Urban ecosystem services and human well-being: The role of urban green spaces

This version: 1 March 2013

Abstract:

Urban green spaces provide numerous ecosystem services (ES) for city inhabitants. Besides provisioning and regulating services, they also provide cultural services by giving people the possibility to recreate and experience nature in the city. In this paper, we elicit the value of urban green spaces for human well-being using the life satisfaction approach (LSA). We use self-reported information on life satisfaction as a proxy for well-being to investigate the influence of urban green space on the life satisfaction of the residents of Berlin, the capital city of Germany. In a second step, we use the implicit marginal rates of substitution (MRS) to calculate the willingness-to-pay (WTP) that people have for urban green spaces. We find a statistically significantly positive effect of urban green space on people's life satisfaction. Moreover, our results support psychological findings that not only potential access to green space but also passive views onto parks increase people's well-being.

Keywords: Urban ecosystem services, urban green space, life satisfaction, well-being

JEL Classification: Q51, Q57

1 Introduction

Urban ecosystems provide numerous ecosystem services (ES) for city inhabitants. These services include provisioning and regulating but also cultural ES. Examples for such services are storm water retention or the alleviation of air pollution and noise as well as the provision of room for recreation and relaxation (TEEB, 2011). Urban ES are thus crucial for the well-being of people living in urban environments. Today, around 75% of the European population live in urban areas (World Bank, 2013). By 2050, this number might well have risen to over 80% (United Nations, 2012). This trend of increasing urbanization puts pressure on ecosystems both in and around cities but it also increases the potential demand for ES provided by urban green space.

In this paper, we focus on the role of urban green space for human well-being. There is considerable evidence from the psychological and the medical literature that urban green enhances human health and well-being. This may result from enhanced outdoor activity levels, from the mediation of adverse environmental impacts such as air pollution or noise or from the mere view onto green spaces (see Tzoulas et al. (2007) for an overview). We draw on these findings in an attempt to value urban green space using the life satisfaction approach (LSA). So far, economic valuation of urban green space has mostly been carried out using traditional techniques such as stated or revealed preference approaches (see Brander and Koetse (2011) for a recent meta-analysis). The LSA is an alternative but increasingly popular approach to valuing environmental goods. We follow this approach and use data on self-reported life satisfaction to estimate the effect of having urban green spaces in the vicinity of one's home on individual well-being.

There are very few economic studies investigating the role of urban green space for self-reported life satisfaction. The two published studies we identified cover cities in Australia (Ambrey and Fleming, 2012a) and China (Smyth et al., 2008). They measure urban green as the area of green space within certain administrative boundaries (district or city level). We add to this literature by using individual green space measures and exploring different ways in which urban green might affect the well-being of the residents of Berlin, the capital city of Germany. In Berlin, population has been steadily increasing over the past 20 years. The subsequently increasing demand for housing might put green spaces increasingly under pressure, in particular those in the inner city districts. We use spatially explicit data derived in a customized web survey and from spatially highly disaggregated GIS data to carry out our analyses.

The paper is structured as follows. Section 2 provides an overview of the literature related to the role of urban green for human well-being and the LSA to environmental valuation, including a more detailed discussion of the economic studies on the role of urban green space. Section 3 presents the case study city, survey content, design, and implementation as well as a description of the socio-economic, spatial and environmental variables. Section 4 introduces the LSA and shows and discusses the regression results. Section 5 concludes.

2 The role of urban ecosystem services for human well-being – literature review

2.1 The role of urban green for health and well-being

There is a broad body of literature in psychology and medicine that analyzes the effects of nature in general and urban green in particular on people's health and well-being (see Tzoulas et al. (2007) for an overview). General findings underline that contact with nature and urban green can have various positive impacts on human health and well-being. Firstly, contact with nature has psychological benefits. For example, it can reduce stress and increase positive self-reported emotions (Ulrich, 1983; Ulrich et al., 1991), restore attention (Kaplan and Kaplan, 1989) and affect self-regulation and restorative experiences positively (Hartig et al., 2003; van den Berg et al. 2010, 2007). In addition to psychological benefits, there are also direct health benefits such as increased longevity (Takano et al., 2002) and improved self-reported health (de Vries et al., 2003; Maas et al., 2006). Urban green spaces can also be beneficial for social well-being as they may increase social cohesion and identity (Newton, 2007).

