Assessing selected ecosystem services in urban green spaces in Bulawayo, Zimbabwe

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ABSTRACT

Urbanization has resulted in the building of numerous structures such as buildings and roads which reduces the amount of natural land. Urban space planning has taken this into consideration resulting in planned urban green spaces and remnant land within urban areas. Urban green spaces provide a number of ecosystem services which are beneficial to urban residents. This study sought to determine residents' use and perception of urban green spaces in Bulawayo, the second largest city in Zimbabwe, and to quantify and value four selected ecosystem services, i.e. carbon sequestration by urban trees, urban heat island amelioration, spiritual services and firewood provision. All ecosystem services were valued using local a variety of direct or substitutive methods.

Questionnaires were administered at green spaces to green space users to capture responses on reasons why they use green spaces and their perception of green spaces. Residents' responses showed that they appreciate green spaces as multi-dimensional spaces which provide a number of benefits for cultural and provisioning services. The role of the green spaces in providing regulating services was not well appreciated by the residents as they did not directly experience these benefits. An association was revealed between primary purpose of visit to urban green spaces and household income. Residents in areas of medium and high density housing visited green spaces on a daily basis, whereas those in more affluent, low density housing areas visited green spaces less often, i.e. a few times a month

Carbon sequestration rate was determined by measuring tree diameter within one year to determine increase in carbon sequestered. Bulawayo's urban green spaces sequester 3 290 t/C/yr valued at approximately $13 000/yr. There was a significant difference in carbon sequestration by urban trees between formal and informal green spaces with formal green spaces sequestering more carbon. Indigenous trees were shown to sequester more carbon than exotic trees and trees with bigger stem diameter were determined sequester more carbon than trees with small diameter.

The effect of urban green spaces on ambient temperature was determined by measuring ambient air temperature in green spaces and built up areas over six months. Urban green spaces in Bulawayo play a role in urban micro-climate regulation by reducing the ambient temperature in the green spaces as well as is

built up areas. The mean difference between green spaces and surrounding urban areas was up to 6^0C, with larger green spaces generally showing larger differences. The green spaces extend their cooling effect to surrounding areas thus reducing the temperatures in surrounding residential areas thus reducing the energy demand used for indoor cooling.

To determine why residents worship in green spaces, questionnaires were administered to congregation members to capture reasons why and how often they worship in green spaces, challenges faced by the congregants as well as assistance that can be given by the Bulawayo city council to improve the outdoor worship experience. Green spaces offer ideal places for worship in natural areas for congregants to be in touch with nature. The green spaces are also used by some congregations who ordinarily would worship in buildings but fail to do so due to lack of funds for rent or to purchase or construct a church building to use. The value of Bulawayo's green spaces spiritual services was determined to be $92.50/ha/yr.

Firewood provision was also determined by measuring tree diameter within one year to determine increase in fuelwood. The green spaces showed a significant difference in firewood production among sites. Formal green spaces were shown to produce more firewood as compared to informal green spaces and no difference was determined in growth rates between exotic and indigenous tree species. Bulawayo's green spaces produce 1.9t/ha/yr of firewood with an ecosystem service value of $340 to $490 /ha/yr.

These findings indicate the importance of urban green spaces in Bulawayo. They are multifunctional spaces, providing multiple ecosystem services. The local appreciation of the services provided by urban green spaces differs according to the type of service and location in the city. The value of services provided by green spaces is high, albeit not taken into account in planning decisions.

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ABBREVIATIONS

AA	- Automobile Association
AC	- Avoided costs
ANOVA	- Analysis of Variance
BCC	- Bulawayo City Council
CBD	- Convention on Biological Diversity
CBD	- Central Business District
CV	- Contingent Valuation
DBH	- Diameter at Breast Height
EKC	- Environmental Kuznets Curve
EMA	- Environmental Management Act
EN	- English Nature
ES	- Ecosystem Services
FGS	- Formal Green Spaces
FI	- Factor Income
GDP	- Gross Domestic Product
HP	- Hedonic Pricing
IGS	- Informal Green Spaces
MA	- Millennium Ecosystem Assessment
MCR	- Micro-Climate Regulation
RC	- Replacement Costs
SPSS	- Statistical Package for Social Sciences
TCM	- Travel Cost Method
TEEB	- The Economics of Ecosystems and Biodiversity
TEV	- Total economic valuation
UHI	- Urban Heat Island
USA	- United States of America
WTA	- Willingness to Pay
WTP	-Willingness to accept

Chapter 1

Introduction and Study Area

1.1 What are ecosystem services?

The environment plays a pivotal role in the livelihoods and well-being of humans directly and indirectly through improvement of the quality of life (Chiesura, 2004; Dwivedi et al., 2009). The ecosystem approach provides an important framework for analysing and acting on the link between people and the environment. The Convention on Biological Diversity (CBD) defines the ecosystem approach as 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way' (MA, 2005). The term ecosystem services (ES) has been coined to encapsulate the benefits derived by humans from the environment (MA, 2005; Daniel, et al., 2012). The concept of ecosystem services encompasses the delivery, provision, production, protection or maintenance of a set of goods and services that people perceive to be important (Chee, 2004).

Daily (1997) defines ecosystem services as conditions and processes through which natural ecosystems, and the species that inhabit them, sustain and fulfil human life. This was then developed further, with linkages to broader human well-being as opposed to just life. For example, Boyd and Banzhaf (2007 p.4) define ecosystem services as 'the components of nature, directly enjoyed, consumed, or used to yield human well-being', whilst Fisher and Turner (2008) define ES as the aspects of ecosystems utilized actively or passively to produce human well-being. The definition by Boyd and Banzhaf (2007) indicates that the ES are directly enjoyed. Fisher and Turner's (2008) definition differs with that by Boyd and Banzhaf (2007) because the latter indicate that ecosystem services can benefit human beings passively. Common across all these definitions is that they link the contribution of ecosystems to human well-being.

Costanza et al. (1997) separate the benefits that humans derive from ecosystems into goods (e.g. wood) and services (e.g. waste assimilation). de Groot et al. (2002) categorize ecosystem goods as a subset of ecosystem services and define goods as tangible material or products that result from ecosystem processes. Fisher and Turner (2008) support the MA (2005) which views ecosystem processes and functions as ecosystem services since humans benefit from them as well. Ecosystem functions, which are defined as the physical, chemical and biological processes occurring in ecosystems that are necessary for its self-maintenance, are also actively and passively utilized by humans (de Groot et al., 2012). Humans do not necessarily have to benefit directly from an ecosystem process or function for it to be termed an ecosystem service. Fisher and Turner's (2008) definition of ecosystem services states that services can be enjoyed passively, for example carbon sequestration, where there are net human benefits from this process by mitigating climate change. Boyd and Banzhaf (2007) differentiate benefits from services. They argue that a benefit is something that has an explicit impact on changes in human welfare such as food and recreation. The differentiation between intermediate services, final services and benefits is flexible because the desired service determines what is considered an intermediate service or a final service. In this study both goods and services will be referred to as ecosystem services.

Costanza et al. (1997) describe ecosystem services as limitational inputs to human welfare and state that without them, there would be no welfare. To realize the gain in welfare from ES, other forms of capital in the form of human and social capital may be required (Fisher and Turner, 2008) and the awareness that is important in managing ecosystem services for human benefit is often sensitive to changes in technology, preferences and tastes (de Groot et al., 2012). Humans continuously alter ecosystems to maximize the services enjoyed from ecosystems.

1.2 Ecosystem services categories

Ecosystem services have been categorized in various ways. They have been classified according to functional groups such as regulation, carrier, habitat, production and information services (de Groot et al., 2012). The MA (2005) categorizes ecosystem services into supporting, provisioning, regulating and cultural services. de Groot et al. (2002) have two similarities with the MA (2005), i.e. regulating services and production/provisioning. The categorization of ecosystem services is not hard and fast and any of the categories may be used depending on the purpose for categorizing the services as they are developed upon the specific context in which they are being used (Fisher and Turner, 2008). The categories from the MA (2005) will be used in this study as they are simple to use and widely acknowledged. A summary of the MA (2005) ES categories are presented in Fig. 1.1.

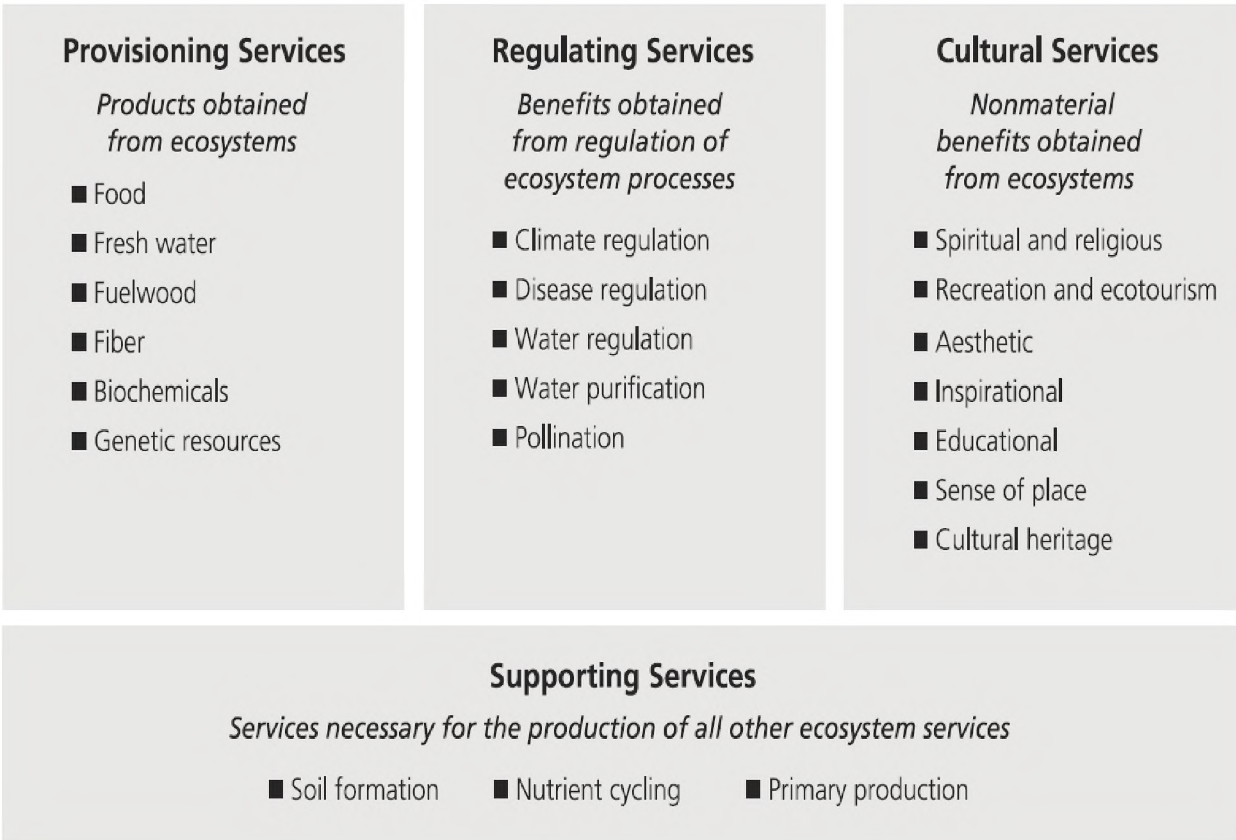

Fig 1.1: Ecosystem services categories. Adapted from MA: Ecosystems and their service (2005), p.9

1.2.1 Supporting services

Supporting services are an underpinning to all other services which enable production of all the three ecosystem services among the MA categories (MA, 2005). The MA (2005) distinguishes these ecosystem services from the other three because supporting services do not directly impact humans and/or the impacts are felt after a long time. Gobster et al. (2007) add that the contribution of supporting services to human livelihoods and well-being is usually indirect and complex. An example is that of nutrient recycling which results in the production of fibre such as wood. The process of nutrient recycling typically takes a long time and does not directly impact on humans, but the results of the nutrient cycling is plant growth which provides wood, shade, food, fruit, fibre and resins. Other examples of supporting services include, soil formation and primary production (MA, 2005)

1.2.2 Provisioning services

Provisioning services are tangible benefits that are obtained from ecosystems. Provisioning services include food, raw materials, fibre, biochemicals, genetic resources and freshwater (MA, 2005) which are essential for meeting human physical needs (Gobster et al., 2007; Egoh et al., 2012). An overlap may occur between provisioning services and other categories of ES. Fresh water, for example, is a provisioning service yet may also appear under regulating services due to the processes that occur for the fresh water to be produced. The freshwater, is considered as a provisioning service because it is the desired product fit for human use (MA, 2005). Provisioning services have been linked to poverty reduction because some of the benefits are used to generate income, such as the selling of food crops, or gathered resources such as firewood or medicinal plants (Kaoma and Shackleton, 2014).

1.2.3 Regulating services

Regulating services are services obtained from the regulation of ecosystem processes (MA, 2005), such as climate control, disease control, water purification, air quality maintenance, erosion control, waste treatment, regulation of human disease, biological control, storm protection, and pollination. Ecosystems control the climate at both micro- and macro-scales by, for example regulating the urban heat island effect in urban areas and absorbing greenhouse gases which affect the global climate, respectively (Schulidiner-Harpaz and Coll, 2013; Lin et al., 2015). Some services may be classified both as a regulating service and in another category. For example, climate regulation can have an impact over local and global climate over different time scales, thus will fall under the regulating service category and the production of oxygen from photosynthesis is categorized as a supporting service (MA, 2005).

1.2.4 Cultural services

Cultural services are non-material benefits that people experience from ecosystems, for example, cultural diversity, spiritual and religious values, knowledge systems, cognitive development, educational values, inspiration, aesthetic values, sense of place, cultural heritage values, reflection and recreation (de Groot et al., 2002; MA, 2005). Cultural services fulfil human non-consumptive needs as well as give value and essence to life (Chiesura, 2004). Most religions attach spiritual and religious values to elements of ecosystems such as mountains, trees and sacred sites (Murugan et al., 2008; Cocks et al., 2012). Cultural diversity is influenced by the diversity of ecosystems (Fagúndez and Izco 2016) as different cultures value different aspects of the environment, thus cultural services are more likely to differ among individuals as compared to perceptions of importance of food production (MA, 2005).

1.3 Ecosystem disservices

Alongside ecosystem benefits come the negative effects of ecosystem processes and functions. Fire, drought, disease, or flood, for example, have the potential to negatively affect human life, yet they are essential for ecosystem function, structuring landscapes, and providing vital regulatory functions (Lyytimaki et al., 2008). These have been termed ecosystem disservices (Lyytimaki et al., 2008; Shackleton et al. 2016). Some indicate that disservices are a result of both natural phenomena and anthropogenic activities (Lyytimaki and Sipila, 2009), whereas others propose they should be of ecosystem origin only (Shackleton et al. 2016). Ecosystem services and disservices are defined by humans who determine their value and importance (de Groot et al., 2002). Consequently, an ecosystem process or good, might be regarding as a disservice or service depending on the context (Lyytimaki and Sipila, 2009; Escobedo et al. 2011), which complicates management options (Shackleton et al. 2016).

Ecosystem disservices peculiar to urban areas include decomposition of structural wood by microbial activity, bird excrement accelerating corrosion of buildings, tree roots damaging pavements, trees falling on residents and property, harmful or parasitic species damaging species that are cared for resulting in economic loss, dense vegetation providing cover for criminals or tree pollen causing allergens (Lyytimaki and Sipila, 2009; Lyytimaki, 2014). Ecosystem disservices may be more pronounced due to disturbance of the ecosystems by human activity, for example, if a predator of a pathogen is eliminated from the ecosystem by human pest control activities the pathogen may grow to uncontrollable numbers resulting in extinction of other species (Dunn, 2010; Shackleton et al., 2016). In such cases, researchers may not only map the known disservices associated with different habitats, ecosystems or regions but also the change of the disservices resulting from changes to the habitats (Dunn, 2010).

The purpose of identifying and understanding ecosystem disservices is to enable development of strategies and plans to curb these negative effects so as to avoid negatively affecting human life or well-being. This would be an ideal situation, but in some instances, there is conflict between conservation and management of ecosystem disservices. One may find that the areas with the most species capable of disservices are in the same area with the species that need to be protected (Dunn, 2010). For example, having invasive species in an urban green space can increase biodiversity and carbon sequestration but decrease ecosystem services such as habitat or food provision (McKinney, 2008). In this scenario, one needs to consider other factors such as the magnitude of the effects caused by species (Dunn, 2010). In some instances, removal of invasive species is difficult even when there is appreciation about the harmfulness of the species (Lyytimaki and Sipila, 2009).

The effects of ecosystem disservices may be directly felt as was explained in the examples of disservices mentioned earlier or indirectly felt such as via economic costs. In an urban area, property value may decrease due to its proximity to an unmanaged green space which reduces the aesthetic value of the area, and large green spaces obstruct motorized transportation resulting in more money spent to create a route which goes around the green space as well as more funds being spent on the actual transportation using a longer route (Lyytimaki and Sipila, 2009).

Disservices may result from an undisturbed well-functioning ecosystem or from side effects of human activities (Lyytimaki, 2014).

1.4 Ecosystem services from urban green spaces

Urban areas are denoted by their concentration of human activities and associated infrastructure such as buildings, roads, water pipes, economic centres, and transport flows often resulting in problems such as noise, carbon emissions, increased ambient temperatures and deforestation (Morancho, 2003; Pickett et al., 2013). This has resulted in a growing emphasis on designing and building sustainable cities that limit or eliminate these problems (Pickett et al., 2013). Moving towards sustainable cities requires many changes, an important one of which is maintenance of and working with green infrastructure (Andersson et al., 2014), of which urban green spaces are an important component (Kambites and Owen, 2006; Tzoulas et al., 2007). The relevant ecosystem services provided by green infrastructure and urban greens spaces in a given city vary greatly depending on the environmental and socio-economic characteristics of each area. For example, barriers to reduce environmental extremes are important for coastal locations, air quality regulation is important for cities with heavy industrial pollution and urban parks are important for high density suburbs (Gomez-Baggethun and Barton, 2013).

The vegetation in a city serves many purposes for the urban population. This vegetation, which may be termed as urban forest, includes street trees, lawns, parks, forests and cultivated land (Bolund and Hunhammar, 1999; Kuruneri-Chitepo and Shackleton, 2011). Bensten et al. (2010) define urban forests as the sum of all tree-based vegetation in and near urban areas, as well as woodlands, public and private urban parks and gardens, urban nature areas, street tree and square plantations, botanical gardens and cemeteries. Urban forests are also defined by Dobbs et al. (2011 p. 2) as 'tree and soil components of an urban ecosystem and are characterized by their structure (e.g. volume), size (e.g. height and diameter), distribution (e.g. covers), and composition (e.g. number of species and soil types)'. This study focuses on vegetated public areas which will be referred to as public urban green spaces.

Most urban green space research focuses on clearly demarcated remnant or formal vegetation for example, parklands and urban forests (Rupprecht and Bryne, 2014). Informal green spaces (IGS) are green spaces which are neither formally recognized by government institutions or property owners as green space designated for agriculture, forestry, gardening, recreation or for environmental protection nor is the vegetation contained therein managed for any of these by the owner or local authority (Rupprecht and Bryne, 2014). The IGS definition provided by Rupprecht and Bryne (2014) excluded remnant vegetation, parks, ornamental plantings, e.g. flower beds, gardens, secondary growth urban forests and agricultural areas. These differ from formal green spaces (FGS) in how they are recognized, managed and developed. FGS result from intentions by the property owner or authority where the vegetation is intentionally planted and maintained, e.g. parks and gardens or intentionally preserved, e.g. remnant bush-land (Rupprecht and Bryne, 2014). This study covers ecosystem services from both formal and informal urban green spaces in Bulawayo, Zimbabwe.

Urban forests play a pivotal role in mitigating several urban problems through, for example, acoustic screens. Urban trees also attenuate noise pollution from construction, traffic and manufacturing through absorption, deviation, reflection and refraction of sound waves (Fang and Ling, 2003). The green spaces provide food in the form of fruits or the land may be used for urban agriculture which may supplement household income (Nkala et al., 2012). More functions of urban green spaces include water flow regulation and mitigation of run off through interception of rainfall by tree canopies which slows flooding effects (Bolund and Hunhammer, 1999). Urban trees regulate urban temperatures by moderating local temperatures and providing humidity and shade (Bolund and Hunhammer, 1999). This in turn results in less money being spent on air conditioning. Mangroves buffer cities from, floods (Costanza et al., 2006). Vegetation in green spaces also stabilizes the ground thus reducing landslides and protecting the cities from environmental extremes, provide medicines, protect biodiversity, facilitate waste treatment, crop pollination, protect cropland and pasture and promote health (Bolund and Hunhammar, 1999; Gomez-Baggethun and Barton, 2013; Nowak and Crane, 2002; Konijnendijk et al., 2006; Morancho 2003; Nowak et al., 2013; Zulu and Richardson, 2013; Dzhambor et al., 2014; Mensah et al., 2016).

In this view, urban green spaces and vegetation are an important contributor to the quality of urban life and health of the urban population (Bezák and Lyytimaki, 2011). Green spaces offer many benefits by performing several functions and providing several benefits in the same spatial area which contributes in achieving a number of urban policy aims and fulfilling the needs of a variety of stakeholder groups (Madureira et al., 2015).

1.5 Urban green space management

To enable urban green spaces to function optimally in providing ecosystem services, they need to be well maintained and appropriately managed, which is only possible if situated within a supportive policy environment (Chishaleshale et al., 2015). Interestingly, many cities and towns lack robust and integrated urban green space or tree management policies, which then limits allocation of personnel and budgets for their management and maintenance. For example, Treiman and Gartner (2004) reported that only 10 % of Missouri (USA) communities had urban tree management plans, whereas Stevenson et al. (2008) found that 27 % of the surveyed municipalities in Pennsylvania (USA) had one. In South Africa, Chishaleshale et al. (2015) found that only 32 % of the municipalities had tree policies, and only 7 % had urban tree management plans.

Maintenance of green spaces requires funds for paying personnel, acquisition and maintenance of equipment and machinery such as lawn mowers and chain saws as well as irrigation systems for the vegetation in the green spaces to survive (Chishaleshale et al., 2015). Regulatory authorities and other stakeholders need to identify and adopt initiatives and strategies which promote urban green spaces as well as identify and mitigate or eliminate barriers to urban green space use and management. Barriers include insufficient funding, low public support and interest, conflicts such as strict regulations, lack of political support, a lack of tools for community outreach and education and policies which support industry development whilst disregarding environmental issues (Li et al., 2005; Gwedla and Shackleton, 2015; Pearce et al., 2015). To address some barriers to urban green space management, authorities may take advantage of passive urban green space management which results in less degradation being made by users as well as less funding required to maintain the green spaces as Parliament Research Department (PRD) (2011) determined that capitalisation are the result of the poor state of Bulawayo's green spaces.

Green spaces should not only be well maintained but should also meet the needs of local residents. The most fundamental measure of that is that greens spaces are of adequate size and distribution. In Sheffield, the regulatory agency for urban green spaces, English Nature (EN), recommended that residents should live at most 300 m from the nearest green space. However, 64% of Sheffield households failed to meet this recommendation. The figure rose to 72% when considering only municipal parks recognized by the local council (Barbosa et al., 2007). Similarly in Beijing, the preferred distance from home to the nearest green space should be less than 400 m, but it was determined that the distance can be more than five kilometres (Herzele and Wiedemann, 2003). In South Africa, McConnachie and Shackleton (2010) revealed how urban green spaces was unevenly distributed within towns, with poor residents having very limited amounts and low proximities to urban green space in comparison to the more affluent areas.

Not only is distribution and abundance of urban green spaces important, but so too is ensuring that they provide a variety of ecosystem services to meet the needs of a diverse array of stakeholders and residents (Bezák & Lyytimaki, 2011; Shackleton and Blair, 2013). Urban green space ecosystem services are used and enjoyed by different user groups in different ways both passively and actively. Green spaces may hold different values to different groups of people based on their different social, cultural, environmental and economic contexts. Involvement of, and communication between policy makers, urban green space managers and users is essential to promote and support urban tree programs (Zhang and Zheng, 2012 in Pearce et al, 2015). It is important to assess people's beliefs and needs about the functions of urban green spaces (Shackleton and Blair, 2013; Madureira et al., 2015). Residents' opinions are important when planning for urban green spaces as they may differ from those of the authorities, who make decisions yet the residents are also users of green spaces. Residents can identify problems and benefits which are not always recognized by authorities (Rupprecht and Bryne, 2014).

Authorities should be encouraged to develop locally applicable strategies to address the needs of the local population. The actions of the residents and general public also play a major role in managing green spaces as trees may be removed or planted by the residents themselves. A one size fits all management strategy will not be successful because areas vary in size and condition of the urban forest, regional climate, available resources, institutional structure and resident's needs (Dwyer et al., 2003).

1.6 Urban green spaces and urban growth

Urban growth is associated with environmental deterioration though the relationship has been shown to be non-linear. The Environmental Kuznets Curve (EKC) hypothesis implies that when urban growth occurs, environmental quality initially deteriorates, then the environment degradation declines if higher level income is reached at which people afford and demand better environmental quality (Chen and Wang, 2013). Jim (2004, in Chen and Wang, 2013) states that rapid urbanization and simultaneous economic development pose both challenges and opportunities for green spaces. Economic development means there are available funds for caring for natural amenities such as trees and increasing urban population yet this also puts pressure on the land due to construction of required infrastructure to accommodate the increased population. By using this and other models to forecast and plan for urban development the relevant authorities need to plan how to balance a city's growth and urban green space provision for the city's residents. Beijing's urban area steadily encroached into green spaces, decreasing green spaces by 32 % between 1992 and 2002 (Li et al., 2005). In Ghana, Mensah (2014a) detailed the steady decline in urban green space in Kumasi, once regarded as the "Garden City". Gumbi et al. (2013) showed declines in woodlands surrounding Bulawayo, the study city for this project, of between 9% and 71% over the last two decades. Some of the reasons why infrastructure encroaches onto land designated for green spaces are severe conflicts between real estate development and public interest, weak enforcement of regulations which protect green spaces, industrial developments, lack of financing and management of green spaces and lack of vision (Li et al, 2005; Mensah, 2014b; Gwedla & Shackleton, 2015). Urban planners need to see green spaces as green infrastructure and give them the same priority as that given to other urban infrastructure. The valuation of urban ecosystem services offered by the green spaces can potentially help in providing a uniform unit of measure to be used in decision making when urban green space conservation is compared to economic development.

1.7 Valuation of ecosystem services

There has been a growing interest in the valuation of the benefits provided by ecosystems since the late 1960s (Hein et al., 2006). Kumar and Kumar (2008) state that ES provide valuable services to humankind and pose the question on how valuable these ecosystem services are. Valuation is the process of expressing a particular value (Blignaut and de Wit, 2004). Economic valuation can be defined as "the attempt to assign quantitative values to the goods and services provided by ecosystems" (Kumar and Kumar, 2008). Activities that do not generate monetary values are also taken into consideration in valuation (MA, 2005). In a neo-classical economic framework, something has economic value only if people consider it desirable and are willing to pay for it (Chee, 2004). The valuation concept is anthropocentric because humans, as the valuing agents, enable the translation of ecological structures and processes in value-laden entities (de Groot et al., 2012).

Value systems are 'intrapsychic constellations of norms and precepts that guide human judgement and action. They refer to the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions' (Farber et al., 2002 p. 1). Costanza (2000) defines value as 'the contribution of an action or object to user-specified goals, objectives or conditions. The value of an entity is either intrinsic or instrumental. The intrinsic value of an entity is the value it holds in contributing towards a sustainable and healthy ecosystem, whereas the instrumental values are anthropocentric in nature in that they reflect the value that an entity has in terms of fulfilling human preferences. The different type of values are summarized in Table 1.1.

When one considers the value of an entity one needs to distinguish between the use value and the exchange value. When considering the value one needs to recognize that economic and ecological values may be at odds with one another. The values that humans place on ecosystem functions, structures and processes may be different from the values of the ecosystem characteristics to species or the maintenance of the ecosystem. Generally, the value of ecosystem services concept does not capture values that are not reducible to individual welfare (Howarth and Farber, 2002).

Table 1.1: Types of value. (Adapted from Gilpin (2000))

Market value	the exchange value or price of a commodity or service in the open market
Intrinsic value	the value of entities that may have little or no market value, but have use value
Intrinsic, non-use	the value attached to the environment and life forms for their own sake
Existence value	the value attached to the knowledge that species, natural environments and other ecosystem services exist, even if the individual does not contemplate ever making active use of them
Bequest/vicarious values	a willingness to pay to preserve the environment for the benefit of other people, intra- and inter-generationally
Present value	the value today of a future asset, discounted to the present
Option value	a willingness to pay a certain sum today for the future use of an asset
Quasi-option value	the value of preserving options for future use assuming an expectation of increasing knowledge about the functioning of the natural environment

Monetary valuation has proven to be the convenient means of valuation since many choices involve the use of monetary values to assess alternate options, whilst also being a readily understandable currency for most societies (Blignaut and de Wit, 2004). Basic economic theory acknowledges four kinds of capital which are human, financial, manufacturing and natural. Most economies have focused on using the first three to transform natural capital into consumer products and services. Natural capital has historically been considered free and abundant which has led to ecosystem services falling outside the sphere of markets and being invisible in economic analysis (Chee, 2004). It has become commonplace for markets to be considered as the ideal institution for efficient allocation of resources and it is this belief which is the root for arguments that ecosystem services should be incorporated in the market economy so that they cease to be thought of as free and to facilitate the scarcity of the services to be reflected by a price (Herendeen, 1998 in Chee, 2004).

