlin explicitly showing the value and benefit of community gardens to the city and its residents. Such a resource can be used in green space planning and management to endorse the wider integration and adoption of community gardens into urban ecological infrastructure as a legitimate and valid urban land-use.

Summary of limitations of the study

Interpretations of findings are restricted by limitations with methods used in the study. Limitations inherent in case study analysis (issues of transferability of outcomes), indicator analysis (indicator quality and relevance) and questionnaires (participation limitations) impact the applicability and relevance of outcomes in this study to an extent. These influences are addressed in the research, in part, by using multiplicity in case-study contexts (Yin, 2014) and literature-derived indicators based on SMART principles (Hernández-Morcillo et al., 2013).

Reflections on relevance of findings to theoretical background

This study offers suggestive evidence that community gardens are critical spaces where Great Transition thinking can be started and practiced, including the ascendance of new principles and values that encourage quality of life, community building through human-connectedness, and eco-communalism (GTI, 2016). Community gardens are spaces in which 'citizens movements' are assembled, and therefore potentially hold immense importance to sustainability in cities. The key to sustainability is changing people's mindsets, particularly in the way they view the environment, and their sense of responsibility towards it. The eco-consciousness that is cultivated in community gardens has the potential to have direct ramifications on human behaviour going into the future. Furthermore, community gardens are ecosystem services and disservices supplying units that contribute to local sustainable urban development objectives in policies in Cape Town and Berlin.

Future avenues of ecosystem services and disservices research to take into consideration

While the idea of ecosystem services is a popularised concept that is successfully integrated and practiced in a number of current environmental research fields (Costanza et al., 1997; Daily, 1997; MA, 2005), ecosystem disservices remains a very much less known and studied concept. A major challenge and key task for future research continues to be the need for integration of the ecosystem disservices concept with ecosystem services (Schaubroeck, 2017).

Indicators that are used in the quantification of ecosystem services have been developed for non-urban landscapes (Kremer et al., 2016) and thus their transfer and use as proxies for urban ecosystem services may have limited applicability to cities – but this remains untested. One avenue of future research could be to test the appropriateness of non-urban derived indicators to city contexts, and see whether a set of specific urban indicators needs to be established. This should also include the continuous development and testing of ecosystem disservices and cultural services indicators, which severally lags behind the rest of the ecosystem service categories.

Urban ecosystem services are facilitated by non-ecological elements in cities like built infrastructure, social practices, and socio-economic and cultural contexts (Andersson et al., 2015). Future research should therefore focus on different city contexts as it is important to further investigate how context-specific factors impact the generation of ecosystem services and disservices.

The degree of implementation and understanding of urban ecosystem services and disservices in urban planning, management and governance varies between cities (Kremer et al., 2016). For the most part, implementation of these concepts in planning and policies remains under recognised and underdeveloped. It is therefore important for research to find improved ways to bridge science-policy gaps between scholars and practitioners.

7.3 Final insights

Studies pertaining to ecosystem services and disservices emanating from community gardens matter. Their results hold value for local municipalities in strengthening planning and management decision-making to improve social and environmental well-being of local residents. These seemingly innocuous urban green spaces hold vast potential for global citizen movements endowed with strong social and environmental ethics and principles - it therefore matters that we make their value explicitly known as impetus for their proliferation throughout the urban fabric. Mostly, the importance of community gardens in terms of the ecosystem services and disservices they provide continues to be unrecognised. This study helps to impart novel data on both the benefits and detriments from these spaces in the first instance and is an important starting point for future research and theory. Community gardeners and garden tenants are local stewards of urban green space and therefore have an important role in protecting urban ecosystem functioning and biodiversity, and building their resilience to threats like environmental and climate change (Speak et al., 2015). Local governments frequently cite citizen participation in adaptation and mitigation strategies towards socio-economic and environmental problems, and green spaces managed by local residents therefore play an essential part in the functioning, safeguarding and resilience of urban ecosystems to these threats.

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Appendices

Appendix A – Comprehensive lists of ecosystem services and disservices indicators derived from the literature.

This appendix shows the comprehensive lists of ecosystem services and disservices and their indicators used in the study. Tables 3.2 (page 62) and 3.3 (page 64) are the abbreviated versions of the following appendix A tables.

Table A1. List of ecosystem services, their indicators, mechanisms and rationale, methodology and references.

Category	Ecosystem Service	Indicator	Indicator Measurements (Units)	Data Needed	Mechanisms, Methods and Rationale	Reference	Reference in Field Protocol & Questionnaire
Provisioning	Food: Crops	Land cover	1. Crop richness (species number) 2. Crop area/total area (%)	1. Species number of crop types grown in each community garden 2. Cultivated area of each community garden (m^2 or %) and the total area of each community garden (m^2)	The proxy indicator used to make inferences about food provisioning was landcover from which crop richness was surveyed, where richness is defined as the number of crop species per community garden area. In addition, the area of cultivated land was calculated as a percentage of the total garden area for individual community gardens (crop area as a % of the total garden area).	Speak et al. (2015); Cabral et al. (2017)	Field Protocol Checklist - Section 2: Crop Listing Questionnaire - Q. 1, 2
	Food: Livestock	Livestock number	1. Livestock richness (species number) 2. Number of livestock (no. of individuals / ha)	1. Species number of food producing livestock present in each community garden 2. Total number of food producing livestock in each community garden (number of individuals) and the total area of each community garden (m^2)	The proxy indicator used to make inferences about food from livestock was number of livestock, where the total number of livestock per community garden area was calculated. As different animals have different functions, uses and by-products for consumption, only those livestock that provided any sort of produce or food was counted in determining the food ecosystem services that come from livestock. In addition, livestock richness was measured for individual gardens.	Egoh et al. (2012)	Field Protocol Checklist - Section 3: Animal Listing Questionnaire - Q. 4, 5
	Raw Materials: Wood/Timber	Fuel yield	1. Kilograms (kg / ha) 2. Wood materials area / total area (%)	1. Amount of raw materials in each community gardens (kg) 2. Area of raw materials (m^2 or %) and the total area of each community garden (m^2)	Wood and timber yield (kilograms / hectare) are proxy indicators relating to raw material provisioning services. In the absence of any raw material accounting where it is not possible to acquire a reliable figure for yield, the area of raw materials was calculated as a percentage of the total garden area for individual community gardens (raw materials as a % of the total garden area).	Egoh et al. (2012)	Questionnaire - Q. 6, 7
	Fresh Water Supply	Number and capacity of fresh water resources	1. Number of fresh water sources and water collection tanks (no. of sources and tanks / ha) 2. Total capacity of water collection tanks (l)	1. Total number of fresh water sources and water collection tanks in each community garden and the total area of each community garden (m^2) 2. Capacity (l) of water tanks in each community garden.	The proxy indicator used to make inferences about fresh water supply was the number of fresh water resources and water collection tanks per garden area were counted. In addition, the total capacity of fresh water tanks (l) per community garden area was calculated and used as a proxy to illustrate capacity potential for fresh water supply. Additional information regarding the fresh water usage per month in each community garden was collected to illustrate whether the provisioning of fresh water in the community gardens was able to meet the needs of the garden itself.	Egoh et al. (2012); Speak et al. (2015)	Field Protocol Checklist - Section 4: Water Resources Questionnaire - Q. 8 - 12
	Medicinal Resources	Land cover	1. Medicinal species richness (species number)	1. Species number of medicinal plants grown in each community garden	The indicator used to make inferences about medicinal resources was medicinal species richness where the number of medicinal species per garden area was used as a proxy to illustrate the community gardens capacity for provisioning this ecosystem service.	Clarke and Jenerette (2015)	Field Protocol Checklist - Section 2: Crop Listing Field Protocol Checklist - Section 5: Vegetation Survey Questionnaire - Q. 3

	Ecosystem Service	Indicator	Indicator Measurements (Units)	Data Needed	Mechanisms, Methods and Rationale	Reference	Reference in Field Protocol & Questionnaire
Regulating	Local Climate Regulation	Land cover	1. Vegetated area / total area (%)	1. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2)	The vegetated area of community gardens a percentage of the total garden area was calculated and used as a proxy to show the gardens' capacities for energy absorption, higher albedo reflectance and evaporative cooling from transpiration compared to artificial surfaces.	Rowntree and Nowak (1991); Whitford et al. (2001); Tratalos et al. (2007); Escobedo et al. (2011); Bastian et al. (2012); Egoh et al. (2012); Dobbs et al. (2014)	Field Protocol Checklist - Section 1: Site Description Field Protocol Checklist - Section 6: Tree Survey Questionnaire - Q. 13
		Shaded area	2. Digitised area under canopy (m^2 or %)	2. Digitised shaded area of each community garden (m^2 or %) and the total area of each community garden (m^2)	Shaded area under tree canopies was digitised per garden area (m^2 and %) using aerial photos and used as a proxy to illustrate the community gardens capacity for regulating/maintaining local climates by cooling. This is because tree canopies intercept UV radiation and therefore cool local air, ground and soil temperatures through evapotranspiration to combat the urban heat island effect.		
		CO_2 storage and sequestration by trees	3. Total carbon storage (tonnes C / ha) Annual carbon sequestration (tonnes C / ha / yr)	3. Digitised tree canopy area of each community garden (m^2 or %) and the total area of each community garden (m^2)	Rowntree and Nowak (1991), Whitford et al. (2001), Tratalos et al. (2007), and Dobbs et al. (2014) all used the Rowntree-Nowak Equations to calculate generalised and conservative estimates of total carbon storage and annual carbon sequestration from urban trees using percentage tree cover that is digitised from aerial photos. Tree canopies were digitised per garden area (m^2 and %) using aerial photos and used in Rowntree-Nowak Equations to estimate the community gardens' capacities for regulating/maintaining local climates by carbon storage and sequestration.		
	Local Air Quality Regulation	Land cover	1. Tree density (Trees / ha) 2. Vegetated area / total area (%)	1. Number of trees in each community garden and the total area of each community garden (m^2) 2. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2)	The indicator used to make inferences about air quality regulation was land cover where the tree density was measured per garden area and used as a proxy to illustrate the community gardens' capacities for regulating the air and providing air quality regulation services. This because trees sequester carbon dioxide (CO_2) and other major gaseous urban air pollutants like carbon monoxide (CO), ozone (O_3), nitrogen oxides (NO_x), sulphur dioxide (SO_2), benzene (C_6H_6) and particulate matter ($PM_{2.5}$ PM_{10}) through uptake via their stomata or adsorption to leaf surfaces. In addition, the vegetated areas of the gardens were used as a proxy to show the gardens' capacities for pollutants uptake and adsorption out of the atmosphere.	Egoh et al. (2012); Speak et al. (2015)	Field Protocol Checklist - Section 1: Site Description Field Protocol Checklist - Section 6: Tree Survey Questionnaire - Q. 14
	Moderation of Extreme Events: Rain and Wind Storms, Flood Prevention	Land cover	1. Tree density (Trees / ha) 2. Vegetated area / total area (%)	1. Number of trees in each community garden and the total area of each community garden (m^2) 2. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2)	The indicator used to make inferences about moderation of extreme events was land cover where the tree density was measured per garden area and used as a proxy to illustrate the community gardens' capacities for interception of rainfall intensity and severe wind associated with rain and wind storms. This is because tree canopies intercept extreme events like storms with intense rainfall and thus moderate the energy of rainfall. This is particularly true for larger trees with big canopy cover and so it is important to consider tree size in this regard. In addition, the vegetated area of the garden can be used as a proxy to show the gardens' capacities for attenuating flood runoff in extreme storm or flood events.	Gómez-Baggethun and Barton (2013)	Field Protocol Checklist - Section 1: Site Description Field Protocol Checklist - Section 6: Tree Survey Questionnaire - Q. 15

	Ecosystem Service	Indicator	Indicator Measurements (Units)	Data Needed	Mechanisms, Methods and Rationale	Reference	Reference in Field Protocol & Questionnaire
	Water Flow Regulation and Runoff Mitigation	Land cover	1. Sealed surface area / total area (%)	1. Sealed surface area of each community garden (m^2 or %) and the total area of each community garden (m^2)	The indicator used to make inferences about water flow regulation and runoff mitigation was impermeable landcover, where the area of sealed surfaces compared to the total garden area (%) was used as a proxy to illustrate the community gardens capacity for water infiltration into the ground and runoff mitigation. In addition, it is recognised that not all impermeable surfaces are completely impervious, so those surfaces categorised as impervious were scored according to a scale by DIN (2016) of permeability for artificial surfaces.	Gómez-Baggethun and Barton (2013); Speak et al. (2015); DIN (2016); Cabral et al (2017)	Field Protocol Checklist - Section 1: Site Description
			2. Surface impermeability scores (0 - 1)	2. Types of artificial surfaces in the garden and associated DIN (2016) scores relating to artificial surfaces' impermeability levels.			
	Erosion Prevention and Maintenance of Soil Stability	Land cover	1. Vegetated area / total area (%)	1. Vegetated area of each community garden (m^2 or %) and the total area of each community garden (m^2)	The indicator used to make inferences about erosion prevention and maintenance of soil fertility was vegetative cover where the total vegetative cover (%) was measured per garden and used as a proxy to illustrate the community gardens' capacities for regulating erodibility and soil retention. This is because vegetation and its roots trap and bind soil particles, reducing their susceptibility to erosion and promoting soil stability. In addition, the sealed surface area of the garden (%) can be used as a proxy to show the gardens' capacities for water infiltration and thus the gardens capacity for maintaining optimum soil moisture content which promotes plant growth. Together this indicator can be used with information on a gardens composting practices to make inferences on its capacity for maintaining an optimum level of soil fertility.	Egoh et al. (2012); Albert et al. (2016b)	Field Protocol Checklist - Section 1: Site Description Questionnaire - Q. 16
			2. Sealed surface area / total area (%)	2. Sealed surface area of each community garden (m^2 or %) and the total area of each community garden (m^2)		Egoh et al. (2012); Gómez-Baggethun and Barton (2013); Speak et al. (2015)	
Habitat / Supporting	Maintenance of Genetic Diversity	Species Diversity	1. Shannon Diversity Index (H)	1. Number of species and their relative abundance (proportion) in each community garden	The indicator used to make inferences about the maintenance of genetic diversity is species diversity, where the Shannon Diversity Index was calculated as a proxy for biodiversity in each community garden. In addition, species richness was also recorded. Both species richness and diversity are important for ecosystem productivity and functioning, and thus the delivery of ecosystem services.	Dobbs et al. (2014); Speak et al. (2015)	Field Protocol Checklist - Section 2: Crop Listing Field Protocol Checklist - Section 3: Animal Listing Field Protocol Checklist - Section 5: Vegetation Survey Field Protocol Checklist - Section 6: Tree Survey
			2. Species richness (plants, trees, animals)	2. The number of different species in each community garden			

	Ecosystem Service	Indicator	Indicator Measurements (Units)	Data Needed	Mechanisms, Methods and Rationale	Reference	Reference in Field Protocol & Questionnaire
Cultural	Recreation and Mental and Physical Health	Land use	1. Recreation functions of community garden spaces	1. Recreational functions of garden spaces observed in community gardens and recreational functions obtained by questionnaire respondents on their personal interactions/experiences with community gardens.	The indicator used to make inferences about recreation and mental and physical health was land use where the recreational and health functions of the community garden was recorded per garden area and used as a proxy to illustrate the community gardens capacity for recreational and health potential. Recreational and health function of land use is defined by the author as any space, facility or apparatus in the garden that can either be used for relaxation, enjoyment, refreshment or restoration beyond the scope of work. Furthermore, any space, facility or apparatus that is perceived to cater to a person's mental and/or physical health or needs was included in this categorisation.	Escobedo et al. (2011); Dobbs et al. (2014); Albert et al. (2016b); La Rosa et al. (2016)	Field Protocol Checklist - Section 7: Recreation, Cultural and Physical Functions Questionnaire - Q. 18, 19, 21, 23, 27
	Tourism	Visitor numbers	1. Number of visitors per month	1. Total number of visitors per month for each community garden and the potentials of tourism in community gardens as perceived by questionnaire respondents on their personal interactions/experiences with community gardens.	The indicator used to make inferences about tourism was visitor numbers where the average number of visitors per month was recorded per community garden and used as a proxy to illustrate the community gardens' capacities for tourism services. In addition, a questionnaire to try and gauge people's perceptions on community gardens' tourism potential was used.	Egoh et al. (2012); La Rosa et al. (2016)	Questionnaire - Q. 30, 31
	Aesthetic Appreciation	N/A		1. Aesthetic appreciation as perceived by questionnaire respondents on their personal opinions regarding their interactions/experiences with community gardens.	Questionnaires were disseminated within community gardens to ascertain people's perceptions on how they view the aesthetic value and potential of community gardens in the overall urban setting.	Egoh et al. (2012); Hernández-Morcillo et al. (2013); La Rosa et al. (2016)	Questionnaire - Q. 24, 25, 26, 29
	Spiritual Experience and Sense of Place	N/A		1. Spiritual and sense of place experiences as perceived by questionnaire respondents on their personal opinions regarding their interactions/experiences with community gardens.	Questionnaires were disseminated within community gardens to ascertain people's perceptions on how, based on their interactions and use of the garden, these influence their perceived experiences of spiritual and sense of place services.	Hernández-Morcillo et al. (2013); La Rosa et al. (2016)	Questionnaire - Q. 20, 22, 28,

Ecosystem services categories adapted from TEEB (2011).

Table A2. List of ecosystem disservices, their indicators, mechanisms and rationale, methodology and references.

Category	Ecosystem Disservice	Indicator	Indicator Measurements (Units)	Data Needed	Mechanisms, Methods and Rationale	Reference	Reference in Field Protocol & Questionnaire
Ecological Impacting	Displacement of Native by Invasive Species	Invasive species richness	1. Invasive species richness (species number)	1. Species number of alien invasive and neophytes in each community garden	Indicators used to make inferences about the displacement of native species by invasive species is invasive species richness, where species richness is the number of invasive species / neophytes recorded in each community garden. It is important to note that introduced and invasive species are different, although introduced species are foreign, they need not necessarily cause ecological harm – but can. Invasive species are those species which outcompete others for resources and niche space to the other species' detriment.	Escobedo et al. (2011); von Döhren and Haase (2015)	Field Protocol Checklist - Section 5: Vegetation Survey Field Protocol Checklist - Section 6: Tree Survey Questionnaire - Q. 33
Economic Impacting	Damage to Infrastructure by Urban Nature	Amount of affected infrastructure	1. Amount of infrastructure damaged by nature (m^2)	1. Total amount of infrastructure damaged by nature in each community garden and damage as experienced as perceived by questionnaire respondents on their personal opinions regarding their interactions / experiences with community gardens.	The indicator used to make inferences about the damage to infrastructure by urban nature is amount of affected infrastructure, where amount of affected infrastructure (m^2) is the total area of damaged infrastructure recorded in each community garden.	Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013); von Döhren and Haase (2015)	Field Protocol Checklist - Section 1: Site Description Questionnaire - Q. 34
	Maintenance and Repair Costs associated with Urban Nature	Cost of maintenance and repairs	1. Financial costs of maintenance, repairs, energy (€)	1. Total monthly costs experienced in each community garden related to maintenance, repairs and energy.	The indicator used to make inferences about the costs associated with repairs and maintenance in community gardens is monetary costs associated with maintenance, repairs and energy requirements were obtained for each community garden.	Lyytimäki et al. (2008); Escobedo et al. (2011); von Döhren and Haase (2015)	Questionnaire - Q. 35 - 37
Health Impacting	Allergy/Respiratory Problems Caused by the Spread of Pollen	Allergenic potentials of species	1. Species OPALS values	1. Plant and tree species allergenic potentials classified according to OPALS (Ogren Plant Allergy Scale)	The indicator used to make inferences about the allergy problems caused by the spread of pollen in community gardens is allergenic potentials of plants where OPALS for each species and average OPALS were calculated for each community garden. These OPALS were used as a proxy to show the community gardens potential for causing allergies. In addition, questionnaires disseminated in community gardens asked participants to identify if they experienced any allergies / respiratory problems in the garden.	Gómez-Baggethun and Barton (2013); Dobbs et al. (2014); Ogren (2015)	Field Protocol Checklist - Section 5: Vegetation Survey Field Protocol Checklist - Section 6: Tree Survey Questionnaire - Q. 38
	Fear and Anxiety Caused by Wild or Semi-Wild Animals	Presence of unwanted species	1. Observed presence of unwanted species (species number)	1. Number of unwanted species in each community garden	The indicator used to make inferences about wild or semi-wild animals that cause anxiety over fear of attack, safety or inconvenience is presence of unwanted species where participants of the questionnaire were asked to identify those species present in the garden they considered problematic. Since abundances of animal species are hard to measure accurately over time by virtue of the fact that they are constantly mobile, it is difficult to gauge the true abundances of those species in the garden that cause inconvenience in any way. As such, this indicator takes into account their presence only as a proxy for their potential capacity to cause anxiety and inconvenience – defined as those species that either caused physical harm or fear of physical harm to a person or the garden i.e. destroying produce etc.	Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013)	Field Protocol Checklist - Section 3: Animal Listing Questionnaire - Q. 39

	Ecosystem Disservice	Indicator	Indicator Measurements (Units)	Data Needed	Mechanisms, Methods and Rationale	Reference	Reference in Field Protocol & Questionnaire
Psychological Impacting	Unwanted Smells, Sounds or Behaviours from People, Plants or Animals	Presence of unwanted smells, sounds or behaviours	1. Observed presence of unwanted smells, sounds or behaviours	1. Observed presence of unwanted smells, sounds or behaviours from people, plants or animals in each community garden	The indicator used to make inferences about smells, sounds and behaviours that may be considered a nuisance or inconvenience is presence of unwanted smells, sounds or behaviours where participants of the questionnaire were asked whether they experienced any smells, sounds or behaviours present in the garden they considered problematic, a nuisance or that cause annoyance. During garden visits, it was also noted if any unwanted smells, sounds or behaviours could be identified and observed.	Lyytimäki et al. (2008); von Döhren and Haase (2015)	Questionnaire - Q. 40, 41
	Aesthetic and Hygiene Impacts due to Animal Excrement	Presence of animal excrement	1. Observed presence of animal excrement	1. Observed presence of animal excrement in each community garden	The indicator used to make inferences about aesthetic and hygiene impacts due to animal excrement is presence of animal excrement where participants of the questionnaire were asked whether they experienced or observed any animal excrement they considered problematic. During garden visits, it was also noted if any animal excrement could be identified and observed.	Lyytimäki et al. (2008)	Questionnaire - Q. 42
	Aesthetic Unpleasantness due to Overgrown Vegetation	Land cover	1. Observed aesthetic unpleasantness	1. Observed aesthetic unpleasantness in each community garden	The indicator used to make inferences about aesthetic unpleasantness due to vegetative litter from dense or overgrown vegetation is land cover where observed aesthetic unpleasantness as a result of the existing landcover was recorded during community garden visits. In addition, participants of the questionnaire were asked whether they experienced or observed any aesthetic unpleasantness from superfluous vegetative litter or overgrown vegetation in the garden.	Lyytimäki et al. (2008); von Döhren and Haase (2015)	Field Protocol Checklist - Section 1: Site Description Questionnaire - Q. 43
	Feelings of Insecurity Associated with Overgrown/Dark Green Spaces	Area of non-illumination	1. Area of non-illumination (m^2)	1. Total area of non-illumination in each community garden	The indicator used to make inferences about feelings of insecurity/fear associated with overgrown or dark urban green spaces is area of non-illumination where the area of non-illumination in each community gardens was measured. In addition, participants of the questionnaire were asked whether they experienced feelings of insecurity or fear due to overgrown or dark spaces in the garden, particularly at night.	Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013); von Döhren and Haase (2015)	Field Protocol Checklist - Section 1: Site Description Questionnaire - Q. 45
	Vegetation Can Block Views	Land cover	1. Tall trees close to buildings (distance, number, size)	1. Number of trees and their distance to adjacent buildings/infrastructure in each community garden	The indicator used to make inferences about vegetation that blocks views is land cover where observed vegetation or tree cover was used as a proxy for obstruction to views to or from the garden. View obstruction is a subjective concern as appreciation for certain views change between people, therefore this is a difficult indicator to quantify. As such, those gardens where participants stated they experienced vegetation obstructions to views were focused on. This involved identifying that vegetation considered to obstruct the views to/from the garden, recognizing the possible number and size of the obstructing vegetation and estimating its distance to the garden or its infrastructure.	Lyytimäki et al. (2008); Gómez-Baggethun and Barton (2013); von Döhren and Haase (2015)	Field Protocol Checklist - Section 1: Site Description Field Protocol Checklist - Section 6: Tree Survey Questionnaire - Q. 44

	Ecosystem Disservice	Indicator	Indicator Measurements (Units)	Data Needed	Mechanisms, Methods and Rationale	Reference	Reference in Field Protocol & Questionnaire
General Impacting	Restricted Use of a Green Space	Area of private / restricted access	1. Area of private / restricted access (m^2)	1. Total area of private / restricted access in each community garden	The indicator used to make inferences about restricted areas in gardens is areas in gardens where private or inaccessible land due to conservation protection measures were recorded. The presence of protected or private areas in gardens restricts the use of that area, hindering benefit of those seeking to enjoy nature.	Lyytimäki et al. (2008); von Döhren and Haase (2015)	Questionnaire - Q. 46

Ecosystem disservices categories adapted from von Döhren and Haase (2015).

Appendix B – Field Protocol: site walkover procedure (A) and field protocol checklist (B).

A. Site Walkover Procedure

In order to assess the ecosystem services and disservices obtained from urban community gardens, the following procedure was carried out during field site walkovers for all sampled community gardens:

1. Site Description

An initial site description was conducted.

a. The amount of vegetative area in each garden (as a whole) was visually estimated and described using the decimal scale adapted by Londo (1976) - [The Londo scaling uses a modified Braun-Blanquet scale with smaller intervals for estimating species coverages in a vegetation community]. It was also noted if any aesthetic unpleasantness due to poorly maintained or overgrown vegetation existed, or if superfluous or excessive vegetative/leaf litter was present.
b. The amount of area taken up by impermeable surfaces (pavement, paths, surfaces, patios, buildings etc.) in each garden was measured with a meter wheel or tape measure. Each type of impermeable surface was noted and its degree of (im)permeability was recorded according to the run-off coefficients as set out in DIN 1986-100: 2016-09.
c. The land use of the surrounding environments in the immediate vicinity of each garden was recorded and described using the classification by Stewart and Oke (2012) in order to contextualise the garden locations within the urban fabric.
d. Other additional characteristics of the garden were recorded, if possible and available. This included any recording and measuring areas of structural damage by nature, measuring areas of non-illumination, recording land-use practices of the garden (incl. composting, treatments, maintenance, cultivation), and documenting institutional structures and garden history.

2. Crop Listing

A list of vegetables and fruits grown in each garden was identified and compiled. The area of the garden occupied by crop production (cultivated land) was measured with a meter wheel or measuring tape and recorded.

3. Animal Listing

A list of livestock and wild animals present in each garden compiled and identified, and number of individuals of each species noted if possible. Gardeners were also personally asked to identify any wildlife they may have observed in the garden before.

4. Water Resources

A list of fresh water sources in each garden was recorded and described. It was noted if these sources were used for irrigation purposes or if irrigation was done from sources from outside the garden. It was further noted if there were any water tanks or other collection methods (such as rainwater collection) used in the garden to collect fresh water, and these resources' storage capacity were recorded. It was noted if the garden had access to municipal supplied tapped water.

5. Vegetation Survey

Vegetation surveys in each garden (for all other spontaneous or deliberately planted vegetation besides crops) were conducted by identifying plant species and estimating their abundance using the Londo (1976) scale. This was done for all plants growing in dominance and along garden boundaries, pathways, verges or un-worked areas. Additional uses of the plants grown (e.g. medicinal or herbal uses) were also noted if possible.

Cape Town: Vascular plants and trees were identified using Pienaar and Smith (2011), Manning (2013) and SANBI (2017).