There are different ways in which green spaces can influence well-being and health positively. Proximity to parks may increase physical activity levels (Kaczynski and Henderson, 2007). Physical activity in turn unequivocally increases human health, both in physical and psychological terms. Bowler et al. (2010) carried out a meta-analysis analyzing whether activities in natural environments increase health more than activities in more synthetic environments. They find evidence that lower negative emotions, such as anger, mental fatigue, or sadness, are reported after exposure to a natural environment in comparison to a more synthetic environment. See Coon et al. (2011) for a similar meta-analysis.

But not only activities in natural environments also passive views onto natural elements may improve health and well-being. Kaplan (2001), for example, shows that natural elements in the view from a window can contribute to the residents' satisfaction with their neighbourhood and to different aspects of their well-being. Nature can also act as a buffer to moderate adverse conditions (e.g. Evans, 2003; Wells and Evans, 2003). Gidlöf-Gunnarsson and Öhrström (2007), for example, provide evidence that perceived availability of nearby green space can help to alleviate noise annoyances.[1]

[1] However, if green spaces are perceived as unmanaged, their effect on well-being might also be negative due to increasing anxiety caused by crime and fear of crime (e.g. Bixler and Floyd, 1997; Kuo et al., 1998).

2.2 Valuation of urban green using stated and revealed preference methods

The fact that nature provides important ES and benefits for humans has been recognized by environmental economists for a long time. Being aware of this relationship, economists have tried to value different types of benefits provided by different types of ecosystems using different valuation methods. These methods include stated preference methods such as contingent valuation (CV) or choice experiments (CE) and revealed preference methods such as hedonic pricing (HP) or travel costs (TC). While the whole literature on environmental valuation using these methods is very broad (and much too broad to be reviewed in this paper), there are considerably fewer valuation studies on urban ES and even fewer that specifically focus on urban green spaces or parks.

There are two recent meta-analyses that analyze a range of CV and HP studies that focus on different types of urban ecosystems and have different regional foci. Brander and Koetse (2011) provide a meta-analysis of international CV and HP studies valuing urban open spaces with a focus on the USA. They find that most of the CV studies referred to urban forests and urban agriculture and much fewer studies investigated urban green spaces and parks.[2] HP studies, in contrast, have mostly investigated the role of urban parks and green spaces for property prices.[3] Also Perino et al. (forthcoming) carry out a meta-analysis, investigating CV and HP studies valuing urban green spaces and parks in the UK. More CV and HP studies have recently been carried out in China focusing on urban green spaces and urban forests respectively (Lo and Jim, 2010; Jim and Chen, 2009).

With respect to CE, there are even fewer examples for studies investigating urban ES. The only studies that value urban green spaces or parks that we are aware of are Bullock (2006), who uses a CE to value the different attributes of urban green space in Dublin, Ireland, and Lanz and Provins (2011), who use CE to estimate the WTP for a range of local environmental improvements in Seaham, UK.

2.3 Valuation of environmental amenities and disamenities using the life satisfaction approach

Over the past two decades, economists have increasingly used subjective well-being data for valuing environmental amenities and disamenities. In contrast to stated preference methods, the LSA does not ask people to place a monetary value on a complex environmental good in a hypothetical situation. Instead, self-reported information on life satisfaction is used to calculate the implicit MRS between income and the environmental good. Compared to CV, this may reduce biases resulting from the hypothetical nature of the decision and from

[2] Examples for CV studies on urban green spaces and parks are Jim and Chen (2006), Lindsey and Knaap (1999), and Lockwood and Tracy (1995).