Proponents of valuation argue that making choices and trade-offs implies valuation and placing a monetary value brings about consistency in decisions and policy formulation, and that valuation acts as a channel to integrate ecological understanding and economic considerations to remedy the traditional neglect of ecosystem services in policy decisions. Valuation can also improve understanding of problems and trade-offs, be used directly to make decisions and demonstrate the distribution of benefits which will in turn facilitate the cost-sharing for management initiatives (Opschoor, 1998; de Groot et al., 2002; Turner et al., 2003; Chee, 2004; Daniel et al., 2012; Egoh et al., 2012; Mullaney et al., 2015). For example, estimating the economic benefits of trees can provide a measurable basis for maintaining municipal tree programs and planting more trees (Mullaney et al., 2015). As some advocates for the approach point out, valuation of ecosystem services should be one of the tools used in pursuit of conservation, though there is a risk that economic arguments will override and outweigh non-economic justifications for conservation which may be detrimental to the long term survival of ecosystems (Redford and Adams, 2009). Despite the potential utility of valuation studies in guiding trade-offs and decision making, they are very few from developing country context and almost none from Sub-Saharan Africa (Roy et al., 2012; Shackleton, 2012).

1.7.1 Methods of ecosystem services valuation

Valuation of ecosystem services is based on various methods which are dependent on the characteristic of each case, the ES to be valued and by data availability (MA, 2005). Total economic valuation (TEV) is the value determined from both use and non-use (existence) values and can either be direct or indirect (Turner et al., 2003), i.e., market values as well as the values placed on services by society, respectively.

The direct costs for ES is the market value of the price and reflects the value of goods and services at the margin (Noggard, 2000). It is an easy way of valuation as it relies primarily on the production or cost data which is relatively easy to obtain. This method is however questionable as it uses the value of an ecosystem service based on prices for services observed in real markets which do not value the actual services sufficiently (Noggard, 2000). Valuation at the margin becomes difficult when one considers whose demands or needs are to count and how the stakeholders are to be weighted.

Indirect valuation methods includes avoided costs, replacement costs, factor income, travel costs method, hedonic pricing, contingent valuation and group valuation. Avoided costs (AC) are costs which are avoided due to the presence of the service (Blignaut and de Wit, 2004). For example, flood control avoids property damage and waste treatment by wetlands avoids health costs (Farber et al., 2002).Replacement costs (RC) also known as restoration costs assess the cost by determining the cost of replacing or restoring the service after it has been damaged. This also aids to determine the value of services which could be replaced with human made systems, e.g. waste treatment by marshes which could be replaced by treatment plants. Some variations in the descriptions of the characteristics of the ecosystem services to be replaced could result in variation in the values determined (Blignaut and de Wit, 2004; Chee, 2004). Factor income (FI) is the cost based on ecosystem services which enhance income, e.g., natural water quality improvement results in more fish in a water body which in turn results in more income for fishermen (Farber et al., 2002).

The travel cost method (TCM) is a common approach for valuation of non-tradable services and it is determined from the amount paid to access a place or service of interest, the cost is an indication of the inferred value of the service (Blignaut and de Wit, 2004). This applies mostly to non-market goods where consumption is equivalent with the costs of travel to acquire it and is mostly applied to outdoor recreation, but it may be used for other ecosystem services (Blignaut and de Wit, 2004). TCM has the limitation that it may overstate or understate the aggregated value of an ecosystem service (Zandersen and Tol, 2009). For example, the closer an ecosystem is to a large human settlement, the more likely it is to have more frequent visitors and the more likely that the aggregated costs will be high and vice versa. If visitors fail to identify the importance of a certain characteristic of an ecosystem then that characteristic will be absent in the valuation of that ecosystem. This may occur for ecosystem services which are not visible such as pollination which are unlikely to form part of the site values (Chee, 2004).

Hedonic pricing (HP) relies on the idea that the value placed on a service is based on its characteristics (Garrod and Willis, 1999 in Chee, 2004).The service demand is reflected in the price people pay, for example, more money is paid for houses near green spaces (Blignaut and de Wit, 2004). However, identifying the suitable variables to measure can be challenging. For one to develop a model and estimate parameters relies on prior transactions which are typically absent from ecosystem service valuation (Chee, 2004).

Contingent valuation (CV) is a technique based on the amount that people are willing to pay to attain an ecosystem service if they do not own them or the willingness to accept payment to forgo them if they do own them (Chee, 2004; Blignaut and de Wit, 2004). The advantage of this technique is that is elicits monetary value for goods and services which do not have exchange value (Freeman, 1993 in Chee, 2004). Chee (2004) identifies several stages to CV which are: i. setting up the CV market, ii. obtaining the WTP or WTA amounts, iii. evaluating bias and calibrating responses, iv. estimating the mean and median WTP and WTA amounts, and v. aggregating the amounts and assessing validity of the study. The value of the ecosystem service determined using the CV method can be over or under-stated because respondents may genuinely believe that the ecosystem service is not worth anything, when respondents are opposed to paying due to a lack of understanding of what is being valued or as a protest against proposed payment (Carson et al., 2001). Hence the third stage indicated by Chee (2004) in the determination of CV is important to try and reduce the bias caused by the respondents' perceptions. Group valuation is based on a group agreeing on a price rather than an aggregation of individual preferences (de Groot et al., 2012; Blignaut and de Wit, 2004).

The lack of formal valuation of urban green spaces in Sub-Saharan Africa (Roy et al., 2012) may prevent them from being properly considered in the cost-benefit analyses of public urban planning policies (Morancho, 2003). Without quantitative assessments, these services tend to be ignored by those making land-use and land-management decisions, especially with the high opportunity costs associated with undeveloped land in urban areas. Figure 1.2 illustrates the relationship between ecosystems, their services, values, institution and decisions.

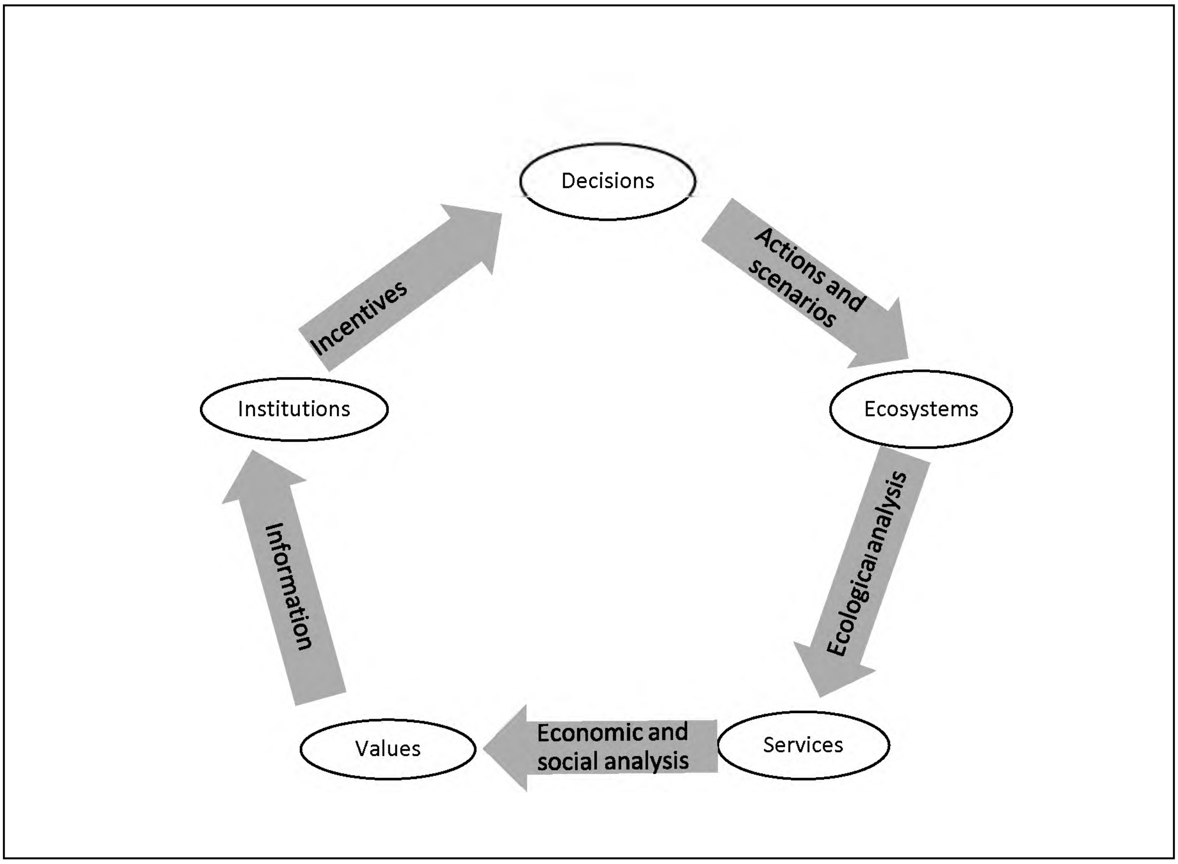

Fig 1.2: Ecosystem services in decision making. (Adapted from Daily et al. (2009, p.23))

The importance of urban green spaces can be understood and appreciated if the value of urban ecosystem services is determined. Costanza et al. (1997) estimated the world's ecosystem services at $33 trillion per year and have re-valuated the value to $125 trillion per year on the basis of updated unit values and changes to biome areas (Costanza, et al. 2014). In Guangzhou China, the value placed on urban green spaces based on recreation and amenity use was determined to be US$88.9 million per year, which was estimated to be six times the annual expenditure on urban green spaces and US$ 11 000 per year for removal of sulphur, nitrogen oxides and total suspended particulates (Jim and Chen, 2006; 2009). A value of US$22 500 was determined for Stockholm National Urban Park using the cost of replacing the seeding service of oak trees through human means (Hougher et al., 2006). Although ecosystem service values have been determined, most studies are done in Asia, Europe and North America (Morancho, 2003; Jim and Chen, 2006; Tong et al., 2007), with none as yet for urban green spaces in Sub-Saharan African cities. Ecosystem services are complex and non-linear in nature and thus gives challenges in ecosystem services valuation (Chee, 2004).

1.8 Objectives and justification

The aim of this study was to quantify and valuate a selection of ecosystem services from urban green spaces in Bulawayo, the second largest city in Zimbabwe. It included at least one service from each of the MA (2005) categories other than supporting services. A service from supporting services was not selected because supporting services are valued indirectly as the resulting provisioning, cultural and regulating services. Consequently, it included carbon sequestration by urban trees, local climate regulation (both regulating services), fuel wood provision (provisioning) and spiritual benefits (cultural services). The criterion for selecting the services was based on prior knowledge that the services apply to the city of Bulawayo as well as the ease of measuring the services. Fuel wood provision and local climate regulation were selected due to electricity shortages faced by the City of Bulawayo. Wood is used as fuel for cooking in domestic areas and the reduction of temperatures by forests in urban areas reduces power used. Carbon sequestration was selected due to the growing concern on global warming, considering that Bulawayo is a rapidly growing city whose activities such as manufacturing industries and motor vehicle movement release carbon dioxide. Spiritual services were selected because some of the Bulawayo residents are members of the churches which worship in open spaces who are at risk of being banned by local authorities from worshipping in open spaces (Tshuma, 2012).

There is no information on the value of urban forest ecosystem services for most Sub-Saharan African countries, including Zimbabwe, yet it is important to understand ecosystem dynamics and make decisions on how to accommodate green infrastructure and environmental protection in urban growth. The study will contribute in filling this knowledge gap and will aid in informing policy with regards to urban planning and management. Thus, whilst the study is specific to the City of Bulawayo in Zimbabwe it was aimed at determining a value for selected ecosystem services from urban forests in an African country. The objectives of the study were to:

1. Determine the use and perception of urban green spaces by residents in Bulawayo.
2. Quantify selected ecosystem services.
3. Value selected ecosystem services.

The study followed the framework used by Hein et al. (2006), which is applicable to natural and semi-natural environments. Following this framework, valuation of ecosystem services consists of four steps: (a) specification of the boundaries of the ecosystem to be valued; (b) assessment of the ecosystem services supplied; (c) valuation of the ecosystem services and (d) comparing the values of the services.

Valuation and analysis of an object requires definition of the object. Following this method, boundaries were set for ecosystem services to be valued in spatial terms i.e ecosystem services in urban Bulawayo. Using this framework, the ecosystem were selected as they provide the basis of the valuation. Ecosystem services were selected under the categories provisioning, regulation and cultural as explained previously. The selected ecosystem services were assessed in bio-physical terms using methods detailed later in the study. The ecosystem services were then valued using applicable valuation techniques which included market value, replacement cost method and travel cost method. The determined values were then compared using 1 ha of land as the common unit of measure amongst the ecosystem services.

This study is comprised of seven chapters. The first chapter is the introduction above. Chapters two to six each describe the methods used to identify, quantify and valuate the selected ecosystem services, followed by results, data analysis and discussions. The final chapter concludes the study.

1.9 Study area

1.9.1 Location and Climate

This study was conducted on green spaces in Bulawayo. This city was chosen as the study area because of its typical characteristics of an urban area and according to PRD (2011) report, the city's parks are in a poor state due to lack of capitalization, hence the need to determine the resident's use and perceptions of the place as well as the ecosystem services from the green spaces in order to make informed decisions about managing them. Bulawayo is the second largest city in Zimbabwe after the capital Harare. It is in the savannah biome and covers an area of 546 km^2 (Bulawayo Master Plan, 1981), but has since been expanding on the northwest part of the city.

Bulawayo is located in the southwest part of Zimbabwe (20°9'0" S, 28°35'0" E). It has a sub-tropical climate(PRD, 2011)). The city is at an altitude of 1 353 m and is characterized by warm summers (September-April) and cold winters (May-August). The summer average temperatures range from 14°C to 29°C and the winter temperatures range from 8°C to 20°C. The average precipitation for the wet months (December, January, and February) is 110 mm per month and the mean annual rainfall is 570 mm. The dry season is from May to September. The annual evapotranspiration rate is about 2 000mm (Meteorological office, Goetz Observatory, 2014).

1.9.2 Demographics

The city currently has a population of 653,377 and average natural increase is 1.8 % per annum. It has 165 345 households with an average size of about 3.9 persons (ZimStat, 2012). Bulawayo is divided into 29 wards which are a mixture of low, middle and high density suburbs as well as commercial and industrial areas (ZimStat, 2012). High density suburbs have been termed eastern suburbs due to their location within the city and low density suburbs have been termed western suburbs because they are located on the western side of Bulawayo. Ninety-one percent of residents live in modern brick buildings with the rest living in pole and clay houses in the city's outskirts or in informal housing units (ZimStat, 2012).

1.9.3 Green spaces in Bulawayo

Various green spaces such as parks, play grounds, golf courses, nature reserves and urban forests occur in the city and most roads are lined by trees (PRD, 2011). The Bulawayo city council's (BCC) housing and community services department (parks section) is responsible for maintenance of these green spaces. The council maintains the spaces by planting trees, removing dead and old trees as well as cutting grass (Ndlovu pers comm, 2014, 8 October 2014). Usually indigenous trees are planted in formal green spaces and exotic trees planted along roads. The city has a total of 47 formal and informal green spaces with the majority (22) in low density areas which also happen to be the biggest green areas. High density areas also have a similar number of green areas (19), middle (5), industrial (1) and none in the central business district (CBD). The green spaces, both formal and informal, make up a total area of 6.4% of the city area according to the Bulawayo master plan (1981). For this study an assumption was made that the master plan reflects the current layout of the city.

The city's green spaces are governed by the Bulawayo (Protection of Lands and Natural Resources) by-laws of 1975 which prohibit excavation, refuse dumping, construction as well as cutting down of trees from any municipal land. However, this does not stop residents from getting fuelwood from these areas. The city's waste management system occasionally faces challenges in collecting waste due to shortages of fleet and equipment (Mudzengerere and Chigwenya, 2012). This has since improved but residents still dump waste in undesignated areas such as in urban green spaces, resulting in land pollution which, in turn, could affect the growth of trees as well as the aesthetic value of the green spaces. Green spaces are used for defecation by a minority 1.3% of households within the city who do not have ablution facilities in their homes (Zimstat, 2012). Green spaces are also used by residents for urban agriculture, planting crops such as maize and vegetables to supplement food for household consumption as well as to sell to generate income (Nkala et al, 2012). This has diversified their urban livelihood portfolios, introducing a degree of entrepreneurialism (Moyo, 2015). Although essential for urban food security, urban agriculture has had negative impacts on the city's green space landscape (PRD, 2011).

1.9.4 Economic and social activity

The city’s location in the southwest of the country makes it a strategic link between South Africa and Botswana and the rest of the country. Its proximity to South Africa makes it ideal for trade, coupled by a well-established road and rail link to the rest of the country (PRD, 2011). Bulawayo has historically been known as the nation’s industrial hub and referred to as “the Manchester of Rhodesia” until a few years ago when the economic down-turn resulted in numerous industries shutting down (PRD, 2011). The majority 61% of the population is economically active i.e. 15-64 years of age (ZimStat, 2012). Of the 61% economically active population, 72% are employed. The main economic activities include heavy and light industrial manufacturing, public transport provision, public service and informal trade. Since Bulawayo is closely linked to the borders of South Africa, Botswana and Zambia some residents engage in cross border trading as a source of livelihood and some are full-time vendors (PRD, 2011). The unemployment rate was further increased as a result of about 18 000 jobs that were lost in 2015 after a court ruling that employers can fire employees by giving them three months’ notice (Mugabe, 2015). The literacy rate is 96% for ages 15 and above (ZimStat, 2012).

Bulawayo is a multicultural city which is inhabited by ethnic groups such as Ndebele, Shona, Tonga, Kalanga, Venda and Sotho. Leisure opportunities are offered in sports facilities, gardens, nature reserves, cultural and arts and crafts centres (PRD, 2011). Bulawayo experiences some problems faced by rapid urbanization with the increase in population resulting in a heavy strain on the city’s water and sanitation delivery system (PRD, 2011).

Chapter 2

Urban residents' use and perceptions of Bulawayo's green spaces

2.1 Introduction

Land-use planners in urban areas make provision for green spaces prompted by legislation and policy fulfilment or a particular vision of the future for their city and its residents (Broussard et al., 2008; Gwedla and Shackleton, 2015). Of concern is that the land-use planners may plan for, and establish urban green spaces without considering why residents use green spaces or how they perceive green spaces (Tyrvainen et al., 2007; Broussard et al. 2008). Green spaces are composed of grass, amenities, flowers, animals and trees all of which offer different benefits to users. Trees for example, meet various needs of different users within a community such as shade, aesthetics, provision of fruits, firewood and contributing to a sense of place. Five overlapping themes have been developed from accounts of human-tree relations based on interviewing users (Pearce et al., 2015). These are trees as; (i) producers of wanted and unwanted products, (ii) messengers of social information, (iii) reference points to places and experiences, (iv) significant elements in participant's lives and (v) important elements of the local community (Pearce et al., 2015). From these themes, one can view green spaces and trees therein as important elements in the lives of residents.

Users of green spaces may use them for a number of purposes and activities such as for biking, observing animals and plants, barbeques, horse riding, exercise, playing, dog walking, nature enjoyment, education, socialization and acquiring building material, freshwater and food (de Groot et al., 2012; Gobster et al., 2007; Egoh et al., 2012; Shackleton and Blair, 2013; Bhaktiari et al., 2014). In Melbourne, Australia, residents identified tree products such as flowers, food, landscape, light, shade, privacy, scent, sound (the way trees whisper in the wind), timber, compostable leaves and view trees as contributing in the fabric of their lives, not just as passive background objects (Pearce et al., 2015). Recently Palliwoda et al. (2016) emphasized that it is not just the broader green spaces and the elements within, but that visitors also interact with specific species in green spaces. With a lot of interaction between green spaces and humans, it is important to determine the residents' opinions and needs regarding green spaces in different settings. Cultural ecosystem services for example, are often well explained by the user who directly experiences them and planners would need to understand these experiences when planning for green spaces (Gobster et al., 2007). A high percentage (89%) of residents in Bari, Italy, felt that it was important to be involved in the planning of green spaces in their city (Sanesi and Chiarello, 2006).

Among users of urban green spaces there may be in-group conflicts occurring within a group using the green space for the same purpose (Bhaktiari et al., 2014). For example, users of public green spaces engaged in a picnic may complain of noise from other picnicking groups. In contrast, out-group conflicts occur when users doing totally different activities conflict with each other. In Denmark, 21% of green space users felt disturbed by activities carried out by other green space users and the elderly felt disturbed the most (Bhaktiari et al., 2014). Such information can only be acquired by interviewing the actual users of the green spaces. This should enable the authorities who design and manage green spaces to cater for the varying needs of the different users.

Challenges are faced in balancing the needs of residents and ecological considerations during planning. Faehnle et al. (2014) are of the opinion that ecological considerations tend to override residents' opinions and challenges are faced in determining at what point these opinions should be considered in decision making when establishing green spaces. Countries such as Finland have gone as far as legislating the participation of residents in green space planning but the legislation is still not clear on how exactly these opinions are then considered in planning (Faehnle, et al., 2014).

The increased use of information systems is increasingly shaping views and expectations about nature. Lyytimaki and Sipila (2009) assert that because of growing media use and urbanization, biodiversity becomes increasingly conveyed and received through media rather than by direct contact with nature which promotes growing detachment of urban residents from nature. To avoid this, green spaces should be made suitable for residents so as to encourage them to directly interact with, and in green spaces.

Not only are green spaces required to fulfil multiple functions, but their distribution and use is frequently uneven between different social groups. It is not unusual to find differences in use frequencies, or types of activities engaged in, between different wealth, age, gender or education classes or between residential areas (Ward et al., 2010; Shackleton and Blair, 2013; Ode Sang et al., 2016), which may themselves reflect different social groupings. The different residential density classes in Bulawayo i.e., high, medium and low, are characterized by different housing stand sizes, with the low density areas having the biggest stands. Due to the size of the stands and houses, the residential classes have been associated with household income and social standing, with the low density areas occupied by the wealthier and connected in society (McConnachie and Shackleton, 2010). The household income and the general living conditions of residents could be a determining factor in the use of green spaces. The 2012 census showed a 27% unemployment rate amongst the 61% economically active population within Bulawayo (Zimstat, 2012). Consequently, one would assume that the urban population, especially with low income, may make use of urban green spaces for provisioning services such as gathering food, fetching firewood or acquiring building material as shown by Kaoma and Shackleton (2014) so as to supplement their income by selling the goods or substituting bought goods.

Apart from the biophysical characteristics of green spaces, socio-demographic characteristics such as age and gender need to be considered when planning for green spaces. The gender that visits green spaces more often and the reasons why they visit green spaces need to be known, and vice versa. For example, in Los Angles (USA), Cohen et al. (2007) found that fewer women visited public green spaces than men, yet in Sheffield, England, age and gender were not found to be predictors of frequency of visits to a green space (Dallimer et al., 2014). Natural England Commissioned report (2011) showed that frequency of green space visits reduced with age and there was no difference in green space visit frequencies between male and female in Bristol, England.

The objectives of this chapter were to determine residents' use, perception and knowledge on functions of urban green spaces in Bulawayo. To understand the use and perception of urban green spaces I posed the following questions: (i) why do residents visit public green spaces in Bulawayo? (ii) How frequently do residents visit public green spaces in Bulawayo? (iii) Do users of green spaces in Bulawayo find urban green spaces in Bulawayo desirable?

I posed the following null hypotheses:

1. Primary purpose of visit is not influenced by household income.
2. Primary purpose of visit is not influenced by residential class.
3. Frequency of visits to public green spaces is not influenced by age and gender.
4. Frequency of visits to public green spaces is not influenced by residential class.
5. Frequency of visits to public green spaces is not influenced by household income.
6. Frequency of visits to public green spaces is influenced by having a home garden.
7. Desirability and adequacy of a green space are not influenced by residential class.
8. Residents do not prefer to visit green spaces in their residential class.
9. Benefits of green spaces perceived by residents are not influenced by household income.

2.2 Methods

A structured interview using questionnaires (Appendix 1) was conducted to capture information related to green space use, residents' perceptions of green spaces, benefits of green spaces as well as personal information. Structured interviews were conducted in English, Ndebele or Shona, by trained research assistants interviewing 385 users of green spaces in 12 green spaces in low, medium and high density areas. An online Raosoft sample calculator was used to determine the sample size (385 respondents) from the population of Bulawayo of 653 377 residents at 5% error margin, 95% confidence interval and 50% response distribution. The sample size was divided by 3 to determine the target number of respondents (≈105 respondents) from each class of residential area, i.e. low, middle and high density areas. Users who declined were replaced by interviewing the next user so as to get the desired number of responses.The green spaces were randomly selected from lists of areas in the different residential classes. Selected green spaces are shown in Table 2.1. The interviews were conducted between 10 am and 4 pm, for seven days a week, for 4 weeks in February 2015 to capture responses of users of the green spaces during the week as well as weekends. Questionnaires were administered at the sites to get responses from the actual users of the green spaces because use of telephone interviews may have captured responses from potential users of green spaces and not the actual users. The information was analysed using SPSS to determine frequencies of responses and Chi square analysis at 95% confidence interval was used to determine the correlation of various responses given by respondents.

Table 2.1: Green spaces sampled and number of responses from each green space.

Area	Housing density	Nature of green space	Number of respondents
Hillcrest	Low	Informal	36
Khumalo	Low	Informal	38
Famona	Low	Informal	36
Hillside	Low	Informal	37
Northend	Medium	Informal	26
Parddonhurst	Medium	Informal	30
Queens Park	Medium	Informal	25
Barham Green	Medium	Informal	31
Mpopoma	High	Informal	31
Nketa	High	Formal	30
Luveve	High	Formal	32
Nkulumane	High	Formal	31

Legend:		
1-Famona	5-Nkulumane	9-Paddornhurst
2-Hillside	6-Nketa	10-Khumalo
3-Hillcrest	7-Luveve	11-Northend
4-Bargam Green	8-Queenspark	12-Mpopoma

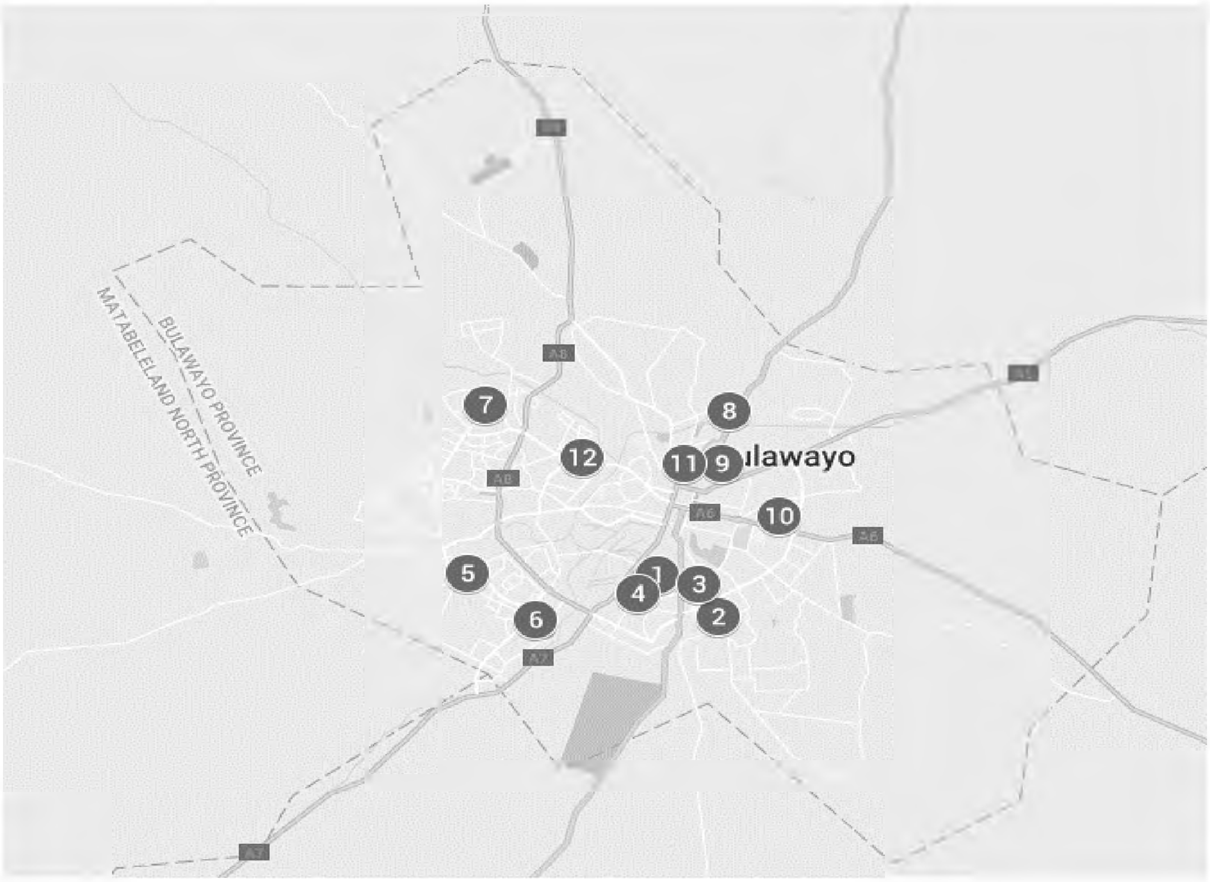

Fig. 2.1: Location of green spaces in Bulawayo

2.3 Results

2.3.1 Respondents' profiles

Of the respondents 44% were female and 56% were male, closely mirroring the city population determined during the 2012 census, i.e. 46% female and 54% male (ZimStat, 2012). The largest percentage of respondents (33.0%) were 19 to 25 years old followed by 27.5% who were 26 to 40 years old, 8.6% were 18 years and below and another 8.6% were between 41 to 65 years of age. The smallest percentage of respondents (0.3%) was above 65 years of age. Forty-seven percent of the respondents' highest level of education was secondary school, 21.3% had received tertiary education, 3.6% had gone as far as primary school and 1.8% had postgraduate qualifications. None of the respondents had lacked any formal education.