Berlin: Vascular plants and trees were identified using Throll (2013), Spohn et al. (2015), Hofmann (2016) and Kremer (2016).

6. Tree Survey

The proportion of total tree cover in each garden was estimated using the Londo (1976) scale. Tree surveys in each garden were then conducted by counting individual numbers and identifying tree species. Measurements needed to estimate tree height were also recorded. These included:

a) Using a clinometer, walk backwards from the tree until you measure 45° angle of inclination between eye level and the top of the tree.

b) Using a tape measure, measure the distance you are away from the tree. Trigonometry dictates that tan (45º) = 1, therefore your distance away from the tree is the tree's height above your eye level.
c) Measure the height between your eye level and the ground, and add this to the distance from the tree.
d) Calculate the final tree height.

It was further noted whether trees in the garden were situated near infrastructure or obscuring views, and had the potential to destroy or impact this infrastructure in any way.

7. Recreation, Cultural and Physical Function

A list of recreational and physical activity facilities present in each garden was recorded, counted and described. Such amenities included anything deemed to have recreational, physical and mental health and spiritual benefit, for example, jogging areas or paths, playground areas or jungle-gym apparatus, exercise apparatus, benches and picnic spots, etc.

B. Field Protocol Checklist

Data gathered and measured during site walkover procedures were collected using a field protocol checklist data sheet. This checklist was principally designed from the literature-derived lists of ecosystem services and disservices and their associated indicators and used during site walkover procedures to measure and record in-situ field data of ecosystem services and disservices. One checklist was compiled for each garden visited.

*Data sheets have been shortened for ease of display in the appendix. Redundant rows have been removed and are shown using the '…..' at the end of each section.

Field Data Collection		
Field Worker:	Place (Co-ordinates):	
Urban Garden Type:	Urban Garden Reference:	Date:
Garden Area (m^2):		

1. Site Description		
a. Vegetative Cover (of garden as a whole)	Vegetative Area / Total Area (%) [Londo Scale]	Description (incl. aesthetic unpleasantness due to poorly maintained/overgrown vegetation or surfaces,superfluous vegetative litter, etc.)

b. Impermeable Surfaces (pavement type, building type, patios, etc.)	Total area of whole garden:	Surface (im)permeability (%) [Bunzel 1992]	Description
…..	…..	…..	…..

c. Landuse of Surrounding Environments	Local Climate Zones / Landcover Types [Stewart and Oke, 2012]	Description
…..	…..	…..

d. Additional Characteristics	Structural Elements (trees, compost, benches, shelters/buildings, no. of parcels, etc.)	Elements Damaged by Nature (m^2)	Area of Non-Illumination (m^2)	Practices (land-uses, composting, treatment/ cultivation/maintenance)	Institutions (management and governance structure, property rights, ownership, associations, etc.)	History (founding year, aim, development, etc.)
…..	…..	…..	…..	…..	…..	…..

2. Crop Listings	
Name (Species)	Description (if necessary, including additional comments e.g medicinal uses)
…..	…..

3. Animal Listings		
a. Is livestock present on site? Yes / No		
b. Are wild animals present on site? Yes / No		
Name (Species)	Number of Individuals	Description (if necessary)
…..	…..	…..

4. Water Resources		
a. Are any fresh water sources present on site? Yes / No?		
b. Is irrigation used on the site? Yes/No		Specify:
Water Source Type	Description	Water Volume (L)
…..	…..	……

5. Vegetation Survey		
Name (Species)	Abundance [Londo Scale]	Description (if necessary)
…..	…..	…..

6. Tree Survey				Tree [H_t] (m)		
Name (Species)	Abundance [Londo Scale]	Number of Individuals	Potential to destroy infrastructure [Distance to infrastructure/buildings] (m)	Distance from tree	Height above ground	Angle of elevation
…..	…..	…..	…..	…..	…..	…..

7. Recreation, Cultural and Physical Functions		
Amenity Type (Running path, sport apparatus, playground apparatus, benches, picnic spots)	Number of Amenities	Description
…..	…..	…..

Appendix C – Questionnaire disseminated in this study.

This appendix includes both the English and German versions of the questionnaire that was disseminated in community gardens during site visits.

Supplementary Information CD: An excel file is available on the attached CD showing the following:

- Statistical breakdown of questionnaire participant types, according to city
- Descriptive statistics tables of closed-ended questions, according to city
- Frequency tables of closed-ended questions, according to city

Assessment of Ecosystem Services and Disservices of Urban Community Gardens.

UNIVERSITÄT LEIPZIG

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University of Leipzig

Johannisallee 19a
04103 Leipzig
Germany

Questionnaire Cover Letter

Background Information

This questionnaire forms part of a doctoral thesis by Ms. Tristan Duthie at the Institute for Geography at the University of Leipzig, Germany. This research is under the guidance of Prof. Dr. Ulrike Weiland and the Institute for Geography, and is funded by the EUROSA project of the European Commission.

The purpose of this study is to assess which ecosystem services and disservices are produced by urban community gardens, and to determine the benefits and detriments gardeners and users obtain from their interaction with these green spaces in a city environment. Two international cities are being used as case-study areas: Berlin (Germany) and Cape Town (South Africa). Information and outcomes gathered in this questionnaire will enable the author to fill a necessary gap in current ecosystem services and disservices research, and will also greatly inform future sustainable development research in urban environments.

Participation and Information Confidentiality

Participation in this questionnaire is anonymous and entirely voluntary, and respondents are free to withdraw at any stage or not complete particular questionnaire items at their own discretion. All appropriate precaution has been taken by the author to try and ensure participants have not been intruded upon or biased in any way, questions formulated to be non-threatening or offensive, and that the validity and reliability of the questionnaire is sound.

Information gathered from participants will remain anonymous, confidential, and non-traceable throughout all stages of the research. This includes during the completion of the questionnaire, analysis of the results by the author, and how the results are presented and disseminated in the final thesis.

Informed Consent

I, the respondent, recognise that participation in this questionnaire is on a voluntary basis and I am free to withdraw at any time using my own discretion. I have not been influenced or pressured into participating by any other person, and my answers are based solely on my own perceptions, thoughts, and judgments. I acknowledge that this questionnaire is anonymous and any information I give herein will remain confidential at all times.

____

(Signature of Participant, Place, Date)

<u>Assessing Ecosystem Services and Disservices of Urban Community Gardens.</u>

This questionnaire will take approximately 20 minutes to complete.

1. General Information of Participant

Date:	City:	Garden Name:

Please tick one of the following based on your situation:

The participant type you identify as (multiple answers possible).

	Manager in the community garden	Gardener in the community garden	Visitor in the community garden	Other (please specify)
Participant Type				

2. Questionnaire

Questions should be answered in the following manner:

1. Read the question, and based on your answer, select the corresponding 'No' or 'Yes' columns.
2. If 'No' place a mark in column 0.
3. If 'Yes' place a mark in one of the columns 1 - 5 based on a scale of your level of agreement with a statement.
4. For questions where respondents are asked to elaborate or specify (if possible), please answer in the space provided.

2.1. Benefits Produced by Urban Community Gardens

This section of the questionnaire asks participants to determine the benefits produced by urban community gardens that they obtain, and score these benefits on a scale between 0 – 5, where 0 = disagree, 1 = very low agreement, 2 = low agreement, 3 = medium agreement, 4 = high agreement, and 5 = very high agreement.

	Disagree	Very Low Agreement	Low Agreement	Medium Agreement	High Agreement	Very High Agreement
Questions	No	Yes				
	0	1	2	3	4	5
Provisioning Services						
1. Food crops (such as vegetables, fruits, herbs) are grown in the garden.						
2. I benefit directly from these crops (for e.g. through eating the vegetables or fruits).						
For participants who grow their own crops, please provide an estimate of average monthly/annual yield (kg per month/year) for your crops (if possible).						
3. Certain crops or plants grown have additional uses such as being used for medicines or ornamental value.						
If yes, please specify which are used and for what purpose (if possible).						
4. Domestic livestock (such as chickens, geese, ducks, rabbits, etc.) is present in the garden.						
5. I benefit directly from this livestock (for e.g. through direct consumption of livestock or certain by-products of the livestock such as eggs, milk, etc.).						
6. The garden provides raw materials such as wood or timber that can be used.						
7. I benefit directly from these raw materials.						
For participants who makes use of raw materials such as wood or timber, please provide an estimate of monthly/annual yield (kg per month/year) of how much you use (if possible).						
8. Fresh water resources (such as ponds, lakes, reservoirs) are present in the garden.						
9. I benefit directly from these fresh water resources.						
10. I collect fresh water through the use of rainwater tanks or other collection methods.						
11. Water is used for irrigation in the garden and comes from these fresh water resources or through my collection methods.						
If no, please specify where the water comes from (e.g. the water comes from tapped water or from outside the garden).						
12. If possible, please estimate how much water is used in the garden each month.						
Regulating Services						
13. I find the local temparture of the garden area to be cooler than compared to other non-green areas of the city.						
14. I find the air in the garden to be cleaner than compared to other non-green areas of the city.						
15. I consider the garden and its vegetation to act as a buffer or protection area against the impacts of extreme weather events such as storms, flooding or wind.						
16. In my experience, the garden area and its vegetation prevent extreme erosion and maintain the stability of the soil.						
17. In my experience, noise pollution associated with cities (e.g. from cars, machinery, transport networks and people) is reduced in the garden area.						

2.1 Benefits Produced by Urban Community Gardens (continued...)

Questions	Disagree	Very Low Agreement	Low Agreement	Medium Agreement	High Agreement	Very High Agreement
	No	Yes				
	0	1	2	3	4	5
Cultural Services						
18. The garden contributes to my livelihood, either through helping to earn a living or activities that helps me to secure necessities of life like food and water.						
19. I use the garden for physical activity and health purposes such as gardening, walking, jogging or other exercises.						
20. The garden is used for social and cultural integration of migrants, or jobless and deprived people.						
21. I use the garden for recreational purposes such as picnics, family outings or social interaction with other people.						
22. My interaction with the garden and other people in the garden helps me feel like I am a part of a group and not so isolated from others.						
23. The garden is used for educational purposes (e.g. environmental or health education, or skills development).						
24. I consider the garden as a space of innovation (e.g. a place where new or alternative gardening technologies/skills are developed, or new or modified modes of management or governance are practised).						
25. In my experience, the garden enhances my appreciation of nature and natural landscapes.						
26. In my experience, the garden improves the overall attractiveness and beauty of the city as a whole.						
27. Through my experience with the garden, I feel benefits such as less stress and increased relaxation.						
28. When I am in the garden, I feel a sense of being in touch with nature and a sense of belonging.						
29. In my opinion, the garden provides the opportunity to contribute to transform the city to be more sustainable and resilient in the face of issues such as climate and environmental change.						
30. The benefits I gain from the garden are such that I would be willing to pay for the use of the garden if necessary.						
31. How many visitors would you say visit the garden per month? Please specify.						

32. If you experience any other benefits produced from the garden not stated in any of the questions above, please specify and rank:

2.2. Detriments Produced by Urban Community Gardens

This section of the questionnaire asks participants to determine the detriments produced by urban community gardens that they obtain, and score these benefits on a scale between 0 – 5, where 0 = disagree, 1 = very low agreement, 2 = low agreement, 3 = medium agreement, 4 = high agreement, and 5 = very high agreement

	Disagree	Very Low Agreement	Low Agreement	Medium Agreement	High Agreement	Very High Agreement
Questions	**No**	**Yes**				
	0	**1**	**2**	**3**	**4**	**5**
Ecological Impacts						
33. In my experience, invasive plant or animal species cause problems in the garden (e.g weed species).						
If yes, please specify how these species cause a problem, and which species they are (if possible).						
Economic Impacts						
34. Infrastructure in the garden is often damaged by nature (e.g damage from plant growth or roots, corrosion from weather, animal damage to structures, or extreme weather events, etc.).						
Please specify which infrastructure is damaged, and by what natural element it was damaged.						
35. Would you consider the financial costs associated with the maintenance of the garden to be high?						
Estimated financial cost associated with maintenance (per month or per year):						
36. Would you consider the opportunity costs associated with maintenance of the garden to be high? [Opportunity cost refers to money, time or other resources that may need to be spent on maintenance and up-keep at the expense of other important things for e.g. money for new infrastructure or buildings].						
37. Would you consider the energy costs associated with maintenance and running of the garden to be high?						
Estimated energy cost associated with maintenance (per month or per year):						
Health Impacts						
38. I have allergies which are made worse by certain plants in the garden .						
If yes, please specify which plants influence your allergies (if possible).						
39. There are certain wild or semi-wild animals present in the garden that are an inconvenience to me, or cause me to feel fear or anxiety over my safety.						
If yes, please specify which (if possible).						
Psychological Impacts						
40. There are certain smells or sounds from plants or animals in the garden that I consider a nuisance and cause me some form of discomfort or annoyance.						
If yes, please specify:						
41. There are certain smells or noises from garden neighbours that I consider a nuisance and cause me some form of discomfort or annoyance.						
If yes, please specify:						
42. Animal excrement and waste is a problem in the garden.						
43. There is a lot of overgrown or poorly maintained vegetation in the garden that looks untidy and unpleasant.						
44. There is tall vegetation that blocks views or obstructs transportation networks to or from the garden which affects me.						
45. There are areas of the garden that are not illuminated at night, that would cause me to have feelings of insecurity or fear in the dark.						
General Impacts on Human Well-Being						
46. There are areas of the garden which have restricted or private access, such as conservation areas, which I am not allowed to access but would like to.						

47. If you experience any other detriments produced from the garden not stated in any of the questions above, please specify and rank:

2.3. Garden Background Information and General Characteristics

Garden Managers Only. This section of the questionnaire asks for background information, and general characteristics and attributes of the garden. Questions are open-ended and respondents are encouraged to answer as fully and specifically as possible.

48. Garden Structural Elements and Practices

a) Do you use compost or other additional products to help the vegetation/crops grow? Please specify.

b) Do you use any treatment to kill weeds or undesired plants? Please specify.

49. Garden Institutional Framework

a) What kind of management or governance structure exists in the garden? Please specify.

b) Who does the garden belong to in terms of property or ownership rights? Please specify.

c) Do any planned or structured educational activities occur within the garden? Please specify.

50. Garden History

a) Do you know the founding year of the garden? Please specify.

b) Why was the garden started? What was the intention or aim? Please specify.

c) Please explain in a few sentences how was the garden developed? Please specify.

Thank you for time and effort in answering the questionnaire. In case of any further questions or concerns, please do not hesitate to contact me: Tristan Duthie (tjduthie@gmail.com)

Please return all questionnaires to one of the following: tjduthie@gmail.com or collection in person upon site visit.

Bewertung von Ökosystemleistungen und -nachteilen Urbaner Gemeinschaftsgärten

UNIVERSITÄT LEIPZIG

Das Anschreiben

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Hintergrundinformationen

Dieser Fragebogen ist ein Teil der Doktorarbeit von Frau Tristan Duthie am Institut für Geographie an der Universität Leipzig. Diese Forschung steht unter der Leitung von Prof. Dr. Ulrike Weiland und dem Institut für Geographie und wird durch das EUROSA-Projekt der Europäischen Kommission finanziert.

Der Zweck dieser Studie ist zu beurteilen, welche Ökosystemleistungen und -nachteile durch Urbane Gemeinschaftsgärten produziert werden, um die Vor- und Nachteile zu ermitteln, die aus ihrer Interaktion mit diesen Grünflächen in einer Stadtumgebung resultieren. Dazu werden zwei Großstädte als Fallstudien genutzt: Berlin (Deutschland) und Kapstadt (Südafrika). Die gesammelten Informationen und Ergebnisse helfen der Autorin, eine wichtige Lücke in der aktuellen Forschung zu Ökosystemleistungen und -nachteilen zu schließen. Außerdem sollen sie als Grundlage für zukünftige Forschungen zu nachhaltiger Stadtentwicklung dienen.

Teilnahme und Informationssicherheit

Die Teilnahme an diesem Fragebogen ist anonym und freiwillig und die Befragten können jederzeit freiwillig zurücktreten oder bestimmte Fragebogenelemente nach eigenem Ermessen abschließen. Sorgfältige Vorsicht wurde vom Autor ausgeübt, um sicherzustellen, dass die Teilnehmer nicht in irgendeiner Weise beeinflusst werden, und dass die Fragen nicht bedrohlich oder beleidigend sind, und dass der Fragebogen valide ist.

Die von den Teilnehmern gesammelten Informationen werden in allen Stadien der Forschung anonym und vertraulich behandelt; d.h. während der Durchführung der Befragung, der Analyse der Ergebnisse und der Präsentation und verbreitung der Ergebnisse der Arbeit.

Informierte Zustimmung

Ich, der Befragte, erkenne an, dass die Teilnahme an diesem Fragebogen freiwillig ist und dass ich jederzeit freiwillig von der Beantwortung zurücktreten kann. Ich wurde nicht durch eine andere Person beeinflusst oder unter unter Druck gesetet an der Befragung teilzunehmen,, und meine Antworten basieren nur auf meinen eigenen Wahrnehmungen, Gedanken und Urteilen. Ich erkenne an, dass dieser Fragebogen anonym ist und dass alle hierin enthaltenen Informationen jederzeit vertraulich behandelt werden.

____

(Unterschrift, Ort, Datum)

Bewertung von Ökosystemleistungen und -nachteilen Urbaner Gemeinschaftsgärten

Die Beantwortung dieses Fragebogens wird etwa 20 Minuten dauern.

1. Angaben zur Teilnehmerin / zum Teilnehmer

Datum:	Stadt:	Name des Gartens:

Bitte kreuzen Sie zutreffendes an:

Funktion(en), die sie im Garten ausüben (Mehrfachantworten möglich)

	Manager/in im Gemeinschaftsgarten	Gärtner/in im Gemeinschaftsgarten	Besucher/in im Gemeinschaftsgarten	Andere (bitte angeben)
Funktion(en)				

2. Fragebogen

Die Fragen sollten auf folgende Weise beantwortet werden:

1. Lesen Sie die Frage zuerst, wählen Sie bitte die entsprechenden‚Nein‘ oder ‚Ja‘ Spalten.
2. Wenn ‚Nein‘, markieren Sie bitte die Spalte "0".
3. Wenn "Ja", markieren Sie bitte eine der Spalten von 1 - 5 aus der unten erläuterten Skala.
4. Bitte schreiben Sie Ihre Antworten auf die offenen Fragen in die dafür vorgesehenen Formularfelder.

2.1. Vorteile Urbaner Gemeinschaftsgärten

Dieser Abschnitt fragt nach den Vorteilen Urbaner Gemeinschaftsgärten, die Sie wahrgenommen haben. Bitte schätzen Sie die Vorteile Ihres Gartens auf einer Skala zwischen 0 - 5 ein.

	keine Zustimmung	sehr niedrige Zustimmung	niedrige Zustimmung	mittlere Zustimmung	hohe Zustimmung	sehr hohe Zustimmung
Fragen	**Nein**	**Ja**				
	0	**1**	**2**	**3**	**4**	**5**
Versorgungsleistungen						
1. Im Garten werden Nutzpflanzen (wie Gemüse, Früchte, Kräuter) angebaut.						
2. Ich profitiere direkt von diesen Nutzpflanzen (z. B. durch das Essen von Gemüse oder Früchten).						
Teilnehmer, die Nutzpflanzen selbst verzehren, geben bitte eine Schätzung der durchschnittlichen monatlichen / jährlichen Ernte (kg pro Monat / Jahr) für Ihre Nutzpflanzen an!						
3. Bestimmte (Nutz-)Pflanzen haben zusätzliche Leistungen, sie können z.B verschenkt werden, zur Zierde dienen oder für Medikamente verwendet werden.						
Wenn ja, bitte angeben, welche Pflanzenarten zu welchem Zweck verwendet werden (wenn möglich) - Sie können gerne auch andere als die o.g. Zwecke angeben!						
4. Viehbestand (wie Hühner, Gänse, Enten, Kaninchen, etc.) ist im Garten vorhanden.						
5. Ich profitiere direkt vom Viehbestand des Gartens (z. B. durch direkten Verzehr oder Nebenprodukten wie Eier, Milch usw.).						
6. Der Garten bietet Rohstoffe wie Holz, das verwendet werden kann.						
7. Ich profitiere direkt von den Rohstoffen.						
Für Teilnehmer, die Rohstoffe wie Holz verwenden, geben Sie bitte eine Schätzung der monatlichen / jährlichen Ernte (kg pro Monat / Jahr), die Sie verwenden (wenn möglich).						
8. Im Garten gibt es frische Wasserressourcen (wie Teiche, Seen, Stauseen).						
9. Ich profitiere direkt von diesen frischen Wasserressourcen.						
10. Ich sammle frisches Wasser durch den Einsatz Regenwassertanks oder anderen Sammelmethoden.						
11. Wasser kommt aus diesen Süßwasserressourcen oder durch meine Sammelmethoden und wird für die Bewässerung im Garten verwendet.						
Wenn nein, bitte angeben, woher das Wasser kommt (z.B. aus einem benachbarten Haus oder von Vorkommen außerhalb des Gartens).						
12. Wenn möglich, schätzen Sie bitte wie viel Wasser im Garten monatlich verwendet wird.						
Regulierungsleistung						
13. Ich finde die lokalen Temperaturen der Gartenfläche sind kühler im Vergleich zu den anderen Nicht-Grünflächen der Stadt.						
14. Ich finde die Luft im Garten ist sauberer im Vergleich zu den anderen Nicht-Grünflächen der Stadt.						
15. Ich halte den Garten und seine Vegetationen für einen Puffer oder Schutzbereich gegen die Auswirkungen von extremen Wetterereignissen wie Stürmen oder Überschwemmungen.						
16. Nach meinen Erfahrungen verhindert die Gartenanlage und ihre Vegetation extreme Erosion und tragen zur Stabilität des Bodens bei.						
17. Aus meinen Erfahrungen wird die Lärmbelastung im Gartenbereich reduziert (z. B. Lärm von Autos, Maschinen, Verkehrsnetzen und Personen).						

	keine Zustimmung	sehr niedrige Zustimmung	niedrige Zustimmung	mittlere Zustimmung	hohe Zustimmung	sehr hohe Zustimmung
Fragen	**Nein**	**Ja**				
	0	**1**	**2**	**3**	**4**	**5**
Kulturelle Dienstleistungen						
18. Der Garten trägt zu meinem Lebensunterhalt bei, z.B. entweder zum Verdienen des Lebensunterhalts oder zur Sicherung der Lebensbedürfnisse wie Nahrung und Wasser.						
19. Ich benutze den Garten für körperliche und gesundheitliche Aktivitäten wie Gartenarbeit, Wandern, Joggen oder andere Übungen.						
20. Der Garten kann Migranten, Arbeitslosen und benachteiligten Menschen eine Möglichkeit bieten, sich sozial und kulturell zu integrieren.						
21. Ich benutze den Garten für Freizeitzwecke wie Picknicks, Familienausflüge oder soziale Interaktion mit anderen Menschen.						
22. Interaktion mit dem Garten und anderen Menschen im Garten bringen mir das Gefühl, dass ich ein Teil einer Gruppe und nicht so isoliert von den anderen bin.						
23. Der Garten kann für pädagogische Zwecke verwendet werden (z. B. Umwelt- oder Gesundheitserziehung oder die Entwicklung körperlicher Fertigkeiten).						
24. Ich betrachte den Garten als einen Innovationsraum (z. B. zur Entwicklung neuer oder alternativer Gartentechnologien und gärtnerischer Fähigkeiten, oder in dem neue Organisationsformen (Governance) ausprobiert und eingeübt werden.						
25. Erlebnisse im Garten verstärken meine Wertschätzung für Natur und Landschaften.						
26. Nach meiner Erfahrung erhöht der Garten die gesamte Attraktivität und Schönheit der Stadt.						
27. Erlebnisse im Garten bringen mir weniger Stress und erhöhte Entspannung.						
28. Wenn ich im Garten bin, fühle ich mich näher an der Natur und ihr mehr zugehörig.						
29. Meiner Meinung nach macht der Garten die Stadt nachhaltiger und widerstandsfähiger angesichts Klima- und Umweltwandel.						
30. Ich würde gern für die Leistungen bezahlen, die ich aus dem Garten bekomme, falls nötig.						
31. Wie viele Leute besuchen den Garten pro Monat?						

32. Wenn Sie andere Vorteile kennen, die aus dem Garten entstehen aber nicht in den oben genannten Fragen angegeben sind, bitte angeben und einordnen.

2.2 Nachteile Urbaner Gemeinschaftsgärten

Dieser Abschnitt fragt nach negativen Auswirkungen Urbaner Gemeinschaftsgärten, die die Teilnehmer erlebt haben. Bitte tragen Sie Ihre Erfahrungen in der Skala unten ein.

	keine Zustimmung	sehr niedrige Zustimmung	niedrige Zustimmung	mittlere Zustimmung	hohe Zustimmung	sehr hohe Zustimmung
Fragen	**Nein**	**Ja**				
	0	**1**	**2**	**3**	**4**	**5**
Ökologische Auswirkungen						
33. Verursachen invasive Pflanzen oder Tierarten nach Ihren Erfahrungen ein Problem im Garten (z. B. Unkraut)?						
Wenn ja, bitte angeben, welche Arten welches Problem verursachen (wenn möglich).						
Wirtschaftliche Auswirkungen						
34. Werden die Infrastruktureinrichtungen im Garten öfter durch Naturgeschehen beschädigt (z. B. Schäden durch Pflanzenwachstum oder Wurzeln, Korrosion, tierische Schäden oder extreme Wetterereignisse usw.)?						
Bitte angeben, welche Infrastrukturen beschädigt wurden und durch welche natürlichen Elemente sie beschädigt wurden						
35. Finden Sie, dass die finanziellen Ausgaben für die Erhaltung des Gartens hoch sind?						
Geschätzte Kosten im Zusammenhang mit der Instandhaltung (pro Monat oder pro Jahr):						
36. Finden Sie, dass die Gelegenheitskosten für die Erhaltung des Gartens hoch sind? [Gelegenheitskosten beziehen sich auf Geld, Zeit oder andere Ressourcen, die für die Wartung und Aufrechterhaltung auf Kosten anderer wichtiger Dinge für z.B. Geld für neue Infrastruktur oder Gebäude aufgebracht werden müssen].						
37. Finden Sie, dass die Energiekosten im Zusammenhang mit der Instandhaltung und dem Betrieb des Gartens hoch sind?						
Geschätzte Energiekosten im Zusammenhang in Euro (pro Monat oder pro Jahr):						
Gesundheitliche Auswirkungen						
38. Ich habe Allergien, die von bestimmten Pflanzen im Garten ausgelöst oder verstärkt werden.						
Wenn ja, bitte angeben, welche Pflanzen Ihre Allergien beeinflussen (wenn möglich).						
39. Gewisse wilde oder halb wilde Tiere, die im Garten vorkommen, stören mich, oder ich möchte den Garten aus Angst oder Unsicherheit wegen der Tiere verlassen.						
Wenn ja, bitte angeben, welche (wenn möglich).						
Psychische Auswirkungen						
40. Es gibt bestimmte Gerüche oder Geräusche von Pflanzen oder Tieren im Garten, die mir Unbehagen bereiten oder ärgerlich sind.						
Wenn ja, bitte angeben:						
41. Es gibt bestimmte Gerüche oder Geräusche aus der Nachbarschaft, die mir Unbehagen bereiten oder ärgerlich sind.						
Wenn ja, bitte angeben:						
42. Tierische Exkremente und Abfälle sind ein Problem im Garten.						
43. Es gibt wild wuchernde oder schlechte gepflegte Vegetation im Garten, die unordentlich und unangenehm aussieht.						
44. Große Pflanzen in oder in der Nähe des Gartens beeinträchtigen die Aussicht oder Verkehrswege.						
45.Einige Bereiche des Gartens sind nachts nicht beleuchtet: das führt zur Unsicherheitsgefühlen oder Angst im Dunkeln.						
Allgemeiner Einfluss auf das menschliche Wohlbefinden						
46. Es gibt eingeschränkten oder nur privaten Zugang zu bestimmten Bereichen im Garten (z.B Schutzgebiete), auf die ich gern zugreifen würde.						
47. Wenn Sie andere schlechte Erfahrungen gesammelt haben, die aus dem Garten entstehen aber nicht in den oben genannten Fragen angegeben sind, bitte angeben und in die Skala einordnen.						