[3] Recent examples for HP studies on urban green spaces and parks are Palmquist and Fulcher (2006) and Anderson and West (2006).

potentially strategic behavior. In comparison to the HP method, the LSA does not rely on decisions being reflected in actual market transactions. Thus, it is not affected by biases resulting from the assumption that the housing market is in equilibrium, which it often is not. Moreover, biases from distorted risk perceptions may play a lesser role. However, the LSA also has some disadvantages. For example, it relies on the assumption that self-reported life satisfaction can be used as a proxy for well-being and utility. See Welsch and Kühling (2009) for a deeper discussion of relevant conceptual and methodological issues concerning the LSA. For a discussion of the underlying assumptions and implications of the LSA in comparison with CV and HP see Frey et al. (2010).[4]

Classifying the LSA studies by type of environmental good or service, we find that most of the studies have looked at air pollution. Most recent examples are Levinson (2012), Ferreira and Moro (2010), Luechinger (2009, 2010), MacKerron and Mourato (2009), and Rehdanz and Maddison (2008). Other environmental issues investigated include climate (Ferreira and Moro, 2010; Brereton et al., 2008; Rehdanz and Maddison, 2005; Frijters and van Praag, 1998), noise (Rehdanz and Maddison, 2008; van Praag and Baarsma, 2005), scenic amenity (Ambrey and Fleming, 2011), protected areas (Ambrey and Fleming, 2012b), proximity to coasts or beaches (Brereton et al., 2008), droughts (Carroll et al., 2009), and floods (Luechinger and Raschky, 2009). For a recent review see Welsch and Kühling (2009).

Many of the earlier studies look at nationwide or cross-country data sets and suffer from the lack of more disaggregated environmental data (e.g. Welsch, 2006 or Rehdanz and Maddison, 2005) and are thus not able to take more disaggregated spatial controls into account. Some studies do include spatial controls, e.g. accounting for the fact whether people live in urban, rural or peri-urban areas (e.g. Ferreira and Moro, 2010). Only few studies explicitly deal with urban environments or data sets customized to urban environments. One exception is MacKerron and Mourato (2009), who look at air quality in London using spatially disaggregated data.

There are only few studies that try to value urban green spaces using the LSA. Using wave 5 of the HILDA survey, Ambrey and Fleming (2012a) investigate the role of public green space for the well-being of people in major Australian cities. The green space measure they use is the percentage of public green space in the resident's Collection District.[5] The estimated implicit WTP for a one per cent (equivalent to 143 m^2) increase in public green space in the area around the respondent's home is AUD 1,168 in terms of annual household income.

[4] As opposed to CV and HP, which rely on the concept of choice or decision utility, the LSA is based on the concept of experienced utility as described by Kahneman et al. (1997). For an overview of the history of the concept of utility and well-being used in economics and psychology see Kristoffersen (2010). For a discussion on the potential role of experienced utility in policy evaluation, see Kahneman and Sugden (2005).

[5] The Collection District (CD) is the smallest spatial unit in the Australian Standard Geographical Classification. Assuming each CD takes the shape of a circle, the median radius from the centroid is approximately 750m (Ambrey and Fleming, 2012a).

Smyth et al. (2008) use survey data gathered from the inhabitants of 30 Chinese cities to estimate the effects of pollution, disasters, congestion and green space on human well-being. The green space measure they use is the area of green space per capita on city-level. They find a statistically significantly positive effect of green space on life satisfaction for the model specification with city dummy variables. However, WTP estimates are not reported.

We add to this literature by carrying out the first study that evaluates the role of urban green space for the life satisfaction of the inhabitants of Berlin, Germany. We use spatially explicit data derived in a customized web survey together with spatially highly disaggregated GIS data on urban green spaces.[6] Unlike Ambrey and Fleming (2012a) and Smyth et al. (2008), we use an individual green space measure that captures the area of green space in a pre-defined buffer area surrounding a respondent's home. We explore the effect of different buffer areas as well as the possibility of non-linear effects. In addition, we investigate if the view onto a park from a respondent's home influences overall well-being.