2.3.2 Reasons for visiting green spaces

Primary purpose of visit

The highest percentage of respondents (26.8%) identified their primary purpose of visiting the green space as relaxing with friends, 23.5% identified walking through to the other side and the smaller percentages identified were exercising (4.7%), collecting poles for fencing or building (0.6%) and collecting wild foods (0.4%). Accessing of provisioning services were thus low, and of cultural services was the highest (Fig. 2.2).

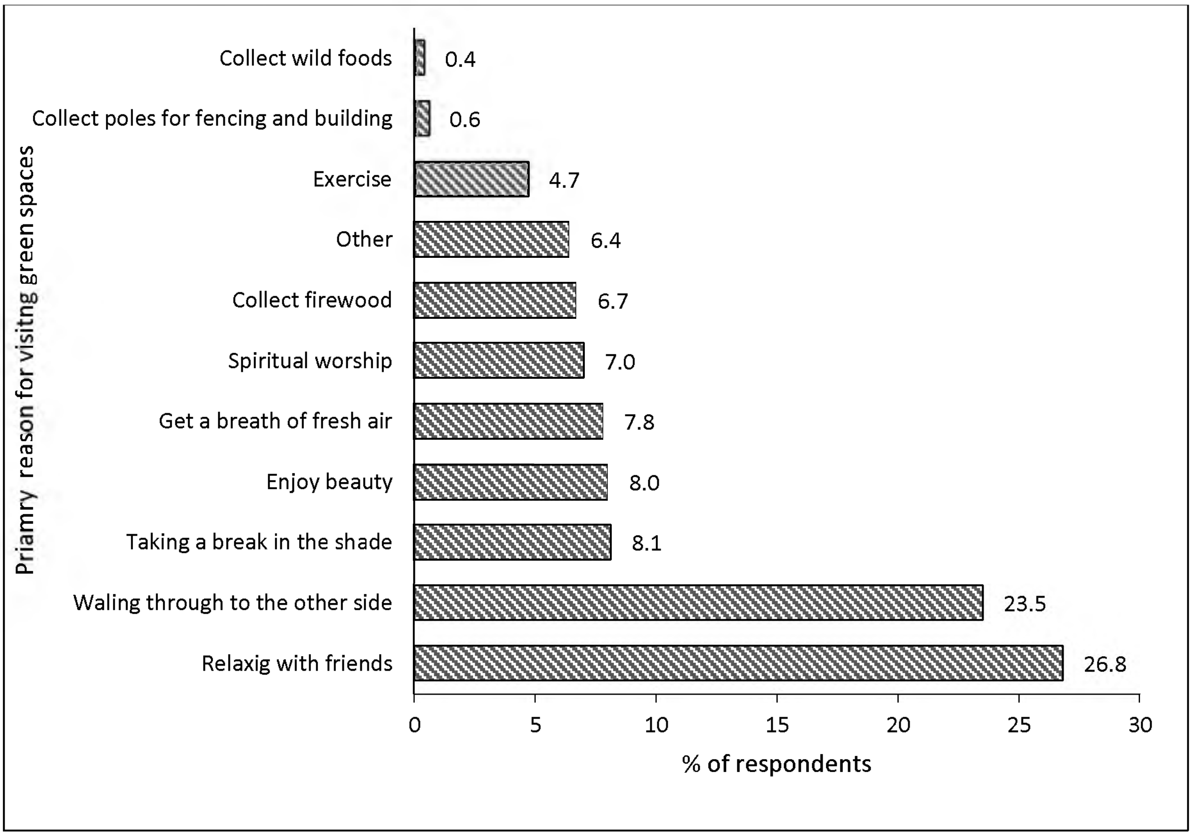

Fig. 2.2: Primary purpose of visit to green spaces

Some respondents did not reside in the area of the green space in which they were visiting, in other words, they had travelled some distance to access that specific green space. The reasons for this were for its beauty (33.9%) and they were well maintained (20.6%). Twenty-nine percent of the respondents mentioned quietness as a reason for visiting the green space. Very few respondents (1.1%) visited a more distant green space primarily because of its safety (Fig 2.3).

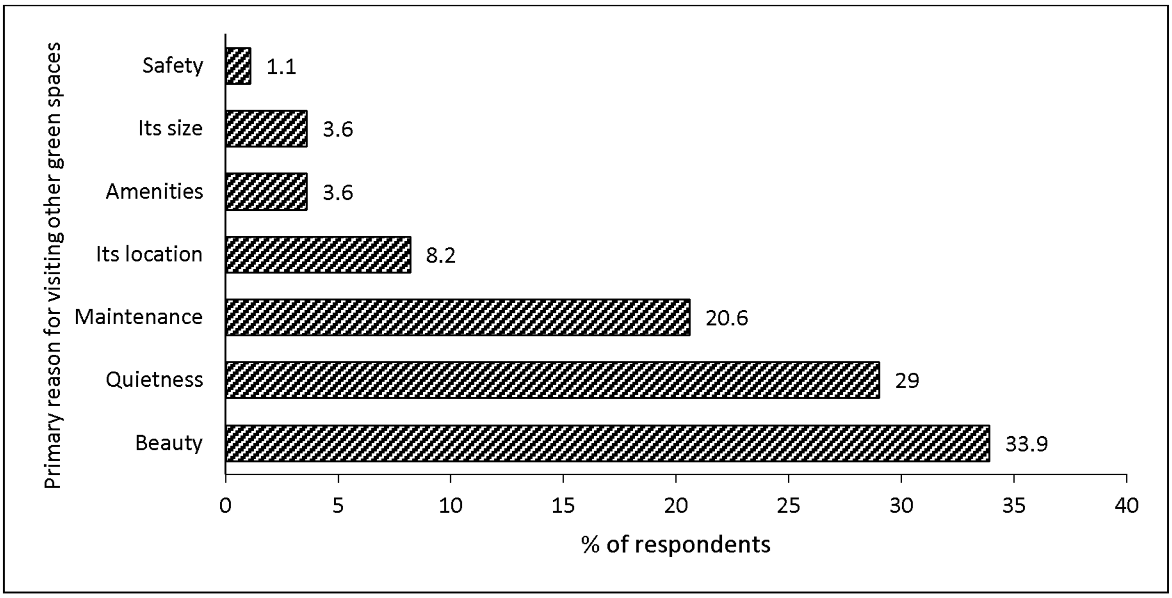

Fig. 2.3: Reasons why respondents are attracted to other green spaces

<u>Primary purpose of visit and household income</u>

An association was determined between primary purpose of visit and household income ($\chi 2$ =165.8, df = 44, p<0.05). Amongst the different income groups per month, the highest percentages of residents with income \$401 to \$2 000 (13.0%) used the green spaces mostly for walking through to the other side. A similar percentage (12.9%) of those with income \$401 to \$2 000 used green spaces for relaxing with friends and family. Walking through to the other side had the second highest responses for those earning \$101-\$400 (6.3%) and \$401-\$ 2 000 (9.8%). Across all income categories, the collection of wild foods was very low ranging from 0% to 0.4%, similarly across all residential classes, collection of poles for fencing and building ranged from 0% to 0.3%. About five percent of those who went to green spaces primarily to worship fell in the \$1-\$101 income category. The trend showed a decrease in respondents as the income increased with those earning above \$2 000 not going to green spaces primarily to worship. An average of about 2% of residents in all household income categories visited green spaces to enjoy the beauty (Table 2.1).

Table 2.1: Relationship between primary purpose of visit and income class (% respondents)

		Household income per month ($)				
		>1, ≤101	>101- ≤400	>400, ≤2000	> 2000	Total
Primary purpose of visit	Walking through to other side	3.1	6.3	13	1.1	23.5
	Relaxing with friends and family	2.7	9.8	12.9	1.4	26.8
	Exercise	1.0	2.0	1.0	0.7	4.7
	Spiritual worship	5.2	1.3	0.5	0.0	7.0
	Take a break in the shade	1.4	2.2	3.8	0.7	8.1
	Get a breath of fresh air	0.9	3.6	2.8	0.5	7.8
	To enjoy beauty	2.0	2.4	1.5	2.1	8.0
	To collect firewood	0.5	3.9	2.3	0.0	6.7
	To collect wild foods	0.0	0.4	0.0	0.0	0.4
	To collect poles for fencing or building	0.3	0.0	0.0	0.3	0.6
	Other	0.5	2.7	3.2	0.0	6.4
Total		17.6	34.6	41.0	6.8	100.0

<u>Primary purpose of visit in relation to residential area</u>

There was an association between primary purpose of visit and the residential area ($\chi2$ =109.3, df = 22, $p<0.05$). Residents in high density housing areas went to green spaces to relax with friends and family (18.4%), while respondents in medium (10.4%) and low density (8.8%) areas went to green spaces whilst walking across to the other side. The least percentages (0% to 0.4%) for all three residential classes indicated collecting wild fruits and collecting poles for fencing or building. About 4%

of those who went to green spaces primarily to collect firewood were from low density areas and a decrease in respondents was noted as residential density increases (Table 2.2).

Table 2.2: Relationship between primary purpose of visit and residential density class (% respondents)

		Residential density class			
		High	Medium	Low	Total
Primary purpose of visit	Walking through to other side	4.3	10.4	8.8	23.5
	Relaxing with friends and family	18.4	3.4	5.1	26.8
	Exercise	2.5	1.1	1.0	4.7
	Spiritual worship	2.6	2.5	1.9	7.0
	Take a break in the shade	3.7	2.8	1.7	8.1
	Get a breath of fresh air	3.7	1.7	2.4	7.8
	To enjoy beauty	2.0	2.2	3.8	8.0
	To collect firewood	1.1	1.4	4.2	6.7
	To collect wild foods	0.0	0.0	0.4	0.4
	To collect poles for fencing or building	0.3	0.0	0.3	0.6
	Other	0.0	4.5	1.9	6.4
	Total	38.5	30.1	31.4	100.0

2.3.3 Frequency of visits to green spaces

When asked about the frequency of their visits to green spaces, 23.7% of the respondents indicated visiting green spaces daily, 22.6% visited two to four days a month, 21% visited on most weekends, 18.3% visited one to two times a month, whilst 0.8% responded that this was their first time visit (Fig 2.4). No relationship was found between frequency of visit to green spaces and age ($\chi2$ =14.3, df = 24, p>

0.05), neither was there a relationship found between frequency of visit to green spaces and gender ($\chi 2 = 8.3$, df = 6, $p > 0.05$).

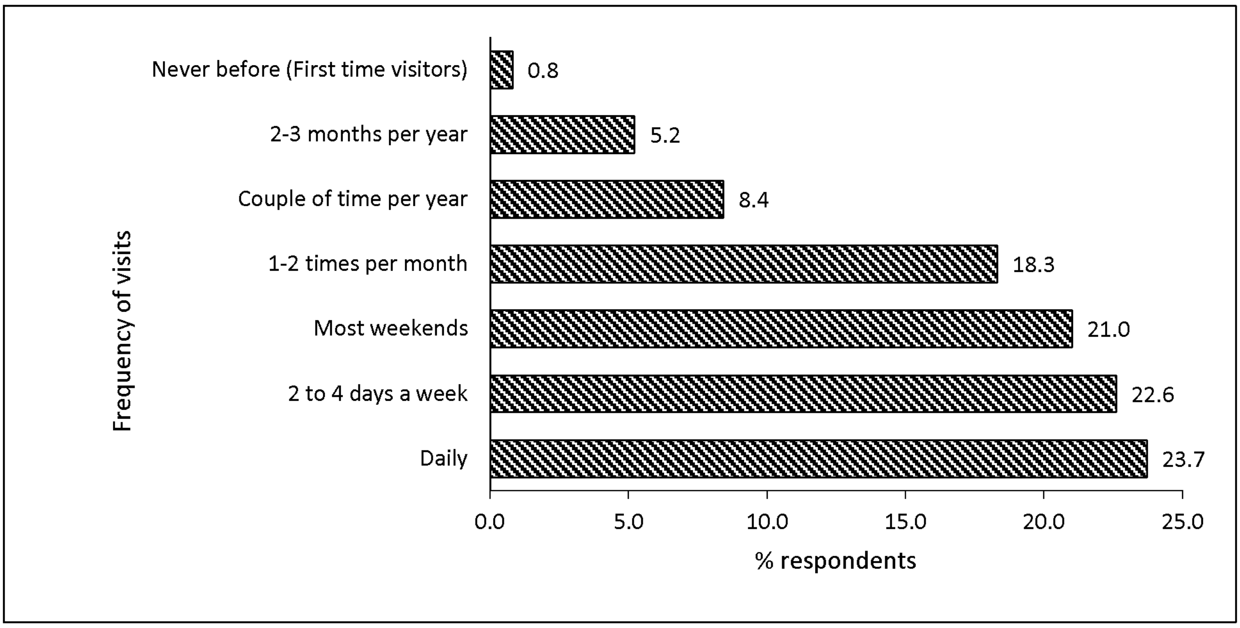

Fig. 2.4: Frequency of visits to green spaces

Frequency of visits and residential density class

A relationship was determined between frequency of visits and residential density class ($\chi 2 = 27.0$, df = 12, $p < 0.05$). High density areas did not have first time visitors and first time visitors recorded the lowest percentages across all residential classes. The highest percentage of respondents in the high density areas (10.4%) visited green spaces daily, as was also the case in the medium density areas (9.2%), whilst and the highest in low density areas visited green spaces two to four days a week and one to two times a month (8.5%) (Table 2.3).

Table 2.3: Relationship between frequency of visits and residential class

Frequency of visits	Residential class			Total
	High	Medium	Low	
Daily	10.4	9.2	4.1	23.7
2-4 days	7.7	6.6	8.5	22.6
Most weekends	10.7	4.6	5.7	21.0
1-2 times per month	4.9	4.9	8.5	18.3
2-3 months	2.2	1.1	1.9	5.2
Couple of times per year	2.7	3.5	2.2	8.4
Never	0.0	0.3	0.5	0.8
Total	38.5	30.1	31.4	100.0

Relationship between frequency of visit and household income

There was no relationship between frequency of visit and household income ($\chi2$ =21.7, df = 24, p> 0.05). The highest percentage response range (8.5% to 10.3%) was observed for income categories $101 to $400 and $401 to $2 000 for visit frequencies: daily, two to four days and most weekends. Those with income above $2 000 had the least percentages for each frequency of visit (Table 2.4)

Table 2.4: Relationship between frequency of visit and household income (% respondents)

		Household income per month ($)				
		1-100	101-400	401-2000	Above 2000	Total
How often do you visit this green space?	daily	2.8	8.5	8.5	2.1	22.1
	2-4 days	6.3	10.3	9.9	0.5	26.8
	Most weekends	2.8	8.9	10.3	1.9	24.4
	1-2 times per month	2.8	1.9	7.5	0.9	13.1
	2-3 months/year	1.0	2.4	1.3	0.5	4.7
	A couple of times/ year	1.9	2.3	2.8	0.9	8.0
	Never (First time visitors)	0.0	0.5	0.5	0.0	0.9
Total		17.6	34.8	40.8	6.8	100.0

Relationship between frequency of visits to green spaces and having a home garden

Residents were asked if they had gardens at home and 75% indicated that they did. No relationship was determined between having a green space at home and frequency of visits to public green spaces ($\chi 2 = 3.2$, df = 6, $p>0.05$) (Table 2.5).

Table 2.5: Relationship between frequency of visit and having a home garden (% respondents)

		Frequency of visiting green spaces							Total
		Daily	2-4 days	Most weekends	1-2 * times /month	2-3 months/ year	Couple times/ year	Never before (First time visitors)	
Do you have a green area/garden at your home in Bulawayo?	Yes	18	19.5	18.8	9.1	3.4	5.3	0.9	75
	No	4.1	7.3	5.6	4.0	1.3	2.7	0.0	25
	Total	22.1	26.8	24.4	13.1	4.7	8.0	0.9	100

2.3.4 Other green spaces visited

Apart from the green spaces they were interviewed in, residents were asked if they visit other green spaces and 55.3% of respondents indicated that they did. Of these, 47% visit Centenary Park, 22% visit hillside dams and 3% visit Nketa and Bradfield (Silver Queen) green spaces (Fig. 2.5).

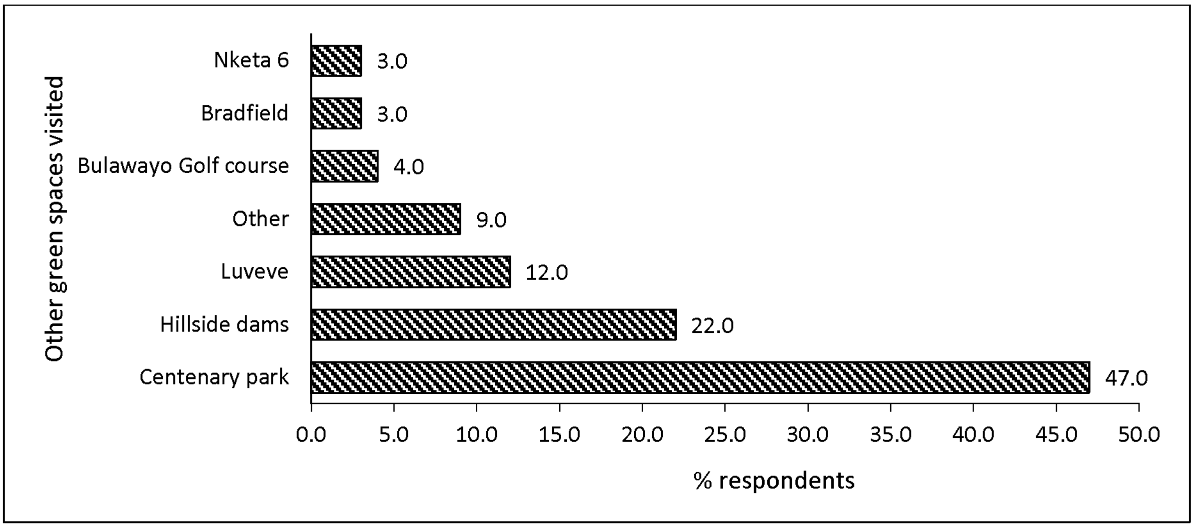

Fig. 2.5: Other green spaces visited

2.3.5 Desirability of, and preference for green spaces

A Likert scale was used to determine the residents' opinions on the desirability of the green spaces. Almost half (49.7%) of the participants were of the opinion that the green spaces are not well maintained (Table 2.2). When asked if the green space had enough amenities, the largest fraction of respondents (58.8%) strongly disagreed and only 2.6% strongly agreed. About 38.0% of respondents agreed that the green space was suitable for relaxation while 10.1% strongly disagreed. A large percentage of respondents (37.5%) agreed that they felt safe in the green space, whilst 17.2% strongly disagreed (Table 2.6).

Table 2.6: Residents perceptions of green spaces (% of respondents)

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
This green space is well maintained	4.3	13.7	10.9	21.4	49.7	100.0
This green space is a nice place to relax	15.2	38.0	20.4	16.3	10.1	100.0
This green space is too small	12.7	18.9	33.9	24.7	9.8	100.0
This green space has enough trees	11.8	35.9	25.9	17.2	9.2	100.0
This green space has enough amenities	2.5	7.6	11.5	19.6	58.8	100.0
Many people come to this green space	17.8	28.7	37.9	11.4	4.2	100.0
I feel safe in this green space	14.3	37.5	19.0	12.0	17.2	100.0
Local people respect this green space	3.9	11.4	22.6	41.8	20.3	100.0
This green space should be used for residential stands	9.5	5.6	9.2	7.1	68.6	100.0

The highest percentage from all residential classes strongly disagreed that their green spaces were well maintained with 47.8% in high density suburbs, 56.1% in medium density and 45.7% in low density suburbs. The highest percentage of respondents in low (39.5%) and medium density (46.2%) areas were neutral when asked if the green space had adequate amenities and 29% strongly disagreed in high density suburbs. Most respondents agreed that the green space was safe across all residential classes. The highest percentage of respondents in low and medium density areas, 39.4% and 46.2% respectively, were neutral when asked if the green space was too small and 29% disagreed in high density suburbs (Table 2.7).

Table 2.7: Green space desirability and residential class (% of respondents)

	Suburb density	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
Green space maintenance	High	4.3	13.7	11.7	22.5	47.8	100.0
	Medium	3.7	9.4	10.3	20.6	56.1	100.0
	Low	5.7	18.1	9.5	21.0	45.7	100.0
	Total	4.4	13.7	10.7	21.3	49.9	100.0
Adequacy of amenities	High	17.4	16.7	20.3	29.0	16.7	100.0
	Medium	11.3	24.5	46.2	13.2	4.7	100.0
	Low	8.3	16.5	39.5	29.4	6.4	100.0
	Total	12.3	19.2	35.3	23.9	9.3	100.0
Safety	High	22.0	41.1	17.0	8.5	11.4	100.0
	Medium	12.3	33.0	17.0	12.3	25.5	100.0
	Low	6.4	37.6	22.9	16.5	16.5	100.0
	Total	13.6	37.3	19.0	12.4	17.8	100.0
Green space size	High	17.4	16.7	20.3	29.0	16.7	100.0
	Medium	11.3	24.5	46.2	13.2	4.7	100.0
	Low	8.3	16.5	39.4	29.4	6.4	100.0
	Total	12.7	19.0	34.0	24.4	9.9	100.0

2.3.6 Adequacy and size of green spaces

More than half (58.2%) of the respondents felt that their residential areas had enough green spaces and 56.1% felt that Bulawayo as a whole had enough green spaces (Fig. 2.6). No relationship was determined between the residential class and opinions on adequacy of green spaces ($\chi 2$ =1.2, df=2, p>0.05). Most respondents from all residential classes felt that the green spaces in their residential areas were adequate.

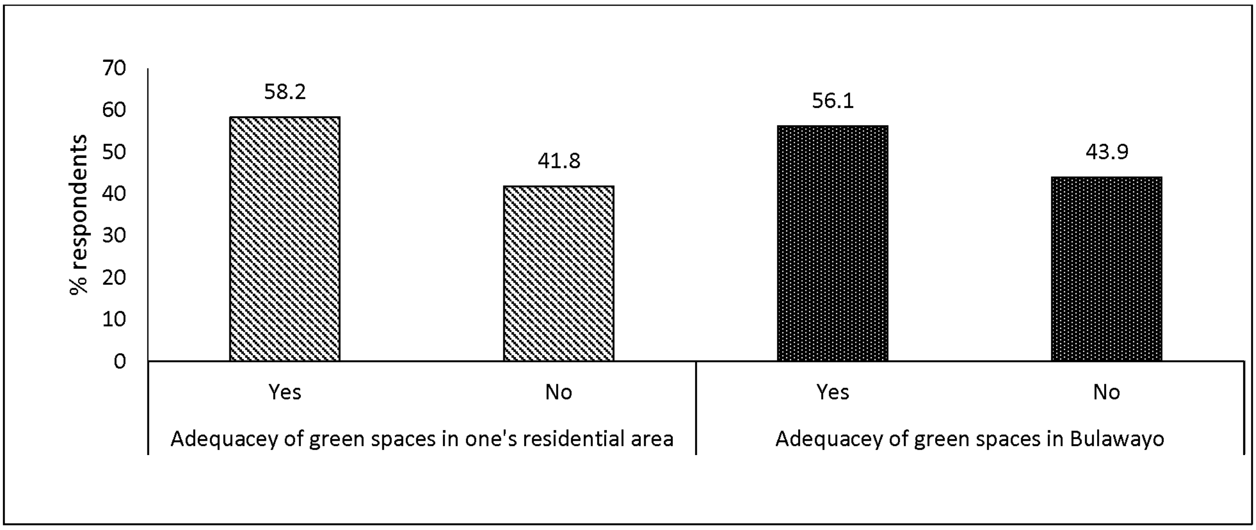

Fig. 2.6: Adequacy of green spaces (% respondents)

No relationship was determined between green space size and residential class ($\chi 2 = 24.16$, df = 20, $p > 0.05$). The largest mean green space area was in high density areas (13.2±16.8 ha), followed by low density areas (9.9±6.2 ha) (Table 2.8).

Table 2.8: Sizes of green spaces

Nature of green space	Name of green space	Size of green space (ha)	Mean area per residential class (ha)
Low	Hillcrest	14.9	9.9±6.2
	Khumalo	15.5	
	Famona	4.2	
	Hillside	4.8	
Medium	Northend	5.7	6.1±1.5
	Parddonhurst	4.3	
	Queens Park	7.9	
	Barham Green	6.5	
High	Mpopoma	3.9	13.2±16.8
	Nketa 6	5.9	
	Luveve	4.7	
	Nkulumane	38.3	

Relationship between the respondents' place of residence and location of green space

Participants were asked in what suburb they resided since it was not given that the suburb of the green space they were visiting is the suburb in which they reside. Among the residents residing in high density suburbs, 86.2%, 3.2 % and 11.9% visited green spaces located in high density, medium density and low density suburbs, respectively. Among those residing in medium density suburbs, 10.5%, 84.4% and 8.3% visited green spaces located in high, medium and low density suburbs, respectively. Among the respondents residing in low density areas, most (79.8%) visited other green spaces in low density areas, whilst 11.4% and 3.4 % visited medium and high density areas, respectively. About one percent of the respondents in medium density green spaces resided in the central business district (CBD) and no respondents from high and low density green spaces resided in the CBD (Table 2.9). The highest percentage of responses for each residential class showed that they preferred visiting green spaces in their own residential class ($\chi 2 = 421.12$, df = 6, $p<0.05$).

Table 2.9: Relationship between the respondent's place of residence and location of green space (% respondents)

Green space suburb	**Residential suburb of respondent**				**Total**
	High	Medium	Low	CBD	
High	86.2	10.4	3.4	0.0	100.0
Medium	3.2	84.4	11.4	1.1	100.0
Low	11.9	8.3	79.8	0.0	100.0

2.3.7 Benefits of green spaces

Residents were asked about the benefits of having green spaces in the city. The most frequently mentioned benefits were; beautifying the city (53.5%), provision of firewood (50.9%), provision of a place for relaxation (48.6%) and attracting tourists (43.1%). The least identified benefits of green spaces were; helping to create local identity (8.8%), allowing water to go into the soil (7.8%), provision of wild food (6.5%), helps reduce energy costs (6.0%), traps dust (5.2%) and provision of timber (3.9%) (Fig. 2.7).

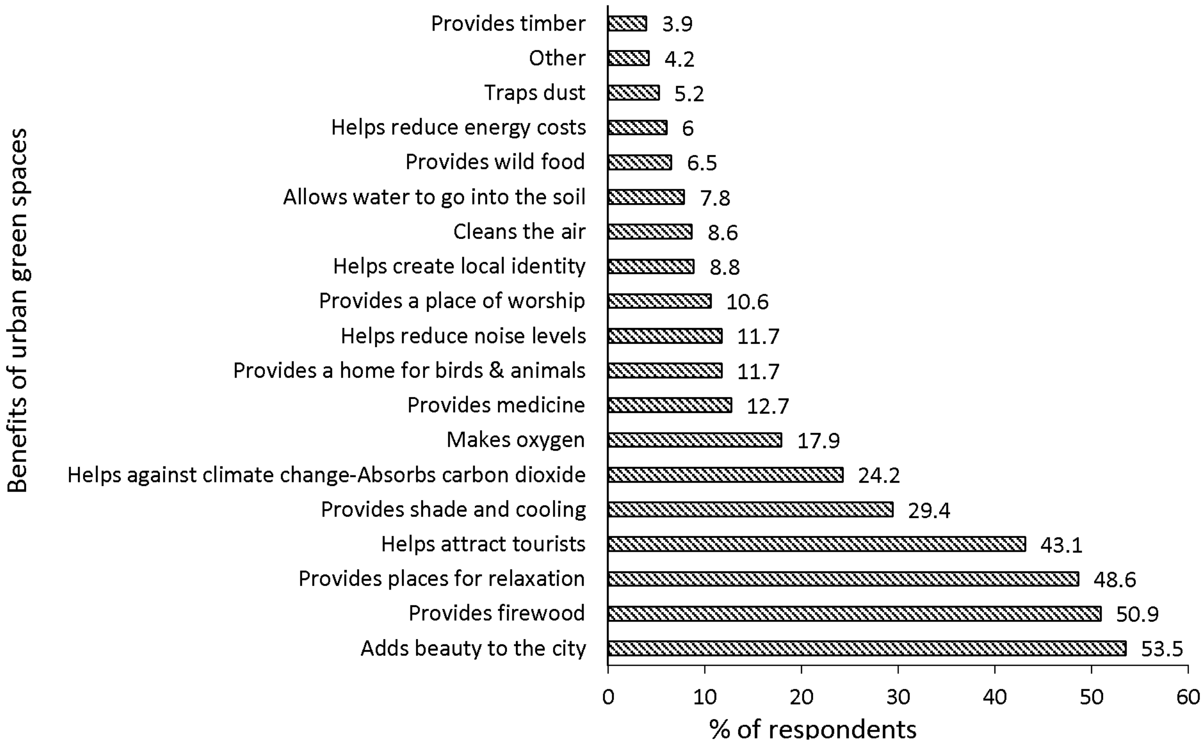

Fig. 2.7: Benefits of green spaces

<u>Relationship between perceived benefits and household income</u>

A relationship was determined between household income and: i) adding beauty to the city ($\chi2=34.03$, df=4, $p<0.05$), ii) firewood provision ($\chi2=12.02$, df=4, $p<0.05$), iii) providing a place for relaxation ($\chi2=16.02$, df=4, $p<0.05$), and iv) helps against climate change ($\chi2=11.931$, df=4, $p<0.05$).There was no relationship between household income and providing shade and cooling ($\chi2=28.32$, df=4, $p>0.05$) (Table 2.10).