2.3 Hintergrundinformationen und allgemeine Eigenschaften des Gartens

Nur für Manager/in im Gemeinschaftsgarten. Dieser Abschnitt fragt nach Hintergrundinformationen und allgemeinen Eigenschaften und Attributen des Gartens. Die Fragen sind offen; bitte beantworten Sie sie so umfassend und genau wie möglich.

48. Gartenbauteile und -praktiken

a) Nutzen Sie Kompost oder andere zusätzliche Produkte als Hilfsmittel? Bitte angeben.

b) Welche Behandlungen benutzen Sie, um Unkraut oder unerwünschte Pflanzen zu entfernen? Bitte angeben.

49. Rechtlicher und institutioneller Rahmen des Gartens

a) Welche Organisationsstrukturen oder Governance Formen gibt es im Garten? Bitte angeben.

b) Wem gehört der Garten in Bezug auf Eigentum oder Eigentumsrechte? Bitte angeben.

c) Gibt es geplante oder strukturierte Bildungsaktivitäten im Garten? Bitte angeben.

50. Gartengeschichte

a) In welchem Jahr wurde der Garten gegründet? Bitte angeben.

b) Warum wurde der Garten gebaut? Was war die Absicht oder das Ziel? Bitte angeben.

c) Bitte erklären Sie in wenigen Sätzen wie der Garten entwickelt wurde? Bitte angeben.

Mit vielem herzlichen Dank für Ihre Mühe und Unterstützung dieser Forschungsarbeit! Wenn Sie noch weitere Fragen oder Anliegen haben, zögern Sie bitte nicht, mich zu kontaktieren unter

Tristan Duthie

Email: tjduthie@gmail.com

Bitte senden Sie alle Fragebögen an Email: tjduthie@gmail.com oder: Sammlung persönlich vor Ort.

Appendix D – Additional information for results of ecosystem services and disservices assessments.

Garden abbreviations are used in presentation of additional information tables. Please refer to Chapter Five - Figures 5.1 and 5.2 (pg. 90 – 91) for Cape Town and Berlin garden names and their abbreviations.

Crop Richness

Table D1. Crop type inventory list for community gardens in Cape Town. Totals at the bottom of each column represent the crop richness for each individual garden. Produce is listed alphabetically.

SWVCG	OZCF	ANOCG	CMCCG	VOCVG	KSCG_A	KSCG_B	WPG	OJSG	CRCHG	SFL	CVOFG	KFG
Artichokes	Aubergine	Aubergine	Beetroot	Artichokes	Aubergine	Aubergine	Artichokes	Aubergine	Cabbage	Artichokes	Beetroot	Aubergine
Aubergine	Beetroot	Beetroot	Chives	Butternut	Broccoli	Beetroot	Beetroot	Baby Marrows	Celery	Beetroot	Broccoli	Beetroot
Beetroot	Broad Radish	Butternut	Lettuce	Cabbage	Butternut	Broccoli	Celery	Broad Beans	Cocktail Tomatoes	Broccoli	Cabbage	Bush Beans
Cabbage	Broccoli	Cabbage	Spinach	Celery	Cauliflower	Chilli	Chives	Broccoli	Onions	Bush Beans	Pumpkin	Cocktail Tomatoes
Carrots	Bush beans	Carrots	Spring Onions	Chilli	Celery	Chives	Hybrid Squash	Bush Beans	Pumpkin	Cabbage	Spinach	Cucumber
Chilli	Cabbage	Onions		Chives	Chilli	Maize	Peppers	Cabbage	Purple Cabbage	Carrots	Tomatoes	Gem Squash
Chives	Carrots	Peanuts		Lettuce	Chives	Onions	Radish	Carrots	Spinach	Cauliflower	Wheat	Lettuce
Maize	Cauliflower	Peppers		Peppers	Cocktail Tomatoes	Peppers	Spinach	Cauliflower	Spring Onions	Celery		Maize
Onions	Celery	Potatoes		Spinach	Kale	Pumpkin	String Beans	Celery	Tomatoes	Chives		Onions
Peppers	Kale	Spinach		Spring Onions	Leeks	Spinach	Tomatoes	Chilli		Cocktail Tomatoes		Peppers
Pumpkin	Leeks	Tomatoes		Tomatoes	Lettuce	Spring Onions		Kale		Cow Peas		Pumpkin
Spinach	Lettuce				Peppers	Tomatoes		Leeks		French Beans		Spinach
Spring Onions	Onions				Red Lettuce			Lettuce		Japanese Pumpkin		Strawberries
Strawberries	Peppers				Rocket			Maize		Jugo Beans		String Beans
String Beans	Radish				Spinach			Melons		Kale		Watermelons
Tomatoes	Red Onions				Tomatoes			Onions		Lettuce		
	Spinach				Rocket			Peppers		Maize		
	Spring Onions							Rhubarb		Onions		
	Strawberries							Runner Beans		Peanuts		
	Swiss Chard							Spinach		Pink Cow Peas		
	Tomatoes							Spring Onions		Pumpkin		
	Turnips							Strawberries		Red Kale		

SWVCG	OZCF	ANOCG	CMCCG	VOCVG	KSCG_A	KSCG_B	WPG	OJSG	CRCHG	SFL	CVOFG	KFG
								Sweet Melons		Rhubarb		
								Swiss Chard		Runner Beans		
								Tomatoes		Sorrel		
								Watermelons		Spinach		
										Spring Onions		
										Strawberries		
										Tomatoes		
16	22	11	5	11	17	12	10	26	9	29	7	15

Table D2. Crop type inventory list for community gardens in Berlin. Totals at the bottom of each column represent the crop richness for each individual garden. Produce is listed alphabetically.

GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Beetroot	Beetroot	Asian Lettuce	Aubergines	Blackberries	Blackberries	Bush Beans	Asian Lettuce	Beetroot	Aramis Bush Beans	Beetroot	Beetroot	Artichokes
Blackberries	Blackcurrants	Asparagus	Barley	Carrots	Blackcurrants	Carrots	Beetroot	Belana Potatoes	Asian Lettuce	Black Cocktail Tomatoes	Blackberries	Beetroot
Blackcurrants	Cantare Bush Beans	Barley	Beetroot	Celery	Broccoli	Celery	Blackberries	Blackberries	Aubergine	Black Truffle	Blackcurrants	Broad Beans
Broccoli	Chives	Broad Beans	Blackberries	Fire Beans	Chives	Highbush Blueberries	Cabbage	Blackcurrants	Beetroot	Blackberries	Carrots	Broccoli
Cocktail Tomatoes	Cocktail Tomatoes	Butterhead Lettuce	Blackcurrants	Golden Currant Tomatoes	Garlic	Maize	Carrots	Broccoli	Bogus Fruchta Tomatoes	Blackcurrants	Cauliflower	Buckwheat
Kale	Gooseberries	Carrots	Brazowa Siberian Blueberries	Gooseberries	Garlic Chives	Onions	Chives	Buckwheat	Bok Choy	Blue Congo Potatoes	Celery	Carrots
Kohlrabi	Kiwi	Chili	Broccoli	Kohlrabi	Gooseberries	Rocket	Cucumber	Carrots	Broad Beans	Bush Beans	Chili	Celery
Lettuce	Kohlrabi	Chives	Cabbage	Lettuce	Kale	Strawberries	Honeydew Melon	Chives	Butterhead Lettuce	Carrots	Cucumber	Chili
Peas	Peas	Cucumber	Cauliflower	Maize	Maize	Tomatoes	Kale	Cocktail Tomatoes	Carrots	Cauliflower	European Blueberries	Chives
Peppers	Raspberries	European Blueberries	Dwarf Tamarilloes	Rote Murmel Tomatoes	Purple Chokeberries	Winter Squash	Kohlrabi	Cucumber	Caruso Bush Beans	Chives	Kohlrabi	Cucumber
Raspberries	Red Leaf Lettuce	Fire Beans	European Blueberries	Senga Sengana Strawberries	Red Kohlrabi		Lettuce	Gooseberries	Cauliflower	Cocktail Tomatoes	Lettuce	Gojiberries
Red Kohlrabi	Rhubarb	Garlic	Gooseberries	Swiss Chard	Red Leaf Lettuce		Onions	Jostaberries	Chili	Cucumber	Maize	Gooseberries
Red Leaf Lettuce	Rocket	Hinrichs Kiesen Bush Beans	Iceberg Lettuce		Redcurrants		Peas	Kale	Chives	Désirée Potatoes	Pepino	Kale
Redcurrants	Spring Onions	Honeydew Melon	Kiwi		Spring Onions		Peppers	Kohlrabi	Cocktail Tomatoes	European Blueberries	Peppers	Lettuce
Rhubarb	Strawberries	Husk Tomatoes	Lettuce		Strawberries		Radish	Lettuce	Cucumber	Guernsey Island Tomatoes	Radish	Maize
Rocket	Tomatoes	Jersey Cabbage	Maize		Tree Onions		Red Kohlrabi	Linda Potatoes	Dorenia Tomatoes	Highbush Blueberries	Raspberries	Onions
Runner Beans	Zucchini	Maize	Pepino		Winter Squash		Red Leaf Lettuce	Maize	Garlic Chives	La Diva Cucumber	Red Kohlrabi	Peas

GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Spinach		Mexican Sour Gherkin	Radish		Zucchini		Rocket	Onions	Jalapeno Chili	Langa Cucumber	Red Leaf Lettuce	Peppers
Spring Onions		Oakleaf Lettuce	Raspberries				Runner Beans	Patty Pan	Kale	Peas	Romaine Lettuce	Radish
Strawberries		Oca	Red Kohlrabi				Spinach	Peppers	Kohlrabi	Radish	Runner Beans	Red Leaf Lettuce
Swiss Chard		Peppers	Red Leaf Lettuce				Spring Onions	Raspberries	Lettuce	Raspberries	Spinach	Redcurrants
Tomatoes		Purple Syrian Carrots	Rhubarb				Strawberries	Red Kohlrabi	Maize	Red Cabbage	Spring Onions	Rhubarb
Winter Squash		Purple Teepes Bush Beans	Rocket				Swiss Chard	Red Leaf Lettuce	Mountain Onions	Red Emmalie Potatoes	Strawberries	Rocket
		Radish	Siniglaskaya Siberian Blueberries				Tomatoes	Redcurrants	Peas	Red Kuri Squash	Swiss Chard	Runner Beans
		Raspberries	Spinach				Winter Pumpkin	Rocket	Peppers	Red Leaf Lettuce	Tomatoes	Strawberries
		Red Leaf Lettuce	Spring Onions				Yellow Zucchini	Runner Beans	Potatoes	Red Siberian Tomatoes	Zucchini	Sweet Potatoes
		Rocket	Strawberries				Zucchini	Strawberries	Radish	Redcurrants		Tomatoes
		Runner Beans	Sweet Potatoes					Swiss Chard	Raspberries	Rhubarb		Yellow Zucchini
		Soya Beans	Swiss Chard					Tomatoes	Red Kohlrabi	Rocket		
		Strawberries	Tomatoes					Valerie Potatoes	Red Leaf Lettuce	Runner Beans		
		Swiss Chard	Winter Squash					Whitecurrants	Red Savina Chili	Sieglinde Potatoes		
		Yacon						Winter Squash	Redcurrants	Spinach		
								Zucchini	Rhubarb	Strawberries		
									Rocket	Sweet Dumpling Squash		
									Runner Beans	Swiss Chard		

GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
									Senga Sengana Strawberries	Whitecurrants		
									Spinach	Zucchini		
									Strawberries			
									Swiss Chard			
									Tatsoi			
									Tomatoes			
									Toscana Strawberries			
									Wild Celery			
									Yellow Zucchini			
									Zucchini			
23	17	32	31	12	18	10	27	33	45	37	26	28

Crop Area

Table D3. Area of cultivated land (m^2) and area of cultivated land as a percentage of the total garden area (%) for community gardens in Cape Town.

	Area of cultivated land (m^2)	Area of garden (m^2)	Area of garden occupied by cultivated land (%)
SWVCG	1610	1910	84
OZCF	2195	3025	73
ANOCG	184	190	97
CMCCG	57	57	100
VOCVG	360	1410	26
KSCG_A	343	520	66
KSCG_B	384	2215	17
WPG	112	2925	4
OJSG	187	342	55
CRCHG	38	56	68
SFL	700	4650	15
CVOFG	185	185	100
KFG	1763	5225	34
Total	**8119**	**22710**	***36**

** The total (36%) in the 'area of garden occupied by cultivated land' column has been calculated by (8119 / 22710) x 100. It does not represent an average of the right-hand column values.*

Table D4. Area of cultivated land (m^2) and area of cultivated land as a percentage of the total garden area (%) for community gardens in Berlin.

	Area of cultivated land (m^2)	Area of garden (m^2)	Area of garden occupied by cultivated land (%)
GAK	5300	8000	66
BGG	70	395	18
PRG	1580	5500	29
PLG	170	750	23
KSS	153	300	51
LSG	506	1150	44
SKR	110	300	37
KFS	1736	8000	22
SFM	465	660	70
IGH	875	1700	51
GPT	422	1450	29
GCF	496	700	71
KLG	215	3670	6
Total	**12098**	**32575**	***37**

** The total (37%) in the 'area of garden occupied by cultivated land' column has been calculated by (12098 / 32575) x 100. It does not represent an average of the right-hand column values.*

Livestock

Table D5. Individual and total livestock numbers for Cape Town community gardens.

	Livestock present (Y/N)	Number of individuals
SWVCG	N	0
OZCF	N	0
ANOCG	N	0
CMCCG	N	0
VOCVG	N	0
KSCG_A	N	0
KSCG_B	N	0
WPG	Y	43
OJSG	N	0
CRCHG	N	0
SFL	Y	5
CVOFG	N	0
KFG	Y	5
Total		**53**

Table D6. Individual and total livestock numbers for Berlin community gardens.

	Livestock present (Y/N)	Number of individuals
GAK	Y	2
BGG	N	0
PRG	Y	7
PLG	N	0
KSS	N	0
LSG	N	0
SKR	N	0
KFS	Y	2
SFM	N	0
IGH	N	0
GPT	Y	5
GCF	N	0
KLG	N	0
Total		**16**

Fresh Water Supply

Table D7. Fresh water resource characteristics of community gardens in Cape Town. Fresh water sources (other than tapped municipal water), number of water collection tanks and their total capacities (l), and average monthly estimates of fresh water usage in each garden are shown. All community gardens had access to tapped water from the municipality.

	Number of fresh water sources	Rainwater collection (Y/N)	Number of water collection tanks	Total capacity of collection tanks (l)	Water usage per month (l)
SWVCG	0	Y	2	10000	20000
OZCF	0	N	0	0	30000
ANOCG	0	Y	3	12500	1000
CMCCG	0	N	0	0	100
VOCVG	0	N	0	0	-
KSCG_A	0	Y	1	5000	7000
KSCG_B	1	N	1	5000	6000
WPG	1	N	1	9000	5000
OJSG	0	Y	2	10000	4000
CRCHG	0	N	0	0	200
SFL	0	Y	4	20000	20000
CVOFG	0	N	0	0	-
KFG	1	Y	3	30000	30000
Total	**3**		**17**	**101500**	**123300**

* Average monthly estimates of water usage were not available for VOC Vegetable Garden and Constantia Village Organic Food Garden.

Table D8. Fresh water resource characteristics of community gardens in Berlin. Fresh water sources (other than tapped municipal water), number of water collection tanks and their total capacities (l), and average monthly estimates of fresh water usage in each garden are shown. All community gardens had access to tapped water from the municipality.

	Number of Fresh Water Sources	Rainwater Collection (Y/N)	Number of Water Collection Tanks	Total Capacity of Collection Tanks (l)	Water Usage per Month (l)
GAK	0	N	6	6000	-
BGG	0	N	1	210	-
PRG	0	Y	20	10000	-
PLG	0	Y	1	1000	-
KSS	0	N	0	0	-
LSG	0	Y	2	1000	200
SKR	0	N	1	210	-
KFS	1	Y	3	2500	-
SFM	0	Y	3	1500	-
IGH	0	N	0	0	-
GPT	0	Y	1	1000	-
GCF	0	N	0	0	-
KLG	0	Y	4	4000	1000
Total	**1**		**42**	**27420**	**1200**

* Average monthly estimates of water usage were not available for all community gardens except Lichtenberger Stadtgarten and Klunkergarten.

Landcover Infiltration Capacity

Table D9. Run-off coefficients classified by DIN 1986-100: 2016-09 used for building and land drainage systems, and that were applied to artificial gardens surfaces in this study. Middle run-off coefficients (C_m) were used as average values rather than the high-end coefficient values (C_s). Source: Table from DIN (2016).

Auszug aus der DIN 1986-100:2016-9 (Tabelle 9)

Anmerkung: Die abflusswirksame Fläche Au ergibt sich aus der Multiplikation der befestigten Fläche im Grundriss mit dem jeweils zugehörigen Abflussbeiwert C, (Grundleitung: Au = A · C_s); (Rückhaltung: Au = A · C_m).

Nr.	**Art der Fläche** Fläche mit Abfluß zum Entwässerungssystem	Spitzenabfluß-beiwert C_s	mittl. Abfluß-beiwert C_m
1	***Wasserundurchlässige Flächen***		
	- Dachflächen		
	Schrägdach		
	Metall, Glas, Schiefer, Faserzement	1,00	0,90
	Ziegel, Dachpappe	1,00	0,80
	Flchdach (bis 3° / 5%)		
	Metall, Glas Faserzement	1,00	0,90
	Dachpappe	1,00	0,90
	Kiesschüttung	0,80	0,80
	begrünte Dachflächen		
	Extensivbergünung (> 5°)	0,70	0,40
	Intensivbegrünung, ab 30 cm Aufbau (≤ 5°)	0,20	0,10
	Extensivbegrünung, ab 10 cm Aufbau (≤ 5°)	0,40	0,20
	Extensivbegrünung, bis 10 cm Aufbau (≤ 5°)	0,50	0,30
	- Verkehrsflächen (Straßen, Plätze, Zufahrten, Wege)		
	Betonflächen	1,00	0,90
	Schwarzdecken (Asphalt)	1,00	0,90
	befestigte Flächen mit Fugendichtung (Pflaster mit Verguss)	1,00	0,80
	- Rampen		
	Neigung zum Gebäude, unabhängig von der Neigung und derBefestigungsart	1,00	1,00
2	***Teildurchlässige und schwach ableitende Flächen,***		
	- Verkehrsflächen (Straßen, Plätze, Zufahrten, Wege)		
	Betonsteinpflaster, in Sand oder Schlacke verlegt, Flächen mit Platten	0,90	0,70
	Pflasterflächen, mit Fugenanteil > 15 %, z. B. 10 cm × 10 cm und kleiner oder fester Kiesbelag	0,70	0,60
	wassergebundene Flächen	0,90	0,70
	lockerer Kiesbelag, Schotterrasen z. B. Kinderspielplätze	0,30	0,20
	Verbundsteine mit Sickerfugen, Sicker- / Drainsteine	0,40	0,25
	Rasengittersteine (mit häufigen Verkehrsbelastungen, z. B. Parkplatz)	0,40	0,20
	Rasengittersteine (ohne häufige Verkehrsbelastungen, z. B. Feuerwehrzufahrt)	0,20	0,10
	- Sportflächen mit Dränung		
	Kunststoff-Flächen, Kunststoffrasen	0,60	0,50
	Tennenflächen	0,30	0,20
	Rasenflächen	0,20	0,10
3	***Wasserdurchlässige Flächen***		
	- Parkanlagen, Rasenflächen, Gärten		
	flaches Gelände	0,00	0,00
	steiles Gelände	0,00	0,00

Water Flow Regulation and Runoff Mitigation

Table D10. Area of impermeable surfaces (m^2) and area of sealed surfaces as a percentage of the total garden area (%) for community gardens in Cape Town.

	Area of impermeable surfaces (m^2)	Area of garden (m^2)	Percentage area of garden occupied by sealed surfaces (%)
SWVCG	136	1910	7
OZCF	96	3025	3
ANOCG	6	190	3
CMCCG	0	57	0
VOCVG	897	1410	64
KSCG_A	102	520	20
KSCG_B	81	2215	4
WPG	163	2925	6
OJSG	98	342	29
CRCHG	9	56	16
SFL	300	4650	6
CVOFG	0	185	0
KFG	644	5225	12
Total	**2531**	**22710**	***11**

** The total (11%) in the 'percentage area of garden occupied by sealed surfaces' column has been calculated by (2531 / 22710) x 100. It does not represent an average of the right-hand column values.*

Table D11. Area of impermeable surfaces (m^2) and area of sealed surfaces as a percentage of the total garden area (%) for community gardens in Berlin.

	Area of impermeable surfaces (m^2)	Area of garden (m^2)	Percentage area of garden occupied by sealed surfaces (%)
GAK	80	8000	1
BGG	18	395	5
PRG	2500	5500	45
PLG	180	750	24
KSS	0	300	0
LSG	9	1150	1
SKR	60	300	20
KFS	85	8000	1
SFM	45	660	7
IGH	649	1700	38
GPT	423	1450	29
GCF	130	700	19
KLG	3225	3670	88
Total	**7404**	**32575**	***23**

** The total (23%) in the 'percentage area of garden occupied by sealed surfaces' column has been calculated by (7404 / 32575) x 100. It does not represent an average of the right-hand column values.*

Tree canopy area/shaded area

Table D12. Area of garden shaded under tree canopy (m²) carbon storage (tons Carbon) and carbon sequestered (tons Carbon per year) for community gardens in Cape Town.

	Area of garden (m^2)	Area of garden under tree canopy (m^2)	Proportion of garden area under tree canopy (%)	Carbon storage (t C)	Carbon sequestered (t C / year)
SWVCG	1910	196	10	2,083	0,0162
OZCF	3025	350	12	3,721	0,0290
ANOCG	190	17	9	0,178	0,0014
CMCCG	57	0	0	0,000	0,0000
VOCVG	1410	26	2	0,281	0,0022
KSCG_A	520	10	2	0,104	0,0008
KSCG_B	2215	1257	57	13,358	0,1040
WPG	2925	1088	37	11,567	0,0900
OJSG	342	47	14	0,501	0,0039
CRCHG	56	2	3	0,020	0,0002
SFL	4650	2225	48	23,647	0,1841
CVOFG	185	29	16	0,310	0,0024
KFG	5225	96	2	1,025	0,0080
Total	**22710**	**5343**	***24**	**56,80**	**0,4421**

** Portion of garden area under tree canopy (%) refers to digitised tree canopy area from aerial photos. The total (24%) in the proportion of garden under tree canopy column has been calculated by (5343 / 22710) x 100 and does not represent an average. Carbon storage (t C) is calculated using Rowntree-Nowak Equation 1: 1,063 x % digitised tree cover x area of garden (ha). Carbon sequestered (t C / year) is calculated using Rowntree-Nowak Equation 2: 8,275 x 10^{-3} x % digitised tree cover x area of garden (ha).*

Table D13. Area of garden shaded under tree canopy (m²) carbon storage (tons Carbon) and carbon sequestered (tons Carbon per year) for community gardens in Berlin.

	Area of garden (m^2)	Area of garden under tree canopy (m^2)	Proportion of garden area under tree canopy (%)	Carbon storage (t C)	Carbon sequestered (t C / year)
GAK	8000	96	1	1,020	0,0079
BGG	395	142	36	1,509	0,0118
PRG	5500	3929	71	41,765	0,3251
PLG	750	302	40	3,210	0,0250
KSS	300	86	29	0,914	0,0071
LSG	1150	427	37	4,539	0,0353
SKR	300	207	69	2,200	0,0171
KFS	8000	2604	33	27,681	0,2155
SFM	660	5	1	0,053	0,0004
IGH	1700	421	25	4,475	0,0348
GPT	1450	483	33	5,134	0,0400
GCF	700	220	31	2,339	0,0182
KLG	3670	4	0	0,043	0,0003
Total	**32575**	**8926**	***27**	**94,88**	**0,7386**

** Portion of garden area under tree canopy (%) refers to digitised tree canopy area from aerial photos. The total (27%) in the proportion of garden under tree canopy column has been calculated by (8926 / 232575) x 100 and does not represent an average. Carbon storage (t C) is calculated using Rowntree-Nowak Equation 1: 1,063 x % digitised tree cover x area of garden (ha). Carbon sequestered (t C / year) is calculated using Rowntree-Nowak Equation 2: 8,275 x 10^{-3} x % digitised tree cover x area of garden (ha).*

Vegetated area

Table D14. Area of vegetated surfaces (m^2) area of vegetated surfaces as a percentage of the total garden area (%) for community gardens in Cape Town.

	Area of garden (m^2)	Total vegetated area of garden (m^2)	Proportion of garden with vegetated surfaces (%)
SWVCG	1910	1774	93
OZCF	3025	2929	97
ANOCG	190	184	97
CMCCG	57	57	100
VOCVG	1410	513	36
KSCG_A	520	418	80
KSCG_B	2215	2134	96
WPG	2925	2762	94
OJSG	342	244	71
CRCHG	56	47	84
SFL	4650	4350	94
CVOFG	185	185	100
KFG	5225	4581	88
Total	**22710**	**20179**	***89**

** The total (89%) in the 'proportion of garden with vegetated surfaces' column has been calculated by (20179 / 22710) x 100. It does not represent an average of the right-hand column values.*

Table D15. Area of vegetated surfaces (m^2) area of vegetated surfaces as a percentage of the total garden area (%) for community gardens in Berlin.

	Area of garden (m^2)	Total vegetated area of garden (m^2)	Proportion of garden with vegetated surfaces (%)
GAK	8000	7920	99
BGG	395	377	95
PRG	5500	3000	55
PLG	750	570	76
KSS	300	300	100
LSG	1150	1141	99
SKR	300	240	80
KFS	8000	7915	99
SFM	660	615	93
IGH	1700	1051	62
GPT	1450	1027	71
GCF	700	570	81
KLG	3670	445	12
Total	**32575**	**25171**	***77**

** The total (77%) in the 'proportion of garden with vegetated surfaces' column has been calculated by (25171 / 32575) x 100. It does not represent an average of the right-hand column values.*

Air quality regulation

Table D16. Number of deciduous and evergreen trees in Cape Town community gardens.

	Tree Species - Deciduous	Tree Species - Evergreen	
0.0 - 4.9m	52 (24%)	71 (32%)	
5.0 - 9.9m	21 (10%)	28 (13%)	
>10m	3 (1%)	44 (20%)	
Total	**76**	**143**	**219**
Total (%)	**35**	**65**	**100**

Table D17. Number of deciduous and evergreen trees in Berlin community gardens.

	Tree Species - Deciduous	Tree Species - Evergreen	
0.0 - 4.9m	25 (20%)	0 (0%)	
5.0 - 9.9m	10 (8%)	1 (1%)	
>10m	87 (70%)	2 (1%)	
Total	**122**	**3**	**125**
Total (%)	**98**	**2**	**100**

Moderation of extreme events

Table D18. Tree height categories for community gardens in Cape Town. Tree numbers for gardens have been grouped according to small (0 – 4.9 m), medium (5 – 9.9 m) and large (>10 m). Also shown are the tree density per hectare for each tree height category for community gardens in Cape Town.

	Tree Height			
	0.0 - 4.9 m	**5.0 - 9.9 m**	**>10 m**	**Total**
SWVCG	12	4	2	18
OZCF	35	0	1	36
ANOCG	0	1	0	1
CMCCG	5	0	0	5
VOCVG	35	0	0	35
KSCG_A	5	0	0	5
KSCG_B	6	0	16	22
WPG	2	5	14	21
OJSG	2	10	1	13
CRCHG	1	0	0	1
SFL	12	18	14	44
CVOFG	0	0	1	1
KFG	8	9	0	17
Total	**123**	**47**	**49**	**219**
Density (trees/ha)	**54**	**21**	**22**	**96**

Table D19. Tree height categories for community gardens in Berlin. Tree numbers for gardens have been grouped according to small (0 – 4.9 m), medium (5 – 9.9 m) and large (>10 m). Also shown are the tree density per hectare for each tree height category for community gardens in Berlin.