3 Case study area and data

3.1 Case study city Berlin and regulatory framework in Germany

Berlin is the capital city of Germany. It covers an area of 892 km^2 and had a total population of 3.5 million as of December 2011 (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2012a; Amt für Statistik Berlin-Brandenburg, 2012a). It is a City State located in the East of Germany and forms the center of the metropolitan area of Berlin-Brandenburg. Its maximal expanse is 38 km from north to south and 45 km from East to West (Amt für Statistik Berlin-Brandenburg, 2011). Berlin is composed of 12 districts, which are displayed in Figure 1.

[6] Spatial data is gathered from the European Urban Atlas (EEA, 2012). The minimum mapping unit (MinMU) of the green urban areas within the Urban Atlas is 0.25 ha; minimum width is 10 m (EU, 2011).

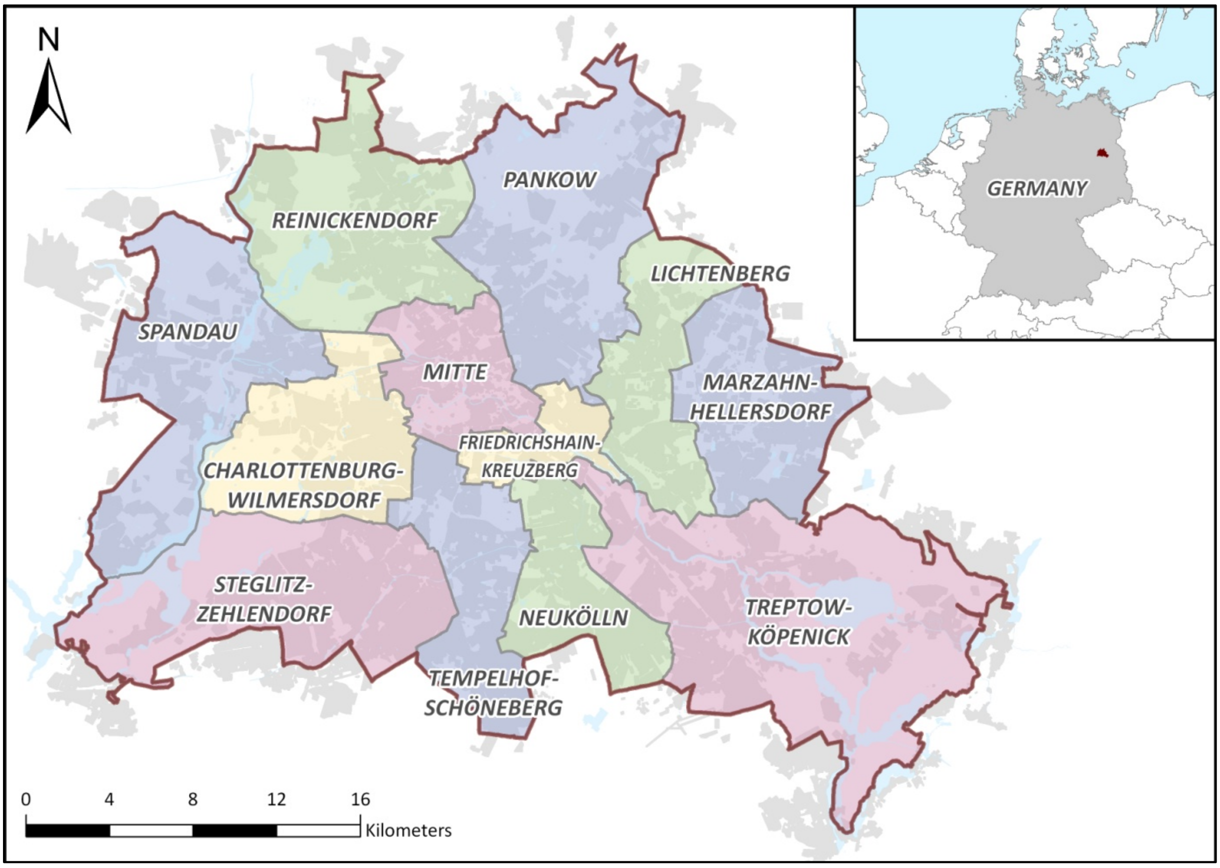

Figure 1. The city of Berlin and its administrative districts. Own presentation based on data from Geofabrik (2012).

As of December 2011, 40% of the area of Berlin was composed of public green spaces, forests, rivers, and lakes (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2012a; see also Figure 2). See Appendix 1 for a map displaying the distribution of urban green spaces in Berlin. These green spaces fulfill important services for city inhabitants. On the one hand, they provide regulating services such as storm water retention, climate