Table 2.10: Relationship between benefits and household income (% respondents)

Perceived benefit of green spaces	Household income per month ($)				
	1-100	101-400	401-2000	Above 2000	Total
Provides beauty to the city	11.5	36.0	49.6	2.9	100.0
Provide firewood	18.7	39.3	33.9	8.0	100.0
Provides a place for relaxation	14.6	35.5	47.3	2.7	100.0
Provides shade and cooling	7.3	29.0	50.7	13.0	100.0
Attracts tourists	9.6	35.7	53.1	1.7	100.0
Helps against climate change by absorbing oxygen	9.1	36.4	53.0	1.5	100.0

About half (49.6%) of respondents with household income $401 to $2 000 felt that green spaces beautified the city, followed by those with income $101 to $400. A similar trend was noted for providing a place for relaxation, providing shade for cooling and attracting tourists and helping against climate change. Those with income above $2 000 did not feel that the green spaces attracted tourists and helped against climate change. The highest response for perceived benefits in the $1 to $100 household income category was provision of firewood followed by provision of a place for relaxation.

2.4 Discussion

2.4.1 Residents' use of green spaces

Bulawayo residents use green spaces mostly for cultural services such as relaxing and admiring the scenery, all of which are social activities. Residents also indicated that they visit other green spaces apart from the ones they were interviewed in primarily for beauty of the green spaces. These results are similar to those by Jim and Chen (2006) who determined that urban green spaces are mostly used for relaxing, with 53 % of residents in Guangzhou, China, indicating that it was very important for urban green spaces to be suitable for relaxation. Sullivan et al. (2004) observed that 83% of urban residents engaged in social activities in green spaces rather than barren land in Chicago. Urban parks have generally been viewed as places where people escape from the noisy and busy urban life so as to relax (Bhaktiari et al., 2014) and this is the case for Bulawayo residents as well. Being a relatively industrial and commercial town, Bulawayo is characterized by noise from manufacturing processes and traffic resulting in residents going to green spaces to relax in a quiet environment away from all the urban buzz.

In some urban areas, green spaces are used as a source of food, for example residents in Melbourne, Australia, indicated that they gather mushrooms and berries from green spaces (Bhaktiari et al., 2014), as do residents in several cities in the USA (McCain et al., 2014). In both cases the participants do so more for recreation and education than out of need. In contrast, Kaoma and Shackleton (2014) reported quite extensive collection of wild foods and firewood from private and public greens spaces by poorer communities in three South African towns. In Bulawayo, a low percentage identified provision of wild fruits as a primary reason for visiting from green spaces. The low percentages for wild fruits indicate the limited engagement of individual's collecting their own food, or, alternatively, the unavailability of wild foods in green spaces in Bulawayo. This may also be attributed to most residents buying fruit rather than collecting it themselves from the urban green spaces. Very few residents also identified agriculture under 'other' primary purpose of visit. Some of Bulawayo's green spaces are used by cooperatives where the crops grown therein are irrigated (Nkala et al., 2012). Agriculture is practiced only in the informal green spaces and the fringes of formal green spaces. Legislation prohibits agriculture in green spaces yet this can be used to facilitate urban food security if both legal and policy barriers which prevent green infrastructure projects are eliminated (Dunn, 2010).

Acquiring poles for fencing and building from green spaces is not common among Bulawayo's residents. For all residential areas, most buildings are constructed of brick and cement surrounded by brick walls, fences with metal poles as well as hedges, thus showing limited or no need for poles for building and fencing. A high percentage (95%) of residents in Bulawayo live in modern type buildings and a negligible 1% occupy dwelling units which are either traditional (pole and dagga/bricks with thatched roof) or mixed (built of material more modern than pole, dagga/bricks and thatch) (ZimStat, 2012). The Zimbabwean government implemented Operation *Murambatsvina* (Operation Drive out Rubbish) in 2005, which was officially known as Operation Restore Order, aimed at forcibly clearing slums across the country (Vambe, 2008). Some of the structures in the informal settlements were constructed of material such as building poles, plastic and metal sheets. After that operation, very few such settlements have been emerging in the city of Bulawayo with an average of 0.3% of the population living in shacks (ZimStat, 2012). The fairly satisfactory availability of formal accommodation (owned and rented) relates to residents appreciating the use of land as urban green spaces instead of being used for residential stands. Most respondents strongly disagreed that green spaces should be used as residential stands.

The 2012 census showed a 27% unemployment rate amongst the 61% economically active population within Bulawayo. Consequently, one would assume that the urban population, especially with low income, would make use of urban green spaces for provisioning services such as gathering food, fetching firewood or acquiring building material as shown by Kaoma and Shackleton (2014) so as to supplement their income by selling the goods or substituting bought goods. Accordingly, 50% of low income respondents identified firewood as a benefit but only 6.7% go to green spaces primarily to get firewood. The residents may be acquiring provisioning services from other areas apart from the area in which they dwell or purchase them, but this was not investigated during this study. In rural areas where firewood competes with inferior fuels such as dung, consumption of firewood rises with income (Gebreegziabher and Cornelis van Kooten, 2013).

All income groups in Bulawayo visit green spaces for cultural services. This is contrary to what was determined by Mapira and Munthali (2011) in Masvingo, Zimbabwe, who determined that deforestation was occurring around high density areas which accommodated low income citizens as trees were being felled for firewood. Similarly, Kaoma and Shackleton (2015) reported that approximately 20% of household income came from urban sourced provisioning goods in three towns in South Africa. Dunn (2010) is of the opinion that green infrastructure can create jobs and facilitate urban food security, but these were not evident in this Bulawayo sample.

The primary purpose of visit had an association with residential class with those from high density areas visiting green spaces to relax with friends and family (social reason) and with those in medium and low density areas visiting green spaces primarily to walk to the other side (utility). High density areas in Bulawayo are generally known to be a more close knit community compared to low density areas characterized by high dura-walls and an emphasis on individual privacy. This may explain why most residents in high density green spaces go to green spaces to relax with friends as the residents in those are familiar with each other and have better relations. Urban green spaces provide neutral space for people to come together and interact socially (College of the Environment, 2016).

2.4.2 Frequency of visiting green spaces

Green spaces are used regularly by Bulawayo residents. Most visit green spaces quite frequently, i.e. on a daily basis, on most weekends or two to four days a month. In Denmark, the average adult citizen visits forests 33 to 38 times per year for recreational purposes (Bhaktiari et al., 2014), while in Bari 43 % of the interviewees claimed to visit green spaces quite frequently (Sanesi and Chiarello, 2006). In neighbouring South Africa, Shackleton and Blair (2013) reported most respondents visited public green spaces weekly and it was higher in more affluent suburbs than poorer ones. Respondents from all three studies show that urban green spaces are generally visited frequently by residents. No relationship was determined between frequency of visits and gender, neither was there a relationship between frequency of visits and age.

The study sought to assess the relationship between having a green space at home and the frequency of visiting public green spaces. No relationship was found between having a green space at home and the frequency of visiting public green spaces but Sawaki and Kamihogi (1995) determined that residents living in areas with little vegetation show less nature affinity than those with more nature contact experience. From the results one can infer that having a green garden at home shows the love for nature and greenery but does not mean that one visits public green spaces a lot more or a lot less due to being content with the greenery in one's own yard.

2.4.3 Desirability of green spaces

Green spaces in Bulawayo are generally perceived as being poorly maintained and lacking amenities. The highest percentage of respondents across all residential classes strongly disagreed that the green spaces were well maintained and that they had adequate amenities. This may be due to the nature of the green spaces included in the study as both formal and informal green spaces were considered for the study. Most urban green space studies focus on formal green spaces. Rupprecht and Byrne (2014) however, focused on informal urban green spaces and were of the opinion that informal urban green spaces offer similar benefits to formal green spaces and are preferred by some users because of the lower human influence and more natural appearance. Herzele and Wiedemann (2003) also opine that both formal and informal green spaces are important for availing a full variety of goods and services and experiences. The Bulawayo city council maintains both formal and informal green spaces by cutting tall grass in informal green spaces and planting lawn and flowers in formal green spaces, although not all formal green spaces are adequately maintained as evidenced by dry grass and flowers during the dry season and damaged swings and other play facilities for children. Some formal green spaces have paved paths as well as benches and play areas for children yet the informal green spaces have no amenities at all. Dry lawn, shrubs and flowers were observed in the formal green spaces in Luveve and Nketa 6 high density suburbs. If amenities are included in the green spaces, more residents may visit the places more often as maintenance and availability of amenities may encourage residents to visit the green spaces. Urban residents typically prefer well maintained green spaces (Jim and Chen, 2009; Sanesi and Chiarello, 2006; Chon and Shafer, 2009; Zhao et al., 2010). More focus may need to be placed on maintenance of green spaces because they can improve daily life by adding to urban green space experiences (Rupprecht and Bryne, 2014).

Herzele and Wiedemann (2003) explain that safety is a pre-condition for use of green spaces. Very few respondents visited the green spaces away from the one they were interviewed in solely because of safety. This implies that respondents already feel safe in the green spaces near their places of residence and do not necessarily have to go to a different safer green space as shown by most respondents in each residential class agreeing that they felt safe in green spaces in their suburbs. The results in this study are similar to those determined by Maas et al. (2009) in a study conducted amongst Dutch citizens, but are contrary to results determined by Sanesi and Chiarello (2006) where more than half of residents interviewed in Bari believed that urban parks were not safe, especially for women and the elderly. Safety hazards in Bari were identified as syringes, substandard facilities and harassment. Sanesi and Chiarello (2006) commented that the maintenance of the green spaces is a contributor to safety as substandard facilities may cause harm to users of green spaces and portray an atmosphere of neglect which can attract anti-social activities. As mentioned earlier, Bulawayo's residents feel that the green spaces are not well maintained yet they feel safe in the green spaces. Bulawayo's residents' idea of hazards in a green space may only be confined to being harmed by human beings and animals and thus do not associate substandard facilities with harm.

Residents in Bulawayo generally prefer visiting green spaces in their own residential class. One might hypothesize that residents in high density areas would prefer visiting green spaces in the more affluent and quieter low density areas but this is not the case in Bulawayo. This could be attributed to being familiar in one's own territory and finding green spaces in one's own neighbourhood desirable. This study also showed that the residents feel that the green spaces are not well maintained and that they do not have enough amenities across all residential classes and hence one would not be eager to visit a green space in a more affluent residential class if the general maintenance is poor across all classes.

2.4.4 Adequacy and size of green spaces

Residents were of the opinion that their residential areas as well as the city of Bulawayo as a whole have enough green spaces. Bulawayo's green spaces cover slightly more than 6% of the city (Bulawayo City Council, 1981). This is large compared to countries such as Italy which have cities with urban green space being as low as 1% or less in area. Sanesi and Chiarello (2006), determined that the residents felt that Bari's green spaces were inadequate and should be increased especially in residential areas and the outskirts. The more the green spaces, the higher the chances of travelling a shorter distance to access the nearest green space. Measuring the distance to the nearest green space was not included in this study and adequacy of green spaces is generalized based on residents' opinions.

Most residents in high and medium density suburbs were neutral when asked about the size of the green space. The highest percentage of respondents in low density areas disagreed that the green spaces were too small, implying that they were content with the sizes of the green spaces in their suburbs. The percentage of neutral respondents could be an indication of the resident's lack of appreciation of the size of an ideal green space relative to function. Residents in Bari were able to give their perceptions of green spaces based on what was set in their legislation on the size of green spaces (Sanesi and Chiarello, 2006). According to the City of Bulawayo Master plan (1981), the green spaces range from 3.5 ha to over 200 ha, which is quite big in size although green spaces considered for this study were 100 ha or less. The mean size across the ten towns surveyed by McConnachie et al. (2008) in South Africa was only 1.7 ha, ranging between 0.9 ha to 2.7 ha.

2.4.5 Benefits of green spaces

Beautifying an area and relaxation were ranked high as benefits of green spaces. Like a typical urban area, Bulawayo is characterized by roads, buildings and industrial infrastructure. However, due to a weak macro-economy, many buildings are not adequately maintained and the roads are potholed. The greenness and the bright colours of flowers in green spaces beautify the city. Some green spaces have sculptures and statues which further make the city look attractive. The aesthetic enhancement by green spaces was also ranked highly in a study by Jim and Chen

(2006) in China. Similarly, residents in Fort Beaufort and Port Alfred in South Africa ranked provision of space for recreation and relaxation highly, comprising about 30% of the reasons provided (Shackleton and Blair, 2013).

When asked about the benefits of green spaces, firewood was identified as one of the main benefits from green spaces, even though few respondents ranked it as the main reason for their visit. This is likely due to electricity load-shedding which has affected not only the city but the whole nation. Firewood is acquired by individual households directly from the green spaces or purchased from traders. Firewood is also used during the winter season to warm the home. Firewood is used by many households in Malawi where biomass accounts for 56-59% of energy used within urban areas (Openshaw, 2010). In urban households in Osun State of Nigeria, firewood is used by 23% of the people as their fuel of choice for cooking (Kersten et al., 1998). The challenge with this is the potential for land degradation which occurs as people cut down trees (Mapira and Munthali, 2011). City authorities and residents should be encouraged to be involved in activities which promote environmental protection, in particular, promotion of greenery to encourage the replacement of the trees cut down by residents within the city. In Zimbabwe, the first Saturday of December every year has been named the national tree planting day where everyone is encouraged to plant a tree to combat deforestation. This may help reduce the rate of degradation if the general public is made aware of the consequences of degradation and is encouraged to take part in tree planting activities. Further efforts are being made by a funeral parlour, Nyaradzo Funeral Services, who encourage afforestation by donating a tree and encouraging families to plant a tree after burying their loved ones who held a funeral policy with Nyaradzo. If trees are replaced at a rate faster than they are cut, Bulawayo's residents may be able to supplement their fuel needs by cutting down trees in the informal green spaces or dead trees in formal green spaces for firewood.

When asked about the benefits offered by green spaces, the residents identified regulation services the least. These generally low scores may be because regulatory services are not directly experienced by residents and a lack of education on these could be a contributing factor. For example, in Guangzhou, regulatory services attracted the highest average scores (Jim and Chen, 2006), which were attributed to publicity and public education programs on urban green space benefits. Such programs are uncommon in Bulawayo. The role of green spaces in allowing water to seep into the soil was ranked low because the residents do not appreciate the role played by green spaces in water infiltration as it is remote as compared to the more tangible benefits. Bulawayo generally has a poor drainage system with flooding during the rainy season. Storm drains are blocked due to litter resulting in the rate of discharge of storm water being slow (Moyo, 2015). The use of more pervious surfaces such as green spaces would help to solve this problem but the function of green spaces in doing so was not widely recognized by residents.

Thermal buffering and consequent potential reduction of household energy costs was identified by a few respondents. Green spaces reduce the amount of energy spent on air conditioning by reducing ambient temperatures in built up areas (Zhang et al., 2014). Green spaces are cooler than built up areas due to shading and evapotranspiration and extend their cooling effect to neighbouring built up areas thus resulting in less energy being required for air conditioning (Akbari et al., 2001). These effects are not common knowledge among residents as little awareness, if any, has been given on energy cost reduction. Focus on energy cost saving has been put on saving energy by using eco-friendly appliances, switching off electrical appliances when not in use but neither the electricity supply authority nor the city council have explained the green spaces' potential in saving energy and associated costs.

2.5 Conclusion

Bulawayo residents appreciate and use green spaces within their residential areas and do not necessarily view them as spaces that have been allocated by city planners for unknown reasons. The responses show that the residents appreciate green spaces as multi-dimensional spaces which provide a number of benefits for cultural and provisioning services. The role of the green spaces in providing regulating services is not well recognized by the residents as they do not directly experience these benefits. The residents feel that the green spaces are adequate and safe to use but are not well maintained. Residents visit green spaces quite often ranging from daily visits to a couple of visits per month.

An association was determined between primary purpose of visit and household income. Across all household income categories, provisioning services had low responses. Primary purpose of visit was determined by residential class with residents in low and medium density areas using green spaces to walk through to the other side and those in high density areas using green spaces to relax with friends and family.

Frequency of visits was not associated with gender and age, neither was it associated with household income but an association was determined with residential class. High and medium density area green space users visited green spaces on a daily basis and low density residents visited green spaces less often i.e. a few times a month. No association was determined between having a home garden and the frequency of visiting public green spaces.

The size and desirability of green spaces were not influenced by residential class. Green space users in Bulawayo felt that the green spaces are not well maintained, do not have adequate amenities, are safe and were neutral when asked about the size of the green spaces. Green space users generally visited green spaces in their own residential class. Perceived benefits that were identified by most respondents were beautifying the city, provision of firewood, a place to relax and those identified the list were provision of timber, trapping dust and reducing energy costs.

Chapter 3

Carbon sequestration by urban trees in urban green spaces in Bulawayo

3.1 Introduction

The burning of fossil fuels and other anthropogenic activities has increased the amount of carbon dioxide (CO_2) in the atmosphere which in turn contributes to global warming (Zhao et al., 2010). In extensively forested countries, forests can be central to the control of anthropogenic CO_2 emissions through the uptake of CO_2 during photosynthesis (Backeus et al., 2005).

In cities, one of the environmental functions performed by urban forests is to absorb various pollutants (Blanusa et al., 2015; Livesley et al., 2016) and CO_2 emissions, through carbon sequestration (Morancho, 2003) and store excess carbon as biomass (Poundyal et al., 2011; Livesley et al., 2016). This aids in reducing the amount of CO_2 in the atmosphere, which in turn combats the global warming effect impacting on biodiversity, agriculture and human vulnerability (Schuldiner-Harpaz and Coll, 2013). Consequently, any reduction in forest areas adversely influences the carbon balance as carbon stored in the forest is released to the atmosphere (Dwivedi et al., 2009). Urban green spaces sequester carbon from urban areas as well as other distant areas (Dwivedi et al., 2009), thus potentially playing a contributory role in atmospheric CO_2 reduction, since the carbon cycle is not confined to urban boundaries (Hutyra et al., 2011).

Nowak and Crane (2002) show that if urban tree cover is increased, it will result in an increase in carbon storage and sequestration, with large trees sequestering about 90 times more carbon than small trees. This would mean that green spaces with larger, older trees sequester more carbon than younger, smaller trees or newly developed areas (McGovern and Pasher, 2016) or that tree species that grow large would be most preferred over small statured species for carbon storage (Nagendra and Gopal, 2011). Large trees also offer greater habitat diversity and hence support a greater diversity of urban fauna and flora (Stagoll et al., 2012; Shackleton, 2016). In addition to the size of tree, the origin of tree species can affect the amount of carbon sequestered and stored by trees as shown by Homoro (2012).

Bulawayo's urban green spaces comprise both formal and informal green spaces. Investigation of both formal and informal green spaces and their contribution to environmental protection and urban ecosystem services is important for policy formulation (Rupprecht and Byrne, 2014). Such investigations should include carbon sequestration as this will guide in planning the type of green spaces which have the potential to contribute significantly towards CO_2 reduction.

The net, long-term carbon release and intake dynamics of forests change over time as trees grow, die and decay. While young trees sequester CO_2 as they grow, dead trees will eventually decompose, thereby releasing the stored CO_2 back into the atmosphere (Hutyra et al., 2011; Strohbach et al., 2012). Whilst urban forests sequester carbon, the management of these urban forests can contribute to carbon emissions because chain saws, chippers and trucks release CO_2 when used during maintenance of urban forests, which could lead to forests being net emitters of carbon. In such a case, natural forests are preferred to ones which need a lot of maintenance. In urban areas maintenance of urban trees is necessary as they can cause problems such as pavement damage, obstruction on pedestrian paths as well as the risk of branches falling on residents if not properly maintained (Lyytimaki and Sipila, 2009).

Although urban forests store carbon, the overall benefit is likely to be small because they constitute only a small fraction of urban areas (Baro et al., 2014) and anthropogenic emissions in urban areas are typically high, often dwarfing the amounts sequestrated by urban trees. For example, in the Twin Cities area of Minnesota (USA), urban trees sequestered only 1 % of emissions (Zhao et al., 2015). In Bulawayo 6% of the city is public urban green space (Bulawayo City Council , 1981), compared to 6% to 15% of urban areas in neighbouring South Africa (McConnachie et al., 2008) and 22% in Shenyang, China (Liu and Li, 2012). From 2004 to 2006, the urban forests in Shenyang were estimated to offset 0.7% of the carbon emissions from fossil fuels in the city, which were estimated at 11.6 million tonnes annually (Liu and Li, 2012). From these figures, it is evident that currently urban green spaces contribute, but not much towards CO_2 pollution reduction. Nowak et al. (2013) are of the opinion that urban forests mitigate climate change but are not well understood, resulting in them being disregarded as viable mitigation options in many countries. With proper planning and optimization of planting opportunities, the extent of carbon sequestration by urban forests could be greatly enhanced (O'Donoghue and Shackleton, 2013).

Three principles on the reduction of greenhouse gases are illustrated by Marland et al. (2001). First, release of CO_2 to the atmosphere should be avoided. Second, when CO_2 is produced it should be collected at the point of discharge. Third, if emitted, CO_2 is moved a short distance through the atmosphere and absorbed by vegetation. Urban green spaces then play a very important role in the third strategy because as much as the urban spaces may be small, they can be situated close to the industrial areas where most of the activities produce CO_2 from industrial manufacturing, motor vehicles and power generating plants. In Bulawayo, the high and medium density housing areas are generally closer to industrial zones, which produce CO_2 during manufacturing processes, than low density areas. Considering the third principle of Marland et al. (2001), the high and medium density areas would need to sequester more carbon as compared to low density areas.

Trees provide various ecosystem goods and services to humans, therefore, it is important to determine the monetary value of carbon sequestration, as well as other competing services in, or uses of, green spaces to have a common measuring unit to enable comparisons when planning for green space use or when considering future developments (Blignaut and de Wit, 2004).Thus, the objective of this chapter was to quantify and valuate carbon sequestration by trees in Bulawayo's urban green spaces. The study answered the following research questions: (i) How much carbon is sequestered per hectare by Bulawayo's urban green spaces per annum? (ii) What is the annual value of tree carbon sequestration by Bulawayo's urban green spaces?

I posed the following null hypotheses:

1. There is no significant difference in tree carbon sequestration between green spaces.

2. There is no significant difference in tree carbon sequestration between indigenous and exotic tree species.
3. There is no significant difference in tree carbon sequestration between formal and informal green spaces.
4. Larger trees do not sequester more carbon than smaller trees.

3.2 Methods

To obtain answers for the key questions and hypotheses above, vegetation sampling was done via 4 m x 100 m transects. The number of transects per green space varied in relation to the size of the green space (Table 3.1). A total of 53 transects were sampled. Any signs of chopping were recorded. For each tree taller than 2 m within each transect, the height and diameter at breast height (DBH) were recorded. If the tree was multi-stemmed, all stems were recorded.

Table 3.1: The number of transects used per green space

Area (ha)	≤20	20-40	41-60	61-80	>80
Number of transects	5	7	9	11	13

The allometric equation of Mugasha et al. (2013) in Tanzania was used to convert the height and DBH readings to biomass per stem. This equation was primarily because no allometric equations are available for Zimbabwean tree species. The equation was the chosen because both areas have sub-tropical climates and similar altitude although Tanzania has higher mean annual rainfall of about 1 000 mm against 570 mm for Bulawayo.

Biomass = $\mathbf{0.0763\ dbh^{2.2046}\ ht^{0.4918}}$ ....eq. 1

The annual production of biomass per green space was determined by measuring the annual stem diameter increment. A total of 173 trees were marked in 12 green spaces in September 2014 and re-measured in September 2015. Equation 1 was used to determine the biomass per stem and equation 2 and equation 3 by Nowak (1994) in Nowak and Crane (2002) were used to determine carbon sequestered for conifers and hardwoods respectively.

Carbon sequestered for conifers = **Biomass * 0.48**……………eq. 2

Carbon sequestered for hardwoods= **Biomass * 0.56**………...eq. 3

ANOVA was used to determine differences in carbon sequestration rates between residential classes. T-tests were used to determine the difference in sequestration rates between formal and informal green spaces, origin of trees and the type of green space. Regression was used to determine the relationship between tree diameter and carbon sequestered. Values for each green space were determined by multiplying the amount of carbon sequestered per hectare per year by the global carbon price of US$ 4 per tonne carbon (Hamrick and Goldstein, 2015).

3.3 Results

3.3.1 Carbon sequestration rate by urban trees

The mean carbon sequestration rate in the different residential areas ranged from 203 to 1 856 kg/ha/yr (Table 3.2), with a mean of 943±520 kg/ha/yr. Green spaces cover approximately 3 490 ha in Bulawayo and extrapolated to the city scale, carbon sequestered by Bulawayo's urban green spaces is therefore about 3 290 t/yr. The three highest areas of carbon sequestration were in Khumalo (low density), Northend (medium density) and Nketa (high density) and the three lowest were in Queens Park (medium density), Barham Green (medium density) and Nkulumane (High density). The annual rates differed significantly between residential classes ($F=3.51$, $df=18\ 3$, $p<0.05$), being lowest in the medium areas and highest in the low density areas, because of higher tree densities.

Table 3.2: Carbon sequestration in residential classes

Residential class	Area	Carbon (kg/ha/yr)	Class mean (kg/ha/yr)
Low	Hillcrest	1 013	1 223±458
	Khumalo	1 856	
	Famona	795	
	Hillside	1 226	
Medium	Northend	1 448	681±552
	Parddonhurst	705	
	Queens Park	203	
	Barham Green	368	
High	Mpopoma	551	927±534
	Nketa	1 433	
	Luveve	1 335	
	Nkulumane	386	
Mean			943±520

3.3.2 Relationship between carbon sequestration and origin of tree species

The mean carbon sequestration rates for indigenous species was 193.3±115.5 kg/tree/yr and 188.9±92.1 kg/tree/yr for exotic species. No significant difference was determined in carbon sequestration rates between indigenous and exotic species ($t=0.19$, $df=109$, $p>0.05$).

3.3.3 Formal and informal green spaces and carbon sequestration rate

Formal green spaces had a significantly higher mean carbon sequestration rate (1 188±344 kg/ha/yr) as compared to informal green spaces (862±560 kg/ha/yr), ($t=2.67$, $df=22.25$, $p<0.05$), (Table 3.3). The four sites which sequestered the lowest carbon per hectare per year were all informal green spaces and the highest sequestration was recorded in an informal green space.

Table 3.3: Carbon sequestered in formal and informal green spaces

Nature of green space	Area	Carbon sequestered (kg/ha/yr)	Mean carbon sequestered per nature of green space (kg/ha/yr)
Informal	Hillcrest	1 013	862±560
	Khumalo	1 856	
	Nkulumane	386	
	Hillside	1 226	
	Northend	1448	
	Parddonhurst	705	
	Queens Park	203	
	Barham Green	368	
	Mpopoma	551	
Formal	Nketa	1 433	1 188±344
	Luveve	1 335	
	Famona	795	

3.3.4 Relationship between carbon sequestered and stem diameter

Carbon sequestered was positively related to tree size (F (1, 11) =131.9, $p<0.05$, R^2_{Adj}=0.54, y=carbon sequestration =2.83x + 22.9), (Fig. 3.1).

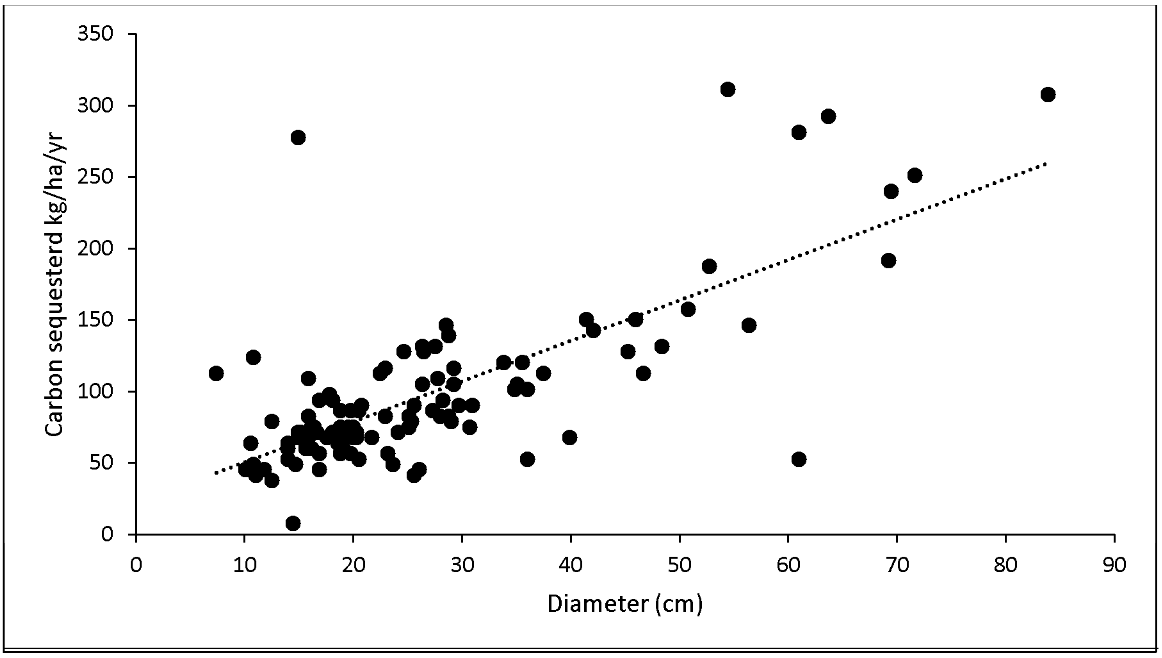

Fig. 3.1 Relationship between carbon sequestered and stem diameter

3.3.5 Value of carbon sequestration by urban trees

The value of carbon sequestration as an ecosystem service was determined by the amount of carbon sequestered (Table 3.4). The mean carbon sequestration was 943±521 kg/ha/yr and the value at US$ per tonne was determined to be, on average, $3.70/ha/yr. Khumalo green space was determined to have the highest carbon sequestration value ($7.60/ha/yr), followed by Northend ($5.60/ha/yr) and Nketa ($5.60/ha/yr). Low density green spaces recorded the highest value ($4.90/ha/yr) and medium density recorded the least ($2.70/ha/yr).