	Tree Height			
	0.0 - 4.9 m	**5.0 - 9.9 m**	**>10 m**	**Total**
GAK	3	0	3	6
BGG	0	0	2	2
PRG	2	0	23	25
PLG	2	0	8	10
KSS	2	1	3	6
LSG	4	0	10	14
SKR	2	0	3	5
KFS	3	5	16	24
SFM	1	0	0	1
IGH	0	0	5	5
GPT	1	5	9	15
GCF	4	0	7	11
KLG	1	0	0	1
Total	**25**	**11**	**89**	**125**
Density (trees/ha)	**8**	**3**	**27**	**38**

Species richness

Full lists of vascular plant, tree and animal species richness are shown for Cape Town and Berlin community gardens.

Cape Town – Vascular Plants

Table D20. Vascular plant species richness observed in Cape Town community gardens. Values in columns represent Londo scale abundance percentages as decimal proportions (%), where 1,00 = 100% and 0,01 = 1% coverage of a species in a particular community. Species represented in ***red*** *(n=5) denote invasive species according to the National Environmental Management: Biodiversity Act 10 of 2004 list of invasive species (Government of South Africa, 2004) and in* ***green*** *those species having medicinal properties (n=52).*

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Creeping Foxglove	*Asystasia gangetica* (L.) T. Anders.	Acanthaceae				0,01									
Ribbon Bush	*Hypoestes aristata* (Vahl) Sol. ex Roem. & Schult.	Acanthaceae					0,01								
Agapanthus	*Agapanthus africanus* (L.) Hoffmanns.	Agapanthaceae										0,02			0,01
Agapanthus	*Agapanthus praecox* Willd.	Agapanthaceae											0,02		
Agapanthus	*Agapanthus spp*	Agapanthaceae	0,01		0,01					0,02					
Purple Sour Vig	*Carpobrotus deliciosus* (L.) L. Bolus	Aizoaceae										0,02			
Sour Fig	*Carpobrotus edulis* (L.) L. Bolus	Aizoaceae					0,01								
Wild Garlic	*Tulbaghia violacea* Harv.	Alliaceae					0,01			0,01			0,02		
Cats Tail	*Amaranthus caudatus* L.	Amaranthaceae								0,01					
Hanekam	*Celosia cristata* L.	Amaranthaceae													0,02
Nettle-Leaf Goosefoot	*Chenopodium murale*L.	Amaranthaceae			0,1				0,02						
Globe Amaranth	*Gomphrena globosa* L.	Amaranthaceae													0,04
Bush Lily	*Clivia miniata* [Lindl.] Regel	Amaryllidaceae											0,01		
Nana Berry	*Searsia dentata* (Thunb.) F.A. Barkley	Anacardiaceae									0,01				
Dill	*Anethum graveolens* L.	Apiaceae	0,01												
Corriander	*Coriandrum sativum* L.	Apiaceae	0,01												
Thai Corriander	*Eryngium foetidum* L.	Apiaceae											0,01		

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Fennel	*Foeniculum vulgare* Mill.	Apiaceae	0,01	0,01			0,02	0,04						0,01	
Parsley	*Petroselinum crispum* Mill.	Apiaceae	0,01				0,02	0,04				0,01	0,01		
Natal Plum	*Carissa macrocarpa* (Eckl.) A.DC	Apocynaceae					0,01								
Num Num	*Carissa bispinosa* (L.) Desf. ex Brenan	Apocynaceae									0,01				
Taro	*Colocasia esculenta* (L.) Schott	Araceae								0,01					
Delicious Monster	*Monstera deliciosa* Liebm.	Araceae											0,04		
Duckweed	*Spirodela polyrhiza* (L.) Schleid.	Araceae								0,01					
Arum Lily	*Zantedeschia aethiopica* (L.) Spreng.	Araceae								0,01			0,01		
Paper Plant	*Fatsia japonica* (Thunb.) Decne. & Planch.	Araliaceae								0,01					
Ground Ivy	*Hedera helix* L.	Araliaceae										0,1			
Bamboo Palm	*Chamaedorea seifrizii* Willd.	Arecaceae								0,02					
Silver Ribbon	*Liriope muscari* 'Varegata' (Decne.) L.H. Bailey	Asparagaceae								0,01					
Tuberose	*Polianthes tuberosa* L.	Asparagaceae													0,04
Mother in Law's Tongue	*Sansevieria trifasciata* Prain	Asparagaceae				0,04				0,01					
Elephant's Foot Yucca	*Yucca elephantipes* Lem.	Asparagaceae				0,1									
Garden Aloe	*Aloe arborescens* Mill.	Asphodelaceae				0,04				0,04	0,02		0,02		
Bitter Aloe	*Aloe ferox* Mill.	Asphodelaceae				0,04	0,01								
Unknown Aloe	*Aloe spp*	Asphodelaceae						0,01							
Tree Aloe	*Aloe striata* Haw.	Asphodelaceae								0,04					
Tuinaalwyn	*Aloe striata x Aloe maculata*	Asphodelaceae				0,04									
Cat's Tail	*Bulbinella floribunda* (Aiton) T. Durand & Schinz	Asphodelaceae											0,02		
Yarrow	*Achillea millefolium* L.	Asteraceae											0,01		
Marguerite Daisy	*Argyranthemum frutescens* (L.) Sch.Bip.	Asteraceae											0,01		
Wilde Als	*Artemisia afra* Jacq. ex Willd.	Asteraceae									0,01				
Blackjack	*Bidens pilosa* L.	Asteraceae			0,1									0,01	
Gousblom	*Calendula officinalis* L.	Asteraceae		0,04			0,01								

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
China Aster	*Callistephus chinensis* (L.) Nees	Asteraceae													0,02
Chrysanthemum	*Chrysanthemum morifolium* Ramat.	Asteraceae													0,04
Horseweed	*Conyza bonariensis* (L.) Cronquist	Asteraceae			0,01										
Pink Cosmos	*Cosmos bipinnatus* Cav.	Asteraceae													0,04
Cosmos	*Cosmos sulphureus* Cav.	Asteraceae	0,01												
Red/Orange Cosmos	*Cosmos sulphureus* Hybrid	Asteraceae													0,04
Ganskos	*Cotula turbinata* L.	Asteraceae													0,04
Globe Artichoke	*Cynara cardunculus* L.	Asteraceae													0,02
Dahlia	*Dahlia pinnata* Cav.	Asteraceae													0,04
Wild Rosemary	*Eriocephalus africanus* L.	Asteraceae					0,01				0,01		0,02		
Botterblom	*Gazania kresbiana*	Asteraceae									0,02				
Gazania Hybrids	*Gazania spp*	Asteraceae													0,02
Sun Flower	*Helianthus annuus*	Asteraceae		0,02				0,01					0,01		0,02
Jerusalem artichoke	*Helianthus tuberosus*	Asteraceae									0,01				
Kooigoed	*Helichrysum petiolare* Hilliard & B.L. Burtt	Asteraceae									0,01				
Geelsewejaartije	*Helichrysum splendidum* (Thunb.) Less.	Asteraceae			0,01										
Creeping Marguerite	*Osteospermum fruticosum* (L.) Norl.	Asteraceae								0,01					
Bush Tickberry	*Osteospermum moniliferum subsp. Moniliferum* L.	Asteraceae						0,01							
Cape Everlasting	*Syncarpha eximia* (L.) B. Nord.	Asteraceae								0,01					
African Marigold	*Tagetes erecta* L.	Asteraceae	0,02				0,01	0,04	0,02						0,02
Marigold	*Tagetes patula* L.	Asteraceae	0,02	0,04			0,01	0,04	0,02				0,04		
Dandelion	*Taraxacum officinale* (L.) Weber ex F.H. Wigg	Asteraceae		0,04	0,1				0,02		0,01	0,01		0,01	
Jakobregop	*Zinnia elegans* Jacq.	Asteraceae													0,02
Busy Lizzy	*Impatiens walleriana* Hook.f.	Balsaminaceae	0,02												
Borage	*Borago officinalis* L.	Boraginaceae									0,01				
Pattersons Curse	*Echium plantagineum* L.	Boraginaceae							0,01						

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Comfrey	*Symphytum officinale* L.	Boraginaceae									0,02		0,01	0,02	
Rocket	*Eruca sativa* Mill.	Brassicaceae	0,02												
Yellow King Humbert	*Canna spp*	Cannaceae						0,01							
Kanna	*Canna x generalis*	Cannaceae													0,02
Sweet William	*Dianthus barbatus* L.	Caryophyllaceae													0,04
Carnation	*Dianthus caryophyllus* L.	Caryophyllaceae													0,04
Pinks	*Dianthus x allwoodii*	Caryophyllaceae													0,04
Cape Saffron	*Cassine peragua* L.	Celastraceae								0,01					
Pig's Ear	*Cotyledon orbiculata* L.	Crassulaceae					0,01				0,01	0,02			
Fairy Crassula	*Crassula multicava subsp. multicava* Lem.	Crassulaceae				0,01									
Stonecrop	*Crassula obovata var. obovata* Haw.	Crassulaceae				0,01									
Jade Plant	*Crassula ovata* Haw.	Crassulaceae					0,01								
Gollum	*Crassula ovata cv* 'Gollum'	Crassulaceae						0,01							
Chayote	*Sechium edule* (Jacq.) Sw.	Cucurbitaceae								0,01					
Sedge	*Carex spp*	Cyperaceae											0,04		
Cape Scabius	*Scabiosa africana* L.	Dipsacaceae							0,02						
Rooibos	*Aspalathus linearis* (Burm.f.) R. Dahlgren	Fabaceae									0,01				
Cancer Bush	*Sutherlandia frutescens* (L.) R.Br.	Fabaceae									0,01		0,01		
Bergtee	*Geranium incanum* Burm.f.	Geraniaceae					0,01				0,01				
Rose-Scented Pelargonium	*Pelargonium capitatum* (L.f.) L'Hér.	Geraniaceae					0,01								
Lemon-Scented Pelargonium	*Pelargonium citronellum* J.J.A. van der Walt	Geraniaceae					0,01								
Ligularia	*Pelargonium conradiae*	Geraniaceae											0,04		
Wildemalva	*Pelargonium gravedens*	Geraniaceae					0,01								
Rose Geranium	*Pelargonium graveolens* L'Hér.	Geraniaceae									0,02		0,02		
Peppermint-Scented Pelargonium	*Pelargonium tomentosum* Jacq.	Geraniaceae					0,01				0,02	0,02	0,02		
Garden Regal Pelargonium	*Pelargonium x domesticum*	Geraniaceae													
Nutmeg Geranium	*Pelargonium x fragrans*	Geraniaceae									0,02				

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Hydrangea	*Hydrangea macrophylla* (Thunb.) Ser.	Hydrangeaceae								0,02					
Blue Stars	*Aristea ecklonii*	Iridaceae					0,01								
Wild Iris	*Dietes grandiflora* DC	Iridaceae								0,01					
Freesia	*Freesia x hybrida*	Iridaceae						0,02	0,02						
Iris hybrids	*Iris spp*	Iridaceae	0,02								0,01				
English Lavender	*Lavandula angustifolia* Mill.	Lamiaceae	0,01							0,01					
French Lavender	*Lavandula dentata* L.	Lamiaceae	0,01			0,02	0,01	0,02		0,01	0,01	0,04	0,01	0,02	
Wild Dagga	*Leonotis leonurus* (L.) R.Br.	Lamiaceae					0,01				0,02				
Lemon Balm	*Melissa officinalis* L.	Lamiaceae											0,01		
Spearmint	*Mentha spicata* L.	Lamiaceae											0,02		
Mint	*Mentha spp*	Lamiaceae	0,01					0,02	0,01		0,01		0,01		
Catmint	*Nepeta cataria* L.	Lamiaceae	0,01										0,02		
Basil	*Ocimum basilicum* L.	Lamiaceae	0,01	0,01			0,02	0,04	0,02		0,01	0,01	0,02		
Marjoram	*Origanum majorana* L.	Lamiaceae									0,01		0,02		
Oregano	*Origanum vulgare* L.	Lamiaceae	0,01										0,02		
Vlieebos	*Plectranthus ecklonii* Benth.	Lamiaceae					0,01								
Pink Spur Flower	*Plectranthus fruticosus* L'Hérit.	Lamiaceae				0,04							0,04		
Spur Flower	*Plectranthus neochilus* Schltr.	Lamiaceae										0,02			
Painted Nettle	*Plectranthus scutellariodes* Hybrid	Lamiaceae											0,01		
Unknown	*Plectranthus spp*	Lamiaceae									0,04				
Plectranthus Cultivar	*Plectranthus spp* 'Mona Lavender'	Lamiaceae				0,04									
Rosemary	*Rosmarinus officinalis* L.	Lamiaceae	0,01				0,02	0,04			0,01		0,02	0,01	
Sage	*Salvia officinalis* L.	Lamiaceae	0,01				0,02				0,01	0,01	0,02	0,01	
Lamb's Ear	*Stachys byzantina* K. Koch	Lamiaceae				0,04									
Thyme	*Thymus vulgaris* L.	Lamiaceae	0,01				0,02	0,04			0,01			0,01	
Hibiscus	*Hibiscus rosa-sinensis* L.	Malvaceae								0,01					
Red Sun Rose	*Aptenia cordifolia* (L.f.) N.E.Br.	Mesembryanthemaceae					0,01								

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Wax Berry	*Morella quercifolia* (L.) Killick	Myricaceae					0,01								
Bougainvillea	*Bougainvillea x buttiana*	Nyctaginaceae								0,04					
Bougainvillea	*Bougainvillea x buttiana* 'Killie Campbell'	Nyctaginaceae										0,04			
Yellow Water Lily	*Nymphaea caerulea* Sav. 'Sulurea'	Nymphaeaceae									0,01				
Cape Blue Water Lily	*Nymphaea capensis* Thunb.	Nymphaeaceae		0,01											
Creeping sorrel	*Oxalis corniculata* L.	Oxalidaceae	0,01		0,01										
Purple Granadilla Vine	*Passiflora edulis* Sims	Passifloraceae	0,02								0,02				
Ice Cream Bush	*Breynia disticha* J.R.Forst. & G.Forst.	Phyllanthaceae				0,01									
Plantain	*Plantago lanceolata* L.	Plantaginaceae			0,02				0,01						
Statice	*Limonium sinuatum* (L.) Mill.	Plumbaginaceae													0,04
Vetiver Grass	*Chrysopogon zizanioides* (L.) Roberty	Poaceae									0,02				
Lemon Grass	*Cymbopogon citratus* (DC.) Stapf	Poaceae					0,01						0,02		
Kikuyu grass	*Pennisetum clandestinum* Hochst.	Poaceae	0,02						0,02					0,01	
Spekboom	*Portulacaria afra* Jacq.	Portulaceae		0,02		0,01		0,01					0,01		
Protea	*Protea spp*	Proteaceae								0,04					
Delphinium	*Delphinium grandiflorum* L.	Ranunculaceae													0,04
Cape Reed	*Ceratocaryum argenteum*	Restionaceae									0,01				
Cape Thatching Reed	*Elegia capensis* (Burm.f.) Schelpe	Restionaceae								0,02					
Restios Grass	*Restio spp*	Restionaceae											0,04		
Wild Rose Bush	*Rosa canina* L.	Rosaceae					0,01								
Boegoe	*Agathosma ovata* (Thunb.) Pillans	Rutaceae											0,02		
Rue	*Ruta graveolens* L.	Rutaceae									0,02				
Yesterday-Today-Tomorrow	*Brunfelsia pauciflora* 'Magnifica' (Cham. & Schltdl.) Benth.	Solanaceae						0,01							
Petunia	*Petunia x hybrida*	Solanaceae						0,02	0,02				0,01		
Potato Bush Plant	*Solanum rantonnetii* (Carrière) Bitter	Solanaceae											0,01		
Bird of Paradise	*Strelizia spp*	Strelitziaceae								0,04					0,02
Nasturtium	*Tropaeolum majus* L.	Tropaeolaceae									0,02				

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Lemon Verbena	*Aloysia citrodora* Paláu	Verbenaceae	0,01							0,01	0,01				
Garden Verbena	*Verbena x hybrida*	Verbenaceae						0,01	0,01						
Garden Pansy	*Viola x wittrockiana*	Violaceae		0,04				0,02	0,01				0,01		
Grape Vine	*Rhoicissus spp*	Vitaceae				0,01	0,04				0,01		0,01		
Cycad	*Encephalartos spp*	Zamiaceae								0,04					
Devils Thorn	*Tribulus terrestris* L.	Zygophyllaceae							0,01						

Cape Town – Trees

Table D21. Tree species richness observed in Cape Town community gardens. Values in columns represent number of trees counted during field work. Species represented in ***red*** *(n= 9) denote invasive species according to National Environmental Management: Biodiversity Act 10 of 2004 list of invasive species (Government of South Africa, 2004).*

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Elderberry	*Sambucus canadensis* L.	Adoxaceae											4		
Brazilian Pepper Tree	*Schinus terebinthifolius* Raddi	Anacardiaceae							1						
Fragipani	*Plumeria rubra* L.	Apocynaceae								1					
Papaya Tree	*Carica papaya* L.	Caricaceae		1									2		
Assegai	*Curtisia dentata* (Burm.f.) C.A.Sm.	Cornaceae											1		
Sweet Thorn Tree	*Vachellia karroo* (Hayne) Banfi & Glasso	Fabaceae									2				
Port Jackson Wattle	*Acacia saligna* (Labill.) H.L.Wendl.	Fabaceae							5						
Carob Tree	*Ceratonia siliqua* L.	Fabaceae	2								3				
Coral Tree	*Erythrina spp*	Fabaceae								3					
Keurboom	*Virgilia oroboides* (P.J.Bergius) Salter	Fabaceae									1				
Pin Oak Tree	*Quercus palustris* Münchh.	Fagaceae	7												
English Oak Tree	*Quercus robur* L.	Fagaceae											5	1	
Camphor Tree	*Cinnamomum camphora* (L.) J.Presl.	Lauraceae								1					
Avocado Tree	*Persea americana* Mill.	Lauraceae									1	1			
Wild Pear Tree	*Dombeya spp*	Malvaceae													1
Cape Ash Tree	*Ekebergia capensis* Sparrm.	Meliaceae								2					
Wild Fig Tree	*Ficus sur* Forssk.	Moraceae				1		3		4			5		
Mulberry Tree	*Morus alba* L.	Moraceae													1
Banana Palm	*Ensete ventricosum* (Welw.) Cheesman	Musaceae											3		2
Guava Tree	*Psidium guajava* L.	Myrtaceae						2							1
Wild Olive Tree	*Olea europaea* L. *subsp. africana*	Oleaceae								3	1		1		
Pine Tree	*Pinus spp*	Pinaceae							16				7		

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Yellow Wood	*Podocarpus latifolius* (Thunb.) R.Br.	Podocarpaceae								5					
Quince Tree	*Cydonia oblonga* Mill.	Rosaceae					15								5
Apple Tree	*Malus spp*	Rosaceae					20						5		1
Apricot Tree	*Prunus armeniaca* L.	Rosaceae											3		
Plum Tree	*Prunus domestica* L.	Rosaceae									1		3		1
Peach Tree	*Prunus persica* (L.) Batsch	Rosaceae									2		3		
Nectarine Tree	*Prunus persica var. nucipersica*	Rosaceae									1				
Wild Pomegranate Tree	*Burchellia bubalina* (L.f.) Sims	Rubiaceae				1									3
Lime Tree	*Citrus aurantifolia*	Rutaceae		35											
Lemon Tree	*Citrus limon* (L.) Osbeck	Rutaceae	9			3					1				2
Manatoka Tree	*Myoporum tenuifolium* G.Forst	Scrophulariaceae			1										
Cape Gooseberry	*Physalis peruviana* L.	Solanaceae								2					
Tamarillo Tree	*Solanum betaceum* Cav.	Solanaceae											2		

Cape Town – Animals

Table D22. Animal species richness observed in Cape Town community gardens. Values in columns represent number of individuals observed either by the author during field work or members of the community gardens. Species in ***red*** *(n=5) are those species considered a pest by members of the community gardens.*

Class	Species	SWVCG	OZCF	ANOCG	CMCCG	VOCVG	KSCG_A	KSCG_B	WPG	OJSG	CRCHG	SFL	CVOFG	KFG
		Community Gardens												
Class	**Invertebrates**													
Insecta	African Monarch Butterfly (*Danaus chrysippus aegyptius*)		10			3							2	
	Aphids (Aphididae Family)			10						10				
	Black Soldier Flies (*Hermetia illucens*)								10					
	Bumblebee (*Bombus spp*)											1	1	1
	Butterflies (Order Lepidoptera - 4 spp)								4			4		4
	Butterflies (Order Lepidoptera - 5 spp)									5				
	Cape Honey Bee (*Apis mellifera capensis*)	10							2	3		10	3	5
	Dragonflies (Sub-order Anisoptera)		10			2			3			5		2
	Labybird (Coccinellidae Family)									1				
	Praying Mantis (Order Mantodea)									1				
	Wasp (Order Hymenoptera)										2	1	2	
	Vertebrates													
Aves	African Sacred Ibis (*Threskiornis aethiopicus*)												1	
	Cape Canary (*Serinus canicollis*)									1				
	Cape Robin-Chat (*Cossypha caffra*)		1											
	Cape Sparrow (*Passer melanurus*)									1		1		
	Cape Turtle Dove (*Streptopelia capicola*)	1		3										3
	Cape White-Eye (*Zosterops virens*)		1			6								2
	Domestic Pigeon (*Columba livia domestica*)		5			25	15	5						
	Egyptian Goose (*Alopochen aegyptiaca*)		2											

	Hadeda Ibis (*Bostrychia hagedash*)									3		5		
	Helmeted Guinea Fowl (*Numida meleagris*)		3											
	King Gull (*Chroicocephalus hartlaubii*)						2							
	Malachite Sunbird (*Nectarinia famosa*)									1				
	Olive Thrush (*Turdus olivaceus*)									2				
	Owl (4 different spp)		4											
	Piet-my-vrou (*Cuculus solitarius*)									1				
	Red-Winged Starling (*Onychognathus morio*)		4	1		10				10			2	
	Speckled Pigeon (*Columba guinea*)		1											
	Spotted Thick-Knee (*Burhinus capensis*)									2				
	Sunbird (Nectariniidae Family)											1		
	Yellow-Billed Kite (*Milvus aegyptius*)									1				
Osteichthyes	Mozambique Tilapia (*Oreochromis mossambicus*)								10					
	Ornamental Koi		20						10					
Reptilia	Cape skink (*Trachylepis capensis*)		1							1		5		
Mammalia	Black rats (*Rattus* spp)		10	5						1				5
	Grey squirrel (*Sciurus carolinensis*)		2			2								5
Amphibia	Gray's Stream Frog (*Strongylopus grayii*)									1				

Berlin – Vascular plants

Table D23. Vascular plant species richness observed in Berlin community gardens. Values in columns represent Londo scale abundance percentages as decimal proportions (%), where 1,00 = 100% and 0,01 = 1% coverage of a species in a particular community. Species represented in ***purple*** *(n=65) denote neophyte species according to Das Bundesamt für Naturschutz Neophyten Liste (Bundesamt für Naturschutz, 2017),* ***red*** *(n=4) illustrates those species classified as invasive according to Das Bundesamt für Naturschutz Schwarze und Graue Liste (Bundesamt für Naturschutz, 2013) and in* ***green*** *(n=57) those species having medicinal properties.*

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Black-Eyed Susan Vine	*Thunbergia alata* Bojer	Acanthaceae													0,01
Heartleaf Ice Plant	*Aptenia cordifolia* (L.f.) N.E.Br.	Aizoaceae			0,02										
Sutherland Hardy Ice Plant	*Delosperma sutherlandii*	Aizoaceae			0,01										
Common Ice Plant	*Mesembryanthemum crystallinum* L.	Aizoaceae			0,01										
Blood Amaranth	*Amaranthus cruentus* L.	Amaranthaceae	0,01								0,01	0,01			0,01
Red Orach	*Atriplex hortensis* L.	Amaranthaceae				0,01			0,01	0,01		0,01	0,01	0,01	0,01
Good King Henry	*Blitum bonus-henricus* (L.) Rchb.	Amaranthaceae			0,01										
Leafy Goosefoot	*Blitum virgatum* L.	Amaranthaceae										0,01			
Lamb's Quarters	*Chenopodium album* L.	Amaranthaceae					0,01						0,01		
Purple Goosefoot	*Chenopodium giganteum* D.Don	Amaranthaceae				0,02		0,02	0,02	0,02		0,02			
Agapanthus	*Agapanthus praecox* Willd.	Amaryllidaceae	0,01											0,01	
Blue Globe Onion	*Allium caeruleum* Pall.	Amaryllidaceae											0,01		
Round-Headed Leek	*Allium sphaerocephalon* L.	Amaryllidaceae											0,01		
Summer Snowflake	*Leucojum aestivum* L.	Amaryllidaceae						0,01							
Wild Garlic	*Allium ursinum* L.	Amaryllidaceae		0,01									0,01		
Dill	*Anethum graveolens* L.	Apiaceae	0,03	0,02						0,02	0,02				0,02
Norwegian Angelica	*Angelica archangelica* L.	Apiaceae			0,01										
Hemlock	*Conium maculatum* L.	Apiaceae	0,02	0,01											
Coriander	*Coriandrum sativum* L.	Apiaceae								0,02					0,02
Wild Carrot	*Daucus carota* L.	Apiaceae						0,01			0,01		0,01	0,01	0,01

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Fennel	*Foeniculum vulgare* Mill.	Apiaceae	0,02	0,02	0,02					0,02	0,02	0,02		0,02	0,02
Lovage	*Levisticum officinale* W.D.J.Koch	Apiaceae				0,01		0,01							
Cicely	*Myrrhis odorata* (L.) Scop.	Apiaceae			0,01										
Parsley	*Petroselinum crispum* (Mill.) Fuss	Apiaceae	0,02	0,02	0,02	0,02			0,02	0,02	0,02	0,02		0,02	0,02
Venus' Comb	*Scandix pecten-veneris* L.	Apiaceae						0,01							
Butterfly Weed	*Asclepias tuberosa* L.	Apocynaceae				0,01									
Holly	*Ilex aquifolium* L.	Aquifoliaceae													0,04
Konjak	*Amorphophallus konjac* K. Koch	Araceae			0,01										
Farge's Cobra Lily	*Arisaema fargesii*	Araceae			0,01										
English Ivy	*Hedera helix* L.	Araliaceae					0,03	0,03	0,03			0,03	0,03		0,03
European Wild Ginger	*Asarum europaeum* L.	Aristolochiaceae			0,01										
St Barnard's Lily	*Anthericum liliago* L.	Asparagaceae				0,02				0,02					
Glory-of-the-Snow	*Chionodoxa forbesii* Baker	Asparagaceae													0,01
Lily of the Valley	*Convallaria majalis* L.	Asparagaceae			0,01										0,01
Hosta Cultivar	*Hosta spp*	Asparagaceae		0,02					0,02						0,02
Hosta 'Pacific Sunset'	*Hosta spp*	Asparagaceae			0,02										
Solomon's Seal	*Polygonatum multiflorum* (L.) All.	Asparagaceae			0,01										0,01
Yucca	*Yucca filamentosa* L.	Asparagaceae													0,01
Yucca Cultivar	*Yucca spp*	Asparagaceae							0,01					0,01	
Torch Lily	*Kniphofia uvaria* L.	Asphodelaceae	0,01	0,01											
Yarrow	*Achillea millefolium* L.	Asteraceae				0,02		0,02		0,02	0,02	0,02	0,02	0,02	0,02
Red Velvet Yarrow	*Achillea millefolium 'Red Velvet'*	Asteraceae											0,01		
Golden Marguerite	*Anthemis tinctoria* L.	Asteraceae	0,03							0,03		0,03			0,03
Greater Burdock	*Arctium lappa* L.	Asteraceae						0,01							
Woolly Burdock	*Arctium tomentosum* Mill.	Asteraceae									0,01				
Tarragon	*Artemisia dracunculus* L.	Asteraceae						0,01				0,01			0,01