regulation, or reduction of noise annoyance. On the other hand, they provide cultural services by providing recreational opportunities, enhancing physical and mental health, or facilitating environmental education.

The fact that urban green is important for human well-being has also influenced policy-making and city development in Germany.[7] For example, federal laws now require that open spaces in urban and peri-urban areas, including urban parks, forests, etc., have to be preserved and developed where they are not sufficiently available (§ 1 Abs. 6 BNatSchG, 2009).[8] This is also reflected in the German National Strategy on Biological Diversity, which asks for an increase in green space in settlement areas (BMU, 2007). However, city

[7] On the national level, for example, it is part of the German Sustainability Strategy to reduce the sealing of surfaces from 77 ha per day in 2010 to 30 ha per day in 2020 (German Federal Government, 2012).
[8] Similar regulations can also be found in the Environmental Protection Law of Berlin (NatSchGBln, 1979).

development always has to deal with trade-offs and conflicting interests between inner development, e.g. for housing, and the preservation of green and open spaces (Schetke et al., 2012).

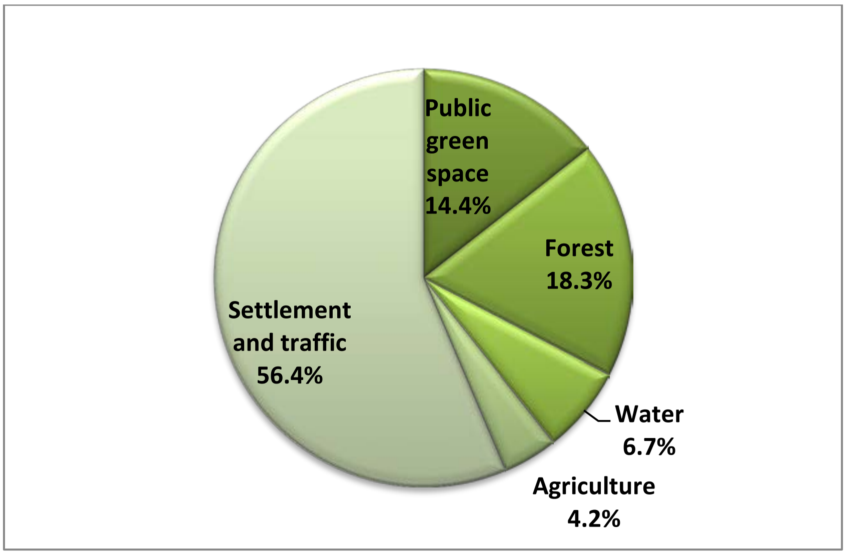

Figure 2. Land use types in Berlin. Own presentation based on data from Senatsverwaltung für Stadtentwicklung und Umwelt Berlin (2012a).