Table 3.4: Value of carbon sequestered

Residential class	Area	Carbon (t/ha/yr)	Value ($)	Class mean value ($/ha/yr)
Low	Hillcrest	1.0	4.00	4.90±1.80
	Khumalo	1.9	7.60	
	Famona	0.8	3.20	
	Hillside	1.2	4.80	
Medium	Northend	1.4	5.60	2.70±2.20
	Parddonhurst	0.7	2.80	
	Queens Park	0.2	0.80	
	Barham Green	0.4	1.60	
High	Mpopoma	0.5	2.00	3.70±2.10
	Nketa	1.4	5.60	
	Luveve	1.3	5.20	
	Nkulumane	0.4	1.60	
Mean			0.9±0.5	3.70

3.4 Discussion

3.4.1 Carbon sequestration rate by urban trees

This study has shown that carbon sequestered in a sample of Bulawayo's green spaces ranges from 203 to 1 856 kg/ha/yr, with a mean of 943±520 kg/ha/yr. With approximately 3 490 ha of green space in the city, then, Bulawayo's urban green spaces sequester about 3 290 tC/yr. In comparison, in Charlotte Metropolitan Region, USA, the total amount of carbon stored in the local forests is 3.8 million t/yr (Godwin et al., 2015), likely reflecting a larger city and with a greater coverage by green space. The inner city area of Melbourne Australia with approximately 10 000 trees is estimated to sequester one million tC/yr (Moore, 2009). Canopy cover was approximately 19% of the urban area in Leipzig, Germany where above-ground carbon storage was estimated to be 11 tC/ha/yr (Strohbach and Haase, 2012). In 2002 the City of Tshwane, South Africa, provided a strategy to plant 115 200 indigenous street trees which were estimated to sequester 54 630 tC/yr.

Bulawayo's urban green spaces cover a smaller area and sequester less carbon than bigger green spaces in areas such as in Canada. However, this does not make the contribution that they have to sequestering carbon insignificant as the combined effect of the carbon sequestered by urban green spaces plays some role, however small, in the reduction of CO_2 in the atmosphere. Moreover, if current rates are low, it provides planners with information and a prompt to design and implement strategies to increase annual rates. The rates of carbon sequestration per area vary due to various methodologies used, the different tree species and different climates. For example, Stohbach and Haase (2012) used colour infrared orthophotos and allometric equations which were specific for each species but these are not available for species in Zimbabwe, therefore a general equation was used to determine carbon sequestration rate by trees.

3.4.2 Carbon sequestration and residential class

There was a significant difference in the carbon sequestration rates between green spaces in different residential areas. The spaces in low housing density areas sequestered more carbon than medium and high density housing areas. Similarly, in Barcelona, the highest ratio among all land use classes was in the low-density residential stratum (1.33 t/ha) (Baro et al., 2014). Ideally, the areas with the most emissions would need to have larger areas of green spaces which sequester the most CO_2 in order for the green spaces to be effective means of reducing emissions. The high density areas had the second highest sequestration rate per hectare per year and they are the closest to industrial areas. Consideration should be made in creating green spaces which sequester high amounts of carbon in the high density areas so as to increase carbon sequestration rate. Knowing which areas sequester more carbon helps authorities to prioritize certain areas for conservation or tree planting (Stohbach and Haase, 2012; Zhao et al., 2015). Many factors affect tree carbon sequestration such as nitrogen deposition and climate change (de Vries and Posch, 2011). It is necessary to investigate the underlying factors which control carbon sequestration in Bulawayo's urban areas.

3.4.3 Carbon sequestration and origin of tree species

There was no significant difference in carbon sequestration rates between indigenous and exotic trees but generally, indigenous trees sequestered more carbon than exotic species. Ndlovu (2014, pers comm., 8 October 2014) explained that exotic trees in Bulawayo are mostly planted along streets and not in formal green spaces. Indigenous trees are found mostly in the informal green spaces which are in the form of unaltered land. Since the study showed that there is no significant difference in Carbon sequestration, both exotic and indigenous species can be planted for Bulawayo's green spaces to be effective means of reducing CO_2 in the atmosphere.

More work needs to be done to determine the carbon sequestration rates for the individual tree species in Bulawayo as the study did not determine which exact species sequester the most carbon. More accurate sequestration projections can be calculated if the specific allometric equations are available for all tree species within the city. For example, Stoffberg et al. (2010) in neighbouring South Africa, who estimated the amount of carbon (54 630 t of carbon) which would be stored by 115 200 indigenous trees.

3.4.4 Carbon sequestration and type of green space

Formal green spaces were determined to sequester more carbon as compared to informal green spaces. A reason for the findings could be that the informal green spaces are remnant pieces of land which may not be monitored regularly resulting in trees being chopped down for other purposes, thus reducing carbon sinks, yet formal green spaces are sometimes patrolled by city council guards resulting in less or no trees being chopped down by residents.

Trees account for 75% of terrestrial gross primary production and store more carbon in biomass and soils than is stored in the atmosphere (Pan et al., 2011). In addition to urban green spaces, carbon may be sequestered by other vegetation within the city such as street trees and vegetation in domestic homesteads (Baro et al. 2014) and corporate grounds and parking lots (O'Donoghue and Shackleton 2013). Urban trees had the highest storage of carbon (28.9 kg/m^2) in Leicester's (UK) publicly owned areas as compared to domestic gardens (0.76 kg/m^2) and herbaceous land cover (0.14 kg/m^2) (Davies et al., 2011). Although the same pattern may not be true for Bulawayo due to differences in location and city design, this is an indication that public urban green spaces sequester a considerable amount of carbon in urban areas when compared to other areas within the city as most of the areas are generally built up areas.

3.4.5 Stem diameter and carbon sequestration rate

Not unsurprisingly, a significant, positive relationship was determined between tree stem diameter and carbon sequestered. This is supported by Nowak and Crane (2002) who showed that if urban tree cover is increased, this will result in an increase in carbon storage and sequestration with large trees sequestering about 90 times more carbon than small trees. Similarly, Stoffberg et al. (2010) argued that larger trees with higher growth rates are more beneficial in ameliorating global warming by sequestering more carbon than the smaller trees. Species of trees which grow to be large may be selected if they are solely planted for the function of carbon sequestration. This is not always possible for street trees because large street trees may interfere with utilities and signage, but urban green spaces are ideal for large trees.

To allow trees to grow to a size that will sequester a considerable amount of carbon, the Bulawayo city council needs to take measures to ensure that trees are not indiscriminately chopped down by residents for various reasons. The city already has legislation that protects trees in green spaces from being chopped down, i.e. Bulawayo (Protection of Lands and Natural Resources) by-laws of 1975. Whilst promoting use of trees for carbon sequestration, the council should not affect livelihoods by totally banning chopping down of trees but need to develop monitored community woodlots specifically for growing trees for firewood.

3.4.6 Value of carbon sequestration by urban tree

Trees both in urban and rural green spaces serve various purposes. Some uses are destructive, such as harvesting timber and firewood yet some promote conservation such as respecting trees for spiritual reasons. The valuing of carbon sequestration helps to make economic decisions on the use of trees and investments in greens spaces. In Bulawayo the value of carbon sequestration was determined to be $3.70/ha/yr and about $13 000 per year for the whole city. This is very low in comparison to other places, such as $1.19 million in Shayang, China (Liu and Li, 2012). The total amount of carbon stored in the local forests in Charlotte Metropolitan Region, USA was determined to be 3.8 million tonnes worth $298 million with an average carbon density of 53.5 t/ha (Godwin et al., 2015). The above values show that when future trade becomes operational for urban forests, the forests have the potential to reduce greenhouse gases and to become a valuable source of revenue for the municipality (Stoffberg et al., 2010). In Barcelona, the total biophysical value of net carbon sequestration is estimated at 5 187 t/yr and 536 kg/ha/yr with an economic value of $407 000/yr. This value considered the net carbon sequestered taking into account the maintenance of green spaces (Baro et al., 2014).As mentioned before, trees are multifunctional, and therefore decisions on conservation of green spaces as well as introduction of new green spaces can be guided by the value of carbon sequestration as an ecosystem service.

3.6 Conclusion

Bulawayo is the second largest city in Zimbabwe with a lot of vehicles and anthropogenic activities which emit carbon. In light of this, Bulawayo, as well as the rest of Zimbabwe, should join the rest of the world in reducing global warming. This contribution can be made by Bulawayo’s green spaces. Bulawayo’s urban green spaces currently play a contributory role in carbon sequestration which in turn reduces global warming, by however small an amount. The urban green spaces sequester 3 290 t/yr which has a value of about $13 000/yr.

There was a significant difference in carbon sequestration between green spaces and between formal and informal green spaces with formal green spaces sequestering more carbon. Indigenous trees were shown to sequester more carbon than exotic trees and trees with bigger stem diameter were determined sequester more carbon than trees with small diameter.

The value of carbon sequestered and the potential for sequestration determined by this study may aid the Bulawayo city council to make decisions on the city's future developments and the trade-offs between economic development and environmental protection may be compared using a common comparison, i.e. the monetary value.

Chapter 4

Micro-climate regulation

4.1 Introduction

Urban areas, many of which have been labelled as concrete jungles, are a novel ecosystem characterized by impervious surfaces from buildings, paved surfaces, roads, and limited water bodies, bare soil and vegetated areas (Takebayashi and Moriyama, 2007; Zinzi and Agnoli, 2012). Establishment and expansion of urban areas involves replacement of vegetated areas by artificial surfaces made of brick, concrete and asphalt. These surfaces have low albedo resulting in absorption of incident rays from the sun and slowly releasing heat, thus increasing ambient temperatures in urban areas as compared to surrounding rural areas (Dimoudi and Nikolopoulou, 2003; Bowler et al., 2010; Ng, 2015). This is known as the Urban Heat Island (UHI) effect (Chow and Roth, 2006).

Buildings change the flow of energy and matter through urban ecosystems (Oberndorfer et al., 2007) which also results in an increase in temperatures. Akbari et al. (1992) showed that in Los Angeles the maximum temperature increased by 2.5°C and minimum temperature increased by 4°C from 1920 to 1980 and attributed this to replacement of vegetated areas with built up areas. The UHI effect results in increases in ambient air temperatures which in turn results in increase in energy consumption when cooling buildings, reduction in thermal comfort and acceleration of urban smog production (Akbari et al., 2001; Kardinal Jusuf et al., 2007; Ng, 2015). The increased temperatures affect thermal comfort, and if sufficiently high can increase the probabilities of adverse health effects, such as heat stroke and hospitalization (Conti et al., 2005; Son et al., 2014; Livesley et al., 2016). Indeed, Mitchell and Chakraborty (2015) state that heat waves cause more deaths in the USA than any other natural hazard. Additionally, the effects are not uniformly distributed, with higher mortalities in poorer areas of cities, partially correlated with lower urban greenery (Mitchell and Chakraborty, 2015). Linking this with global warming, then the dangers of high temperatures in urban areas, especially in tropical and sub-tropical countries already, pose real threats to urban health and well-being.

Consequently, mechanisms to reduce the UHI are receiving ever more attention, with urban trees being a widely advocated strategy.

Vegetation, especially trees, reduces the UHI effect (Wong and Yu, 2005). There is a correlation between land use and ambient temperature, with ambient temperature decreasing from industrial, to residential to forest areas (Wong and Yu, 2005). Green spaces act as cooling islands in an urban matrix as a result of tree shading, greenery foliage shading and evapotranspiration (Lin et al., 2015; Mullaney et al., 2015; Livesley et al., 2016). A green space's cooling effect extends beyond its boundary into the surrounding streets and buildings because of the air movement and heat exchange (Cohen et al, 2012). Landsat images of Beijing revealed that cooling effects of green spaces extend as much as 35 to 840 m away from the park periphery for parks ranging in size from 0.14 km^2 to 10.09 km^2 (Lin et al., 2015). The extent of the cooling effects of parks is largely influenced by the size of the park, and the character of the area around the park (Lin et al., 2015; Jaganmohan et al., 2016). The larger the park, the greater the cooling effects of the park (Lin et al., 2015). In Singapore there was a 4°C temperature difference between built up and green areas, with green areas recording lower temperatures due to shading and evapotranspiration during the daytime (Kardinal Jusuf et al., 2007). Individual trees alter indoor temperatures by shading buildings and reducing wind speed during the cold season (Bolund and Hunhammer, 1999).

Trees provide energy savings for heating and cooling of buildings by providing shade on buildings, reducing summer temperature and providing wind-chill protection in winter (McPherson and Simpson, 2002; Mullaney et al., 2015). Three shade trees in the right position can save up to US$200 annually in energy costs per home in Los Angeles (Rosenfield et al., 1998). These savings are likely to be highest in cities with climatic extremes, either very hot or very cold, typically demanding high use of cooling or heating strategies and therefore high energy costs. Increasing the size of urban green areas and the number of trees in these areas produces a greater reduction in ambient air temperatures in hot seasons (Dimoudi and Nikolopoulou, 2003). One indirect effect of planting urban trees is reducing carbon emissions generated during energy production. Akbari et al. (2001) showed that CO_2 emissions avoided by reduced energy demand are less than the amount sequestered after being emitted. For example, a tree reduces the emission of 18 kg of carbon annually in energy production but sequesters a quarter (4.5 kg) of the emitted carbon (Rosenfield et al., 1998). Therefore it is better to plant one tree to reduce energy consumption instead of planting four trees to absorb CO_2 released during energy production.

Bulawayo is a city that has been hard hit by electricity cuts which fosters the need to reduce energy consumption as much as possible. Bulawayo's energy crisis has been attributed to malfunctioning equipment at power generating plants and at some point was attributed to low water levels at Kariba Dam where hydroelectric power is produced (Mawonde, 2015). Reduction of urban temperature by green spaces is a viable option to contribute to reducing the demand for electricity for cooling. This chapter presents results and discussions of the micro-climate regulation (MCR) effect of green spaces in Bulawayo and the value of urban heat amelioration by green spaces. To determine the contribution of UHI amelioration I answered the question, what is the value of the UHI amelioration ecosystem services provided by green spaces in Bulawayo?

I posed the following null hypotheses:

1. There is no significant difference between temperatures in urban green spaces and built up areas.

2. There is no significant difference in heat island amelioration between winter and summer.

3. There is no relationship between green space size and UHI amelioration.

4.2 Methods

Starting in the middle of each sample green space, temperatures were measured every 100 m across the green space to 2 km beyond the green space periphery. Measurements were taken 1.5 m above ground using a Kestrel weather monitor. The direction of measurement from the centre of the green space was chosen based on the path of measurement, i.e. direction with a clear path with no obstructions in the form of buildings, were chosen. Readings were taken at 21 points with the first point being the centre of the green spaces. The distance between points was 100 m. Readings were taken fortnightly every month in May, June, July (cold months)

September, October, November (hot months). Temperatures were taken only when the wind speed was below 5 m/s.

The power used for the most common air conditioner in Bulawayo's residential areas which is a split type fixed speed air conditioner was determined to be at least 2 600 Watts (Gee's refrigeration services technician, 2014, pers comm, 18 August 2015) and the energy used when run for eight hours per day was determined to be 20.8 kWh, assuming that an air conditioner is used every day of the year.

The data was analysed using SPSS v 20. A t-test was used to determine if there was a significant difference in temperatures in green spaces as compared to built up areas and regression was used to determine the relationship between the green space size and the extent of cooling in surrounding built up areas.

4.3 Results

4.3.1 Temperature trend from green spaces to built up areas

Temperatures increased from the centre of the green space outwards. The increase in temperature fluctuated as readings were taken away from the green space, although they showed a general increase. The temperature differences between green spaces and built up areas in summer ranged from 0.9 °C to 6.1 °C. In winter the temperature difference ranged from 0.9 °C to 5.7 °C (Table 4.1).Cooling effects were observed to extend up to 1.7 km beyond the green space (Fig 4.1 and 4.2).A t-test showed that there was a significant difference between the means in built up areas and those in green spaces ($t = -4.563$, $df = 21$, $p<0.05$). The mean difference between the temperatures in built up areas and those in green spaces was 3.6 °C.

Table 4.1: Temperature differences between built up areas and green spaces in winter and in summer

Green space	Temperature difference (°C)													
	Summer							Winter						
Month	Sep		Oct		Nov		Mean	May		Jun		Jul		Mean
	1st reading	2nd reading	1st reading	2nd reading	1st reading	2nd reading		1st reading	2nd reading	1st reading	2nd reading	1st reading	2nd reading	
Famona	3.6	4.6	4.3	3.1	3.2	2.4	3.5±0.8	2.5	5.4	2.9	2.8	3.5	2.7	3.5±1.4
Hillcrest	4.1	4.5	4.1	4.0	5.0	2.5	4.0±0.8	4.4	5.7	3.9	4.0	3.9	4.4	4.3± 1.1
Hillside	3.4	2.3	3.3	5.4	6.1	3.6	4.0±1.4	2.5	3.1	4.1	4.0	5.5	4	4.1± 2.3
Khumalo	4.3	4	4.3	4.1	4.8	3.6	4.2±1.7	3.0	4.0	2.8	3	3.1	2.6	3.3± 1.3
Northend	2.9	3.7	2.4	4.1	3.9	4.8	3.6±1.9	4.0	3.0	2.3	2.6	5.7	2.9	3.4±2.4
Queenspark	4.3	5.2	3.9	3.8	2.7	2.6	3.8±1.1	2.6	4.6	0.9	4.7	3.6	2	3.3±2.4
Parddonhurst	3.6	3.1	2.8	4.8	3.1	3.4	3.5±1.9	3.9	3.1	4.5	4.0	3.3	4.2	3.8±1.5
Barham Green	5.8	4.0	4.0	4.4	3.3	1.2	3.8±2.0	4.3	1.8	1.8	3.8	4.1	0.9	2.7±2.9
Luveve	2.9	4.7	5.2	1.8	2.7	3.8	3.5±1.0	2.9	1.8	1.8	3	5.2	2.7	3.0±2.6
Nketa 6	1.2	6.1	6	5.1	0.9	1.8	3.5±2.3	3.2	2	2.2	4.2	5.4	2.6	3.3±2.7
Nkulumane	4.4	4.5	4.3	5.4	5.5	1.1	4.2±2.6	2.7	4.4	3.1	2.4	4.1	4.2	3.7±1.8
Mpopoma	3.1	2.7	3.1	2.4	3.7	3.1	3.0±1.6	4.0	3	2.5	1.8	3.1	2.6	2.7±1.4
Mean difference	3.6±1.1	4.1±1.1	4.0±1.0	4.0±1.1	3.7±1.4	2.8±1.1		3.3±0.7	3.5±1.3	2.7±1.1	3.4±0.9	4.2±1.0	3.0±1.0	

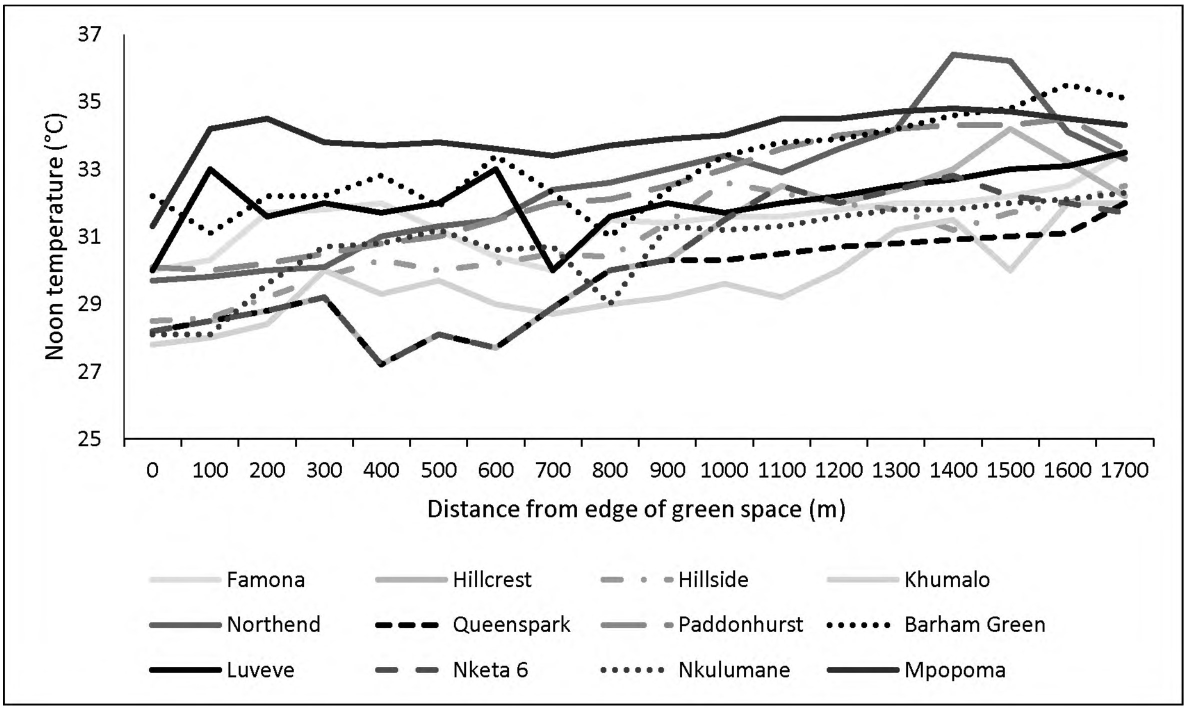

Fig. 4.1: Increase in temperature in summer

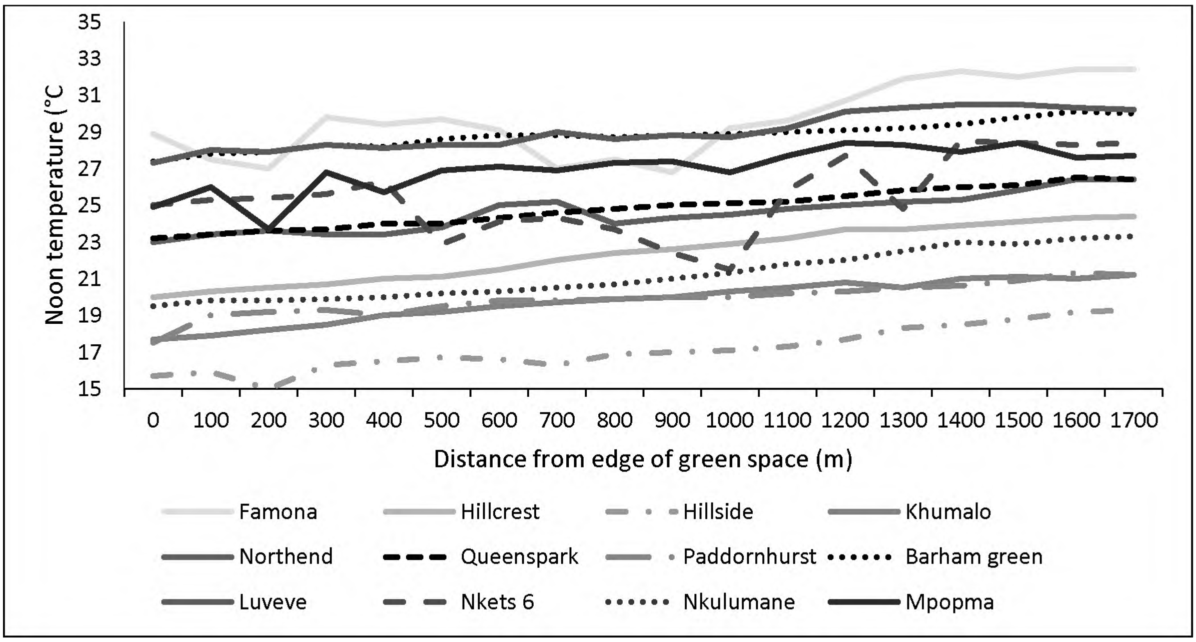

Fig. 4.2: Increase in temperature in winter

4.3.2 Green space size and temperature differences

The results show a general increase in temperature differences between green spaces and built up areas as green space size increases. The temperature differences in summer and winter varied but were determined not to be statistically different, ($t = 1.21$, $df=13$, $p>0.05$).

Table 4.2: Green space size and temperature difference between green and built up areas

Green space	Area (ha)	Mean temperature difference between green and built up areas (°C)	
		Summer	Winter
Mpopoma	3.93	3.0±1.6	2.7±1.4
Famona	4.24	3.5±0.8	3.5±1.4
Parddonhurst	4.27	3.5±1.9	3.8±1.5
Luveve	4.70	3.5±1.0	3.0±2.6
Hillside	4.81	4.0±1.4	4.1± 2.3
Northend	5.67	3.6±1.9	3.4±2.4
Nketa 6	5.94	3.5±2.3	3.3±2.7
Barham Green	6.47	3.8±2.0	2.7±2.9
Queenspark	7.91	3.8±1.1	3.3±2.4
Hillcrest	14.98	4.0±0.8	4.3±1.1
Khumalo	16.53	4.2±1.7	3.3±1.3
Nkulumane	38.34	4.2±2.6	3.7±1.8
Mean	9.8±9.9	3.7±0.4	3.4±0.5

About half (45%) of the variation in temperature difference in summer was explained by the size of the green space ($F=8.21$, $p<0.05$, $R^2_{Adj}=0.40$. Temperature difference $=18.9x - 60.5$. Less than half (7%) of the variation in temperature difference in winter was explained by the size of the green space. It was found that size of the green space determined the cooling effect of green spaces ($F=0.86$, $p<0.05$, $R^2_{Adj}=0.01$, temperature difference $=5.6x +9.4$ (Fig 4.1).

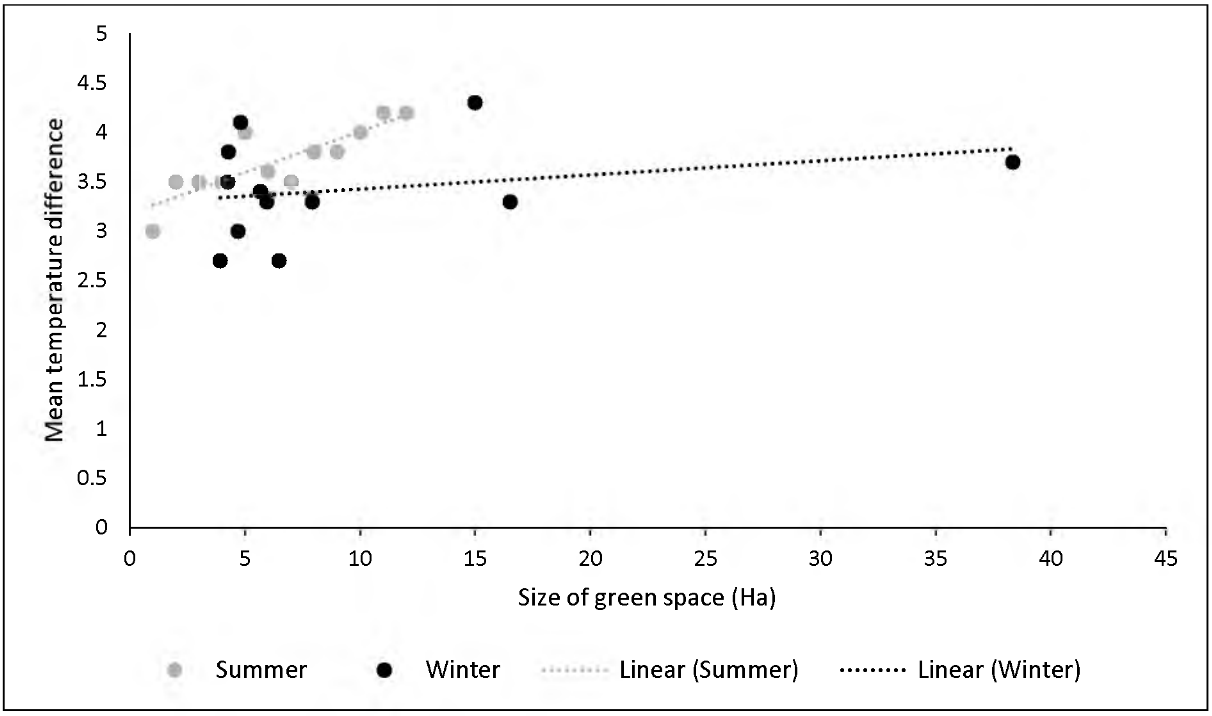

Fig. 4.3: Relationship between mean temperature difference and green space size in summer and winter

4.3.4 Value of the urban heat amelioration ecosystem services in Bulawayo?

The mean temperature difference in summer was 3.7±0.4°C and 3.4±.0.5 in winter, this translates to about 20.8 kWh of air conditioning energy saved for an eight hour day. The price of electricity was determined to average US$0.12 per kWh (ZETDC, 2015). This equates to US$835/household/yr.