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Calliope	*Aster laevis* L.	Asteraceae													0,01
Calendula	*Calendula officinalis* L.	Asteraceae	0,02	0,02	0,02	0,02	0,02		0,02	0,02	0,02	0,02	0,02	0,02	0,02
Cornflower	*Centaurea cyanus* L.	Asteraceae	0,02	0,02		0,02			0,02	0,02	0,02	0,02	0,02	0,02	0,02
Brown Knapweed	*Centaurea jacea* L.	Asteraceae									0,01				
Tansy	*Chrysanthemum vulgare* (L.) Bernh.	Asteraceae								0,01	0,01			0,01	
Chicory	*Cichorium intybus* L.	Asteraceae			0,01						0,01				
Creeping Thistle	*Cirsium arvense* (L.) Scop.	Asteraceae													0,01
European Marsh Thistle	*Cirsium palustre* (L.) Scop.	Asteraceae								0,01					
Lance Coreopsis	*Coreopsis lanceolata* L.	Asteraceae	0,01												
Plains Coreopsis	*Coreopsis tinctoria* Nutt.	Asteraceae				0,01				0,01	0,01				
Cosmos	*Cosmos bipinnatus* Cav.	Asteraceae			0,01						0,01		0,01	0,01	
Dahlia Cultivar	*Dahlia spp*	Asteraceae	0,01	0,01	0,01					0,01				0,01	0,01
Dahlia 'Bishop of Canterbury'	*Dahlia spp 'Bishop of Canterbury'*	Asteraceae											0,01		
Dahlia 'Colarette'	*Dahlia spp 'Colarette'*	Asteraceae				0,01									
Dahlia 'Hapet Vinete'	*Dahlia spp 'Hapet Vinete'*	Asteraceae											0,01		
Dahlia 'Natal'	*Dahlia spp 'Natal'*	Asteraceae											0,01		
Dahlia 'Red Pygmy'	*Dahlia spp 'Red Pygmy'*	Asteraceae											0,01		
Dahlia 'Vancouver'	*Dahlia spp 'Vancouver'*	Asteraceae											0,01		
Dahlia 'Waltzing Matilda'	*Dahlia spp 'Waltzing Matilda'*	Asteraceae											0,01		
Purple Coneflower	*Echinacea purpurea* (L.) Moench	Asteraceae										0,01			0,01
Great Globe-Thistle	*Echinops sphaerocephalus* L.	Asteraceae												0,01	0,01
Fleabane	*Erigeron annuus* (L.) Pers.	Asteraceae							0,02	0,02	0,02	0,02	0,02	0,02	
Hemp-Agrimony	*Eupatorium cannabinum* L.	Asteraceae												0,01	
Blanketflower	*Gaillardia aristata* Pursh	Asteraceae	0,01	0,01								0,01		0,01	0,01
Gallant Soldier	*Galinsoga parviflora* Cav.	Asteraceae			0,02	0,02	0,02		0,02		0,02	0,02		0,02	
Sunflower	*Helianthus annuus* L.	Asteraceae	0,01			0,01	0,01				0,01	0,01	0,01	0,01	0,01
Jerusalem artichoke	*Helianthus tuberosus* L.	Asteraceae	0,01		0,01								0,01	0,01	

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Dwarf Everlast	*Helichrysum arenarium* (L.) Moench	Asteraceae				0,01									
Summer Sun	*Heliopsis helianthoides* (L.) Sweet	Asteraceae		0,01							0,01				0,01
Ox-Eye Daisy	*Leucanthemum vulgare*	Asteraceae						0,01							0,01
Summer Ragwort	*Ligularia dentata* (A.Gray) H.Hara	Asteraceae			0,01										
Chamomile	*Matricaria chamomilla* L.	Asteraceae	0,01		0,01		0,01			0,01	0,01	0,01	0,01	0,01	0,01
Cotton Thistle	*Onopordum acanthium* L.	Asteraceae			0,01					0,01		0,01			
Black Eyed Susan	*Rudbeckia hirta* L.	Asteraceae	0,01											0,01	
Olive Herb	*Santolina viridis* L.	Asteraceae						0,01							
Spanish Salsify	*Scorzonera hispanica* L.	Asteraceae								0,01					
Narrow-Leaf Ragwort	*Senecio inaequidens* DC	Asteraceae						0,01							
Milk Thistle	*Silybum marianum* (L.) Gaertn.	Asteraceae			0,01										0,01
Field Milk Thistle	*Sonchus arvensis* L.	Asteraceae	0,01							0,01	0,01			0,01	
Sowthistle	*Sonchus oleraceus* L.	Asteraceae					0,01						0,01		
Mexican Marigold	*Tagetes erecta* L.	Asteraceae	0,02	0,02	0,02									0,02	0,02
Irish Lace	*Tagetes filifolia* Lag.	Asteraceae		0,02											
French Marigold	*Tagetes patula* L.	Asteraceae	0,02			0,02	0,02			0,02	0,02	0,02		0,02	0,02
Signet Marigold	*Tagetes signata* Bartling	Asteraceae													
Feverfew	*Tanacetum parthenium* (L.) Sch. Bip.	Asteraceae			0,01	0,01		0,01							
Zinnia	*Zinnia elegans* Jacq.	Asteraceae								0,01					
Fern	*Athyrium filix-femina* (L.) Roth	Athyriacea					0,03	0,03	0,03						
Thunberg's Barberry	*Berberis thunbergii* DC	Berberidaceae								0,01					
Barberry	*Berberis vulgaris* L.	Berberidaceae	0,01												
Fröhnleiten	*Epimedium x perralchicum*	Berberidaceae			0,01										
Trumpet Creeper	*Campsis × tagliabuana 'Madame Galen'*	Bignoniaceae		0,02											
Dyer's Alkanet	*Alkanna tinctoria* (L.) Tausch	Boraginaceae													0,01
Borage	*Borago officinalis* L.	Boraginaceae	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01		0,01

			Community Gardens												
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Viper's Blugloss	*Echium vulgare* L.	Boraginaceae					0,01				0,01				
Lacy Phacelia	*Phacelia tanacetifolia* Benth.	Boraginaceae	0,01	0,01		0,01	0,01			0,01	0,01	0,01	0,01		0,01
Lungwort	*Pulmonaria officinalis* L.	Boraginaceae						0,01							
Comphrey	*Symphytum officinale* L.	Boraginaceae	0,01												
Garlic Mustard	*Alliaria petiolata* (M.Bieb.) Cavara & Grande	Brassicaceae			0,01										
Horseradish	*Armoracia rusticana* G.Gaertn., B.Mey. & Scherb.	Brassicaceae	0,01												
Lilac Bush	*Aubrieta deltoidea* (L.) DC	Brassicaceae													0,01
Yellow Rocket	*Barbarea vulgaris* R.Br.	Brassicaceae	0,02								0,02		0,02	0,02	0,02
Hoary Alyssum	*Berteroa incana* (L.) DC	Brassicaceae	0,02			0,02		0,02		0,02	0,02				0,02
Black Mustard	*Brassica nigra* L.	Brassicaceae			0,01							0,01			
Coralroot	*Cardamine bulbifera* (L.) Crantz	Brassicaceae					0,01								
Treacle Mustard	*Erysimum cheiranthoides* L.	Brassicaceae				0,01									
Dame's Rocket	*Hesperis matronalis* L.	Brassicaceae								0,01	0,01				
Woad	*Isatis tinctoria* L.	Brassicaceae	0,01									0,01			0,01
Garden Cress	*Lepidium sativum* L.	Brassicaceae										0,01			
Wild Radish	*Raphanus raphanistrum* L.	Brassicaceae					0,01				0,01	0,01		0,01	
Creeping Yellow Cress	*Rorippa sylvestris* (L.) Besser	Brassicaceae			0,01	0,01									
Butterfly Bush	*Buddleja davidii* Franch.	Buddlejaceae					0,04							0,04	
Clips White	*Campanula carpatica* Jacq.	Campanulaceae				0,01									
Creeping Bellflower	*Campanula rapunculoides* L.	Campanulaceae							0,01					0,01	
Nettle-Leaved Bellflower	*Campanula trachelium* L.	Campanulaceae						0,01							
Sheeps Bit Scabious	*Jasione montana* L.	Campanulaceae				0,01									
Garden Lobelia	*Lobelia erinus* L.	Campanulaceae												0,01	
Cannabis	*Cannabis sativa* L.	Cannabaceae							0,01						
Wild Teasel	*Dipsacus fullonum* L.	Caprifoliaceae				0,01				0,01					
Evergreen Honeysuckle	*Lonicera henryi*	Caprifoliaceae													0,01
Honeysuckle	*Lonicera x heckrottii*	Caprifoliaceae													0,01

			Community Gardens												
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Valerian	*Valeriana officinalis* L.	Caprifoliaceae			0,01			0,01							
Common Corncockle	*Agrostemma githago* L.	Caryophyllaceae				0,01									
Sweet William	*Dianthus barbatus* L.	Caryophyllaceae	0,01												
Carthusian Pink	*Dianthus carthusianorum* L.	Caryophyllaceae	0,01												
Carnation	*Dianthus caryophyllus* L.	Caryophyllaceae		0,01											
Cheddar	*Dianthus gratianopolitanus*	Caryophyllaceae				0,01				0,01			0,01		
Wild Pink	*Dianthus plumarius* L.	Caryophyllaceae		0,01											0,01
Ragged-Robin	*Lychnis flos-cuculi* L.	Caryophyllaceae													0,01
Soapwort	*Saponaria officinalis* L.	Caryophyllaceae	0,01			0,01									0,01
Maidenstears	*Silene vulgaris* (Moench) Garcke	Caryophyllaceae				0,01				0,01	0,01	0,01	0,01	0,01	0,01
Cistus	*Cistus spp*	Cistaceae													0,01
Hedge Bindweed	*Calystegia sepium* (L.) R.Br.	Convolvulaceae	0,01					0,01						0,01	
Morning Glory	*Ipomoea tricolor* Cav.	Convolvulaceae			0,03										
Rolling Hen-and-Chicks	*Jovibarba globifera* (L.) J. Parn.	Crassulaceae		0,02	0,02										0,02
Gray Stonecrop	*Rhodiola pachyclados*	Crassulaceae			0,01										
	Rhodiola saxifragoides	Crassulaceae			0,01										
White Stonecrop	*Sedum album* L.	Crassulaceae							0,01						0,01
Weihenstephaner Gold	*Sedum floriferum*	Crassulaceae			0,01										
Reflexed Stonecrop	*Sedum reflexum* L.	Crassulaceae										0,01			
Rocky Stonecrop	*Sedum rupestre*	Crassulaceae			0,01										
Cobweb House Leek	*Sempervivum arachnoideum* L.	Crassulaceae							0,01						
Common Houseleek	*Sempervivum tectorum* L.	Crassulaceae							0,01						
Juniper	*Juniperus communis* L.	Cupressaceae										0,05			0,05
Japanese Sedge	*Carex morrowii*	Cyperaceae			0,01										
Hergo Buckthorn	*Hippophae rhamnoides* L. 'Hergo'	Elaeagnaceae													0,01
Pollmix 4 Buckthorn	*Hippophae rhamnoides* L. 'Pollmix 4'	Elaeagnaceae													0,01
Rough Horsetail	*Equisetum hyemale* L.	Equisetaceae			0,02										

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Wood Spurge	*Euphorbia amygdaloides* L.	Euphorbiaceae												0,01	
Cancer Weed	*Euphorbia peplus* L.	Euphorbiaceae				0,03	0,03				0,03			0,03	
Blue Wild Indigo	*Baptisia australis* Hort.	Fabaceae													0,01
'Starlite' Prairieblues	*Baptisia x bicolor* 'Starlite' Prairieblues	Fabaceae													0,01
Perennial Pea	*Lathyrus latifolius* L.	Fabaceae						0,02							
Tuberous Pea	*Lathyrus tuberosus* L.	Fabaceae						0,02							
Spring Pea	*Lathyrus vernus* (L.) Bernh.	Fabaceae													0,02
Lupine Cultivar	*Lupinus spp*	Fabaceae												0,01	0,01
Bastard Lucerne	*Medicago x varia*	Fabaceae	0,02			0,02	0,02						0,02		0,02
White Sweet Clover	*Melilotus albus* Medik.	Fabaceae													0,01
Yellow Sweet Clover	*Melilotus indicus* (L.) All.	Fabaceae						0,01						0,01	0,01
Suckling Clover	*Trifolium dubium* Sibth.	Fabaceae	0,01								0,01				
Red Clover	*Trifolium pratense* L.	Fabaceae	0,02	0,02			0,02	0,02		0,02	0,02	0,02	0,02		0,02
White Clover	*Trifolium repens* L.	Fabaceae		0,02		0,02					0,03			0,03	
Tufted Vetch	*Vicia cracca* L.	Fabaceae									0,01				
Bulgarian Geranium	*Geranium macrorrhizum* L.	Geraniaceae			0,01										
Marsh Cranesbill	*Geranium palustre* L.	Geraniaceae					0,01							0,01	
Herb Robert	*Geranium robertianum* L.	Geraniaceae						0,01	0,01	0,01			0,01		
Bloody Cranesbill	*Geranium sanguineum* L.	Geraniaceae						0,01							
Geranium 'Rozanne'	*Geranium spp* 'Rozanne'	Geraniaceae													0,01
Cranesbill	*Geranium wlassovianum*	Geraniaceae			0,01										
Purple Cranesbill	*Geranium x magnificum*	Geraniaceae													0,01
Hydrangea	*Hydrangea macrophylla* (Thunb.) Ser.	Hydrangeaceae		0,03										0,01	0,01
Sweet Mock-Orange	*Philadelphus coronarius* L.	Hydrangeaceae													0,01
St Johns-Wort	*Hypericum perforatum* L.	Hypericaceae			0,02	0,02	0,02	0,02			0,02		0,02		
Safran	*Crocus sativus* L.	Iridaceae											0,01		0,01
Abyssinian Gladiolus	*Gladiolus murielae* Kelway	Iridaceae											0,01		

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Tall Bearded Iris	*Iris barbata-elatior*	Iridaceae			0,01										
Siberian Iris	*Iris sibirica* L.	Iridaceae			0,01										
Narrow-Leaf Blue-Eyed Grass	*Sisyrinchium angustifolium* Mill.	Iridaceae			0,01										
Anisse Hyssop	*Agastache foeniculum* (Pursh) Kuntze	Lamiaceae		0,02	0,02							0,02	0,02	0,02	0,02
Mexican Giant Hyssop	*Agastache mexicana*	Lamiaceae										0,02			
Korean Mint	*Agastache rugosa* (Fisch. & C.A.Mey.) Kuntze	Lamiaceae			0,02								0,02		
Betony	*Betonica officinalis* (L.) Trevis.	Lamiaceae			0,01										
Wild Basil	*Clinopodium vulgare*	Lamiaceae			0,01							0,01			
Moldovian Dragonhead	*Dracocephalum moldavica* L.	Lamiaceae													0,01
Hyssop	*Hyssopus officinalis* L.	Lamiaceae											0,03		
White Nettle	*Lamium album L.*	Lamiaceae				0,01		0,01		0,01				0,01	
Yellow Archangel	*Lamium galeobdolon* (L.) Crantz	Lamiaceae			0,01										
English Lavender	*Lavandula angustifolia* Mill.	Lamiaceae	0,01	0,01	0,01	0,01	0,01	0,01		0,01	0,01	0,01	0,01	0,01	0,01
French Lavender	*Lavandula stoechas* L.	Lamiaceae	0,02												
Motherwort	*Leonurus cardiaca* L.	Lamiaceae										0,01			
Kreta-Melisse	*Melissa altissima*	Lamiaceae			0,01										
Lemon Balm	*Melissa officinalis* L.	Lamiaceae			0,01		0,01	0,01		0,01		0,01	0,01		
American Mint	*Mentha canadensis* L.	Lamiaceae									0,01				
Spearmint	*Mentha spicata* L.	Lamiaceae						0,01				0,01	0,01	0,01	
Apple Mint	*Mentha suaveolens* Ehrh.	Lamiaceae		0,01	0,01								0,01		
Grapefruit Mint	*Mentha suaveolens x piperata*	Lamiaceae										0,01			
Peppermint	*Mentha x piperita* L.	Lamiaceae	0,01	0,01	0,01		0,01	0,01		0,01		0,01	0,01	0,01	0,01
Swiss Mint	*Mentha x piperita 'Swiss'*	Lamiaceae									0,01				
Crimson Beebalm	*Monarda didyma* L.	Lamiaceae				0,01	0,01					0,01	0,01	0,01	0,01
Basil	*Ocimum basilicum* L.	Lamiaceae		0,01	0,01	0,01				0,01		0,01	0,01	0,01	
Cinnamon Basil	*Ocimum basilicum* 'Cinnamon'	Lamiaceae												0,01	
Thai Basil	*Ocimum basilicum var. thyrsiflora*	Lamiaceae										0,01			

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Majoram	*Origanum majorana* L.	Lamiaceae										0,01			
Oregano	*Origanum vulgare* L.	Lamiaceae	0,01		0,01	0,02		0,01		0,02	0,02	0,01	0,01	0,01	0,01
Turkish Sage	*Phlomis russeliana*	Lamiaceae													0,01
	Plectranthus forsteri	Lamiaceae				0,01									
Large Flowered Selfheal	*Prunella grandiflora* (L.) Scholler	Lamiaceae													0,01
Rosemary	*Rosmarinus officinalis* L.	Lamiaceae	0,01	0,01				0,01		0,01				0,01	0,01
Sage	*Salvia officinalis* L.	Lamiaceae	0,01	0,01	0,01	0,01		0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Tricolour Sage	*Salvia officinalis* 'Tricolor'	Lamiaceae												0,01	
Clary Sage	*Salvia sclarea* L.	Lamiaceae			0,01										
Lilac Sage	*Salvia verticillata* L.	Lamiaceae								0,01					
Summer Savory	*Satureja hortensis* L.	Lamiaceae			0,01										
Winter Savory	*Satureja montana* L.	Lamiaceae										0,01			
Lamb's Ear	*Stachys byzantina* K.Koch	Lamiaceae				0,01		0,01							
Wall Germander	*Teucrium chamaedrys* L.	Lamiaceae			0,01										
Lemon Thyme	*Thymus citriodorus* (Pers.) Schreb.	Lamiaceae		0,01								0,01			
Thyme	*Thymus vulgaris* L.	Lamiaceae			0,01	0,01					0,01	0,01		0,01	0,01
Tiger Lily	*Lilium lancifolium* Thunb.	Liliaceae											0,02		
Lily	*Lilium spp*	Liliaceae		0,01			0,01	0,01						0,01	0,01
Tulip	*Tulipa gesneriana* L.	Liliaceae													0,01
Antwerp Hollyhock	*Alcea ficifolia*	Malvaceae	0,01			0,02						0,02			
Hollyhock	*Alcea rosea* L.	Malvaceae	0,02			0,02	0,02	0,02		0,02	0,02	0,02		0,02	0,02
Marsh Mallow	*Althaea officinalis* L.	Malvaceae			0,01										
Hibiscus	*Hibiscus rosa-sinensis* L.	Malvaceae												0,02	
Common Mallow	*Malva sylvestris* L.	Malvaceae	0,01			0,01	0,01			0,01	0,01	0,01		0,01	0,01
Water Lily	*Nymphaea spp*	Nymphaeaceae						0,01							0,01
Lilac	*Syringa vulgaris* L.	Oleaceae				0,01									
Hoary Willowherb	*Epilobium parviflorum*	Onagraceae			0,01										

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Square Stalked Willow Herb	*Epilobium tetragonum* L.	Onagraceae													0,01
Hummingbird Fuchsia	*Fuchsia magellanica* Lam.	Onagraceae													0,01
Fuchsia Cultivar	*Fuchsia spp*	Onagraceae												0,01	
Evening Primrose	*Oenothera oakesiana*	Onagraceae					0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
Wood Sorrel	*Oxalis acetosella* L.	Oxalidaceae							0,03						
Yellow Wood Sorrel	*Oxalis stricta* L.	Oxalidaceae					0,01			0,01			0,01	0,01	
Iron Cross	*Oxalis tetraphylla* Cav.	Oxalidaceae			0,01									0,01	
False Shamrock	*Oxalis triangularis* A.St.-Hil.	Oxalidaceae			0,01										
Greater Celandine	*Chelidonium majus* L.	Papaveraceae	0,01			0,01	0,01		0,01	0,01					
California Poppy	*Eschscholzia californica* Cham.	Papaveraceae	0,01							0,01	0,01				
Long Head Poppy	*Papaver dubium* L.	Papaveraceae	0,02									0,02		0,02	
Common Poppy	*Papaver rhoeas* L.	Papaveraceae		0,02						0,02	0,02				
Opium Poppy	*Papaver somniferum* L.	Papaveraceae	0,01							0,01	0,01		0,01		
Rock Fumewort	*Pseudofumaria lutea* (L.) Borkh.	Papaveraceae					0,01								
Blue Passionfruit	*Passiflora caerulea* L.	Passifloraceae												0,02	
Snapdragon	*Antirrhinum majus* L.	Plantaginaceae				0,02			0,02		0,02		0,02		0,02
Foxglove	*Digitalis purpurea* L.	Plantaginaceae													0,01
Toadflax	*Linaria dalmatica* (L.) Mill.	Plantaginaceae	0,01			0,01									0,01
Plantain	*Plantago lanceolata* L.	Plantaginaceae			0,01	0,01		0,01			0,01				0,01
Broadleaf Plantain	*Plantago major* L.	Plantaginaceae				0,01	0,01							0,01	
Spiked Speedwell	*Veronica spicata* L.	Plantaginaceae											0,01		
Lemon Grass	*Cymbopogon citratus* (DC.) Stapf	Poaceae													0,02
Hakone Grass	*Hakonechloa macra*	Poaceae			0,01										
Blue Hair Grass	*Koeleria glauca* (Schrad.) DC.	Poaceae				0,01			0,01						
Purple Stem Cat's Tail	*Phleum phleoides* (L.) H. Karst.	Poaceae								0,01					
Mexican Feathergrass	*Stipa tenuissima*	Poaceae		0,02											
Garden Phlox	*Phlox paniculata* L.	Polemoniaceae					0,01								

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Jacob's Ladder	*Polemonium caeruleum* L.	Polemoniaceae				0,01									
Mountain Sorrel	*Oxyria digyna* (L.) Hill	Polygonaceae			0,01										
Pale Persicaria	*Persicaria lapathifolia* (L.) Delarbre	Polygonaceae					0,01			0,01				0,01	
Sorrel	*Rumex acetosa* L.	Polygonaceae			0,02							0,02		0,02	0,02
Curly Dock	*Rumex crispus* L.	Polygonaceae						0,01							
Patience Dock	*Rumex patientia* L.	Polygonaceae										0,01			
Redvein Dock	*Rumex sanguineus*	Polygonaceae			0,01										
French Sorrel	*Rumex scutatus* L.	Polygonaceae			0,01										
Creeping Jenny	*Lysimachia nummularia* L.	Primulaceae		0,01											
Oxlip	*Primula elatior* Hill	Primulaceae		0,01											
Wolfsbane	*Aconitum napellus* L.	Ranunculaceae			0,01										
Wood Anemone	*Anemone nemorosa* L.	Ranunculaceae	0,01												0,01
Yellow Anemone	*Anemone ranunculoides* L.	Ranunculaceae													0,01
	Anemone x hybrida	Ranunculaceae					0,01								
Clematis Vine	*Clematis alpina*	Ranunculaceae								0,01					
Clematis 'Pistachio Evirida'	*Clematis florida var. normalis* 'Pistachio Evirida'	Ranunculaceae													0,01
Mountain Clematis	*Clematis montana*	Ranunculaceae		0,01											
Clematis 'Multi Blue'	*Clematis spp* 'Multi Blue'	Ranunculaceae													0,01
Clematis 'Solidarnosc'	*Clematis spp* 'Solidarnosc'	Ranunculaceae													0,01
Larkspur	*Consolida hispanica* (Costa) Greuter & Burdet	Ranunculaceae	0,01												0,01
Stinking Hellebore	*Helleborus foetidus* L.	Ranunculaceae													0,01
Hepatica	*Hepatica nobilis* Schreb.	Ranunculaceae													0,01
Love-in-a-Mist	*Nigella damascena* L.	Ranunculaceae													0,01
Black Cumin	*Nigella sativa* L.	Ranunculaceae								0,01					
Dyer's Rocket	*Reseda luteola* L.	Resedaceae	0,01												
Garden Lady's Mantle	*Alchemilla mollis* (Buser) Rothm.	Rosaceae			0,01										

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Lady's Mantle	*Alchemilla vulgaris* L.	Rosaceae	0,01												0,01
English Hawthorn	*Crataegus laevigata* (Poir.) DC	Rosaceae												0,01	
Wood Avens	*Geum japonicum* L.	Rosaceae							0,01					0,01	
Silverweed	*Potentilla anserina* (L.) Rydb.	Rosaceae			0,01										
Dog Rose	*Rosa canina* L.	Rosaceae								0,01					
Rose	*Rosa spp*	Rosaceae								0,01					
Rose 'Polyantha'	*Rosa spp 'Polyantha'*	Rosaceae				0,01									
Salad Burnet	*Sanguisorba minor* Scop.	Rosaceae						0,01		0,01					
Sweetscented Bedstraw	*Galium odoratum* (L.) Scop.	Rubiaceae	0,01					0,01				0,01			0,01
Lady's Bedstraw	*Galium verum* L.	Rubiaceae			0,01										
Common Madder	*Rubia tinctorum* L.	Rubiaceae	0,01												
Rue	*Ruta graveolens* L.	Rutaceae					0,01	0,01							
Astilbe	*Astilbe arendsii*	Saxifragaceae													0,01
Alternate-Leaved Golden-Saxifrage	*Chrysosplenium alternifolium* L.	Saxifragaceae												0,01	
Heartleaf Foamflower	*Tiarella cordifolia* L.	Saxifragaceae										0,01			
Twinspur	*Diascia barberae*	Scrophulariaceae		0,01											
Denseflower Mullein	*Verbascum densiflorum* Bertol.	Scrophulariaceae	0,02		0,02					0,02			0,02		0,02
Black Henbone	*Hyoscyamus niger* L.	Solanaceae													0,01
Tobacco	*Nicotiana tabacum* L.	Solanaceae			0,01									0,01	0,01
Petunia Cultivar	*Petunia spp*	Solanaceae												0,01	
European Black Nightshade	*Solanum nigrum* L.	Solanaceae												0,01	
Camellia	*Camellia japonica* L.	Theaceae							0,01						
Nasturtium	*Tropaeolum majus* L.	Tropaeolaceae	0,02	0,02	0,02	0,02	0,02		0,02	0,02	0,02	0,02	0,02	0,02	0,02
Variegata Nasturtium	*Tropaeolum majus 'Variegata'*	Tropaeolaceae	0,01												
Broadleaf Cattail	*Typha latifolia* L.	Typhaceae								0,01					
Stinging Nettle	*Urtica dioica* L.	Urticaceae				0,02	0,02	0,02		0,02	0,02		0,02	0,02	
Lemon Verbena	*Aloysia citrodora* Paláu	Verbenaceae			0,01										

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Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Argentina Mint	*Aloysia polystachya*	Verbenaceae		0,01											
Tickberry	*Lantana camara* L.	Verbenaceae		0,02											
Common Verbena	*Verbena officinalis* L.	Verbenaceae													0,01
Pansy	*Viola tricolor* L.	Violaceae								0,02					
Pansy	*Viola x wittrockiana*	Violaceae											0,02		
Common Grape Vine	*Vitis vinifera* L.	Vitaceae				0,01	0,01			0,01		0,01			