The urban development of Berlin was and will be shaped by highly dynamic changes in population. After a decrease in population numbers during the late 1990s following the German reunification, overall population has been increasing steadily in Berlin since 2005 (Amt für Statistik Berlin-Brandenburg, 2012a). The future development of Berlin will be characterized by ongoing demographic change and inner re-urbanization. It is estimated that the overall population of Berlin will increase to around 3.76 million in 2030, above all due to positive net in-migration. At the same time, average age is expected to increase from 42.3 years in 2011 to 44.2 years in 2030 due to ongoing ageing processes. After 2030, population in Berlin is expected to decrease again, in line with the overall German trend of decreasing population numbers due to low birth rates (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2012b).

The expected medium-term population growth and the trend to smaller household sizes require policy action particularly in the fields of infrastructure and housing development. On the one hand, demand for housing will increase in the medium term, which might exert pressure on existing green spaces in Berlin, particularly if a densification strategy is to be followed and urban sprawl is to be avoided. Such a conflict can currently be observed in the case of the Tempelhofer Feld.[9] On the other hand, there are still many open spaces such as brownfields that might be turned into residential or commercial areas (Simons et al., 2012).

Competition for different land use types will above all become pronounced in central locations, which are particularly attractive for the development of residential or commercial areas (Simons et al., 2012). On the other hand, also green spaces are important in those areas of the city because they provide ES that are particularly valuable in densely populated areas. For example, urban core and commercial areas generally have higher temperatures than suburban areas (Wilhelmi and Hayden, 2010) such that people in those areas would benefit most e.g. from reduced heat stress provided by green spaces and parks. The alleviation of heat stress will become even more important in the future if climate change leads to more heat waves (Gill et al., 2007).

3.2 Survey content, design, and implementation

Most of the data used for our analysis come from a web survey carried out in Berlin, Germany, in September 2012.[10] The main objective of this survey was to investigate the role of urban green space, particularly parks, for the well-being of people living in urban environments. For this purpose, the survey included a number of questions on park use patterns, such as frequency and duration of park visits, activities carried out there, or on the perception of the parks. The survey also included questions on socio-economic and demographic characteristics of the respondents, including gender, age, marital status, education, and occupation of the respondent as well as household income. In total, the questionnaire consisted of between 25 and 45 questions, mainly depending on whether the respondents regularly visited parks or not.[11]

As we intended to merge the survey data with spatial data on environmental characteristics, respondents were also asked to indicate their residential address in the survey. This enables us to locate respondents in a spatially explicit way and to link the survey data with GIS data, e.g. on green spaces (see section 3.4 for more details). To take account of the fact that the housing environment is very important for personal well-being in urban surroundings, we also included questions on the housing type and on neighbourhood characteristics in the

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[9] The so-called Tempelhofer Feld is located on the area of the former airport Berlin Tempelhof. The associated free areas including the former airfield have a size of 303 ha. Currently, it can be used by the public e.g. for recreational purposes and is left more or less in its original state (GrünBerlin GmbH, 2013). The current plan is to create a large urban park in the center of the area (ca. 220 ha) (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2012c). Apartments and houses are to be built on the fringes of the area – a plan that is criticized by some inhabitants of Berlin. Currently, a referendum is being carried out to prevent new buildings from being erected on the area of the former airport (see http://thf100.de/start.html).

[10] The survey is part of the pan-European BiodivERsA project URBES (Urban Biodiversity and Ecosystem Services) and was also carried out in three other European cities (Salzburg, Rotterdam, and Stockholm) with only slight adaptations to account for country-specific differences.

[11] Average completion time of the survey was 22 minutes. The whole questionnaire is available from the authors upon request.

survey. Thus, we are also able to compare the respondents' perception of the environment with observable spatial information.