The value of the UHI amelioration of the green spaces was determined to be $835/household/yr based on an eight hour day. Because of the method used, temperature difference could not be linked to size of the green space hence it cannot be linked to energy saved per hectare. This is the replacement cost as this is the amount that will be spent on electricity bills in the event that air conditioners replaced the function of the green spaces, ignoring capital cost of air conditioner.

4.4 Discussion

4.4.1 Increase in temperature from green spaces to built up areas

Air temperatures showed a general increase from green spaces to built up areas. This is consistent with multiple other studies (e.g. Akbari et al., 2001; Kardinal Jusuf et al., 2007; Ng et al., 2012; Lin et al., 2015; Mullaney et al., 2015; Jaganmohan et al., 2016). The mean difference was 3.6 ^{0}C. In Singapore there was a 4 °C temperature difference between built up areas and green spaces, with green spaces recording lower temperatures due to shading and evapotranspiration during the daytime (Kardinal Jusuf et al., 2007). This was attributed to the material used in built up areas as the residential areas around the green spaces have tarred roads, are made of brick walls, tiled with asbestos or metal roofs and some have brick walls surrounding their yards. These materials absorb heat and slowly release heat resulting in the built up areas recording higher temperatures as compared to green spaces. The area furthest away from the green space did not always record the highest reading although these temperatures did not drop to as low as temperatures within 1 km away from the green space. This may be attributed to patches of greenery which were present in the built up areas in the form of lawns, trees and vegetable gardens in private yards. This will have cooled the built up areas to some extent as the temperatures did show a dip in areas with some vegetation within the built up areas. Work on domestic spaces shows that the vegetation within yards reduces the temperature within the home (Rosenfield et al., 1998). Temperatures recorded in the built up areas in October went as high as 37 °C which could be attributed to the heat wave that hit Zimbabwe around that period (Chigogo, 2015). In situations like these, the urban green spaces play a pivotal role in providing a comfortable, or less stressful, environment for residents who are in and near the green spaces and could well help avoid serious ill health effects such as heat stress or stroke, or even mortality (Conti et al., 2005; Mitchell and Chakraborty, 2015).

4.4.3 Temperature difference and area

The results show that the temperature difference increases with increasing size of the green space in summer, when temperatures are highest. This supports Lin et al.

(2015) who determined that the extent of the cooling effects of parks is largely influenced not only by the size of the park but by the character of the area around the park (Lin et al., 2015). Additionally, Lindén et al. (2016) demonstrated that the effects are also influenced by the orientation of streets in relation to the green space and incident radiation. This means that the green space's cooling effect may be enhanced or suppressed by other factors but it has been generally the larger the park, the greater the cooling effects of the park (Lin et al., 2015). A study done by Bowler et al. (2010) showed that temperature within a park was 0.94 °C cooler in the day compared to surrounding built up areas which is fairly low compared to green spaces in Bulawayo which showed temperature differences as high as 6.1 °C. In Bulawayo the smallest green space studied was 3.83 ha but the highest temperature difference between the green space and the built up area was 4.6 °C yet Oliviera al. (2011) determined that a green space as small as 0.24 ha in Lisbon showed a 6.9 °C temperature difference. Factors such as green space size, canopy cover, vegetation structure, season, time of day, sky obstruction and prevailing weather play a role in the influence that green spaces have on urban environment (McPherson et al., 1997; Upmanis and Chen, 1999; Cohen et al., 2012). In Bulawayo tree shading effects play a role in the heat amelioration due to the structure of most residential buildings as they are one storey buildings unlike in areas such as Hong Kong, for example, where most buildings are multi-storied (Ng et al., 2012) and the role played by tree shading in cooling is negligible. The buildings that are most likely to benefit from the shade are the ones adjacent to the green spaces which also showed the lowest temperature readings amongst the built up area readings. McPherson and Simpson (2002) showed that approximately 25% of the total cooling savings in two cities were due to shade on buildings, with the remaining 75% being due to reduced summertime air temperatures due to the presence of trees.

4.4.4 Seasonal differences

No significant difference was found between the summer and winter average temperature differences. In this study the highest temperature difference in summer was 6.1°C and 5.7°C in winter. This is a similar trend to what was observed by Cohen et al. (2012) in Tel Aviv, Israel where an urban park reduced summer temperatures by 3.8 °C and winter temperatures by 2 °C. Deciduous trees result in less shade being produced and less evapotranspiration occurring due to leaf abscission because there will be less leaves for shading as well as less leaf surface area for evapotranspiration during the dry season. This is supported by work done in Mexico, where the maximum cooling intensity was reached in a green space of 3 ha which was not the biggest green space sampled. The cooling intensity was attributed to intense evaporation (Barradas, 1991). This is a preliminary study as it did not further investigate solar and infrared radiation, urban form and the structure of green spaces as the features of the city can enhance the cooling effect of the green spaces on the surrounding environment (Oliveira, 2011).

The study made use of manual readings for ambient temperature using a weather meter. Some similar studies have made use of mobile devices to take readings in a wider area but this study took readings repeatedly i.e., six times in summer and six times in winter as compared to a study by Wong and Yu (2005) who took single readings only. Readings were taken around midday unlike the method done by Wong and Yu (2005) because that is the time when residents will benefit the most from a cooler environment during hot summer days (Oliveira et al., 2011). Ambient temperature was measured at 1.5 m above ground level, echoing the approach of others (Huang et al., 2008; Kolokotroni et al., 2006; Oliveira et al., 2011). Stewart (2011) reviewed studies on UHI and is of the opinion that temperature readings taken at approximately shelter height i.e. 1 m to 2 m above ground level or at least below roof level are aligned to the conceptual model. The distance from the green space in this study, i.e. about 2 km from the green space may be argued that it exceeds the scale of influence of the green space in reducing ambient temperature. Temperatures were measured during calm days when the wind speed was below 5 m/s. During the study period, the highest windiest month was in November with an average wind speed of 5 m/s.

4.4.5 Value of micro-climate regulation

In Bulawayo Electricity tariffs are generally uniform across all residential classes at $0.12 per kilowatt hour (kWh) (Zimbabwe Electricity Supply Authority (ZESA)

Holdings, 2015).This is slightly less than the regional average of \$0.14/kWh (ZESA Holdings, 2015) but high compared to power tariffs in most parts of the world which fall in the range \$0.03c/kWh to \$0.04/kWh (World Bank Group, 2013). The regional tariffs have slightly increased from that determined in 2013 which was US\$0.13 c/kWh in Sub-Saharan Africa (World Bank Group, 2013). Air conditioners vary greatly in size and power consumed. To determine a conservative value for micro-climate regulation by urban green spaces in Bulawayo, the smallest split type fixed speed air conditioner and most efficient air conditioner was used to determine the amount of electricity required to reduce indoor temperature by 3.7±0.4°C in summer and 3.4±.0.5°C in winter for a period of eight hours per day.

The temperature amelioration value of Bulawayo's green spaces was estimated at \$835 /household/year. Since 6% of Bulawayo's area is green space as shown in the Bulawayo Master plan (1981), assumption is that about 6% of households (9 921 households) live near green spaces. This assumption has limitations that developments have occurred within the city hence 6% may not be too accurate. Bulawayo's green spaces cover 6% of the city and the cooling effects of green spaces extend beyond the green spaces in the built up areas. An assumption was made that green spaces are located in or close to residential areas and hence the cooling effects of the 6% green spaces extends to 6% of the households. The aggregated value of temperature amelioration equates to \$8.3 million/ year. In China, Lanzhou's urban forests, which cover an area of 2 789 ha, save up to 81.8 MJ/ha/year valued at \$1 426, Beijing with an urban forest of 16 577 ha was calculated to be worth \$1 553 and Guangzhou with urban forest area of 7 360 ha had a replacement cost of \$9 527 (Leng et al., 2004 in Jim and Chen, 2009; Zhang et al., 2006). It has been shown that most cooling energy savings are a result of evapotranspiration and 10% to 30% are due to shading. Three shade trees can save up to US\$200 annually in energy costs per home in Los Angeles (Rosenfield et al., 1998).

4.5 Conclusion

The study showed that urban green spaces in Bulawayo play a marked role in urban micro-climate regulation by significantly reducing the ambient temperature in the green spaces as well as in built up areas. As parks are used by the general residents for various reasons such as relaxing, the tree shading and reduced temperatures make the urban green space a pleasant place to be in during the day time as it gives thermal comfort to residents.

The green spaces extend their cooling effect to surrounding areas thus reducing the temperatures in surrounding residential areas which in turn reduces the energy demand used for indoor cooling and any thermal discomfort or heat related health risks. This is beneficial for the city of Bulawayo and the rest of Zimbabwe which is already prone to power cuts during load shedding as a result of insufficient power generation by the existing power plants.

The determined ecosystem service that is as a result of trees in green spaces should act as a reason for municipalities to consider not only the amenities they provide in green spaces for the green space users but also the number and type of vegetation that they put in green spaces as well as have stricter ways of safeguarding trees in green spaces. This should also inform the city authorities as to where to establish green spaces.

Chapter 5

Spiritual services in urban green spaces in Bulawayo

5.1 Introduction

Cultural services are the intangible benefits such as capabilities and experiences arising from the relationship between humans and ecosystems (Chan et al., 2012). The cultural services experienced depend upon individual's or group's interpretation of the ecosystem or of specific characteristics of the ecosystem. Benefits humans obtain from cultural services depend upon experiences during visits to the area or indirect experiences derived from an ecosystem, for example, through nature movies. (Hein et al., 2006). Chiesura (2004) revealed that nature gives a sense of belonging, that people go to natural areas to escape stressful urban conditions and the atmosphere of urban parks inspires reflection, meditation, and a general feeling of harmony with the surroundings. As such, interactions with urban green spaces can be important in relieving stress and promoting restorative environments for mental wellbeing (Grahn and Stigsdotter, 2003; Nordh et al., 2009; Ward Thompson et al., 2016).

Most of the work and understanding on the cultural benefits of green spaces relate to their uses for recreation and relaxation. Yet, in many parts of the developing world some formal or informal green spaces are also used for spiritual purposes, such as outdoor worship, or worship of specific trees or sites within urban green spaces, which has not received much research attention (De Lacy and Shackleton, in press). For some, outdoor worship promotes a closer association with the deity being worshipped (Dahill, 2013). Many African cultures reserve a piece of land as a sacred place to worship and to communicate with their ancestors (Egoh et al., 2012). In South Africa, the Xhosa people use forests for ancestral worship and the Xhosa idiom 'God is my forest' shows the forest as a place of shelter and protection (Cocks et al., 2012). The Xhosa people believe that without access to forests, a person becomes spiritually and culturally impoverished. Thicket vegetation, known as *Ihlathi lesiXhosa,* is a sacred place where ancestors communicate with descendants through animals, birds and insects, which are considered as messengers. Rituals are carried out in the forests facilitated by diviners who are guided by the ancestors to a place within the forest where the ritual should be performed (Cocks et al., 2012).

In Zimbabwe there are a number of religious congregations who worship outdoors such as Johane Masowe, Johane Marange, Chitendero ChaVapostoli and Twelve Apostles. Johane Masowe or Vapostori was founded around 1932 by a man named Johane Masowe who, before founding the church, allegedly experienced headaches which ceased when he spent 40 days praying on Muvambi Hill near a town called Norton. During this period, he supposedly survived on wild honey (Reese, 2008). This experience is believed to have formed the basis for outdoor worship which is practiced by the sect. The Masowe congregations worship outdoors, close to barren soil, unoccupied forests, mountains and rivers in a language that draws attention to nature (Mukunyora, 2010). The church has spread to southern, central and eastern Africa (Mukunyora, 2008)

For other groups, outdoor worship is because they do not have land or structures for covered worship, especially in rapidly expanding urban towns or transforming urban spaces. For example, the Chitendero ChaVapostoli-Illanda's Bishop in an interview, indicated that for his congregation, worshipping outdoors is not part of their ritual but they do so because they do not have money to rent, buy or build their own facility (Tshuma, 2011). The Bulawayo city council has previously suggested moving the churches to council schools as places of worship but this was discouraged as schools only close at weekends during the term, yet the church members go to church numerous times during the week (Tshuma, 2012). In Bulawayo, those dwelling in low density areas are perceived to be more affluent as compared to those dwelling in more crowded high density areas. The question then arises as to whether more people living in high density areas worship in public urban green spaces because they do not have funds to acquire facilities, as compared to those in low density areas.

With outdoor worship comes various challenges. For example, the council in Victoria Falls has cited land degradation and threats to tourism as reasons why they discourage open air worship (Ncube, 2015) and have erected signs indicating that open air worship is prohibited in some areas (Ncube, 2015). Some congregations practice open air worship in undesignated areas which is against city by-laws. Councillors have argued that open air worship is a public health problem as it results in littering as well as defecation in green spaces as most open air congregations do not have access to toilets (Tshuma, 2012; Ncube, 2015; Ruwende, 2015). From the examples given, focus has been on the challenges perceived by local authorities and not much work has been done to determine the challenges faced by the congregants themselves.

The distance to a green spaces is often a factor determining visitation rates (Herzele and Wiedemann, 2003). In terms of outdoor worship, this may have a bearing on the frequency of going to church, as a shorter travel distance to an outdoor worship site may increase the frequency of worship. In the United States of America (USA), residents travelled 0.36 person trips per day to school/church and covered 2.24 miles per day (Santos et al., 2009). Related to frequency is the mode of transport used to access the green space. Users of green spaces who live close to the green spaces are more likely to walk to the green space as it does not cost anything to access the green space, whereas those who have to use vehicles might travel to green spaces much less as there is a direct cost associated with travel. In the USA, residents who travelled to school/church walked (9.4%), used private transport (70.7%), public transport (2.2%), and other forms of transport (17.7%) (Santos et al., 2009).

Conservation benefits accrue when the area around worship sites is kept unaltered (Ishii et al., 2010; Shen et al., 2012). In India, sacred groves are believed to be protected by deities, for example gods, demons, ancestors and serpents (Murugan et al., 2008). These groves cover areas from a few square meters to kilometres. The groves are viewed as a social institution which promotes the management of biotic resources through people's participation (Anthwal et al., 2006). The deities are placed under a tree and the temple is surrounded by a vegetated landscape.

Murugan et al. (2008) studied 27 sacred groves in Palakkad, India, and concluded that the groves are effective conservation areas with rare biota and cultural heritage.

Very few studies have attempted to valuate urban green spaces as places of worship. De Groot et al. (2012) analysed papers on valuation from 1960 to 2008 and under cultural services, spiritual experience was valued once, using a direct market approach, out of a total 145 valuation papers on cultural services and once using contingent valuation method. The concept of ecosystem service value can be a useful guide when measuring trade-offs between society and nature (Wright and Eppink, 2016), however, critics of the valuation concept argue that core social values should not (and perhaps cannot) be reduced to financial terms and also ask the question of whose value then counts (Howarth and Farber, 2002; Wenger and Pascual, 2011). Decisions about conservation or restoration actions can lead to the misuse of resources when not guided by value (Howarth and Farber, 2002).

This chapter presents results regarding Bulawayo residents' use of public green spaces as places of worship as well as the valuation of such use of the green spaces. The chapter answers the following research questions:

1. Why do residents worship in green spaces?
2. What challenges are faced by residents who worship in green spaces?
3. What assistance do congregations need to improve their green space worship experience?
4. What is the spiritual services value of urban green spaces in Bulawayo?

I posed the following null hypotheses:

1. The frequency of going to church is not influenced by mode of transport.
2. The primary purpose of worshipping in green spaces is influenced by residential class.
3. Challenges perceived by congregants are not influenced by purpose of worship in green spaces.

5.2 Methods

A total of 12 green spaces were sampled and a questionnaire was administered to congregants who were willing to participate. Of the 12 congregations visited, seven agreed to take part in the study. The congregations in the sampled sites varied in size from five to 30 members on average but not all congregants within those congregations participated. Stratified random sampling was used to select respondents from the congregations to ensure representation of all residential density classes. A total of 43 congregants participated in the study.

Questionnaires were used to capture information related to worship in green spaces, i.e. the reason why residents worship in green spaces, the challenges faced by congregants in green spaces, how authorities may assist the congregants and the cost and/or time taken to travel to specific green spaces to worship. Questionnaires were administered in English, Ndebele and Shona to congregants by trained research assistants after the church service.

The information was analysed descriptively to determine frequencies of responses and Chi square analysis at 95% confidence interval was used to determine the correlation of i) green space value and residential class, ii) frequency of attending church services and mode of transport and iii) challenges perceived and primary reason for worshipping in green spaces. The methodology used to determine value was the Travel Cost Method, which has been widely used to determine 'value' of non-marketable site of specific interest to the users (e.g. Fleming and Cook, 2008; Armbrecht, 2014; Tewari and Srivastava, 2016). The time taken to walk or drive to the green spaces was determined and the value calculated from the hourly-wage rate for those walking or cycling and minimum Zimbabwe Automobile Association (AA) rates for those driving and the actual taxi or bus fares for those using public transport were used.

5.2.1 Ethical considerations

The purpose, nature and end use of the research was explained in writing to all participants, including procedures/ methods used to gather information during the research. All information given by participants was kept confidential. The participants were informed that they were free not to participate in the study and that their names were to be kept anonymous.

5.3 Results

5.3.1 Reasons why residents worship in green spaces

The responses on the primary reason for worshipping in green spaces were categorized as either spiritual (70.8%) or lack of buildings for worship (29.2%) (Fig. 5.1). It was determined that not all congregants worship in green spaces for spiritual reasons, although the majority (70.8%) worshipped in public green spaces for this reason. Box 5.1 shows quotes from some congregation members on reasons why they worship in green spaces.

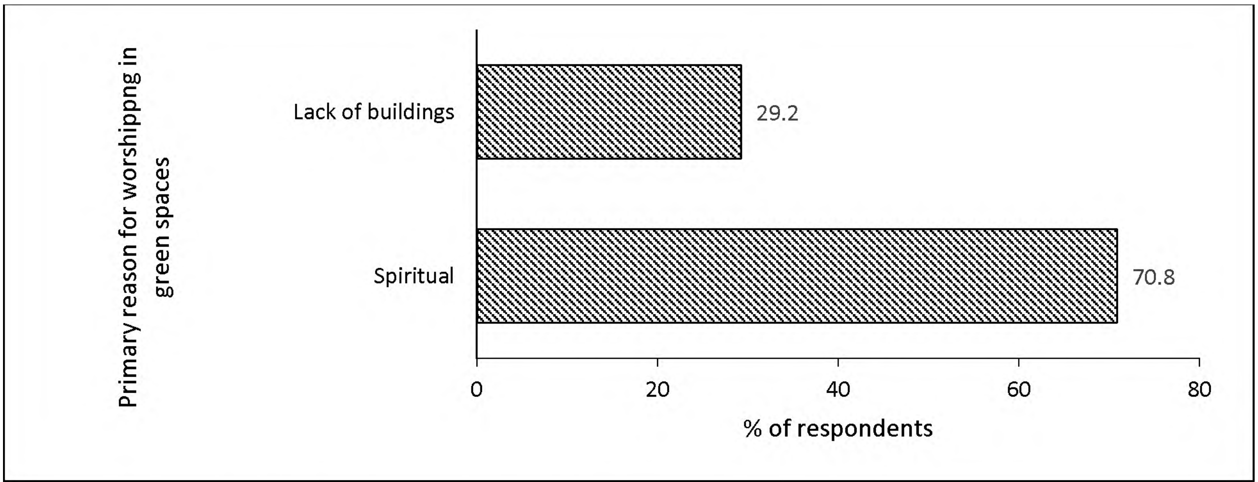

Fig. 5.1: Reasons why residents worship in green spaces

Box 5.1: Responses from respondents in green spaces

Green is life and is a natural colour for trees and grass which also give life......it makes one feel alive and closer to God.......It is easier to talk to God......There is more concentration......One can pray anyhow (Whisper, loud, silently).....I feel that my prayers are answered there and there. Source: Female from Nketa *It appeals to my soul.....it is less formal.......* Source: Male from Hillside *Building a church is expensive, green spaces do not cost anything.* Source: Male from Mpopoma *We worship in green spaces because of financial constraints, we do not have money to acquire buildings for worship.* Source: Female from Nkulumane

5.3.2 Challenges faced when worshipping in green spaces

The major challenges faced by worshippers in green spaces are; i) exposure to harsh weather conditions such as heat, rain and the cold (37.2%), ii) lack of sanitation facilities (23.3%), iii) exposure to animals, insects and reptiles (16.3%) and iv) user group conflicts (16.3%). The lowest percentage of respondents indicated that they did not face any challenges when worshipping in green spaces (Fig. 5.2). The highest percentage of challenges were due to natural causes, i.e. weather (37.2%) and animals (16.3%) which makes a total of 53.3% of the challenges being due to the unaltered green space which appeals to the congregants.

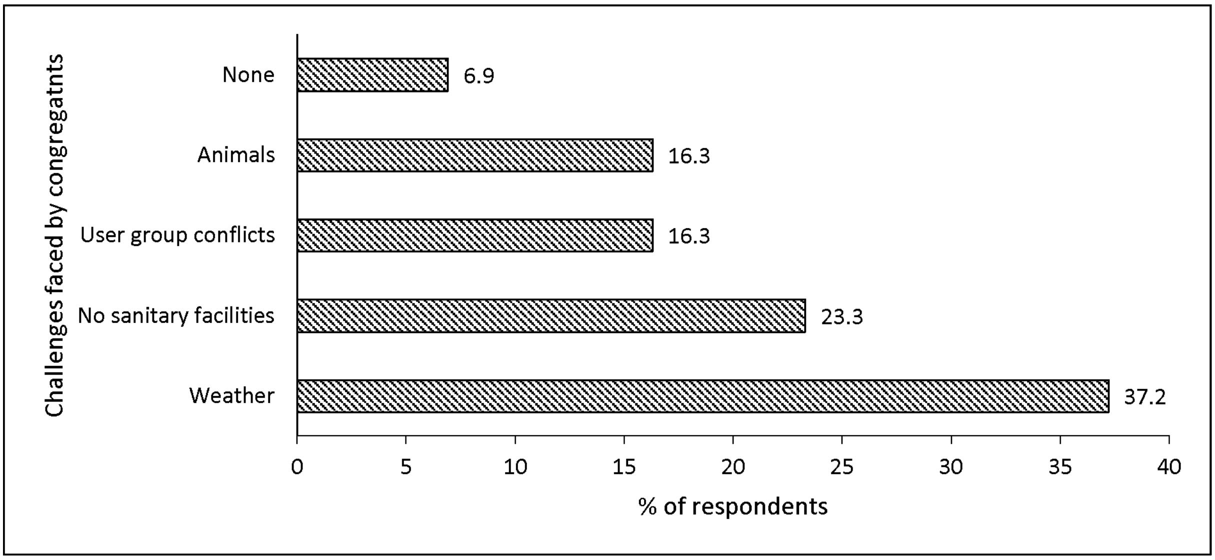

Fig. 5.2 Challenges faced when worshipping in green spaces

5.3.3. Congregants' suggestions on how the city council can assist in improving green space worship

The highest percentage (34.9%) of respondents mentioned being given land for worshipping by the Bulawayo city council as assistance which can be given to them, 16.3% indicated being given stands to construct buildings and the same percentage indicated availing of sanitation facilities. About 9% felt that the council needed to understand how they worship and a similar percentage felt that the council cannot be of any assistance to them. The lowest percentage (4.7%) felt that the council can assist by engaging donors to assist in building the facilities required (Fig. 5.3). Most responses on potential assistance from the council were related to availing of space for worship (60.5%), i.e. provide building to rent (9.3%), avail stands for building (16.3%) and allocate land for worship (34.9.%).

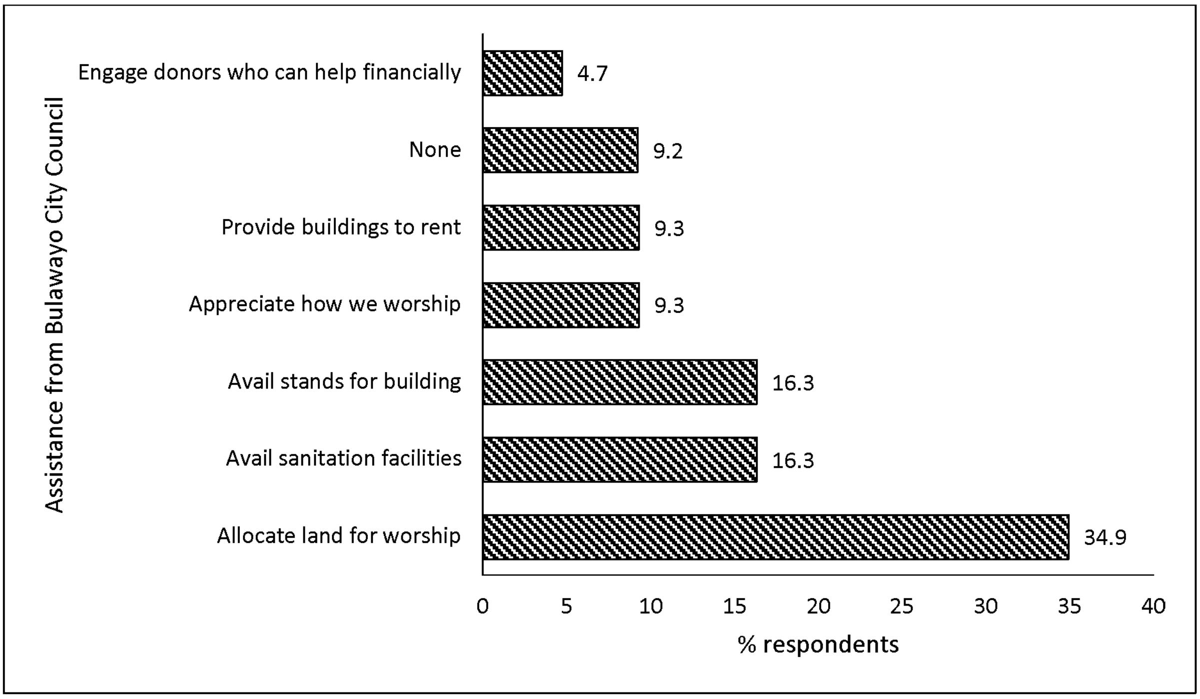

Fig. 5.3: Authorities input in improving green space worship

5.3.4 Frequency of going to church in relation to mode of transport

An association was found between frequency of going to church and mode of transport (X^2 = 20.64, df= 8, $p < 0.05$). Most congregants who attended church services on most weekends walked to church (51.1%). Similar percentages of response rates (4.7%) were evident for those who attended services daily and ride bicycles, travel by taxi or use private vehicles to the green space. For all frequencies, the highest percentage of respondents walked to their place of worship (Table 5.1). Total percentages for the different modes of transport showed that walking has the highest percentage, followed by those using private vehicles and the least percentage used the bus to the worship sites.

Table 5.1: Relationship between frequency of visit and mode of transport to green spaces (% respondents)

Frequency of going to church	Mode of transport					
	Walk	Bicycle	Taxi	Bus	Private vehicle	Total
Daily	7.0	4.7	4.7	0.0	4.7	21.1
Every 2 to 4 days	13.9	0.0	0.0	4.7	2.3	20.9
Most weekends	51.1	2.3	2.3	0.0	2.3	58.0
Total	72.0	7.0	7.0	4.7	9.3	100.0

Residential class in relation to primary purpose of worship in green spaces

Most respondents in all three housing density groups worship in green spaces for spiritual reasons. There is no relationship between residential class and primary purpose of visit (X^2 = 7.68, df= 4, p >0.05) (Table 5.2). Amongst those who primarily worship in green spaces due to lack of buildings, those in high density areas had the highest percentage (19.5%).

Table 5.2: Relationship between residential density class and primary purpose of worship in green spaces (% respondents)

Reasons for worshipping in green spaces	**Location of green space**			**Total**
	High	Medium	Low	
Spiritual	27.0	21.2	22.6	70.8
Lack of buildings	19.5	4.4	5.3	29.2
Total	46.5	25.6	27.9	100.0

Primary reason for worshipping in green spaces in relation to challenges faced by congregants during worship

There is an association between the primary reason for worshipping in green spaces and challenges faced (X^2 = 21.716, df= 8, p< 0.05). The purpose of worship was categorized as either spiritual or lack of buildings. Twenty-six percent of respondents whose primary purpose of worship was spiritual and 11.3% whose primary purpose was lack of buildings had challenges with the weather. These were the highest responses for both categories of primary purpose of worship in green spaces. The second highest for both primary reasons of worship were lack of sanitation facilities, 15.3% for those with spiritual reasons and 8.0% for those who lacked buildings (Table 5.3). Those who worship in green spaces for spiritual reasons also faced challenges with weather (25.9%) and animals (13.4%).