Berlin – Trees

Table D24. Tree species richness observed in Berlin community gardens. Values in columns represent number of trees counted during field work. Species represented in ***purple*** *(n=3) show neophyte species according to Das Bundesamt für Naturschutz Neophyten Liste (Bundesamt für Naturschutz, 2017) and* ***red*** *(n=2) illustrates those species classified as invasive according to Das Bundesamt für Naturschutz Schwarze und Graue Liste (Bundesamt für Naturschutz, 2013).*

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Silver Birch Tree	*Betula pendula* Roth	Betulaceae	3		5					4				2	
Downy Birch Tree	*Betula pubescens* Ehrh.	Betulaceae		1											
European Hornbeam Tree	*Carpinus betulus* L.	Betulaceae						1	1	3				1	
Common Hazel	*Corylus avellana* L.	Betulaceae					1	1						1	
European Cornel Tree	*Cornus mas* L.	Cornaceae								1					
Black Locust Tree	*Robinia pseudoacacia* L.	Fabaceae		1	11	2		3		3			5		
Sweet Chestnut Tree	*Castanea sativa* Mill.	Fagaceae								1					
Common Beech Tree	*Fagus sylvatica* L.	Fagaceae			4										
English Walnut Tree	*Juglans regia* L.	Juglandaceae											1		
Pippala Tree	*Ficus religiosa* L.	Moraceae			2										
Myrtle Tree	*Myrtus communis* L.	Myrtaceae								1					
European Ash Tree	*Fraxinus excelsior* L.	Oleaceae								1					
Oriental Plane Tree	*Platanus orientalis* L.	Plantanaceae				1									
Apple Tree	*Malus domestica*	Rosaceae			2			4		2				2	1
Apple Tree 'Cox Orange'	*Malus domestica* 'Cox Orange'	Rosaceae				1									
Apple Tree 'James Grieve'	*Malus domestica* 'James Grieve'	Rosaceae	1												
Apple Tree 'Shampion'	*Malus domestica* 'Shampion'	Rosaceae				1									
Apple Tree 'Starking'	*Malus domestica 'Starking'*	Rosaceae									1				
Wild Apple Tree	*Malus sylvestris* (L.) Mill.	Rosaceae					1								
Medlar Tree	*Mespilus germanica* L.	Rosaceae							2						
Cherry Tree	*Prunus avium* L.	Rosaceae								1					

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Peach Tree	*Prunus persica* (L.) Batsch	Rosaceae	2												
European Wild Pear Tree	*Pyrus pyraster* (L.) Burgsd.	Rosaceae					1			1				2	
Mountain Ash Tree	*Sorbus aucuparia* L.	Rosaceae											1		
Swedish Whitebeam	*Sorbus intermedia* (Ehrh.) Pers.	Rosaceae								2					
Black Poplar Tree	*Populus nigra* L.	Salicaceae					1						2		
White Willow Tree	*Salix alba* L.	Salicaceae								1				1	
Field Maple Tree	*Acer campestre* L.	Sapindaceae					1						3		
Box Elder Tree	*Acer negundo* L.	Sapindaceae							1	1			1		
Norway Maple Tree	*Acer platanoides* L.	Sapindaceae				5	1	5	1	1				2	
Sycamore Tree	*Acer pseudoplatanus* L.	Sapindaceae								1					
Maple Tree	*Acer spp*	Sapindaceae			1										
Horse Chestnut Tree	*Aesculus hippocastanum* L.	Sapindaceae										5			
European White Elm	*Ulmus laevis* Pall.	Ulmaceae											2		

Berlin – Animals

Table D25. Animal species richness observed in Berlin community gardens. Values in columns represent number of individuals observed either by the author during field work or members of the community gardens. Species in ***red*** *(n=4) are those species considered a pest by members of the community gardens.*

Class	Invertebrates	GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Insecta	Beetle (Order Coleoptera)								1					
	Bumblebee (*Bombus spp*)	10	3	20	1	2	1	3	10	5	2	3	5	2
	Butterflies (Order Lepidoptera - 2 spp)	3							2	2				
	Butterflies (Order Lepidoptera)		1	5		1	1	1			3	1	1	1
	Dragonflies (Suborder Anisoptera)							1	1					
	European Honey Bee (*Apis mellifera*)	20	5	20	1	2	10	1	30	5	3	5	10	5
	Firebug (*Pyrrhocoris apterus*)								1		1			
	Labybird (Coccinellidae Family)	1		1			2			1		1		
	Short-horned leaf beetle (*Clytra spp*)	1				1								
	Wasp (Order Hymenoptera)	1												2
Gastropoda	Leopard Skin Slug (*Limax maximus*)			1					1					
	Snails						3			2	2			
Annelida	Worms for composting (1 box)	1												
	Vertebrates													
Aves	Common Blackbird (*Turdus merula*)	1			1		1	1	1		1		2	
	Common Nightingale (*Luscinia megarhynchos*)								1					
	Common Swift (*Apus apus*)								1					
	Common Wood Pigeon (*Columba palumbus*)		1	3										
	Domestic Pigeon (*Columba livia domestica*)					5		1				2		5
	Eurasian Blackcap (*Sylvia atricapilla*)								1					

Community Gardens: GAK, BGG, PRG, PLG, KSS, LSG, SKR, KFS, SFM, IGH, GPT, GCF, KLG

	Eurasian Tree Sparrow (*Passer montanus*)	1												
	European Starling (*Sturnus vulgaris*)								1					
	Hooded Crow (*Corvus cornix*)	5		1										
	House Sparrow (*Passer domesticus*)	5	2	10			1		5	5	1	1	2	
	Mallard Duck (*Anas platyrhynchos*)							3						
	Ortolan bunting (*Emberiza hortulana)*						1							
	Common Rat (*Rattus norvegicus*)			1	1							1		
	Eurasian Beaver (*Castor fiber*)							1						
Mammalia	Mouse (Muridae Family)			1										
	Rabbit (Leporidae Family)			1	1						1			
	Red Fox (*Vulpes vulpes*)			1	1				1					
Amphibia	Frogs (Order Anura)						1		1					

Recreational and Mental and Physical Health

Table D26. Type and number of recreational and health facilities observed in Cape Town community gardens. Facilities are ranked according to frequency.

Recreational and health facilities in garden	Number of facilities
Benches	48
Wooden Seats	6
Designated Picnic Areas	5
Fish Pond/Water Features	4
Jungle Gym	1
Ornamental Garden Maze	1
Shower Facilities	1
Bathroom Facilities	1
Trampoline Apparatus	1
Total	**68**

Table D27. Type and number of recreational and health facilities observed in Berlin community gardens. Facilities are ranked according to frequency.

Recreational and health facilities in garden	Number of facilities
Benches	134
Wooden Seats	45
Jungle Gym	5
Bar	4
Bathroom Facilities	4
Stage / Entertainment Area	3
Tree House	3
Outdoor Wood oven	3
Restaurant	2
Barbeque/Picnic Area	2
Sandpit	2
Basketball Court	1
Statue / Art Sculpture	1
Total	**209**

Tourism

Table D28. Average visitors per month in Cape Town community gardens.

	Average number of visitors per month
SWVCG	200
OZCF	400
ANOCG	20
CMCCG	100
VOCVG	1000
KSCG_A	60
KSCG_B	10
WPG	50
OJSG	200
CRCHG	10
SFL	400
CVOFG	50
KFG	100
Total	**2600**

Table D29. Average visitors per month in Berlin community gardens.

	Average number of visitors per month
GAK	3000
BGG	20
PRG	5000
PLG	100
KSS	-
LSG	10
SKR	40
KFS	200
SFM	80
IGH	5000
GPT	150
GCF	-
KLG	5000
Total	**18600**

Costs of repairs and maintenance

Table D30. Monthly costs in Euros associated with maintenance and repairs, and energy requirements for community gardens in Cape Town.

	Cost of Maintenance and Repairs (€)	Cost of Energy (€)
SWVCG	552	0
OZCF	-	-
ANOCG	138	0
CMCCG	138	0
VOCVG	-	-
KSCG_A	14	0
KSCG_B	14	0
WPG	828	207
OJSG	62	4
CRCHG	-	-
SFL	-	-
CVOFG	-	-
KFG	345	0
Total	**2090**	**211**

Table D31. Monthly costs in Euros associated with maintenance and repairs, and energy requirements for community gardens in Berlin.

	Cost of Maintenance and Repairs (€)	Cost of Energy (€)
GAK	-	-
BGG	0	0
PRG	5000	60
PLG	30	3
KSS	0	0
LSG	-	-
SKR	17	0
KFS	100	10
SFM	17	0
IGH	-	-
GPT	-	-
GCF	-	-
KLG	-	-
Total	**5164**	**73**

* Gardens with dash values had no available information. Cape Town garden costs were converted from South African Rands to Euros where €1 = R14,50.

Allergy problems caused by the spread of pollen

OPALS values for vascular plant and tree species according to Ogren (2015).

Cape Town – Vascular plants

*Table D32. Vascular plant species OPALS as defined by Ogren (2015) for Cape Town community gardens. Values in columns represent OPALS for individual species as defined in Ogren (2015). Species represented with **yellow cells** denote those species which were not included in Ogren (2015) and with **green cells** those species which were included, but had not yet been given an OPALS.*

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Creeping Foxglove	*Asystasia gangetica*	Acanthaceae													
Ribbon Bush	*Hypoestes aristata*	Acanthaceae					1								
Purple Sour Fig	*Carpobrotus deliciosus*	Aizoaceae										2			
Sour Fig	*Carpobrotus edulis*	Aizoaceae					2								
Wild Garlic	*Tulbaghia violacea*	Alliaceae					5			5			5		
Cats Tail	*Amaranthus caudatus*	Amaranthaceae								6					
Hanekam	*Celosia cristata*	Amaranthaceae													4
Nettle-Leaf Goosefoot	*Chenopodiastrum murale*	Amaranthaceae			10				10						
Globe Amaranth	*Gomphrena globosa*	Amaranthaceae													4
Agapanthus	*Agapanthus africanus*	Agapanthaceae										2			2
Agapanthus	*Agapanthus praecox*	Agapanthaceae											2		
Agapanthus	*Agapanthus spp*	Agapanthaceae	2		2					2					
Bush Lily	*Clivia miniata*	Amaryllidaceae											2		
Nana Berry	*Searsia dentata*	Anacardiaceae									5				
Dill	*Anethum graveolens*	Apiaceae	3												
Corriander	*Coriandrum sativum L.*	Apiaceae	3												
Thai Corriander	*Eryngium foetidum*	Apiaceae											4		
Fennel	*Foeniculum vulgare*	Apiaceae	5	5			5	5						5	

Common Name	*Scientific Name*	Family	SWVCG	OZCF	ANOCG	CMCCG	VOCVG	KSCG_A	KSCG_B	WPG	OJSG	CRCHG	SFL	CVOFG	KFG
			Community Gardens												
Parsley	*Petroselinum crispum*	Apiaceae	4				4	4				4	4		
Natal Plum	*Carissa macrocarpa*	Apocynaceae					2								
Num Num	*Carissa bispinosa*	Apocynaceae									2				
Taro	*Colocasia esculenta*	Araceae								2					
Delicious Monster	*Monstera deliciosa*	Araceae											4		
Duckweed	*Spirodela polyrhiza*	Araceae													
Arum Lily	*Zantedeschia aethiopica*	Araceae								4			4		
Paper Plant	*Fatsia japonica*	Araliaceae								4					
Ground Ivy	*Hedera helix* 'Bulgaria'	Araliaceae										7			
Bamboo Palm	*Chamaedorea seifrizii*	Arecaceae								4					
Silver Ribbon	*Liriope muscari* 'Varegata'	Asparagaceae								3					
Tuberose	*Polianthes tuberosa*	Asparagaceae													4
Mother in Law's Tongue	*Sansevieria trifasciata*	Asparagaceae				1				1					
Elephant's Foot Yucca	*Yucca elephantipes*	Asparagaceae				2									
Garden Aloe	*Aloe arborescens*	Asphodelaceae				1				1	1		1		
Bitter Aloe	*Aloe ferox*	Asphodelaceae				1	1								
Unknown Aloe	*Aloe spp*	Asphodelaceae						1							
Tree Aloe	*Aloe striata*	Asphodelaceae								1					
Tuinaalwyn	*Aloe striata x Aloe maculata*	Asphodelaceae				1									
Cat's Tail	*Bulbinella floribunda*	Asphodelaceae											4		
Yarrow	*Achillea millefolium*	Asteraceae											4		
Marguerite Daisy	*Argyranthemum frutescens*	Asteraceae											4		
Wilde Als	*Artemisia afra*	Asteraceae									8				
Blackjack	*Bidens pilosa*	Asteraceae			4									4	
Calendula	*Calendula officinalis*	Asteraceae		4			4								
China Aster	*Callistephus chinensis*	Asteraceae													5
Chrysanthemum	*Chrysanthemum morifolium* Cultivar	Asteraceae													4

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Horseweed	*Conyza bonariensis L. Cronquist*	Asteraceae													
Pink Cosmos	*Cosmos bipinnatus*	Asteraceae													5
Cosmos	*Cosmos sulphureus*	Asteraceae	5												
Red/Orange Cosmos	*Cosmos sulphureus* Hybrid	Asteraceae													5
Ganskos	*Cotula turbinata*	Asteraceae													4
Globe Artichoke	*Cynara cardunculus*	Asteraceae													3
Dahlia	*Dahlia pinnata* Cultivar	Asteraceae													4
Wild Rosemary	*Eriocephalus africanus*	Asteraceae													
Botterblom	*Gazania kresbiana*	Asteraceae									4				
Gazania Hybrids	*Gazania spp*	Asteraceae													4
Sunflower	*Helianthus annuus*	Asteraceae		3				3					3		3
Jerusalem Artichoke	*Helianthus tuberosus*	Asteraceae									3				
Kooigoed	*Helichrysum petiolare*	Asteraceae									4				
Geelsewejaartije	*Helichrysum splendidum*	Asteraceae			4										
Creeping Marguerite	*Osteospermum fruticosum*	Asteraceae								4					
Bush Tickberry	*Osteospermum moniliferum subsp. moniliferum*	Asteraceae						4							
Cape Everlasting	*Syncarpha eximia*	Asteraceae													
Mexican Marigold	*Tagetes erecta*	Asteraceae	4				4	4	4						4
French Marigold	*Tagetes patula* 'Spry'	Asteraceae	4	4			4	4	4				4		
Dandelion	*Taraxacum officinale*	Asteraceae		5	5				5		5	5		5	
Jakobregop	*Zinnia elegans*	Asteraceae													3
Busy Lizzy	*Impatiens walleriana*	Balsaminaceae	1												
Borage	*Borago officinalis*	Boraginaceae									3				
Pattersons Curse	*Echium plantagineum*	Boraginaceae							5						
Comfrey	*Symphytum officinale*	Boraginaceae									3		3	3	
Rocket	*Eruca sativa*	Brassicaceae													
Yellow King Humbert	*Canna spp* Cultivar	Cannaceae						3							

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Kanna	*Canna xgeneralis*	Cannaceae													3
Sweet William	*Dianthus barbatus*	Caryophyllaceae													2
Carnation	*Dianthus caryophyllus*	Caryophyllaceae													2
Pinks	*Dianthus xallwoodii*	Caryophyllaceae													2
Cape Saffron	*Cassine peragua*	Celastraceae													
Pig's Ear	*Cotyledon orbiculata*	Crassulaceae					2				2	2			
Fairy Crassula	*Crassula multicava subsp. Multicava*	Crassulaceae				2									
Stonecrop	*Crassula obovata var. obovata*	Crassulaceae				2									
Jade Plant	*Crassula ovata*	Crassulaceae					2								
Gollum	*Crassula ovata cv* 'Gollum'	Crassulaceae						2							
Chayote	*Sechium edule*	Cucurbitaceae													
Sedge	*Carex spp*	Cyperaceae											5		
Cape Scabius	*Scabiosa africana*	Dipsacaceae							3						
Rooibos	*Aspalathus linearis*	Fabaceae													
Cancer Bush	*Sutherlandia frutescens*	Fabaceae													
Bergtee	*Geranium incanum*	Geraniaceae					3				3				
Rose-Scented Pelargonium	*Pelargonium capitatum*	Geraniaceae					3								
Lemon-Scented Pelargonium	*Pelargonium citronellum*	Geraniaceae					3								
Ligularia	*Pelargonium conradiae*	Geraniaceae											3		
Wildemalva	*Pelargonium gravedens*	Geraniaceae					3								
Rose Geranium	*Pelargonium graveolens*	Geraniaceae									3		3		
Peppermint-Scented Pelargonium	*Pelargonium tomentosum*	Geraniaceae					3				3	3	3		
Garden Regal Pelargonium	*Pelargonium xdomesticum*	Geraniaceae				3									
Nutmeg Geranium	*Pelargonium xfragrans*	Geraniaceae									3				
Hydrangea	*Hydrangea macrophylla*	Hydrangeaceae								3					
Blue Stars	*Aristea ecklonii*	Iridaceae													
Wild Iris	*Dietes grandiflora*	Iridaceae								2					

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Freesia	*Freesia xhybrida*	Iridaceae						3	3						
Iris hybrids	*Iris spp*	Iridaceae	2								2				
English Lavender	*Lavandula angustifolia*	Lamiaceae	5							5					
French Lavender	*Lavandula dentata*	Lamiaceae	5			5	5	5		5	5	5	5	5	
Wild Dagga	*Leonotis leonurus*	Lamiaceae					5				5				
Lemon Balm	*Melissa officinalis*	Lamiaceae													
Spearmint	*Mentha spicata*	Lamiaceae											3		
Mint	*Mentha spp*	Lamiaceae	3					3	3		3		3		
Catmint	*Nepeta cataria*	Lamiaceae	2										2		
Basil	*Ocimum basilicum*	Lamiaceae	2	2			2	2	2		2	2	2		
Marjoram	*Origanum majorana L.*	Lamiaceae									3		3		
Oregano	*Origanum vulgare*	Lamiaceae	3										3		
Vlieebos	*Plectranthus ecklonii*	Lamiaceae					1								
Pink Spur Flower	*Plectranthus fruticosus*	Lamiaceae				1							1		
Spur Flower	*Plectranthus neochilus*	Lamiaceae										1			
Painted Nettle	*Plectranthus scutellariodes* Hybrid	Lamiaceae											1		
Unknown	*Plectranthus spp*	Lamiaceae									1				
Plectranthus Cultivar	*Plectranthus spp* 'Mona Lavender'	Lamiaceae				1									
Rosemary	*Rosmarinus officinalis*	Lamiaceae	4				4	4			4		4	4	
Sage	*Salvia officinalis*	Lamiaceae	2				2				2	2	2	2	
Lamb's Ear	*Stachys byzantina*	Lamiaceae				3									
Thyme	*Thymus vulgaris*	Lamiaceae	3				3	3			3			3	
Hibiscus	*Hibiscus rosa-sinensis*	Malvaceae								3					
Red Sun Rose	*Aptenia cordifolia*	Mesembryanthemaceae					1								
Wax Berry	*Morella quercifolia*	Myricaceae					5								
Bougainvillea	*Bougainvillea xbuttiana*	Nyctaginaceae								1					
Bougainvillea	*Bougainvillea xbuttiana* 'Killie Campbell'	Nyctaginaceae										1			

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Yellow Water Lily	*Nymphaea caerulea* 'Sulurea'	Nymphaeaceae									1				
Cape Blue Water Lily	*Nymphaea capensis*	Nymphaeaceae		1											
Creeping sorrel	*Oxalis corniculata*	Oxalidaceae	1		1										
Purple Granadilla Vine	*Passiflora edulis*	Passifloraceae	3								3				
Ice Cream Bush	*Breynia disticha*	Phyllanthaceae													
Plantain	*Plantago lanceolata L.*	Plantaginaceae			3				3						
Statice	*Limonium latifolium*	Plumbaginaceae													3
Vetiver Grass	*Chrysopogon zizanioides*	Poaceae									6				
Lemon Grass	*Cymbopogon citratus*	Poaceae					6						6		
Kikuyu grass	*Pennisetum clandestinum*	Poaceae													
Spekboom	*Portulacaria afra*	Portulaceae		2		2		2					2		
Protea	*Protea spp*	Proteaceae								3					
Delphinium	*Delphinium grandiflorum*	Ranunculaceae													3
Cape Reed	*Ceratocaryum argenteum*	Restionaceae													
Cape Thatching Reed	*Elegia capensis*	Restionaceae													
Restios Grass	*Restio spp*	Restionaceae													
Wild Rose Bush	*Rosa Canina*	Rosaceae					2								
Boegoe	*Agathosma ovata*	Rutaceae													
Rue	*Ruta graveolens*	Rutaceae									4				
Yesterday-Today-Tomorrow	*Brunfelsia pauciflora* 'Magnifica'	Solanaceae						2							
Petunia	*Petunia xhybrida*	Solanaceae						2	2				2		
Potato Bush Plant	*Solanum rantonnetii*	Solanaceae											1		
Bird of Paradise	*Strelizia spp*	Strelitziaceae								1					1
Nasturtium	*Tropaeolum majus*	Tropaeolaceae									3				
Lemon Verbena	*Aloysia citrodora*	Verbenaceae	3							3	3				
Garden Verbena	*Verbena xhybrida*	Verbenaceae						3	3						
Garden Pansy	*Viola xwittrockiana*	Violaceae		1				1	1				1		

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Grape Vine	*Rhoicissus spp*	Vitaceae				2	2				2		2		
Cycad	*Encephalartos spp*	Zamiaceae													
Devils Thorn	*Tribulus terrestris*	Zygophyllaceae													
		Average OPALS	**3**	**3**	**4**	**2**	**3**	**3**	**4**	**3**	**3**	**3**	**3**	**4**	**3**

Cape Town – Trees

Table D33. Tree species OPALS as defined by Ogren (2015) for Cape Town community gardens. Values in columns represent OPALS for individual species as defined in Ogren (2015). Species represented with yellow cells denote those species which were not included in Ogren (2015).

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Elderberry	*Sambucus canadensis* L.	Adoxaceae											4		
Brazilian Pepper Tree	*Schinus terebinthifolius* Raddi	Anacardiaceae							10						
Fragipani	*Plumeria rubra* L.	Apocynaceae								4					
Papaya Tree	*Carica papaya* L.	Caricaceae		6									6		
Assegai	*Curtisia dentata* (Burm.f.) C.A.Sm.	Cornaceae													
Sweet Thorn Tree	*Vachellia karroo* (Hayne) Banfi & Glasso	Fabaceae									10				
Port Jackson Wattle	*Acacia saligna* (Labill.) H.L.Wendl.	Fabaceae							10						
Carrob Tree	*Ceratonia siliqua* L.	Fabaceae	7								7				
Coral Tree	*Erythrina spp*	Fabaceae								6					
Keurboom	*Virgilia oroboides* (P.J.Bergius) Salter	Fabaceae													
Pin Oak Tree	*Quercus palustris* Münchh.	Fagaceae	8												
English Oak Tree	*Quercus robur* L.	Fagaceae											8	8	
Camphor Tree	*Cinnamomum camphora* (L.) J.Presl.	Lauraceae								8					
Avocado Tree	*Persea americana* Mill.	Lauraceae									3	3			
Wild Pear Tree	*Dombeya spp*	Malvaceae													3
Cape Ash Tree	*Ekebergia capensis* Sparrm.	Meliaceae													
Wild Fig Tree	*Ficus sur* Forssk.	Moraceae				2		2		2			2		
Mulberry Tree	*Morus alba* L.	Moraceae													10
Banana Palm	*Ensete ventricosum* (Welw.) Cheesman	Musaceae											2		2
Guava Tree	*Psidium guajava* L.	Myrtaceae						3							3
Wild Olive Tree	*Olea europaea L. subsp. africana*	Oleaceae								10	10		10		
Pine Tree	*Pinus spp*	Pinaceae							4				4		

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**SWVCG**	**OZCF**	**ANOCG**	**CMCCG**	**VOCVG**	**KSCG_A**	**KSCG_B**	**WPG**	**OJSG**	**CRCHG**	**SFL**	**CVOFG**	**KFG**
Yellow Wood	*Podocarpus latifolius* (Thunb.) R.Br.	Podocarpaceae								10					
Quince Tree	*Cydonia oblonga* Mill.	Rosaceae													
Apple Tree	*Malus spp*	Rosaceae					3						3		3
Apricot Tree	*Prunus armeniaca* L.	Rosaceae											2		
Plum Tree	*Prunus domestica* L.	Rosaceae									3		3		3
Peach Tree	*Prunus persica* (L.) Batsch	Rosaceae									3		3		
Nectarine Tree	*Prunus persica var. nucipersica*	Rosaceae									3				
Wild Pomegranate Tree	*Burchellia bubalina* (L.f.) Sims	Rubiaceae													
Lime Tree	*Citrus aurantifolia*	Rutaceae		2											
Lemon Tree	*Citrus limon* (L.) Osbeck	Rutaceae	2			2					2				2
Manatoka Tree	*Myoporum tenuifolium* G.Forst	Scrophulariaceae			2										
Cape Gooseberry	*Physalis peruviana* L.	Solanaceae								2					
Tamarillo Tree	*Solanum betaceum* Cav.	Solanaceae											1		
		Average OPALS	**6**	**4**	**2**	**2**	**3**	**3**	**8**	**6**	**5**	**3**	**4**	**8**	**4**

Berlin – Vascular plants

Table D34. Vascular plant species OPALS as defined by Ogren (2015) for Berlin community gardens. Values in columns represent OPALS for individual species as defined in Ogren (2015). Species represented with ***yellow cells*** *denote those species which were not included in Ogren (2015) and those with* ***green cells*** *are species which were included, but had not yet been given an OPALS.*

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Black-Eyed Susan Vine	*Thunbergia alata* Bojer	Acanthaceae													2
Heartleaf Ice Plant	*Aptenia cordifolia* (L.f.) N.E.Br.	Aizoaceae			1										
Sutherland Hardy Ice Plant	*Delosperma sutherlandii*	Aizoaceae			3										
Common Ice Plant	*Mesembryanthemum crystallinum* L.	Aizoaceae													
Blood Amaranth	*Amaranthus cruentus* L.	Amaranthaceae	6								6	6			6
Red Orach	*Atriplex hortensis* L.	Amaranthaceae				5			5	5		5	5	5	5
Good King Henry	*Blitum bonus-henricus* (L.) Rchb.	Amaranthaceae			10										
Leafy Goosefoot	*Blitum virgatum* L.	Amaranthaceae										10			
Lamb's Quarters	*Chenopodium album* L.	Amaranthaceae					10						10		
Purple Goosefoot	*Chenopodium giganteum* D.Don	Amaranthaceae				10		10	10	10		10			
Agapanthus	*Agapanthus praecox* Willd.	Amaryllidaceae	2											2	
Blue Globe Onion	*Allium caeruleum* Pall.	Amaryllidaceae											2		
Round-Headed Leek	*Allium sphaerocephalon* L.	Amaryllidaceae											2		
Spring Snowflake	*Leucojum aestivum* L.	Amaryllidaceae						2							
Wild Garlic	*Allium ursinum* L.	Amaryllidaceae		2									2		
Dill	*Anethum graveolens* L.	Apiaceae	3	3						3	3				3
Norwegian Angelica	*Angelica archangelica* L.	Apiaceae			6										
Hemlock	*Conium maculatum* L.	Apiaceae													
Coriander	*Coriandrum sativum* L.	Apiaceae								3					3
Wild Carrot	*Daucus carota* L.	Apiaceae						10			10		10	10	10