The survey also included a question on overall life satisfaction to be able to carry out a life satisfaction analysis as described in section 2.4. The question was phrased as follows: "All things considered, how satisfied are you with your life these days?" Respondents were asked to answer the question on an 11-point Likert scale ranging from '0' (very dissatisfied) to '10' (very satisfied). This question mode is in line with many large surveys carried out in different countries and used in the economic literature on life satisfaction (Welsch and Kühling, 2009).[12]

The survey was implemented using a pre-selected web-panel with approximately 100,000 registered members throughout Germany and 4,000 members in Berlin aged 18 years or above.[13] Potential survey participants were invited via email to participate in the survey. In this email, a link to the survey was provided but the topic of the survey was not further specified. Having clicked on the link, potential participants were directed to a standard starting screen, which clarified the expected length of the survey and the potential reward to be gained.[14] The topic announced on this starting screen was held very general, only indicating that the survey was related to city life, in order to avoid self-selection in terms of interest in environmental issues.

Survey participants were then first screened to ensure that they had been living in Berlin for more than one year. Only residents of the districts Mitte, Kreuzberg-Friedrichshain, Pankow, Charlottenburg-Wilmersdorf, Tempelhof-Schöneberg, Neukölln and Lichtenberg were included in the survey (see also Figure 1). These districts were selected because they include the inner city districts of Berlin with a relatively homogenous distribution of green space and exclude districts with large shares of water areas and forests. The districts were also selected to be comparable with the whole population of Berlin regarding age and gender. Moreover a balanced distribution between formerly Eastern and Western German parts of the city of Berlin has been aimed at. Respondents not fulfilling the screening criteria were redirected to another survey provided by the polling agency in order to avoid annoyance.

An early version of the questionnaire was pretested with university students. The final version of the survey was pretested with a set of 50 participants. Responses to the survey were checked according to several quality criteria, including time taken to complete the survey and obvious answer patterns that revealed that respondents had clicked through the

[12] We did not ask for the respondents' satisfaction with different domains of their lives as survey time was limited. However, overall life satisfaction can be used as well and has been shown to be a valid measure for subjective well-being (see e.g. Welsch and Kühling, 2009).

[13] The survey was implemented and executed via a professional polling agency.

[14] The survey was announced to last approximately 15 minutes. It was announced that 750 points could be gained for completing the survey. 500 points are equivalent to 1 Euro and can be swapped for money, various tangible goods, or Cadooz vouchers. The money equivalent can also be donated for charitable purposes.

survey without paying attention to questions and answers. Approximately 10% of the observations have thus been eliminated from the sample. In addition, a thorough validity test was carried out, checking answers for obvious inconsistencies in content. This led to a further exclusion of 23 observations from the sample, which resulted in a final sample size of 487 usable observations for Berlin.

3.3 Descriptive statistics of key socio-economic variables

Table 1 provides summary statistics for the socio-economic variables used in the life satisfaction regressions. In the following, we highlight some noticeable data characteristics. As mentioned in section 3.2, we have a total sample of 487 respondents. However, not all of the respondents answered all of the questions in the survey. For example, six of the respondents chose not to answer the life satisfaction question. More importantly, we are confronted with 63 missing observations on income. Consequently, the sample size reduced further to finally 379 observations when we carried out the regressions.[15]

The mean value for life satisfaction was 6.8 on a scale from 0 to 10 with a standard deviation of 2.02. The distribution of gender in our sample is comparable to that of Berlin as a whole and the selected districts, with the share of men being slightly less than 50%. With respect to age, respondents in our sample are aged between 18 and 81. Mean age in our sample is 44.1 years, while it is 42.3 years in Berlin (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2012b) and was 43.7 years in Germany as of December 2010 (Statistisches Bundes-amt, 2012). However, we also observe an overrepresentation of people aged 45 to under 60 in our sample (31.9% compared to 25.7% in Berlin and 24.6% in the selected districts) and an underrepresentation of people aged 60 years or more (17.7% in the sample compared to 29.0% in Berlin and 26.2% in the selected districts) (Amt für Statistik Berlin-Brandenburg, 2012a). This seems unavoidable given that the survey has been implemented as a web survey with limited regional coverage.