Table 5.3: Relationship between primary purpose of visit and challenges faced (% respondents)

Reasons for worshipping in green spaces	**Challenges**					Total
	Weather	Animals	No sanitation facilities	User group conflicts	None	
Spiritual	25.9	13.4	15.3	10.6	5.6	70.8
Lack of buildings	11.3	2.9	8.0	5.7	1.3	29.2
Total	37.2	16.3	23.3	16.3	6.9	100

Valuation of spiritual services

Table 5.4 shows the value of spiritual services in Bulawayo's public green spaces in the various residential classes based on the travel cost method. The value determined ranged from about $29 to $244 /ha/yr. The highest value was determined for a green space in a high density area (Mpopoma) and the lowest for a medium density one (Queenspark). The mean value per hectare per residential class increased with an increase in housing density, although not directly proportional and statistically insignificant (X^2 =6, df = 4, p>0.05). High density areas were determined to have the highest value of $143±100 /ha. The mean spiritual services green space value was determined to be $93 ±79 /ha.

Table 5.4: Value of spiritual services in green spaces

Density class	Green space	Size (ha)	Total value ($)	Value ($/ha/yr)	Residential class mean value ($/ha/yr)
High	Nkulumane	38.3	1 681	44	143±100
	Nketa	5.9	1 440	244	
	Mpopoma	3.9	551	141	
Medium	Northend	5.7	596	105	67±54
	Queenspark	7.9	227	29	
Low	Hillside	4.8	246	51	43±12
	Hillcrest	14.9	503	34	
Mean					93±79

5.4 Discussion

5.4.1 Reasons for worshipping in public green spaces

The study revealed that through worshiping in green spaces congregants felt connected to God spiritually. Worshippers in green spaces revealed that being around nature during worship gives them a sense of closeness to God, makes them feel free and closer to nature. This supports Thurber et al. (2006) who determined that religiously affiliated outdoor camps evidenced growth in spirituality. Green spaces have been associated with human emotions of tranquillity, spirituality and solace which allows one to have a deep sense of introspection (Pratt, 2013). Participating in outdoor worship enhances experience of God as the creator of the beauty in green spaces (Pratt, 2013; De Lacy, 2014). Thurber et al. (2006) examined use of green spaces occasionally during church camps and determined that outdoor camps enable a holistic experience including physical exercise, mental challenges, social skills development and spiritual events (Thurber et al., 2006), showing that spiritual outdoor experience is experienced by many congregations including the ones who ordinarily worship indoors and occasionally worship outdoors.

The study also determined that about 30% of worshippers use green spaces because they cannot afford, or do not have access to, buildings for worship. Therefore, the green spaces are considered as alternative worship areas for those who cannot afford to purchase or rent buildings. This is similar to a situation in China around 2011 when the Shou Wang church, which was an unregistered house church, resorted to worshipping outdoors when they were prevented from renting or buying a church building (Harvey et al., 2014). After starting outdoor worship, they were immediately persecuted (Harvey et al., 2014; Ng, 2015). Some churches in Bulawayo have not been prevented from acquiring premises but have resorted to using green spaces as places of worship due to lack of funds.

No relationship was determined between the primary purpose of worshipping outdoors and residential density class. Across all residential classes, the highest percentage of respondents indicated that they worship in green spaces for spiritual reasons. Although the lower percentages across all residential classes indicated worshipping in green spaces due to lack of buildings, a decrease in respondents as the residential density class decreased was observed. This may be attributed to the financial standing of the residents in the three residential classes as those living in more affluent low density suburbs can afford to acquire buildings for worship and therefore worship outdoors voluntarily and those in less affluent high density suburbs are forced to worship outdoors due to lack of funds to acquire buildings for worship.

5.4.2 Challenges faced in worshipping in green spaces and assistance from the council

The congregants faced challenges such as the bad weather (heat, rain, cold), and animal threats (snakes and chameleons). The bad weather and animals in this sense are viewed as ecosystem disservices which the congregants are willing to endure since their worship involves being in contact with nature. When asked about how they overcome these challenges, some congregants indicated that they run away from reptiles and erecting structures such as tents to shield themselves from the sun and rain. None of the congregants mentioned abandoning the service due to bad weather.

Challenges also included other park visitors dropping litter which congregants deemed as disrespectful of the place in which they worship. Urban green spaces have various uses which can either enhance engagement for others, or cause user group conflict such as the example of littering above. Watts et al. (2013) showed that the presence of litter in a green space reduced the tranquillity rating. Another example of user group conflicts is a situation in Baxter Park in Dundee, UK, over the use of a children's play area. During lunch time older children use the park which negatively affects mothers and younger children as the older children stand around in groups and throw litter around which attracts sea gulls to the area (Dinnie et al., 2013). The issue of user group conflicts emerges as green spaces are public places which may be used by all, with none of the users having the right and authority to control use of the green space by other users.

Daniel et al. (2012) explain that spiritual and religious significance varies across and within societies. Sacred areas vary in size, are marked and used differently by different groups and are usually protected (Bhagwat et al., 2014). In Bulawayo the worship areas are not physically demarcated by the congregation to restrict access by others. Currently in Zimbabwe there aren't any laws which protect people who worship in green spaces. The Harare city council is working on drafting a by-law which makes it an offence for anyone to obstruct the use of an open space or to become a nuisance to other people in the vicinity of any space between 10h00 and 18h00 which is the permitted time for the congregations to worship in the green spaces (Ruwende, 2015). If all cities, including Bulawayo, develop similar by-laws the green space congregations may be able to worship without interference from other users.

The congregants feel that the challenges they face may be overcome if the city council allocates land for them to use which they can then demarcate and control. In some countries and religions, outdoor worship areas, usually rural sites, are protected, restricting who has access and for what purposes (Ormsby, 2013; Bhagwat et al., 2014). In Zimbabwe, however, this is not the case. By being allocated certain sections of informal green spaces as worship sites, the congregations may be able to overcome challenges regarding access as well as erection of ablution facilities to be used by the congregants. Some councillors in

Bulawayo have suggested providing land to religious groups to enable them to build structures where they can worship, but this may not be the best solution for all the church groups as some believe in worshipping outdoors as part of their worship (Tshuma, 2012), as shown by this study.

Another concern in worshipping in green spaces was the lack of sanitation facilities to be used by the congregants during their service. This affects the aesthetics of the green spaces as well as compromises the public health of the users of the green spaces and the general public. The lack of ablution facilities at these sites has also been a concern that the councils in various cities in Zimbabwe have raised. Initially the authorities tried to ban religious groups from worshiping outside. The city of Harare took steps in controlling outdoor worship by drafting a by-law in mid-2015. Harare city council is yet to impose strict regulations and permit fees for churches practicing open air worship with no ablution facilities. This is in a bid to prevent a possible outbreak of diseases such as cholera and typhoid. Under the Harare (control of Worship in Open Spaces) by-laws 2015, the city of Harare prohibits worship in open spaces without a permit from the council. Worship sites are required to have ablution facilities and potable water. The facilities will have to be inspected by an environmental officer in terms of the Public Health Act, Environmental Management Act and other relevant by-laws including anti-litter and public-health by-laws (Matenga, 2015; Ruwende, 2015). A similar approach is being taken by Victoria Falls (Ncube, 2015). This may see more town and city councils taking the legal route in controlling outdoor worship which may result in outdoor worship being difficult in Zimbabwe.

According to the draft Harare (Control of Worship in Open Spaces) by-law 2015, if a permit to worship in a green space is cancelled, it shall not be renewed until a period of one year has lapsed (Matenga, 2015). The question then arises regarding where such congregations will worship within the period when they are banned and are in the process of renewing permits. Some respondents in this study had indicated that they worship in green spaces because it is cheap but this may not be the case for long as the congregations will be obliged to pay for permits to use the green spaces, set up ablution and potable water facilities as well as pay legal fees and fines in the event that they are found in contravention of the law, assuming that similar by laws will be introduced across the country.

The major mode of transport to worship sites was walking indicating that the green spaces where the congregation members worship are close to where they live. Results showed that those who walk to green spaces go to church more often than those who used other modes of transport. By allocating certain areas for worship by the council, the council has to consider proximity to the various suburbs as it has been shown that proximity of a green space is a pre-determining factor in frequency of visits (Herzele and Wiedemann, 2003). Residents who lived more than 1 km from green spaces had a lower chance of using the green space for exercise compared with persons living closer than 300 m from green spaces in Denmark (Toftager et al., 2011). In Copenhagen, Denmark, there is a clear tendency that shorter distances from home to green spaces were related to higher visitation frequencies (Peschardt et al., 2012). Those who travel 300 m and less to green spaces were five times more likely to visit green spaces at least once a week compared to those who lived more that 2 km from the green spaces and those who lived within 500 m were twice as likely to visit the green spaces twice a week compared to those who lived further than 500 m (Peschardt et al., 2012).

5.4.3 Valuation of spiritual services in green spaces

This study sought to determine the value of urban green spaces as the dollar value can be used as a common comparison with other functions of green spaces or developments that the council would like to make on already existing green spaces. The travel cost method (TCM) is determined from the amount paid to access a place, and the cost is a reflection of the implied value of the service. Very few studies have been made to value urban green space spiritual services and the determined value of $92.50/ha/yr for Bulawayo’s green spaces does not have a comparison in terms of spiritual valuation or the value of other ecosystem services on Bulawayo’s urban green spaces. de Groot et al. (2012) showed that a value was determined for spiritual services in one biome, i.e. coastal systems, out of 10 biomes. This value was determined to be $ 21/ha/yr which is more than three times less than that determined for Bulawayo. Recreation was valued the highest at $96 302/ha/yr in coral reefs but had a low value of $7/ha/year in woodlands (de Groot et al., 2012).

5.5 Conclusion

Green spaces offer ideal places for worship in natural areas for congregants to be in touch with their inner-self. The green spaces are also used by some congregations who ordinarily would worship in buildings but fail to do so due to lack of funds for rent or to purchase or construct a church building to use. All users of green spaces are faced with similar challenges such as inclement weather, lack of sanitation facilities and green space user group conflicts.

The aid of the council would be appreciated by the users of the green spaces if sanitation facilities, stands to erect buildings and official allocation of places of worship in various green spaces could be done to make the worshipping experience of the green space users more pleasant. With new legislation being promulgated it may seem that the churches will have to do more in addressing challenges to do with ablution facilities as the councils are taking steps to make it the congregations' obligation to ensure that these are pre-requisites before worshipping in green spaces. The value of Bulawayo's green spaces spiritual services was determined to be $92.50/ha/yr. This value may be used by the council when making future decisions about use of green spaces for worshiping in comparison to other green space uses, since outdoor worship in Zimbabwe is currently on the spotlight.

The study determined that the frequency of going to church is influenced by the mode of transport used as people who walk to green spaces go to church often. The challenges perceived in worshipping in green spaces were not influenced by the primary reason why congregants worship in green spaces and the primary reason why congregants worship in green spaces was not influenced by the residential class.

Chapter 6

Firewood provision in urban green spaces in Bulawayo

6.1 Introduction

Biomass, which includes firewood, is the cheapest and oldest form of energy used by humankind and has traditionally been utilized through direct combustion. (Dermibas, 2001; Anozie et al., 2007). The main reasons why urban residents use firewood include either the unavailability of clean modern energy sources such as electricity or gas, or their high cost relative to biomass such as firewood or charcoal (Babanyara and Saleh, 2010; Openshaw, 2010; Kimemia and Annegran, 2011). Additionally, the high costs of applicances, such as electrical stoves can be another factor (Madubansi and Shackleton, 2006; Shackleton et al., 2007). Yet, some individuals use firewood for cooking because they enjoy the taste of food cooked using direct flame from a wood-fuelled fire and due to tradition which requires certain food to be cooked on a fire (Openshaw, 2010; Mapira and Munthali, 2011; Zafeiriou et al., 2011).

Historically, the major energy sources in Zimbabwe in 1996 at a national level were coal (thermal power) (38%), firewood (32%), hydroelectric power (13%), petroleum fuels (12%), bagasse (4%) and other types of energy such as solar, ethanol and benzol (2%) (Munowenyu, 1996). However, at a household level Mapira and Munthali (2011) identified the following domestic energy mix in Masvingo: firewood (30%), candles (24%), electricity (24%), paraffin (13% and other (9%) which included solar, torch batteries, generators, gas, diesel, cow dung and jelly. In terms of frequency of use, firewood was used most frequently, followed by electricity and paraffin. In Bulawayo, Dube et al. (2014) found that after electricity, firewood was used the most (76%), followed by paraffin (10%), gas (7%), jelly fuel (6%) and coal (1%). The energy use patterns show firewood use as a fuel that is commonly used in urban areas throughout Zimbabwe.

The use of firewood in Zimbabwe is exacerbated by poor and erratic supply of electricity since around the year 2000. This is attributed to the failure of the power supply authority to maintain the infrastructure resulting in residents resorting to other forms of energy. More recently, the electricity crisis has been attributed to low water levels in Kariba dam which feeds a hydropower station (Mawonde, 2015). Zimbabwe has two major power stations, Kariba hydropower station and Hwange thermal power station. Bulawayo has a power station with a capacity of 90 MW but is currently generating only 30 MW (Zimbabwe Power Company (ZPC), 2015). Zimbabwe has the potential to generate 1 870 MW against a peak demand of 2 500 MW. The deficit has to be met through imports of electricity from Mozambique, South Africa and the Democratic Republic of Congo (Dube et al., 2014). About 6% of households in Bulawayo are not connected to electricity (ZimStat, 2012), whilst those that are connected have interrupted access to electricity due to load shedding (ZETDC, 2015). Amongst the residential areas which experience load shedding, the middle and high density housing areas experience more frequent and prolonged load shedding as compared to low density housing areas (Dube et al., 2014). In Bulawayo a high correlation between the duration of electrical power cuts and the use of firewood as a substitute fuel was determined by Dube et al. (2014). The areas that are mostly affected by the power cuts are the high density areas which would imply that firewood is used as a fuel source more often in these areas than in the low density areas and it would therefore be ideal for firewood to be available to the residents compared to other residential classes.

Firewood can either be collected directly by the users or collected by traders and sold to users (Kimemia and Annegarn, 2011; Schure et al., 2014).The commercialization of firewood has positive effects by providing energy for urban residents who are not able to collect the wood themselves and income for vendors (Shackleton et al., 2006; Mapira and Munthali, 2011). In Bulawayo, residents get their firewood from collection of dead wood (43%), chopping of branches from live trees (27%), cutting down live trees (17%) and up-rooting of stumps (13%) (Dube et al., 2014). These patterns for Bulawayo echoes the Zimbabwean energy use trend reported by Munowenyu (1996) and the potential of urban green spaces to supply the urban population with some of their energy would benefit the residents. Gumbi et al. (2013) showed that the woodlands surrounding Bulawayo was declining and that mature trees are scarce. This is attributed to several reasons, including expansion of the city, cultivation and firewood collection.

Open burning of firewood has adverse health effects such as respiratory ailments (Chowdhury et al., 2013). Consequently, open air burning of firewood is often discouraged to reduce indoor air pollution and the actual quantities of wood used (Anozie et al., 2007; Ludwinski et al., 2011). Alternative means of the use of firewood to generate energy include generation of electricity in wood-powered plants. Michigan (USA), for example, supports a 35 MW power plant designed specifically for burning urban wood sourced from dead and dying trees which are routinely removed from urban green spaces (MacFarlane, 2009). The annual yields of wood biomass from dead and dying urban trees determined in a 13 county state in Michigan covering an area of 2.2 million ha are the equivalent in energy content to between 367 000 to 517 000 dry tonnes of biomass which is equivalent to a 97.5 MW power plant. Extrapolated to the United States of America (USA) level, the routinely removed trees could supply 2.8 million people with electricity per year, which in turn saves $48 to $132 per tonne across USA in landfilling costs (MacFarlane, 2009). This is a good indicator on the potential that urban firewood has in improving the livelihoods of urban residents by providing affordable energy and could add to economic reason for the maintenance of urban woodlands (Hiemstra-van der Horst and Hovorka, 2009).

There has been increased attention to potential benefits of firewood use in African urban centres (Hiemstra-van der Horst and Hovorka, 2009). Firewood provision may improve livelihoods, create employment and supplement income. Use of forest biomass instead of fossil biomass can be considered as a way of utilizing forests for mitigating the global increase in atmospheric CO_2 (Backeus et al., 2005). During combustion, firewood releases CO_2 that was absorbed while the plant was growing (Dermibas, 2001). In nature, all biomass decomposes to its molecules with the release of heat, thus the energy obtained from biomass is a form of renewable energy and, in theory, utilizing this energy does not add CO_2 to the environment, in contrast to fossil fuels (Dermibas, 2001; MacFarlane, 2009).

Consumers in Bulawayo have been shown to prefer indigenous trees to exotic trees for firewood, evident by the high use of *Acacia* species and low use of exotic species such as *Eucalyptus* and *Jacaranda* (Dube et al., 2014). This is attributed to indigenous trees having better burning qualities, lasting longer, being easily available and not emitting unpleasant smells during burning (Dube et al., 2014). In addition to the factors considered by Bulawayo residents, firewood properties such as moisture, density, energy value, ash and silica are generally selected for firewood tree species (Singh et al., 2014). Additionally, the production rate of firewood is important to enable the users and councils to determine which trees will produce the most firewood in a given period whilst considering all other factors.

Informal urban green spaces offer similar benefits to formal green spaces and are preferred by some users because of the lack of human influence on the green spaces (Rupprecht and Bryne, 2014).This applies to firewood as well because both areas have trees and the lack of maintenance of informal green spaces could make informal green spaces potential sources of high volumes of firewood. Additionally, urban residents also make use of firewood produced within homestead plots (Kaoma and Shackleton, 2014) or prunings from street tree maintenance (Kimemia and Annegarn, 2011).

A number of studies focus on firewood consumption in rural areas where firewood is the traditional fuel (Johnson and Bryden, 2012; Link et al., 2012; Gebreegziabher and Cornelis van Kooten, 2013). This study focuses on firewood provision as an ecosystem service in an urban area and will add to the limited work that has been conducted on urban firewood as an ecosystem service (MacFarlane, 2009, Kaoma and Shackleton, 2014). The objective of this study was to determine the firewood production in 12 green spaces in three residential housing classes in Bulawayo. The study answered the following questions: (i) at what rate is firewood generated per hectare in green spaces in Bulawayo? (ii) What is the value of firewood provision in Bulawayo's urban area?

I posed the following null hypotheses:

1. There is no significant difference in firewood production among green spaces.
2. Informal green spaces do not generate more firewood compared to formal green spaces.
3. There is no significant difference in firewood generation rates between indigenous and exotic tree species.

6.2 Methods

To obtain answers for the key questions and hypotheses above, firstly, the density of trees per green space was determined using randomly located belt transects. Each transect was 4 x 100 m. For each tree taller than 2 m within the transect, the height and diameter at breast height (DBH) were recorded. If the tree was multi-stemmed, all stems were recorded. The number of transects per green space varied in relation to the size of the green space (Table 6.1). A total of 53 transects were sampled. Any signs of chopping were recorded.

Table 6.1: The number of transects used per green space

Area (ha)	≥1, ≤20	>20, ≤40	>40, ≤60	>60, ≤80	>80, ≤100
Number of transects	5	7	9	11	13

The allometric equation of Mugasha et al. (2013) in Tanzania was used to convert the height and DBH readings to biomass per stem.

Biomass = $\mathbf{0.0763\ dbh^{2.2046}\ ht^{0.4918}}$ .... eq 1

Secondly, the annual production of biomass per green space was determined by measuring the annual stem diameter increment. A total of 173 trees were marked in the 12 green spaces in September 2014 and re-measured in September 2015. Equation 1 was used to determine the biomass per stem, which was then converted to firewood production in kg/ha/yr.

SPSS v. 20 was used to analyse data at 95% confidence interval. ANOVA was used to determine differences in firewood production rates amongst green spaces. A t-test was used to determine the difference in production rates between formal and informal green spaces and to determine the relationship between firewood generation and origin of trees.

Thirdly, the value of firewood was calculated by determining the market price for wood from the three residential classes by averaging the selling price from four vendors per residential class and using the calculated value to determine the value of wood per kg. This value was then used to determine the value of firewood provision in Bulawayo's urban green spaces in kilograms per hectare per year.

6.3 Results

6.3.1 Tree density

Tree density in public green spaces generally decreased with increasing housing density though the difference in means was not significant ($F=2.3$, $df = 2$, $p>0.05$), (Table 6.2). In the low housing density areas tree density was 86 ±10 trees/ha and high density areas it was 61±29 trees/ha, with the medium housing density areas intermediate between these two. Khumalo and Hillside, both low density green spaces, Parddonhurst (medium density) and Nketa (high density) had high tree densities per hectare. Luveve (high density) had the lowest tree density per hectare.

Table 6.2: Tree density in public parks in Bulawayo across three residential housing density areas

Residential class	Urban green space	Size of green space (ha)	No. of trees/ha	Mean no. trees/ ha/ residential class
Low	Hillcrest	14.9	80	86±10
	Khumalo	16.5	95	
	Famona	4.2	75	
	Hillside	4.8	95	
Medium	Northend	5.7	70	69±19
	Parddonhurst	4.3	95	
	Queens Park	7.9	60	
	Barham Green	6.5	50	
High	Mpopoma	3.9	50	61±29
	Nketa	5.9	95	
	Luveve	4.7	40	
	Nkulumane	38.3	43	
Mean			74±21	

6.3.2 Rate of wood production

<u>Firewood production per green space and residential class</u>

Firewood generated per green space ranged from about 405 to 3 713 kg/ha/yr with a mean of 1 890 ±1 67 kg/ha/yr (Table 6.3). This equates to about 6 600 t/yr, across the entire city where green spaces cover approximately 3 494 ha with a population of about 653 000 residents and 165 345 households (ZIMStat, 2012). This provides 0.04 t/hh/yr and 0.01 t/ca/yr.

The highest wood production rates were recorded in Khumalo (low density) Northend (medium density) and Nketa (low density), and the lowest in Barham green (medium density), Queenspark (medium density) and Nkulumane (low density).There was a significant difference between growth rates among the different green spaces ($F=2.642$, $df=11$, $p< 0.05$). A post-hoc Tukey test was conducted and showed that mean difference in firewood production in Luveve significantly differed from Famona, Hillcrest, Hillside and Nkulumane ($p<0.05$). However, there were no significant differences between housing density classes ($F = 1.65$, $df= 2$, $p >0.05$).

<u>Firewood production in informal and formal green spaces</u>

Out of the 12 sampled green spaces, three were formal and nine were informal. The mean production rate of formal green spaces (2 375 ± 687 kg/ha) was higher than that of informal green spaces (1 738 ± 1 122 kg/ha) showing that formal green spaces in Bulawayo produce more firewood than informal green spaces, ($t = 3.2$, $df= 109$, $p <0.05$) (Table 6.3). The highest firewood production rates were recorded in Khumalo (Informal), Northend (Informal), Nketa 6 (Formal) and Luveve (Formal) and the least production rates were determined in Queens Park, Nkulumane and Barham Green (all informal).

Table 6.3: Firewood generated per green space per year

Residential class	Area	Nature of green space	Firewood generated (kg/ha/yr)	Class mean(kg/ha/yr)
Low	Hillcrest	Informal	2 063	2 455 ±910
	Khumalo	Informal	3 713	
	Famona	Formal	1 590	
	Hillside	Informal	2 452	
Medium	Northend	Informal	2 895	1 361±1 104
	Parddonhurst	Informal	1 410	
	Queens Park	Informal	405	
	Barham Green	Informal	735	
High	Mpopoma	Informal	1 103	1 853±1 067
	Nketa	Formal	2 865	
	Luveve	Formal	2 670	
	Nkulumane	Informal	773	
Mean for all green spaces				1 890±1 067
Mean for formal green spaces				2 375 ± 687
Mean for informal green spaces				1 728±1 122

6.3.3 Origin of tree species

The majority (67.6%) of trees in 12 green spaces were indigenous and 33.4% were exotic (Fig. 6.1). The most common species were *Eucalyptus spp.*, *Acacia gerrardii*, *Acacia nilotica, Azanza garkeana, Peltophorum africanum* and *Pinus spp.* In the formal green spaces 42.1% of the trees were exotic and 57.9% indigenous; the ratio was almost identical in the informal spaces (42.3% and 57.7 %, respectively). No relationship was evident between the nature of green space and origin of trees (X^2 = 0.979, df= 1, p >0.05). Differences in firewood production rate and origin of trees were tested. Fuelwood generation for indigenous species was 193.2±115.5 kg/ha/yr and that of exotic species was 189.0±92.1 kg/ha/yr (t = 0.2, df= 84.9, p >0.05).

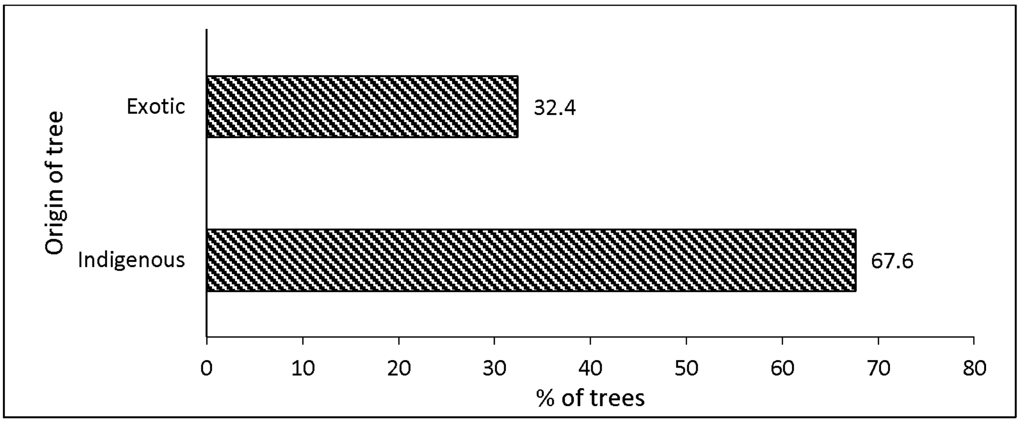

Fig. 6.1: Origin of tree species

6.3.4 Value of firewood provision

The average firewood cost was \$0.25 per kg in the high density and medium density areas and \$0.20 per kg in the low density areas. The average cost of firewood in Bulawayo is \$0.23 per kg. Based on annual firewood production rates the value of firewood provision in Bulawayo's urban green spaces ranges from \$340 and \$463 /ha/yr (Table 6.4). The low density areas recorded the highest value, followed by high density areas and medium density areas recorded the lowest value.

Table 6.4: Annual value of firewood produced in sampled green spaces

Residential class	Firewood production (kg/ ha/yr)	Firewood price (\$)	Value (\$/ ha/yr)
High	1 853	0.25	463
Medium	1 361	0.25	340
Low	2 455	0.20	491
Mean	1 890±548	0.23±0.03	431±80.3

6.4 Discussion

6.4.1 Firewood production rates

Bulawayo's urban green spaces produced an average of 6 600 t of firewood per year. The results show that the production rates amongst the three residential classes and amongst the 12 green spaces were significantly different. Growth rates are influenced by both environmental and anthropogenic effects. The mean firewood production rates decrease as residential density increases. This is likely to be due to the general decrease in tree density as residential density increases. It is an advantage to the high density area residents if high density areas produce more firewood because those living in high population density suburbs account for the bulk of firewood consumption in Bulawayo (Dube et al., 2014).

In 2010 it was determined that Zimbabwe produces 13 million tonnes firewood per year (Merven et al., 2010). This study estimated Bulawayo's urban green spaces to yield 6 600 t of firewood per year. The determined firewood production translates to 0.04 t/household/yr and 0.01 t/ca/yr. Dube et al. (2014) determined firewood use per capita per year to range from 1.1 t to 1.8 t per household in Bulawayo. The amount determined in this study is then insufficient to adequately supply Bulawayo's urban residents as the determined firewood production rate is only a minor fraction mean demand (5 to 11%). This is not unsurprising as green spaces cover only 6.2 % of Bulawayo's land area. The gap in firewood supply is currently covered by firewood sourced from traders who import firewood from surrounding rural areas, as is the case with most large cities using extensive amounts of biomass (Brouwer and Falcão, 2004; Shackleton et al., 2006; Moktan, 2014). The household firewood consumption rate in Bulawayo is quite high compared to the Himalayan region of India where consumption of firewood is 61 kg/ca/yr (Sood et al., 2014). Firewood consumption in a village in Sahel, Mali, ranged from 1.4 to 0.8 kg/ca/day depending on household size (Johnson and Bryden, 2012) and a study of 3 000 households across 10 rural agro-ecological locations in Sub-Saharan Africa determined firewood use to be 2.2 kg/ca/day (Adkins et al., 2012). In Uganda fuelwood consumption was determined to be 1.56 m^3/yr for a household of about seven persons (Agea et al, 2010).

6.4.2 Firewood production and type of green space

There was a relationship between the type of green space, i.e. formal or informal, and the annual firewood production rate, with formal green spaces producing more firewood. Formal green spaces are usually altered by cutting down trees to set up amenities such as benches and may be removed to clear paths used by pedestrians and could have been producing more firewood due to irrigation of the parks. Trees in formal green spaces are also maintained by pruning trees which could, for example, be blocking pedestrian routes. Koeser et al. (2014) determined that urban trees that are maintained and irrigated have higher chances of survival than those which rely on natural rainfall. Trees planted at a site in Florida were reassessed after planting on 26 sites and 93.6% of the trees were alive, but with greater survival (97.7%) on irrigated sites than on non-irrigated sites (73.8%) (Koeser et al., 2014).