Common Name	*Scientific Name*	Family	Community Gardens												
			GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Fennel	*Foeniculum vulgare* Mill.	Apiaceae	5	5	5					5	5	5		5	5
Lovage	*Levisticum officinale* W.D.J.Koch	Apiaceae				3		3							
Cicely	*Myrrhis odorata* (L.) Scop.	Apiaceae			4										
Parsley	*Petroselinum crispum* (Mill.) Fuss	Apiaceae	4	4	4	4			4	4	4	4		4	4
Venus' Comb	*Scandix pecten-veneris* L.	Apiaceae													
Butterfly Weed	*Asclepias tuberosa* L.	Apocynaceae				3									
Holly	*Ilex aquifolium* L.	Aquifoliaceae													4
Devil's Tongue	*Amorphophallus konjac* K. Koch	Araceae													
Farge's Cobra Lily	*Arisaema fargesii*	Araceae			2										
English Ivy	*Hedera helix* L.	Araliaceae					7	7	7			7	7		7
European Wild Ginger	*Asarum europaeum* L.	Aristolochiaceae			1										
St Barnard's Lily	*Anthericum liliago* L.	Asparagaceae													
Glory-of-the-Snow	*Chionodoxa forbesii* Baker	Asparagaceae													2
Lily of the Valley	*Convallaria majalis* L.	Asparagaceae			4										4
Hosta Cultivar	*Hosta spp*	Asparagaceae		1					1						1
Hosta 'Pacific Sunset'	*Hosta spp*	Asparagaceae			1										
Solomon's Seal	*Polygonatum multiflorum* (L.) All.	Asparagaceae			2										2
Yucca	*Yucca filamentosa* L.	Asparagaceae													2
Yucca Cultivar	*Yucca spp*	Asparagaceae							2					2	
Torch Lily	*Kniphofia uvaria* L.	Asphodelaceae	4	4											
Yarrow	*Achillea millefolium* L.	Asteraceae				4		4		4	4	4	4	4	4
Red Velvet Yarrow	*Achillea millefolium 'Red Velvet'*	Asteraceae											4		
Golden Marguerite	*Anthemis tinctoria* L.	Asteraceae	5							5		5			5
Greater Burdock	*Arctium lappa* L.	Asteraceae													
Woolly Burdock	*Arctium tomentosum* Mill.	Asteraceae													
Tarragon	*Artemisia dracunculus* L.	Asteraceae						8				8			8

Common Name	*Scientific Name*	Family	Community Gardens												
			GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Calliope	*Aster laevis* L.	Asteraceae													3
Calendula	*Calendula officinalis* L.	Asteraceae	4	4	4	4	4		4	4	4	4	4	4	4
Cornflower	*Centaurea cyanus* L.	Asteraceae	3	3		3			3	3	3	3	3	3	3
Brown Knapweed	*Centaurea jacea* L.	Asteraceae									3				
Tansy	*Chrysanthemum vulgare* (L.) Bernh.	Asteraceae								5	5			5	
Chicory	*Cichorium intybus* L.	Asteraceae			3						3				
Creeping Thistle	*Cirsium arvense* (L.) Scop.	Asteraceae													9
European Marsh Thistle	*Cirsium palustre* (L.) Scop.	Asteraceae								9					
Lance Coreopsis	*Coreopsis lanceolata* L.	Asteraceae	4												
Plains Coreopsis	*Coreopsis tinctoria* Nutt.	Asteraceae				4				4	4				
Pink Cosmos	*Cosmos bipinnatus* Cav.	Asteraceae			5						5		5	5	
Dahlia Cultivar	*Dahlia spp*	Asteraceae	4	4	4					4				4	4
Dahlia 'Bishop of Canterbury'	*Dahlia spp 'Bishop of Canterbury'*	Asteraceae											4		
Dahlia 'Colarette'	*Dahlia spp 'Colarette'*	Asteraceae				4									
Dahlia 'Hapet Vinete'	*Dahlia spp 'Hapet Vinete'*	Asteraceae											4		
Dahlia 'Natal'	*Dahlia spp 'Natal'*	Asteraceae											4		
Dahlia 'Red Pygmy'	*Dahlia spp 'Red Pygmy'*	Asteraceae											4		
Dahlia 'Vancouver'	*Dahlia spp 'Vancouver'*	Asteraceae											4		
Dahlia 'Waltzing Matilda'	*Dahlia spp 'Waltzing Matilda'*	Asteraceae											4		
Purple Coneflower	*Echinacea purpurea* (L.) Moench	Asteraceae										5			5
Great Globe-Thistle	*Echinops sphaerocephalus* L.	Asteraceae												5	5
Fleabane	*Erigeron annuus* (L.) Pers.	Asteraceae							4	4	4	4	4	4	
Hemp-Agrimony	*Eupatorium cannabinum* L.	Asteraceae												6	
Blanketflower	*Gaillardia aristata* Pursh	Asteraceae	6	6								6		6	6
Gallant Soldier	*Galinsoga parviflora* Cav.	Asteraceae													
Sunflower	*Helianthus annuus* L.	Asteraceae	3			3	3				3	3	3	3	3

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Jerusalem Artichoke	*Helianthus tuberosus* L.	Asteraceae	3		3								3	3	
Dwarf Everlast	*Helichrysum arenarium* (L.) Moench	Asteraceae				4									
Summer Sun	*Heliopsis helianthoides* (L.) Sweet	Asteraceae		5							5				5
Ox-Eye Daisy	*Leucanthemum vulgare*	Asteraceae						5							5
Summer Ragwort	*Ligularia dentata* (A.Gray) H.Hara	Asteraceae			5										
Chamomile	*Matricaria chamomilla* L.	Asteraceae	5		5		5			5	5	5	5	5	5
Cotton Thistle	*Onopordum acanthium* L.	Asteraceae													
Black Exed Susan	*Rudbeckia hirta* L.	Asteraceae	5											5	
Olive Herb	*Santolina viridis* L.	Asteraceae						5							
Spanish Salsify	*Scorzonera hispanica* L.	Asteraceae													
Narrow-Leaf Ragwort	*Senecio inaequidens* DC	Asteraceae						7							
Milk Thistle	*Silybum marianum* (L.) Gaertn.	Asteraceae			5										5
Field Milk Thistle	*Sonchus arvensis* L.	Asteraceae													
Sowthistle	*Sonchus oleraceus* L.	Asteraceae													
Mexican Marigold	*Tagetes erecta* L.	Asteraceae	4	4	4									4	4
Irish Lace	*Tagetes filifolia* Lag.	Asteraceae		4											
French Marigold	*Tagetes patula* L.	Asteraceae	4			4	4			4	4	4		4	4
Signet Marigold	*Tagetes signata* Bartling	Asteraceae	4												
Feverfew	*Tanacetum parthenium* (L.) Sch. Bip.	Asteraceae			5	5		5							
Zinnia	*Zinnia elegans* Jacq.	Asteraceae								3					
Fern	*Athyrium filix-femina* (L.) Roth	Athyriacea					5	5	5						
Thunberg's Barberry	*Berberis thunbergii* DC	Berberidaceae								3					
Barberry	*Berberis vulgaris* L.	Berberidaceae	3												
Fröhnleiten	*Epimedium x perralchicum*	Berberidaceae			1										

Common Name	*Scientific Name*	Family	GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
			Community Gardens												
Trumpet Creeper	*Campsis × tagliabuana 'Madame Galen'*	Bignoniaceae		5											
Dyer's Alkanet	*Alkanna tinctoria* (L.) Tausch	Boraginaceae													
Borage	*Borago officinalis* L.	Boraginaceae	3	3	3	3	3	3	3	3	3	3	3		3
Viper's Blugloss	*Echium vulgare* L.	Boraginaceae					5				5				
Lacy Phacelia	*Phacelia tanacetifolia* Benth.	Boraginaceae	7	7		7	7			7	7	7	7		7
Lungwort	*Pulmonaria officinalis* L.	Boraginaceae						2							
Comphrey	*Symphytum officinale* L.	Boraginaceae	3												
Garlic Mustard	*Alliaria petiolata* (M.Bieb.) Cavara & Grande	Brassicaceae													
Horseradish	*Armoracia rusticana* G.Gaertn., B.Mey. & Scherb.	Brassicaceae	2												
Lilac Bush	*Aubrieta deltoidea* (L.) DC	Brassicaceae													2
Bittercress	*Barbarea vulgaris* R.Br.	Brassicaceae	3								3		3	3	3
Hoary Alyssum	*Berteroa incana* (L.) DC	Brassicaceae	5			5		5		5	5				5
Black Mustard	*Brassica nigra* L.	Brassicaceae			6							6			
Coralroot	*Cardamine bulbifera* (L.) Crantz	Brassicaceae													
Treacle Mustard	*Erysimum cheiranthoides* L.	Brassicaceae				3									
Dame's Rocket	*Hesperis matronalis* L.	Brassicaceae								4	4				
Woad	*Isatis tinctoria* L.	Brassicaceae													
Cress	*Lepidium sativum* L.	Brassicaceae													
Wild Radish	*Raphanus raphanistrum* L.	Brassicaceae													
Creeping Yellow Cress	*Rorippa sylvestris* (L.) Besser	Brassicaceae													
Butterfly Bush	*Buddleja davidii* Franch.	Buddlejaceae					3							3	
Clips White	*Campanula carpatica* Jacq.	Campanulaceae				1									
Creeping Bellflower	*Campanula rapunculoides* L.	Campanulaceae							1					1	
Nettle-Leaved Bellflower	*Campanula trachelium* L.	Campanulaceae						1							
Sheeps Bit Scabious	*Jasione montana* L.	Campanulaceae													
Garden Lobelia	*Lobelia erinus* L.	Campanulaceae												2	

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Cannabis	*Cannabis sativa* L.	Cannabaceae							4						
Wild Teasel	*Dipsacus fullonum* L.	Caprifoliaceae													
Evergreen Honeysuckle	*Lonicera henryi*	Caprifoliaceae													5
Honeysuckle	*Lonicera x heckrottii*	Caprifoliaceae													5
Valerian	*Valeriana officinalis* L.	Caprifoliaceae			3			3							
Common Corncockle	*Agrostemma githago* L.	Caryophyllaceae				4									
Sweet William	*Dianthus barbatus* L.	Caryophyllaceae	2												
Carthusian Pink	*Dianthus carthusianorum* L.	Caryophyllaceae	2												
Carnation	*Dianthus caryophyllus* L.	Caryophyllaceae		2											
Cheddar	*Dianthus gratianopolitanus*	Caryophyllaceae				2				2			2		
Wild Pink	*Dianthus plumarius* L.	Caryophyllaceae		2											2
Ragged-Robin	*Lychnis flos-cuculi* L.	Caryophyllaceae													3
Soapwort	*Saponaria officinalis* L.	Caryophyllaceae	3			3									3
Maidenstears	*Silene vulgaris* (Moench) Garcke	Caryophyllaceae				3				3	3	3	3	3	3
Cistus	*Cistus spp*	Cistaceae													4
Hedge Bindweed	*Calystegia sepium* (L.) R.Br.	Convolvulaceae													
Morning Glory	*Ipomoea tricolor* Cav.	Convolvulaceae			4										
Rolling Hen-and-Chicks	*Jovibarba globifera* (L.) J. Parn.	Crassulaceae		1	1										1
Gray Stonecrop	*Rhodiola pachyclados*	Crassulaceae			2										
	Rhodiola saxifragoides	Crassulaceae			2										
White Stonecrop	*Sedum album* L.	Crassulaceae							2						2
Weihenstephaner Gold	*Sedum floriferum*	Crassulaceae			2										
Reflexed Stonecrop	*Sedum reflexum* L.	Crassulaceae										2			
Rocky Stonecrop	*Sedum rupestre*	Crassulaceae			2										
Cobweb House Leek	*Sempervivum arachnoideum* L.	Crassulaceae							1						
Common Houseleek	*Sempervivum tectorum* L.	Crassulaceae							1						

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Juniper	*Juniperus communis* L.	Cupressaceae										10			10
Japanese Sedge	*Carex morrowii*	Cyperaceae			5										
Hergo Buckthorn	*Hippophae rhamnoides* L. 'Hergo'	Elaeagnaceae													4
Pollmix 4 Buckthorn	*Hippophae rhamnoides* L. 'Pollmix 4'	Elaeagnaceae													4
Rough Horsetail	*Equisetum hyemale* L.	Equisetaceae			5										
Wood Spurge	*Euphorbia amygdaloides* L.	Euphorbiaceae												7	
Cancer Weed	*Euphorbia peplus* L.	Euphorbiaceae				7	7				7			7	
Blue Wild Indigo	*Baptisia australis* Hort.	Fabaceae													2
'Starlite' Prairieblues	*Baptisia x bicolor* 'Starlite' Prairieblues	Fabaceae													2
Perennial Pea	*Lathyrus latifolius* L.	Fabaceae						3							
Tuberous Pea	*Lathyrus tuberosus* L.	Fabaceae						3							
Spring Pea	*Lathyrus vernus* (L.) Bernh.	Fabaceae													3
Lupine Cultivar	*Lupinus spp*	Fabaceae												3	3
Lucerne	*Medicago x varia*	Fabaceae													
White Sweet Clover	*Melilotus albus* Medik.	Fabaceae													5
Yellow Sweet Clover	*Melilotus indicus* (L.) All.	Fabaceae						5						5	5
Suckling Clover	*Trifolium dubium* Sibth.	Fabaceae	3								3				
Red Clover	*Trifolium pratense* L.	Fabaceae	3	3			3	3		3	3	3	3		3
White Clover	*Trifolium repens* L.	Fabaceae		3		3					3			3	
Tufted Vetch	*Vicia cracca* L.	Fabaceae													
Bulgarian Geranium	*Geranium macrorrhizum* L.	Geraniaceae			3										
Marsh Cranesbill	*Geranium palustre* L.	Geraniaceae					3							3	
Herb Robert	*Geranium robertianum* L.	Geraniaceae						3	3	3			3		
Bloody Cranesbill	*Geranium sanguineum* L.	Geraniaceae						3							
Geranium 'Rozanne'	*Geranium spp* 'Rozanne'	Geraniaceae													3
Cranesbill	*Geranium wlassovianum*	Geraniaceae			3										

Common Name	*Scientific Name*	Family	Community Gardens												
			GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Purple Cranesbill	*Geranium x magnificum*	Geraniaceae													3
Hydrangea	*Hydrangea macrophylla* (Thunb.) Ser.	Hydrangeaceae		3										3	3
Sweet Mock-Orange	*Philadelphus coronarius* L.	Hydrangeaceae													3
St Johns-Wort	*Hypericum perforatum* L.	Hypericaceae			5	5	5	5			5		5		
Safran	*Crocus sativus* L.	Iridaceae											2		2
Abyssinian Gladiolus	*Gladiolus murielae* Kelway	Iridaceae											3		
Tall Bearded Iris	*Iris barbata-elatior*	Iridaceae			2										
Siberian Iris	*Iris sibirica* L.	Iridaceae			2										
Narrow-Leaf Blue-Eyed Grass	*Sisyrinchium angustifolium* Mill.	Iridaceae			1										
Anisse Hyssop	*Agastache foeniculum* (Pursh) Kuntze	Lamiaceae		3	3							3	3	3	3
Mexican Giant Hyssop	*Agastache mexicana*	Lamiaceae										3			
Korean Mint	*Agastache rugosa* (Fisch. & C.A.Mey.) Kuntze	Lamiaceae			3								3		
Wild Basil	*Betonica officinalis* (L.) Trevis.	Lamiaceae			2							2			
Moldovian Dragonhead	*Clinopodium vulgare*	Lamiaceae													
Hyssop	*Dracocephalum moldavica* L.	Lamiaceae											3		
White Nettle	*Hyssopus officinalis* L.	Lamiaceae				5		5		5				5	
Yellow Archangel	*Lamium album L.*	Lamiaceae			5										
English Lavender	*Lamium galeobdolon* (L.) Crantz	Lamiaceae	5	5	5	5	5	5		5	5	5	5	5	5
French Lavender	*Lavandula angustifolia* Mill.	Lamiaceae	5												
Motherwort	*Lavandula stoechas* L.	Lamiaceae													
Kreta-Melisse	*Leonurus cardiaca* L.	Lamiaceae													
Lemon Balm	*Melissa altissima*	Lamiaceae													
American Mint	*Melissa officinalis* L.	Lamiaceae									3				
Spearmint	*Mentha canadensis* L.	Lamiaceae						3				3	3	3	
Apple Mint	*Mentha spicata* L.	Lamiaceae		3	3								3		
Grapefruit Mint	*Mentha suaveolens* Ehrh.	Lamiaceae										3			

Common Name	*Scientific Name*	Family	Community Gardens GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Peppermint	*Mentha suaveolens x piperata*	Lamiaceae	3	3	3		3	3		3		3	3	3	3
Swiss Mint	*Mentha x piperita* L.	Lamiaceae									3				
Crimson Beebalm	*Mentha x piperita 'Swiss'*	Lamiaceae				3	3					3	3	3	3
Basil	*Monarda didyma* L.	Lamiaceae		2	2	2				2		2	2	2	
Cinnamon Basil	*Ocimum basilicum* L.	Lamiaceae												2	
Thai Basil	*Ocimum basilicum* 'Cinnamon'	Lamiaceae										2			
Majoram	*Ocimum basilicum var. thyrsiflora*	Lamiaceae										3			
Oregano	*Origanum majorana* L.	Lamiaceae	3		3	3		3		3	3	3	3	3	3
Turkish Sage	*Origanum vulgare* L.	Lamiaceae													3
	Phlomis russeliana	Lamiaceae				1									
Large Flowered Selfheal	*Plectranthus forsteri*	Lamiaceae													2
Rosemary	*Prunella grandiflora* (L.) Scholler	Lamiaceae	4	4				4		4				4	4
Sage	*Rosmarinus officinalis* L.	Lamiaceae	2	2	2	2		2	2	2	2	2	2	2	2
Tricolour Sage	*Salvia officinalis* L.	Lamiaceae												2	
Clary Sage	*Salvia officinalis* 'Tricolor'	Lamiaceae			2										
Lilac Sage	*Salvia sclarea* L.	Lamiaceae								2					
Summer Savory	*Salvia verticillata* L.	Lamiaceae			2										
Winter Savory	*Satureja hortensis* L.	Lamiaceae										2			
Lamb's Ear	*Satureja montana* L.	Lamiaceae				3		3							
Betony	*Stachys byzantina* K.Koch	Lamiaceae			3										
Wall Germander	*Teucrium chamaedrys* L.	Lamiaceae			2										
Lemon Thyme	*Thymus citriodorus* (Pers.) Schreb.	Lamiaceae		3								3			
Thyme	*Thymus vulgaris* L.	Lamiaceae			3	3					3	3		3	3
Tiger Lily	*Lilium lancifolium* Thunb.	Liliaceae											4		
Lily	*Lilium spp*	Liliaceae		4			4	4						4	4
Tulip	*Tulipa gesneriana* L.	Liliaceae													2

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Antwerp Hollyhock	*Alcea ficifolia*	Malvaceae	3			3						3			
Hollyhock	*Alcea rosea* L.	Malvaceae	3			3	3	3		3	3	3		3	3
Marsh Mallow	*Althaea officinalis* L.	Malvaceae			3										
Hibiscus	*Hibiscus rosa-sinensis* L.	Malvaceae												3	
Common Mallow	*Malva sylvestris* L.	Malvaceae													
Water Lily	*Nymphaea spp*	Nymphaeaceae						1							1
Lilac	*Syringa vulgaris* L.	Oleaceae				5									
Hoary Willowherb	*Epilobium parviflorum*	Onagraceae			6										
Square Stalked Willow Herb	*Epilobium tetragonum* L.	Onagraceae													6
Hummingbird Fuchsia	*Fuchsia magellanica* Lam.	Onagraceae													3
Fuchsia Cultivar	*Fuchsia spp*	Onagraceae												3	
Evening Primrose	*Oenothera oakesiana*	Onagraceae					3	3	3	3	3	3	3	3	3
Wood Sorrel	*Oxalis acetosella* L.	Oxalidaceae							1						
Yellow Wood Sorrel	*Oxalis stricta* L.	Oxalidaceae					1			1			1	1	
Iron Cross	*Oxalis tetraphylla* Cav.	Oxalidaceae			1									1	
False Shamrock	*Oxalis triangularis* A.St.-Hil.	Oxalidaceae			1										
Greater Celandine	*Chelidonium majus* L.	Papaveraceae													
California Poppy	*Eschscholzia californica* Cham.	Papaveraceae	3							3	3				
Long Head Poppy	*Papaver dubium* L.	Papaveraceae	3									3		3	
Common Poppy	*Papaver rhoeas* L.	Papaveraceae		3						3	3				
Opium Poppy	*Papaver somniferum* L.	Papaveraceae	3							3	3		3		
Rock Fumewort	*Pseudofumaria lutea* (L.) Borkh.	Papaveraceae													
Blue Passionfruit	*Passiflora caerulea* L.	Passifloraceae												3	
Snapdragon	*Antirrhinum majus* L.	Plantaginaceae				1			1		1		1		1
Foxglove	*Digitalis purpurea* L.	Plantaginaceae													2
Toadflax	*Linaria dalmatica* (L.) Mill.	Plantaginaceae	1			1									1

Common Name	Scientific Name	Family	Community Gardens												
			GAK	BGG	PRG	PLG	KSS	LSG	SKR	KFS	SFM	IGH	GPT	GCF	KLG
Plantain	*Plantago lanceolata* L.	Plantaginaceae			3	3		3			3				3
Broadleaf Plantain	*Plantago major* L.	Plantaginaceae				3	3							3	
Spiked Speedwell	*Veronica spicata* L.	Plantaginaceae											2		
Lemon Grass	*Cymbopogon citratus* (DC.) Stapf	Poaceae													6
Hakone Grass	*Hakonechloa macra*	Poaceae													
Blue Hair Grass	*Koeleria glauca* (Schrad.) DC.	Poaceae				8			8						
Purple Stem Cat's Tail	*Phleum phleoides* (L.) H. Karst.	Poaceae								2					
Mexican Feathergrass	*Stipa tenuissima*	Poaceae													
Garden Phlox	*Phlox paniculata* L.	Polemoniaceae					3								
Jacob's Ladder	*Polemonium caeruleum* L.	Polemoniaceae				2									
Mountain Sorrel	*Oxyria digyna* (L.) Hill	Polygonaceae													
Pale Persicaria	*Persicaria lapathifolia* (L.) Delarbre	Polygonaceae					5			5				5	
Sorrel	*Rumex acetosa* L.	Polygonaceae			6							6		6	6
Curly Dock	*Rumex crispus* L.	Polygonaceae						6							
Patience Dock	*Rumex patientia* L.	Polygonaceae										6			
Redvein Dock	*Rumex sanguineus*	Polygonaceae			6										
French Sorrel	*Rumex scutatus* L.	Polygonaceae			6										
Creeping Jenny	*Lysimachia nummularia* L.	Primulaceae		2											
Oxlip	*Primula elatior* Hill	Primulaceae		4											
Wolfsbane	*Aconitum napellus* L.	Ranunculaceae			4										
Wood Anemone	*Anemone nemorosa* L.	Ranunculaceae	3												3
Yellow Anemone	*Anemone ranunculoides* L.	Ranunculaceae													3
Hybrid Anemone	*Anemone x hybrida*	Ranunculaceae					3								
Clematis Vine	*Clematis alpina*	Ranunculaceae								4					
Clematis 'Pistachio Evirida'	*Clematis florida var. normalis* 'Pistachio Evirida'	Ranunculaceae													4
Mountain Clematis	*Clematis montana*	Ranunculaceae		4											

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Clematis 'Multi Blue'	*Clematis spp* 'Multi Blue'	Ranunculaceae													4
Clematis 'Solidarnosc'	*Clematis spp* 'Solidarnosc'	Ranunculaceae													4
Forking Larkspur	*Consolida hispanica* (Costa) Greuter & Burdet	Ranunculaceae	3												3
Stinking Hellebore	*Helleborus foetidus* L.	Ranunculaceae													4
Hepatica	*Hepatica nobilis* Schreb.	Ranunculaceae													2
Love-in-a-Mist	*Nigella damascena* L.	Ranunculaceae													3
Black Cumin	*Nigella sativa* L.	Ranunculaceae								3					
Dyer's Rocket	*Reseda luteola* L.	Resedaceae	3												
Garden Lady's Mantle	*Alchemilla mollis* (Buser) Rothm.	Rosaceae			4										
Lady's Mantle	*Alchemilla vulgaris* L.	Rosaceae	4												4
English Hawthorn	*Crataegus laevigata* (Poir.) DC	Rosaceae												3	
Wood Avens	*Geum japonicum* L.	Rosaceae							2					2	
Silverweed	*Potentilla anserina* (L.) Rydb.	Rosaceae			3										
Dog Rose	*Rosa canina* L.	Rosaceae								2					
Rose	*Rosa spp*	Rosaceae								2					
Rose 'Polyantha'	*Rosa spp 'Polyantha'*	Rosaceae				2									
Salad Burnet	*Sanguisorba minor* Scop.	Rosaceae						2		2					
Sweetscented Bedstraw	*Galium odoratum* (L.) Scop.	Rubiaceae	2					2				2			2
Lady's Bedstraw	*Galium verum* L.	Rubiaceae			2										
Common Madder	*Rubia tinctorum* L.	Rubiaceae													
Rue	*Ruta graveolens* L.	Rutaceae					4	4							
Astilbe	*Astilbe arendsii*	Saxifragaceae													4
Alternate-Leaved Golden-Saxifrage	*Chrysosplenium alternifolium* L.	Saxifragaceae													
Heartleaf Foamflower	*Tiarella cordifolia* L.	Saxifragaceae										3			
Twinspur	*Diascia barberae*	Scrophulariaceae		2											
Denseflower Mullein	*Verbascum densiflorum* Bertol.	Scrophulariaceae	3		3					3			3		3

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Black Henbone	*Hyoscyamus niger* L.	Solanaceae													
Tobacco	*Nicotiana tabacum* L.	Solanaceae			3									3	3
Petunia Cultivar	*Petunia spp*	Solanaceae												2	
European Black Nightshade	*Solanum nigrum* L.	Solanaceae												3	
Camellia	*Camellia japonica* L.	Theaceae							2						
Nasturtium	*Tropaeolum majus* L.	Tropaeolaceae	3	3	3	3	3		3	3	3	3	3	3	3
Variegata Nasturtium	*Tropaeolum majus 'Variegata'*	Tropaeolaceae	3												
Broadleaf Cattail	*Typha latifolia* L.	Typhaceae								6					
Stinging Nettle	*Urtica dioica* L.	Urticaceae				7	7	7		7	7		7	7	
Lemon Verbena	*Aloysia citrodora* Paláu	Verbenaceae			3										
Argentina Mint	*Aloysia polystachya*	Verbenaceae		3											
Tickberry	*Lantana camara* L.	Verbenaceae		4											
Common Verbena	*Verbena officinalis* L.	Verbenaceae													3
Pansy	*Viola tricolor* L.	Violaceae								1					
Garden Pansy	*Viola x wittrockiana*	Violaceae											1		
Common Grape Vine	*Vitis vinifera* L.	Vitaceae				3	3			3		3			
		Average OPALS	**4**	**3**	**3**	**4**	**4**	**4**	**3**	**4**	**4**	**4**	**4**	**4**	**4**

Berlin – Trees

Table D35. Tree species OPALS as defined by Ogren (2015) for Berlin community gardens. Values in columns represent OPALS for individual species as defined in Ogren (2015).