This study showed that formal green spaces yield firewood at a rate that is similar to that of informal green spaces. Bulawayo's formal green spaces however are patrolled by council authorities and residents do not have formal access to the trees to acquire firewood. Since green spaces serve multiple purpose, the primary reason for establishing a green space should be considered since a formal green space may be established to beautify a place and to relax, but residents may cut down the trees and disrupt other users who will be using the green space for recreational purposes.

Informal green spaces have the potential of generating more firewood if used specifically for growing trees to supply firewood. Informal green spaces which may be in the form of remnant land may be used as community woodlots to grow trees specifically for firewood, as is done in Ethiopia (Gebreegziabher and Cornelis van Kooten, 2013) or Rwanda (Seburanga et al., 2014). The community woodlot approach can be more effective in managing fuel shortages if it is sponsored locally with a buy-in from residents, if the population density is not too large to avoid deforestation and if access to these areas is governed (Gebreegziabher and Cornelis van Kooten, 2013).

6.4.3 Firewood production and origin of tree species

The tree species available in Bulawayo's urban area include both indigenous and exotic species which from analysis did not show a significant difference in production rates. According to Ndlovu (2014, pers comm, 8 October 2014) exotic trees are mostly planted along streets and formal green spaces which explains the low percentage of exotic trees since the formal green spaces studied covered 14.9 ha and informal covered 101.9 ha. Generally, the formal green spaces that are maintained by the city council are small, ranging in size from 4.24 ha to 5.94 ha and the informal green spaces sampled ranged from 3.8 ha to 38.4 ha.

Both indigenous and exotic species grow in these urban green spaces but this does not necessarily mean that all trees are then used by the residents as firewood. In areas further away from the residential areas of Masvingo, residents selected indigenous trees which they cut down for firewood as they were perceived to last longer, have better burning qualities and easily available (Dube et al, 2014) than the exotic trees which are also associated with unpleasant odours when burnt. Trees which supply fruit and have medicinal properties are less likely to be cut down to be used for firewood (Dube et al, 2014). Gebreegziabher and van Kooten (2013) also determined that households in Ethiopia consume more firewood from indigenous tree species but will not change the rate of consumption if only exotic species are available. This implies that, in Bulawayo, in the event that the majority of the species i.e. indigenous are used up, the residents still have the option of using the exotic species as firewood. In the Eastern Cape of South Africa, Shackleton et al. (2006) reported that whilst urban consumers preferred indigenous species for firewood, most used exotic species because they were more readily available.

6.4.4 Deforestation

The selection of firewood species preferred by residents also acts as a way of conservation within green spaces as the less desirable species will not be cut down. In Masvingo, areas closer to residential areas have non-selective deforestation as residents cut down both indigenous and exotic tree species due to the competition between the large numbers of residents who cut down trees (Mapira and Munthali, 2011). Urban harvesters minimize the distance travelled to get wood resulting in peri-urban dry wood becoming scarce and live tree chopping starts occurring near the urban-zone which promotes deforestation (Hiemstra-van der Horst and Horvoka, 2009).

The majority of the self-collecting households travel on foot and urban and agricultural development in urban areas could increase firewood scarcity within walking distance in the future (Hiemstra-van der Horst and Horvoka, 2009). According to Dube et al. (2014) residents in Bulawayo get their firewood from collection of dead wood (43%), chopping of branches from live trees (27%), cutting down live trees (17%) and by uprooting of stumps (13%). Household selection of wood collection sites in Maun, Botswana, is based on dry wood abundance, because of the much higher time and labour investments required to cut and dry wet wood before it can be used, access rights and the relationship of firewood collection to other activities, than on proximity of the collection site (Hiemstra-van der Horst and Horvoka, 2009). Due to this, competition is normally avoided and harvesting patterns are diffuse resulting in less deforestation.

Firewood can be sourced from areas other than the urban areas. For example, in Congo and Ethiopia, producers in rural areas cut down firewood for the urban markets (Troserro, 2002; Gebreegziabher and Cornelis van Kooten, 2013). Schure et al., (2014) report that in two cities in Congo, 80% of the firewood producers sold their produce to the urban areas. Schure et al. (2014) conclude that the commercial value of firewood creates opportunities for the livelihoods of producers, but this requires trade-offs with forest conservation. The potential of firewood to aid in poverty reduction in urban areas should be integrated into forestry and energy supply plans so as to enable development whilst maintaining the natural resource base (Shackleton et al., 2007).

Gebreegziabher and van Kooten (2013) determined that households rely on planted trees only if they are available but that does not necessarily translate into less pressure on natural areas. The Ethiopian government uses tree planting at community and household levels as a means to mitigate deforestation. The rationale behind this is that at least a reasonable part of what is planted will be used as firewood, but a question still arises as to whether the trees will indeed fully or partially be used as firewood (Gebreegziabher and Cornelis van Kooten, 2013) as concern has been raised if there will be adequate firewood to be used in the next few decades (Wangchuk et al., 2014; Felix, 2015).

6.4.5 Value of firewood provision

Firewood costs on average \$0.23 per kg in Bulawayo, with high and medium density area firewood traders selling firewood for \$0.25 per kg and low density areas selling firewood for \$0.20 per kg. The slightly lower cost of firewood in the low density areas may be attributed to a lower demand as compared to the other density classes because they are in a position to use more costly alternative sources of energy such as liquid petroleum gas and petrol or diesel power generators in the absence of electricity. The value per hectare was determined to be about \$340-\$490 /ha/yr. The global average price of firewood is expected to be about \$100/m^3 by 2030 assuming high firewood demand (Buongiorno et al., 2011).

The determined value of firewood provision as an ecosystem service in Bulawayo was \$340 to \$490 ha/yr. The growing of trees for provision of firewood can be compared with other ecosystem service values such as the role of trees in a green space without destroying the trees such as air purification, urban cooling and climate regulation. In Chicago, USA, McPherson et al. (1997) determined the value of air purification to be \$9.2 million /year and \$15 /tree/year for urban cooling. No comparisons could be made for local studies as such studies have not been conducted.

6.5 Conclusion

Bulawayo's green spaces produce 1.9 t/ha/yr of firewood with an ecosystem service value of \$340 to \$490 /ha/yr. The green spaces showed a significant difference in firewood production among sites. Previous studied have determined firewood consumption in Bulawayo to be 1.1 to 1.3 t/ha/yr (Dube et al., 2014) and this study determined that the firewood production rate is much less than the consumption rate (determined by Dube et al. (2014)). This shows that although the green spaces may not adequately meet the firewood demands of the Bulawayo's residents the green spaces are capable of contributing to Bulawayo's firewood energy demands, and that this function has high value, likely to be much higher the maintenance budgets for green spaces in Bulawayo. Formal green spaces were shown to produce more firewood as compared to informal green spaces and no difference was determined in growth rates between exotic and indigenous tree species.

Chapter 7

Conclusions and recommendations

7.1 Introduction

Urbanization and urban growth have resulted in the development and expansion of urban areas leading to the expansion of built up areas to accommodate the new infrastructure and buildings. This usually results in more natural land being cleared to accommodate the developments. In the absence of guided planning of cities, green areas will be reduced to an extent that the benefits that residents enjoy from these green spaces' ecosystem functions will be reduced. The green areas in cities, i.e. urban green spaces, offer multiple ecosystem services to urban populations as well as the environment (Roy et al., 2012; Mensah et al., 2016). These ecosystem services have been categorized as regulating, provisioning, cultural and supporting services (MA, 2005). Whilst there has been increasing recognition and quantification of ecosystem services provided by urban green spaces, many gaps in understanding remain.

A particularly stark gap is the lack of studies in Sub-Saharan Africa (Roy et al., 2012; Shackleton, 2012). The review of Roy et al. (2012) reported that 78.3% of articles on valuing of urban trees came from work in North America and Asia, and only 5.2% from Africa, all from South Africa. Similarly, Shackleton's (2012) review reported that only 21.4 % of published work was from developing countries, most of which came from China, and all but one paper from Sub-Saharan Africa were from South Africa. Wendel et al. (2012) also lamented the relative absence of work on urban ecosystem services in developing country contexts. Consequently, the detailed work reported in this thesis makes a significant contribution.

Another strength of this work is the employment of mixed methods to address a variety of ecosystem services. Once again, the review by Roy et al. (2012) is useful. They state that less than 14 % of papers on valuing ecosystems services of urban trees made any use of social or mixed methods. Most used either solely economic or solely ecological. Moreover, although they reviewed studies assessing the value of urban trees, most did not assign an actual monetary value (Roy et al., 2012). The work in this thesis does both of these, further emphasising its importance and usefulness. However, given the breadth of the work reported here, in terms of assessing several ecosystem services, it was not possible to include ecosystem disservices and costs associated with management of urban green spaces in Bulawayo. Therefore, I have not been able to calculate the benefit: cost ratio for any of the ecosystems services included.

This study aimed at determining the quantities and value of selected ecosystem services offered by Bulawayo's green spaces. At least one ecosystem service was selected from each category, excluding supporting services.The selected ES were micro-climate regulation, carbon sequestration, fuelwood provision and spiritual worship. A total of 12 green spaces were sampled, with four green spaces in high, medium and low residential density classes. Urban green spaces have been shown to mitigate many urban problems including carbon sequestration; regulating temperature; fuelwood provision; noise reduction, and providing food (Fang and Ling, 2003; Backeus et al., 2005; Nkala et al., 2012; Dube et al., 2014).

Green spaces in Bulawayo were determined to cover 6% of the city's area of 654 km^2 (Bulawayo Master plan, 1981) and comprise both formal and informal green spaces. To enable the conservation of these green spaces, the Bulawayo Municipality maintains these green spaces which are governed by the Bulawayo (Protection of Lands and Natural Resources) by-laws of 1975 which prohibit excavation, refuse dumping, construction as well as cutting down of trees from any municipal land.

To support decisions to be made on land-use planning within the cities, a common unit of measure has been identified, i.e. monetary value (Blignaut and de Wit, 2004). This comes about as the concept of ecosystem service valuation which has enabled monetary value to be placed on non-monetary elements of life (Blignaut and de Wit, 2004). Studies have been done on ecosystem services and their value worldwide but little work has been done to date on urban green space ecosystem services valuation in Sub-Saharan Africa (Roy et al., 2012; Shackleton, 2012) and no work has been done in ecosystem services in Bulawayo, Zimbabwe.

The chapter summaries all chapters of the thesis, gives an integrated picture of the study, proposes further research and makes recommendations.

7.2 Summary of the thesis

The study was conducted to fill a knowledge gap on urban green space ecosystem service use, quantification and valuation in Southern Africa, using Bulawayo as a case study. The use and perceptions of residents of green spaces were determined by administering questionnaires to green space users. Ecosystems services that were quantified and value were carbon sequestration, urban heat island amelioration, spiritual services and firewood provision. 12 green spaces used as sites for the study were selected from each residential density class, i.e. Low, medium and high. 4 green spaces were randomly selected from each residential density class.

7.2.1 Residents' use of Bulawayo's green spaces

Chapter two focused on the resident's use and perception of green spaces. Questionnaires were used to capture responses from residents in green spaces on reasons why they use green spaces, their perceptions of green spaces and on the benefits that they enjoy from green spaces. Residents use green spaces for various reasons which are social, for acquiring food and for utility (Gobster et al., 2007; de Groot et al., 2012; Egoh et al., 2012; Bhaktiari et al., 2014). Bulawayo has numerous green spaces across all residential classes and are used by residents for various reasons. This study sught to determine (i) why residents visit public green spaces, (ii) how frequent they visit green spaces (iii) if residents find green spaces in Bulawayo desirable and (iv) what benefits are percieved by residents from green spaces.

Residents in Bulawayo use green spaces quite often i.e., either daily or a couple of visits per month, mostly to relax. Most felt that the green spaces were adequate but were not well maintained. The primary purpose of visit and frequency of visiting green spaces differed between residential density classes. Greens space users in the high and medium density area visited green spaces more often than residents low density green space users. Most of the visitors used green spaces within their own area.

7.2.2 Carbon sequestration by urban trees

Anthropogenic activities in cities have resulted in the emission of green-house gases into the atmosphere, including carbon dioxide. Some countries have already taken steps to include urban forests to offset greenhouse gases, for example, the United Kingdom government has a target to reduce greenhouse gas emissions by 80% by the year 2050 from 1990 and above ground vegetation carbon storage has been identified as one of the strategies to achieve this goal (Fankhauser, et al., 2009). Bulawayo's green spaces have trees which absorb carbon dioxide during photosynthesis (Poundyal et al., 2011) and this study sought to answer the questions: (i) how much carbon is sequestered per hectare by Bulawayo's urban green spaces per annum? (ii) What is the annual value of carbon sequestration by Bulawayo's urban green spaces?

Chapter three focused on carbon sequestration by trees in Bulawayo's green spaces. Biomass increase was measured over a one year interval and the amount of carbon sequestered was calculated using the biomass increase. Carbon sequestration was expresses in kg/ha/yr. The value of the carbon sequestration service of tree was measure in $/kg/ha/yr but multiplying the determined carbon sequestration by the international value for carbon.

The city's green spaces were determined to sequester 3 290 tC/yr valued at $13 000 /yr. Formal green spaces in Bulawayo were determined to sequester more carbon than informal green spaces, indigenous and exotic trees were determined to sequester similar amounts of carbon and trees with larger stems were determined to sequester more carbon than those with smaller stems.

7.2.3 Micro-climate regulation

Construction of roads and infrastructure in urban areas has resulted in the reduction in natural land (Zinzi and Agnoli, 2012) which in turn causes an increase in ambient temperature compared to the surrounding rural area and this is known as the urban heat island effect in urban areas (Chow and Roth, 2006).Bulawayo's green spaces showed a similar trend to what was determined by other studies (Akbari et al., 2001; Kardinal Jusuf et al., 2007; Ng et al., 2012; Lin et al., 2015; Mullaney, 2015).Temperatures increased from green spaces to built-up areas showing the cooling influence that the green spaces have on their surrounding environment. Studies have shown cooling effects by green spaces of up to 6.9 °C (Oliveira et al., 2011).

Chapter four focused on urban heat island amelioration. To determine if green spaces have an effect on ambient temperature reduction the atmospheric temperatures of the area within a green space and up to 2km from a green space into built up areas were measured twice a month for three months in summer and three months in winter. The temperature differences between built up areas and green spaces was then determined. The value was determined using the replacement cost method by determining the amount of electricity required to reduce temperature and the cost of electricity.

Bulawayo's green spaces had a maximum temperature difference of 6.1°C.No significant difference was found between summer and winter mean temperature differences per green space. The cooling effect of public green spaces were determined to have a value of $835 /household/yr which is an indication of the amount of electricity which could be potentially saved by households on indoor cooling.

7.2.4 Spiritual services

Chapter five focused on spiritual services. Some congregations in Bulawayo worship in green spaces and the study sought to determine the reasons why congregations worship in green spaces, the challenges they face as well as the assistance that they would want to be given from the local authorities. The green space value was determined by using the travel cost method. The travel costs using different modes of transport such as bus, taxi and private vehicle were determined considering the time it took to travel to the green space and the cost associated with travelling. For congregants who cycled or walked, the time taken to travel and wage rate were used to determine the travel costs to the site. The cost per hectare was then determined for the different green spaces.

Urban forests provide both active and passive social benefits (Westphal, 2003). The socio-cultural aspects of urban green spaces are becoming increasingly recognized as important benefits. The number of sociocultural research papers published has increased over the last 20 years, of which 75% of these papers have been published since 2002 (Rupprecht and Bryne (2014).

Spending quality time in a well-designed garden allows one to block negative distractions and focus on positive acts such as praying and meditation, which in turn, enhances one's spiritual growth and development (Pratt, 2013). Green spaces in Bulawayo are used as worship sites for congregations who ordinarily worship in green spaces as part of their doctrine and for those who cannot afford to acquire facilities for worship. In using public green spaces, congregants face challenges such as bad weather, lack of ablution facilities and conflicts with other users. The congregants highlighted that their worship experience can be improved if the authorities avail worship sites for them to use exclusively for worship. The value of Bulawayo's green spaces spiritual services was determined to be $92.50 /ha/yr. Generally, frequency of going to worship in greens spaces church was significantly related to mode of transport, with those who walk to worship doing so more often than those who use vehicular transport.

The link between environmental conservation and worship can be made when congregants appreciate God's creation, they are in a better position to conserve nature as a way of respect and as a way of preserving the state of the outdoor environment that they worship in. Outdoor worship promotes conservation as people respect and hence conserve certain elements of the environment as they associate them with worship as determined by Murugan et al. (2008) for sacred groves. Since around 1976 there has been special interest in the role of religion in shaping environmental behaviour and theologians are exploring the teachings of the major world religious traditions with regards to the environment (MA, 2005).

7.2.5 Fuelwood provision

Bulawayo occasionally faces power cuts due to electricity shortages. This has resulted in residents resorting to using firewood as a source of power Chapter six investigated the fuelwood provision potential of trees in Bulawayo's green spaces. Fuelwood generation was determined over a one year period my measuring the trees over a one year interval. The value of the firewood generated was determined by multiplying the amount of fuelwood by the local market price of firewood per kilogram for the three residential densities. The value was expressed in $/kg/ha/yr.

. Bulawayo's green spaces were determined to produce 1.9t /ha/yr of firewood with an ecosystem service value of $340 to $490 /ha/yr. A significant difference was observed in firewood production between the 12 green spaces sampled. Formal green spaces produced more firewood than informal green spaces as they had a greater density of trees. The value of firewood provision as an ecosystem service will enable the council to make economic decisions on green space use as collection of firewood from formal public green spaces is currently prohibited according to the Bulawayo (Protection of Lands and Natural Resources) by-laws of 1975.

7.3 An integrated picture

Each of the results chapters reports on a single ecosystem service, spanning three of the four MA (2005) categories. Yet, the provision and management of ecosystem services in urban settings is complex (Bezák and Lyytimaki, 2011) because of the rapidly changing social and economic environments, which result in marked spatial and temporal changes in green infrastructure, including urban green spaces. Looking across the different services examined in this thesis, together they provide insight into the importance of formal and informal green spaces in Bulawayo, the second largest city in Zimbabwe. Firstly, they confirm that the green spaces are used for a variety of purposes and benefits which are appreciated by residents of Bulawayo.

There are many other ecosystem services that could have been included, and should be investigated in future to help develop a comprehensive picture. However, these four are sufficient to illustrate the considerable use and value of urban green spaces in such a setting, and the complex overlaps between them.

Secondly, this work has shown that although multiple ecosystem services are provided and used, that their distribution is not uniform throughout the city. Thus, differences were noted in the supply and use of ecosystem services from urban green spaces situated in areas of different housing density, which is also likely to be correlated with household wealth. For example, areas of high housing density had lower levels of carbon sequestration, tree density and firewood supply than areas of low housing density. Additionally, residents in high density areas tended to visit green spaces more frequently than those in low density areas, and did so to relax with friends, whereas the latter did so for walking. The unequal distribution of green space in many cities is not unknown, although the underlying causes may be less apparent. For example, in South Africa there is substantial inequality in the distribution of green spaces, being highest in wealthy towns and wealthy suburbs within towns (McConnachie et al., 2008; McConnachie and Shackleton, 2010; Shackleton and Blair, 2013). Many of the poorer suburbs had no formal green spaces at all. This was mirrored further in the unequal distribution of street trees (Kuruneri-Chitepo and Shackleton, 2011).

Lastly, it is tempting to add up the calculated values for the different ecosystem services to determine a total value. However, the danger in doing so is that such a value will then be used by planners or decision makers in as a single definitive value of green spaces in Bulawayo. But it would not be a definitive value because I have looked at only four ecosystem services as examples of what is on offer. There are many other ecosystem services, such as storm water reduction, air quality amelioration, provision of fruits, wind breaks, effects on property values and the like. Thus, the values calculated in this study are only a fraction of the total value of ecosystem services provided by urban green spaces in Bulawayo. Nonetheless, amongst these few, it appears that i) the values are substantial and are likely to well exceed the costs of establishment and maintenance and ii) temperature amelioration was amongst the highest, yet probably the least recognized by city planners and residents. With Bulawayo being in the tropics it naturally experiences high temperatures. But these are likely to be exacerbated with climate change, posing very serious risks to thermal comfort and the physical health of the city's residents, especially the urban poor who have less green spaces, and a lower capacity to afford air-conditioners. Thus, the role of urban trees and green spaces in easing high temperatures needs to be taken seriously by urban planners and decision makers.

At the opposite end, the value of tree carbon sequestration was very small, limited by both the low international price of carbon as well as the low density of trees in the green spaces. The value of the carbon sequestered was far higher in the form of firewood than for trading on carbon markets. However, the provision of firewood by Bulawayo's urban green spaces can meet only a small fraction of the current demand. Yet, the use of firewood is likely to remain a reality for decades to come. The city authorities could ignore it and let firewood be imported from surrounding rural areas, most likely adding to national deforestation concerns (with over 4 000 ha of woodland lost in the Bulawayo area in the last two decades (Gumbi et al., 2013)), or they could attempt to improve supply of firewood within the city limits. It would require vision and innovation, and whilst it is unlikely the full demand could be met, a great deal more could be done through the provision of woodlots, planting of fast growing, non-invasive species in green spaces and the creation of more and larger multifunctional green spaces.

At the start of the study, three objectives were posed, namely to i) determine the use and perception of urban green spaces by residents of Bulawayo, ii) quantify selected ecosystem services and iii) value selected ecosystem services. It is clear that the preceding chapters have met each of these objectives. Chapter 2 has shown that green spaces are used frequently, for a range of purposes and by a wide variety of people throughout Bulawayo. Then chapters 3, 4, 5 and 6 have each quantified the supply of a particular ecosystem service and then used an appropriate method to assign a value to the quantity supplied. Taken together, they provide compelling evidence of the importance of public green spaces in Bulawayo.

7.4 Further research

There has been an increase in ecosystem services research over the past two decades (de Groot et al., 2002; Beaumont et al., 2007;) and the interest in this field could be an indication of the growing awareness of the need to understand and manage natural resources to improve livelihoods as well as to promote sustainable development. The attention given to urban ecosystems is relatively modest (Gomaz-Baggethun and Barton, 2013) with 'most studies focusing on single ecosystem services and/ or value dimensions' (Gomaz-Baggethun and Barton, 2013). Monetary values have been widely examined in the literature but description or measurement of symbolic, cultural, identity and other non-economic values remain unexplored (Chan et al., 2012).

Further research can be done on residents' input in planning for green space use as well as determining adequacy of green spaces based on urban green space area per capita. Such information will help for future urban use planning so as to ensure that adequate green spaces are allocated as the city expands. The distance travelled to the nearest green spaces by residents from their residential areas needs to be determined. Maintenance of green spaces was determined to be poor, and since the authorities do not have adequate funds to maintain the green spaces, further research on existing and alternative green space management options would be beneficial to the city. This was a preliminary study on urban heat island amelioration and further studies need to be done for Bulawayo to take into consideration all the factors that contribute to microclimate regulation when planning for green spaces with the intent of having them contributing towards lowering city temperatures. Further research may also be done to establish the city council's and resident's inputs on green space planning for spiritual services use as factors such as proximity to residential suburbs and proximity to noisy areas need to be considered.

More work needs to be done to determine the tree species most preferred by residents in Bulawayo's green spaces and to determine the firewood production rates for those species to enable the authorities to plan for urban woodlots that will serve as firewood sources for the urban population. It may be possible to control the rate of tree removal by assisting residents and authorities to better align their selection of new trees to their expectation and to reconsider expectations of existing trees.

More work also need to be done in determining the major reasons why residents visit certain green spaces and do not visit others as well as more detailed analysis on the use of green spaces for worship.

7.5 Recommendations

The contribution of informal green spaces could be duly recognized and incorporated into the urban green space planning as residents showed that the green spaces they visit, i.e. either formal or informal offer them both tangible and intangible benefits. Authorities, environmental groups as well as educational institutions need to increase awareness on green spaces and their use since some studies have determined that strong preference is given to ecosystem services that have been promoted in publicity programs. Authorities may also need to promote the use of green spaces by maintaining green spaces in better conditions than they are in. This can be done by allocating adequate resources to the maintenance of green spaces not only for their social benefits but for their economic and ecological functions. Activities in the urban green spaces such as maintenance also results in the introduction of carbon. The determination of the urban tree carbon sequestration potential would even be more beneficial if the carbon emissions by the city of Bulawayo could be determined.

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Appendices

Appendix 1: Use of green spaces in Bulawayo questionnaire

Introduction

My name is Thembelihle Ngulani (ID Number: 84-028238Q56) and I am an MSc student in the Environmental Science Department at Rhodes University being supervised by Professor Charlie Shackleton. I am conducting a study to identify, quantify and determine the value of ecosystem services in green spaces in Bulawayo. The aim of this questionnaire is to gather information on how Bulawayo's residents use green spaces. I will be interviewing approximately 385 people at 12 different parks.

This research has been approved by the Bulawayo City Council. The purpose of the research is for degree purposes, however, reports will be submitted to the Bulawayo council so that they have more information about their green spaces and their use and an article will be written for the local newspapers to publicise the findings.

The questionnaire will take approximately 15 minutes to complete. Your participation in the study is voluntary and your identification will be kept anonymous. You have a right not to answer questions you are not comfortable answering and are free to withdraw from the study at any time even after you have started responding to the questions.

<u>Use of green spaces in Bulawayo</u>

Date: ___________________

Suburb: _______________________________ Green space: _________________________________

1. How often do you use/visit **THIS** green space? (*tick one*)

Daily	Every 2 - 4 days	Most weekends	1 - 2x per month	Every 2 - 3 months	Couple of times a year	Never

2. What is the **PRIMARY** purpose of your visit (i.e. why do you go to the green space)? (*tick one*)

Just walking through to the other side		To enjoy the beauty	
To spend relaxing time with friends or family		To collect firewood	
Exercise (sports/jogging/walking)		To collect medicinal products	
Spiritual worship		To collect wild foods	
To take a break in the shade		To collect poles for fencing or building	
To get a breath of fresh air		Other (specify)	

3. Other than your primary purpose, do you get any other benefits when visiting THIS green space?

   Yes [ ] No [ ] *(If no, go to Q5)*

4. If yes, what other benefits? (*tick as many*)

Beauty/aesthetics		To watch other people enjoying themselves	
Fresh air		Other (specify)	
See the birds/animals		Other (specify)	
Makes me relaxed		Other (specify)	
Good place to think		Other (specify)	
Get away from the troubles in my life		Other (specify)	

5. What do you think about this green space? Please indicate your level of agreement with each of the following statements:

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
This green space is well maintained					
This green space is a nice place to relax					
This green space is too small					
This green space has enough trees					
This green space has enough amenities such as benches, litter bins, paths, etc.					
Many people come to use this green space					
I feel safe in this green space					
Local people respect this green space					
This green space should be used for residential stands					

6. Do you visit other green spaces in Bulawayo?

   Yes [ ] No [ ] *(If no, go to Q13)*

7. If yes, which one do you use most often (name of park/suburb) ___________________________

8. What attracts you most to this **OTHER** green space? (*tick one*)

Its location		Its beauty		Its quietness	
Its size		Its amenities		Other (specify)	
Its safety		Its maintenance		Other (specify)	

9. How do you usually travel there?

Walk/jog		Bicycle		Taxi		Bus		Private vehicle		Other (specify)	

10. If taxi or bus, what does it cost for a one way trip? ______________________________________

11. How often do you use/visit THIS **OTHER** green space? (*tick one*)

Daily	Every 2 - 4 days	Most weekends	1 - 2x per month	Every 2 - 3 months	Couple of times a year

12. What is the **MAIN** purpose of your visit to this **OTHER** one (i.e. why do you go to it)? (*tick one*)

Just walking through to the other side		To enjoy the beauty	
To spend relaxing time with friends or family		To collect firewood	
Exercise (sports/jogging/walking)		To collect medicinal products	
Spiritual worship		To collect wild foods	
To take a break in the shade		To collect poles for fencing or building	
To get a breath of fresh air		Other (specify)	

13. Do you think your suburb has enough green space? Yes [ ] No [ ]

14. Do you think Bulawayo has enough green space? Yes [ ] No [ ]

15. Do you think urban green spaces are distributed equally in Bulawayo?

16. If not, which areas/suburbs have the most and which have the least?

Most		Least	

17. What are the benefits of having green spaces in the city? (*tick as many*)

Provides places for relaxation		It helps reduce the noise levels	
Adds beauty to the city		Allows water to go into the soil	
Helps attract tourists		Provides a home for birds and animals	
Provides shade and cooling		Provides firewood for some people	
Helps reduced energy costs in		Provides medicinal for some people	

neighbouring buildings			
Help create local identity		Provides wild foods for some people	
Provides a place for worship for some		Provides timber for some people	
Traps the dust		Other (specify)	
Cleans the air		Other (specify)	
Makes oxygen		Other (specify)	
Helps against climate change by absorbing carbon		Other (specify)	

18. In what suburb do you reside? ____

19. How long have you lived in Bulawayo? ________________________

20. Do you have a green area/garden at your home in Bulawayo? Yes [ ] No [ ]

21. Was your childhood spent mainly in a rural or an urban area? Rural [ ] Urban [ ] Equal [ ]

22. In what year were you born? ___________________

23. Gender? Female [ ] Male [ ]

24. What is you highest level of education? _____________________________________

25. What is your occupation? _______________________________

26. Who is the primary income earner in your household? ____________________________

27. How is that income earned (i.e. source/type of employment)? _______________________

28. What is your household income per month?

$1- $100		$101-400		$401-$2000		Above $2000	

THANK YOU FOR PARTICIPATING IN THIS SURVEY