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
Silver Birch Tree	*Betula pendula* Roth	Betulaceae	9		9					9				9	
Downy Birch Tree	*Betula pubescens* Ehrh.	Betulaceae		9											
European Hornbeam Tree	*Carpinus betulus* L.	Betulaceae						7	7	7				7	
Common Hazel	*Corylus avellana* L.	Betulaceae					7	7						7	
European Cornel Tree	*Cornus mas* L.	Cornaceae								5					
Black Locust Tree	*Robinia pseudoacacia* L.	Fabaceae		5	5	5		5		5			5		
Sweet Chestnut Tree	*Castanea sativa* Mill.	Fagaceae								4					
Common Beech Tree	*Fagus sylvatica* L.	Fagaceae			6										
English Walnut Tree	*Juglans regia* L.	Juglandaceae											9		
Pippala Tree	*Ficus religiosa* L.	Moraceae			3										
Myrtle Tree	*Myrtus communis* L.	Myrtaceae								5					
European Ash Tree	*Fraxinus excelsior* L.	Oleaceae								4					
Oriental Plane Tree	*Platanus orientalis* L.	Plantanaceae				8									
Apple Tree	*Malus domestica*	Rosaceae			4			4		4				4	4
Apple Tree 'Cox Orange'	*Malus domestica* 'Cox Orange'	Rosaceae				4									
Apple Tree 'James Grieve'	*Malus domestica* 'James Grieve'	Rosaceae	4												
Apple Tree 'Shampion'	*Malus domestica* 'Shampion'	Rosaceae				4									
Apple Tree 'Starking'	*Malus domestica 'Starking'*	Rosaceae									4				
Wild Apple Tree	*Malus sylvestris* (L.) Mill.	Rosaceae					4								
Medlar Tree	*Mespilus germanica* L.	Rosaceae							3						
Cherry Tree	*Prunus avium* L.	Rosaceae								6					
Peach Tree	*Prunus persica* (L.) Batsch	Rosaceae	4												

			Community Gardens												
Common Name	***Scientific Name***	**Family**	**GAK**	**BGG**	**PRG**	**PLG**	**KSS**	**LSG**	**SKR**	**KFS**	**SFM**	**IGH**	**GPT**	**GCF**	**KLG**
European Wild Pear Tree	*Pyrus pyraster* (L.) Burgsd.	Rosaceae					4			4				4	
Mountain Ash Tree	*Sorbus aucuparia* L.	Rosaceae											4		
Swedish Whitebeam	*Sorbus intermedia* (Ehrh.) Pers.	Rosaceae								4					
Black Poplar Tree	*Populus nigra* L.	Salicaceae					5						5		
White Willow Tree	*Salix alba* L.	Salicaceae								6				6	
Field Maple Tree	*Acer campestre* L.	Sapindaceae					6						6		
Box Elder Tree	*Acer negundo* L.	Sapindaceae							5	5			5		
Norway Maple Tree	*Acer platanoides* L.	Sapindaceae				8	8	8	8	8				8	
Sycamore Tree	*Acer pseudoplatanus* L.	Sapindaceae								8					
Maple Tree	*Acer spp*	Sapindaceae			5										
Horse Chestnut Tree	*Aesculus hippocastanum* L.	Sapindaceae										7			
European White Elm	*Ulmus laevis* Pall.	Ulmaceae											7		
		Average OPALS	**6**	**7**	**5**	**6**	**6**	**6**	**6**	**6**	**4**	**7**	**6**	**6**	**4**

Appendix E – Full calculations of final assessment scores used in Burkhard-type matrices.

This appendix shows the calculations of final assessment scores used in the Burkhard-type matrices in Tables 5.12 (pages 197) and 5.13 (page 169).

Ecosystem services

Table E1. Full calculations of final assessment scores used in Burkhard-type matrices for ecosystem services in Cape Town community gardens.

		Qualitative Data	Quantitative Data			Average of qualitative and quantitative scores used for final Burkhard value
Ecosystem Services	**Cape Town**	**SPSS Question Averages**	**Quantitative Averages**	**Calculations of Burkhard Scores**	**Calculation Rationale**	
Provisioning Services	***x̄ = 2***					

<table>
<tr><td rowspan="2">Crops</td><td rowspan="2">3</td><td rowspan="2">3,79</td><td rowspan="2">(4,00 + 1,80) / 2 = 2,90</td><td>Crop richness: 4,00</td><td>A Burkhard score of 4 is given based on Cape Town gardens having a high crop richness of 54 types.</td><td rowspan="2">(3,79 + 2,90) / 2 = 3,35</td></tr>
<tr><td>Crop area: 36 / 100 x 5 = 1,80</td><td>A crop area of 36% of the total community garden area assessed in Cape Town was measured. This 36% was then calculated as a value out of 5 to coincide with Burkhard scores.</td></tr>
<tr><td>Livestock</td><td>1</td><td>0,50</td><td>1,00</td><td>Food producing livestock: 1,00</td><td>A Burkhard score of 1 is given based on those Cape Town gardens assessed having a low 18 units of food producing livestock per hectare of community garden area.</td><td>(1 + 0,50) / 2 = 0,75</td></tr>
<tr><td>Wood Fuel</td><td>0</td><td>0,00</td><td>0,00</td><td></td><td>No wood fuel was observed and quantified in any of the gardens.</td><td>0,00</td></tr>
<tr><td>Timber</td><td>0</td><td>0,00</td><td>0,00</td><td></td><td>No timber was observed and quantified in any of the gardens.</td><td>0,00</td></tr>
<tr><td rowspan="2">Fresh Water Supply</td><td rowspan="2">2</td><td rowspan="2">1,91</td><td rowspan="2">(1,15 + 1,92) / 2 = 1,54</td><td>Fresh water sources: 23 / 100 x 5 = 1,15</td><td>Freshwater supplied by the municipality was severely restricted because of drought conditions. 3 of the 13 gardens (23%) had on-site fresh water sources like boreholes and a mountain spring. 23% was then calculated as a value out of 5 to coincide with Burkhard scores.</td><td rowspan="2">(1,91 + 1,54) / 2 = 1,72</td></tr>
<tr><td>Tank capacity supplying freshwater to meet irrigation requirements: (5 / 13) x 5 = 1,92</td><td>Because of the water use restrictions enforced by the municipality, municipal supplied tapped water was limited for irrigation requirements. As such, only 5 gardens had the capacity supplied from their freshwater tanks to meet their irrigation needs.</td></tr>
<tr><td>Medicinal Resources</td><td>1</td><td>1,29</td><td>1,65</td><td>Medicinal species richness: 33 / 100 x 5 = 1,65</td><td>52 (33%) of the 156 vascular plant species had medicinal properties. This 33% was then calculated as a value out of 5 to coincide with Burkhard scores.</td><td>(1,29 + 1,65) / 2 = 1,47</td></tr>
</table>

Regulating Services	*x̄ = 3*					
Local Climate Regulation	3	3,88	(1,20 + 2,00 + 4,45) / 3 = 2,55	***Shading by trees***: 24 / 100 x 5 = 1,20	A shaded area of 24% of the total community garden area assessed in Cape Town was calculated from aerial photos. This 24% was then calculated as a value out of 5 to coincide with Burkhard scores.	(3,88 + 2,55) / 2 = 3,22
				Carbon sequestration and storage: 2,00	Carbon storage and sequestration capacity in community gardens is limited due to their size and general low number of trees. Carbon storage was estimated at 12 t C per hectare and 0,099 t C per hectare per year were sequestered. A Burkhard score of 2 is given based on these moderate capacities.	
				Area of vegetated surfaces: 89 / 100 x 5 = 4,45	A vegetated area of 89% of the total community garden area assessed in Cape Town was measured. This 89% was then calculated as a value out of 5 to coincide with Burkhard scores.	
Air Quality Regulation	2	3,92	1,00	***Tree density***: 1,00	A low tree density of 96 trees per hectare was recorded for Cape Town gardens. A Burkhard score of 1 is given based on this low density.	(3,92 + 1,00) / 2 = 2,46
Moderation of Extreme Events	2	3,29	1,00	***Tree density***: 1,00	Trees of a larger size and canopy volume are more effective against moderating extreme weather. Cape Town gardens showed the highest density of small trees (54 trees per hectare) and lowest density of large trees (22 trees per hectare), thus had a low capacity for moderating intense winds, rainfall. A Burkhard score of 1 is given based on this low density.	(3,29 + 1) / 2 = 2,15
Water Flow Regulation and Runoff Mitigation	4		4,45	***Sealed surfaces***: 5 - [(11/100x5)] = 4,45	A sealed area of 11% of the total community garden area assessed in Cape Town was measured. Average DIN run-off coefficients above 0.8 for almost all gardens, so sealed surfaces are almost completely impermeable. This 11% was then calculated as a value out of 5 to coincide with Burkhard scores.	4,45
				Area of vegetated surfaces: 89 / 100 x 5 = 4,45	A vegetated area of 89% of the total community garden area assessed in Cape Town was measured. This 89% was then calculated as a value out of 5 to coincide with Burkhard scores.	
Erosion Prevention and Maintenance of Soil Fertility	4	3,71	4,45	***Sealed surfaces***: 5 - [(11/100x5)] = 4,45	A sealed area of 11% of the total community garden area assessed in Cape Town was measured. Average DIN run-off coefficients above 0.8 for almost all gardens, so sealed surfaces are almost completely impermeable. This 11% was then calculated as a value out of 5 to coincide with Burkhard scores.	(3,71 + 4,45) / 2 = 4,08
				Area of vegetated surfaces: 89 / 100 x 5 = 4,45	A vegetated area of 89% of the total community garden area assessed in Cape Town was measured. This 89% was then calculated as a value out of 5 to coincide with Burkhard scores.	

Noise Reduction	3	2,63			Only measured quantitatively in the questionnaire.	
Habitat/Supporting Services	***x̄ = 3***					
Maintenance of Genetic Diversity	3		(3,00 + 2,00) / 2 = 2,50	***Species richness***: 3,00	Cape Town gardens had good capacity for maintaining genetic diversity as species richnesses of 156 vascular plants species (spontaneous and ornamental species, excluding edible crops), 35 tree species and 44 faunal species (excluding livestock) were recorded. A Burkhard score of 3 is given based on these moderate richnesses.	2,50
				Species diversity: 2,00	Cape Town gardens had moderate average Shannon diversity index scores of 1,51 for vascular plants species, 0,97 for tree species and 1,12 for faunal species. A Burkhard score of 2 is given based on these moderate diversities.	
Habitat for Species	3		2,50	***Habitat for Species***: 3,00	Habitat for species services are estimated using same Burkhard values obtained for maintenance of genetic diversity as species diversity and richness were used as indicators of microhabitat presence.	2,50
Cultural Services	***x̄ = 3***					
Recreation and Mental and Physical Health	3	3,18	3,00	***Recreation facilities and spaces***: 3,00	A total of 68 recreational facilities/activities/uses were recorded in Cape Town community gardens. A Burkhard score of 3 is given.	(3,18 + 3,00) / 2 = 3,09
Tourism	2	0,50	3,00	***Number of visitors***: 3,00	A total of 1145 visitors per hectare of garden space was calculated for Cape Town. A Burkhard score of 3 is given.	(0,50 + 3,00) / 2 = 1,75
Aesthetic Appreciation and Inspiration for Culture, Art, Design	4	4,17			Only measured quantitatively in the questionnaire.	
Spiritual Experiences and Sense of Place	4	4,40			Only measured quantitatively in the questionnaire.	

Table E2. Full calculations of final assessment scores used in Burkhard-type matrices for ecosystem services in Berlin community gardens.

		Qualitative Data	Quantitative Data			Average of qualitative and quantitative scores used for final Burkhard value
Ecosystem Services	**Berlin**	**SPSS Question Averages**	**Quantitative Averages**	**Calculations of Burkhard Scores**	**Calculation Rationale**	
Provisioning Services	***x̄ = 2***					
Crops	4	4,23	(5,00 + 1,85) / 2 = 3,43	***Crop richness***: 5,00	A Burkhard score of 5 is given based on Berlin gardens having a very high crop richness of 108 types.	(4,23 + 3,43) / 2 = 3,83
				Crop area: 37 / 100 x 5 = 1,85	A crop area of 37% of the total community garden area assessed in Berlin was measured. This 37% was then calculated as a value out of 5 to coincide with Burkhard scores.	
Livestock	1	0,11	1,00	***Food producing livestock***: 1,00	A Burkhard score of 1 is given based on those Berlin gardens assessed having a low 4 units of food producing livestock per hectare of community garden area.	(0,11 + 1,00) / 2 = 0,56
Wood Fuel	0	0,84	0,00		No wood fuel was observed and quantified in any of the gardens.	0,84 / 2 = 0,42
Timber	0	0,84	0,00		No timber was observed and quantified in any of the gardens.	0,84 / 2 = 0,42
Fresh Water Supply	3	1,88	(0,04 + 5,00) / 2 = 2,70	***Fresh water sources***: 8 / 100 x 5 = 0,40	Freshwater supplied by the municipality was freely and readily available to all gardens. Only 1 of the 13 gardens (8%) had an alternative on-site fresh water source using a well. 8% was then calculated as a value out of 5 to coincide with Burkhard scores.	(1,88 + 2,70) / 2 = 2,29
				Tank capacity supplying freshwater to meet irrigation requirements: 5	Rainfall and water supplied by the municipality was copious and freely available to all gardens in Berlin. As such, all gardens felt that the fresh water supplied to them through harvesting of rainfall in their tanks or tapped water was sufficient to meet their irrigation needs every month.	
Medicinal Resources	2	3,59	0,90	***Medicinal species richness***: 18 / 100 x 5 = 0,90	57 (18%) of the 320 vascular plant species had medicinal properties. This 18% was then calculated as a value out of 5 to coincide with Burkhard scores.	(3,59 + 0,90) / 2 = 2,25
Regulating Services	***x̄ = 3***					
Local Climate Regulation	3	3,18	(1,35 + 3,00 + 3,85) / 3 = 2,73	***Shading by trees***: 27 / 100 x 5 = 1,35	A shaded area of 27% of the total community garden area assessed in Berlin was calculated from aerial photos. This 27% was then calculated as a value out of 5 to coincide with Burkhard scores.	(3,18 + 2,73) / 2 = 2,96

				Carbon sequestration and storage: 3,00	Carbon storage and sequestration capacity in community gardens is limited due to their size and general low number of trees. Carbon storage was estimated at 19 t C per hectare and 0,149 t C per hectare per year were sequestered. A Burkhard score of 3 is given based on these moderate capacities.	
				Area of vegetated surfaces: 77 / 100 x 5 = 3,85	A vegetated area of 77% of the total community garden area assessed in Berlin was measured. This 77% was then calculated as a value out of 5 to coincide with Burkhard scores.	
Air Quality Regulation	2	3,50	1,00	***Tree density***: 1,00	A low tree density of 38 trees per hectare was recorded for Berlin gardens. A Burkhard score of 1 is given based on this low density.	(3,50 + 1,00) / 2 = 2,25
Moderation of Extreme Events	2	2,23	2,00	***Tree density***: 2,00	Trees of a larger size and canopy volume are more effective against moderating extreme weather. Berlin gardens showed the lowest density of small trees (8 trees per hectare) and highest density of large trees (27 trees per hectare), thus had a moderate capacity for moderating intense winds, rainfall. A Burkhard score of 2 is given based on this low density.	(2,23 + 2,00) / 2 = 2,12
Water Flow Regulation and Runoff Mitigation	4		3,85	***Sealed surfaces***: 5 - [(23/100x5)] = 3,85	A sealed area of 23% of the total community garden area assessed in Berlin was measured. Average DIN run-off coefficients above 0.8 for almost all gardens, so sealed surfaces are almost completely impermeable. This 23% was then calculated as a value out of 5 to coincide with Burkhard scores.	3,85
				Area of vegetated surfaces: 77 / 100 x 5 = 3,85	A vegetated area of 77% of the total community garden area assessed in Berlin was measured. This 77% was then calculated as a value out of 5 to coincide with Burkhard scores.	
Erosion Prevention and Maintenance of Soil Fertility	3	2,64	3,85	***Sealed surfaces***: 5 - [(23/100x5)] = 3,85	A sealed area of 23% of the total community garden area assessed in Berlin was measured. Average DIN run-off coefficients above 0.8 for almost all gardens, so sealed surfaces are almost completely impermeable. This 23% was then calculated as a value out of 5 to coincide with Burkhard scores.	(2,64 + 3,85) / 2 = 3,25
				Area of vegetated surfaces: 77 / 100 x 5 = 3,85	A vegetated area of 77% of the total community garden area assessed in Berlin was measured. This 77% was then calculated as a value out of 5 to coincide with Burkhard scores.	
Noise Reduction	3	2,73			Only measured quantitatively in the questionnaire.	

Habitat/Supporting Services	***$\bar{x} = 4$***					
Maintenance of Genetic Diversity	4		(4,00 + 3,00) / 2 = 3,50	***Species richness***: 4,00	Berlin gardens had very good capacity for maintaining genetic diversity as species richnesses of 320 vascular plants species (spontaneous and ornamental species, excluding edible crops), 34 tree species and 31 faunal species (excluding livestock) were recorded. A Burkhard score of 4 is given based on these high richnesses.	3,50
				Species diversity: 3,00	Berlin gardens had high average Shannon diversity index scores of 3,35 for vascular plants species, 1,18 for tree species and 1,67 for faunal species. A Burkhard score of 3 is given based on these moderate diversities.	
Habitat for Species	4		4,00	***Habitat for Species***: 4,00	Habitat for species services are estimated using same Burkhard values obtained for maintenance of genetic diversity as species diversity and richness were used as indicators of microhabitat presence.	4,00
Cultural Services	***$\bar{x} = 4$***					
Recreation and Mental and Physical Health	4	3,51	4,00	***Recreation facilities and spaces***: 4,00	A total of 209 recreational facilities/activities/uses were recorded in Berlin community gardens. A Burkhard score of 4 is given.	(3,51 + 4,00) / 2 = 3,76
Tourism	3	2,73	4,00	***Number of visitors***: 4,00	A total of 5706 visitors per hectare of garden space was calculated for Berlin. A Burkhard score of 4 is given.	(2,73 + 4,00) / 2 = 3,37
Aesthetic Appreciation and Inspiration for Culture, Art, Design	4	3,99			Only measured quantitatively in the questionnaire.	
Spiritual Experiences and Sense of Place	4	4,05			Only measured quantitatively in the questionnaire.	

Ecosystem disservices

Table E3. Full calculations of final assessment scores used in Burkhard-type matrices for ecosystem disservices in Cape Town community gardens.

		Qualitative Data	Quantitative Data			Average of qualitative and quantitative scores used for final Burkhard value
Ecosystem Disservices	**Cape Town**	**SPSS Question Averages**	**Quantitative Averages**	**Calculations with Burkhard Scores**	**Calculation Rationale**	
Ecological Impacts	$\bar{x} = 1$					
Displacement of native by invasive species	1	1,88	0,35	***Invasive species richness***: 7 / 100 x 5 = 0,35	14 (7%) of the 191 floral species were classified as alien invasive. This 7% was then calculated as a value out of 5 to coincide with Burkhard scores.	(1,88 + 0,35) / 2 = 1,12
Economic Impacts	$\bar{x} = 1$					
Damage to infrastructure by nature (plant growth, microbial activity, corrosion, animal damage to structures, extreme events, etc)	1	1,13	0,02	***Damage to infrastructure***: 0,3 / 100 x 5 = 0,02	85 m^2 (0,3%) of the total 22710 m2 of community garden area assessed in Cape Town was measured as damaged infrastructure. This 0,3% was then calculated as a value out of 5 to coincide with Burkhard scores.	(1,13 + 0,02) / 2 = 0,58
Maintenance costs associated with urban vegetation/nature: removal of unwanted species (weeds, invasive species, animals housing in inappropriate places); planting and maintaining vegetation creates substantial costs	1	0,39	2,00	***Garden costs***: 2,00	An average monthly cost of €1013 per hectare of garden space was calculated for Cape Town community gardens, which translates to less than €1 per square meter for maintenance, repair and energy requirements. A Burkhard score of 2 is given based on these low totals.	(0,39 + 2,00) / 2 = 1,20
Health Impacts	$\bar{x} = 1$					
Allergies /respiratory problems caused by spread of pollen	1	0,00	(1,00 + 3,00) / 2 = 2,00	***OPALS potentials***: Vascular plants: 1,00 Trees: 3,00	Average OPALS for vascular plant species in Cape Town gardens were low as all gardens averaged below 5, thus received a Burkhard score of 1. OPALS for tree species in Cape Town were mixed as five gardens averaged above 5 and eight averaged below 5, thus on average received a moderate Burkhard score of 3.	2,00 / 2 = 1,00
Wild or semi-wild animals in urban green spaces can cause anxiety over fear of attack, safety or inconvenience	1	0,88	0,50	***Problematic species***: 10 / 100 x 5 = 0,50	5 (10%) of the total 44 animal species recorded were considered to be problematic and/or cause inconvenience. This 10% was then calculated as a value out of 5 to coincide with Burkhard scores.	(0,88 + 0,50) / 2 = 0,69

Psychological Impacts	***x̄ = 1***					
Certain smells, sounds or behaviours from plants and animals may be considered a nuisance or cause annoyance	0	0,00	0,00		No smells, sounds or behaviours from plants and animals considered a nuisance or causing annoyance were observed and quantified in any of the gardens. A Burkhard score of 0 was therefore given.	0,00
Aesthetic and hygiene impacts due to animal excrement	0	0,00	0,00		No animal excrement was observed and quantified in any of the gardens. A Burkhard score of 0 was therefore given.	0,00
Aesthetic unpleasantness due to vegetative litter from dense/overgrown vegetation, brownfields, wastelands	1	1,08				
Psychological feelings of insecurity / fear associated with overgrown or dark urban green spaces	0	0,00	0,00	***Area of non-illumination***: 0,00	Despite none of the community gardens having lights, and therefore 100% of the area non-illuminated, all of the community gardens in Cape Town were closed at night and not accessible to the public/gardeners. A Burkhard score of 0 was therefore given.	0,00
Vegetation can block views	2	1,29	2,30	***Gardens with blocked views***: 46 / 100 x 5 = 2,30	6 (46%) of the 13 community gardens in Cape Town stated they had vegetation that they considered to block views of the garden to the outside world in an undesirable way. This 46% was then calculated as a value out of 5 to coincide with Burkhard scores.	(1,29 + 2,30) / 2 = 1,80
General Impacts on Human Well-Being	***x̄ = 0***					
Presence of conserved or protected species can restrict the uses of an area, hindering benefit of those seeking to enjoy nature (Habitat competition with humans)	0	0,00	0,00	***Area of prohibited access in garden***: 0,00	No areas of prohibited or protected access were present in any gardens. A Burkhard score of 0 was therefore given.	0,00

Table E4. Full calculations of final assessment scores used in Burkhard-type matrices for ecosystem disservices in Berlin community gardens.

		Qualitative Data	Quantitative Data			Average of qualitative and quantitative scores used for final Burkhard value
Ecosystem Disservices	**Berlin**	**SPSS Question Averages**	**Quantitative Averages**	**Calculations with Burkhard Scores**	**Calculation Rationale**	
Ecological Impacts	$\bar{x} = 1$					
Displacement of native by invasive species	1	1,82	0,10	***Invasive species richness***: 2 / 100 x 5 = 0,10	6 (2%) of the 354 floral species were classified as alien invasive. This 2% was then calculated as a value out of 5 to coincide with Burkhard scores.	(1,82 + 0,10) / 2 = 0,96
Economic Impacts	$\bar{x} = 1$					
Damage to infrastructure by nature (plant growth, microbial activity, corrosion, animal damage to structures, extreme events, etc)	0	0,95	0,00	***Damage to infrastructure***: 0,00	None of community garden area assessed in Berlin had damaged infrastructure. Therefore, a Burkhard score of 0 was given.	0,95 / 2 = 0,48
Maintenance costs associated with urban vegetation/nature: removal of unwanted species (weeds, invasive species, animals housing in inappropriate places); planting and maintaining vegetation creates substantial costs	2	1,27	2,00	***Garden costs***: 2,00	An average monthly cost of €1607 per hectare of garden space was calculated for Berlin community gardens, which translates to less than €1 per square meter for maintenance, repair and energy requirements. A Burkhard score of 2 is given based on these low totals.	(1,27 + 2,00) / 2 = 1,64
Health Impacts	$\bar{x} = 1$					
Allergies /respiratory problems caused by spread of pollen	1	0,36	(1,00 + 4,00) / 2 = 2,50	***OPALS potentials***: Vascular plants: 1,00 Trees: 4,00	Average OPALS for vascular plant species in Berlin gardens were low as all gardens averaged below 5, thus received a Burkhard score of 1. OPALS for tree species in Berlin were high as eleven gardens averaged above 5 and two averaged below 5, thus on average received a high Burkhard score of 4.	(0,36 + 2,50) / 2 = 1,43
Wild or semi-wild animals in urban green spaces can cause anxiety over fear of attack, safety or inconvenience	1	0,45	0,50	***Problematic species***: 11 / 100 x 5 = 0,55	4 (11%) of the total 31 animal species recorded were considered to be problematic and/or cause inconvenience. This 11% was then calculated as a value out of 5 to coincide with Burkhard scores.	(0,45 + 0,55) / 2 = 0,50

Psychological Impacts	***$\bar{x} = 0$***					
Certain smells, sounds or behaviours from plants and animals may be considered a nuisance or cause annoyance	0	0,25	0,00		No smells, sounds or behaviours from plants and animals considered a nuisance or causing annoyance were observed and quantified in any of the gardens. A Burkhard score of 0 was therefore given.	0,00
Aesthetic and hygiene impacts due to animal excrement	0	0,41	0,40	***Animal excrement***: 8 / 100 x 5 = 0,40	1 garden (8%) of the 13 community gardens in Berlin had animal excrement that was observed. This 11% was then calculated as a value out of 5 to coincide with Burkhard scores.	(0,41 + 0,40) / 2 = 0,41
Aesthetic unpleasantness due to vegetative litter from dense/overgrown vegetation, brownfields, wastelands	1	0,91				
Psychological feelings of insecurity / fear associated with overgrown or dark urban green spaces	0	0,68	0,00	***Area of non-illumination***: 0,00	All gardens in Berlin were dark and not-illuminated with lights, except for Prinzessinnengarten that had some lighting in and around the on-site restaurant. Aa an average, a Burkhard score of 0 was therefore given.	0,68 / 2 = 0,34
Vegetation can block views	0	0,45	0,40	***Gardens with blocked views***: 8 / 100 x 5 = 0,40	1 (8%) of the 13 community gardens in Berlin stated they had vegetation that they considered to block views of the garden to the outside world in an undesirable way. This 8% was then calculated as a value out of 5 to coincide with Burkhard scores.	(0,45 + 0,40) / 2 = 0,43
General Impacts on Human Well-Being	***$\bar{x} = 0$***					
Presence of conserved or protected species can restrict the uses of an area, hindering benefit of those seeking to enjoy nature (Habitat competition with humans)	0	0,00	0,00	***Area of prohibited access in garden***: 0,00	No areas of prohibited or protected access were present in any gardens. A Burkhard score of 0 was therefore given.	0,00

Dissertation Dependent Bibliographic Data

Bibliographic Description

Duthie, Tristan Jane

Title: *An Assessment of Ecosystem Services and Disservices in Urban Community Gardens in Berlin (Germany) and Cape Town (South Africa).*

University of Leipzig, Dissertation (2018)

Pages: 330; Number of references: 302; Number of figures: 92; Number of tables: 60; Supplementary material: 1 CD with questionnaire descriptive statistics tables.

Short description of the work

The purpose of this research is to inventory the ecosystem services and disservices that are generated in urban community gardens, using Berlin and Cape Town as case study cities. Such work involved carrying out in-depth field surveys in community gardens across both cities to collect quantitative data, and questionnaires were also answered by garden users during field work visits to collect qualitative data. Quantitative and qualitative data on ecosystem services and disservices were then synthesised into final assessment outcomes using Burkhard-type matrices.

Kurze Beschreibung der Arbeit

Der Zweck dieser Forschung besteht darin, die in Urbane Gemeinschaftsgärten erzeugten Ökosystemleistungen und -nachteile zu erfassen, wobei Berlin und Kapstadt als Fallstudienstädte verwendet werden. Bei der Arbeit werden vertiefende Feldstudien in Gemeinschaftsgärten in beiden Städten durchgeführt, um quantitative Daten zu sammeln. Gleichzeitig werden Fragebögen zur Sammlung der qualitativen Daten von Gartennutzern beantwortet. Quantitative und qualitative Daten über Ökosystemleistungen und -nachteile werden dann unter der Verwendung von Matrizen vom Burkhard-Typ zu endgültigen Bewertungsergebnissen synthetisiert.