Mean net monthly household income was € 1,554 in the selected districts of Berlin and € 1,600 in Berlin as a whole as of December 2011 (Amt für Statistik Berlin-Brandenburg, 2012b). In our survey, mean net monthly household income is in the range of between € 1,500 and € 2,000 indicating a similar, maybe slightly higher income compared to the population of Berlin. In the life satisfaction regressions in section 4, we use individual instead of household income. Total net monthly individual income was calculated by dividing the corresponding household income by the weighted number of household members.[16]

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[15] We also excluded 26 observations following an outlier analysis for the green space variable. See section 3.4 for details.

[16] The weighting was done according to the so-called OECD-modified equivalence scale, which assigns a weight of 1 to the household head, a weight of 0.5 to every additional adult and a weight of 0.3 to each child under the age of 14 in the household (OECD, 2009). As there was no information about children under the age of 14 in

Household income was indicated in ranges. We used the midpoint of the indicated range to calculate the corresponding individual income.[17]

The share of unemployed people in our sample amounts to 6.1%. The rate of unemployment in Berlin amounted to 11.6% as of December 2012, while it was only 6.7% in whole Germany (Bundesagentur für Arbeit, 2013). Unemployment rates in Berlin ranged from 9.4% in Pankow to 16.3% in Neukölln as of December 2012 (Bundesagentur für Arbeit, Regional-direktion Berlin-Brandenburg, 2013). The percentage of single households was approximately 54% in Berlin as of December 2011. Moreover, 48% of the residents of Berlin were recorded to be single (Amt für Statistik Berlin-Brandenburg, 2012b). Both numbers are significantly higher than the share of single persons in our sample. However, it has to be noted that we have an additional category ('partner') that captures those people that live in a relationship but are not married. This category is missing in the official statistics considered.

Table 1. Definitions and summary statistics of socio-economic variables.

Variable name	Definition	Mean	Std. dev.	Min	Max
Life satisfaction (LS_{ij})					
Life satisfaction	Overall life satisfaction; measured on a Likert scale from 0 'very dissatisfied' to 10 'very satisfied'	6.760	2.02	0	10
Individual demographic and socio-economic characteristics (Y_i, X_i)					
Log individual income	Natural logarithm of the total net monthly individual income in Euros	7.421	0.69	4.828	8.923
Gender	Gender dummy; 1 if 'male', 0 if 'female'	0.478	0.50	0	1
Age	Age; measured in years	44.069	14.59	18	81
Migration background	Dummy variable; 1 if at least one parent of the respondent is of a nationality other than German, 0 else	0.340	0.48	0	1
Lifetime	Dummy variable; 1 if respondent has been living in the same district for her whole life	0.119	0.32	0	1
Single	Marital status dummy; 1 if 'single', 0 else; reference category	0.296	0.46	0	1
Married	Marital status dummy; 1 if 'married', 0 else	0.340	0.47	0	1
Partner	Marital status dummy; 1 if 'living in a relationship', 0 else	0.243	0.43	0	1
Separated	Marital status dummy; 1 if 'separated', 0 else	0.018	0.13	0	1
Widowed	Marital status dummy; 1 if 'widowed', 0 else	0.010	0.10	0	1
Very bad health	Health dummy; 1 if 'Very bad health', 0 else; reference category	0.034	0.18	0	1

the household in the survey, this was adapted to children under the age of 12. In sensitivity analyses, we also carried out regressions using the net monthly household income. Results are comparable for both approaches.

[17] The use of midpoints is common in life satisfaction studies if income is given in ranges (see e.g. Carroll et al, 2009 or MacKerron and Mourato, 2009).

Bad health	Health dummy; 1 if 'Bad health', 0 else	0.158	0.37	0	1
Fair health	Health dummy; 1 if 'Fair health', 0 else	0.288	0.45	0	1
Good health	Health dummy; 1 if 'Good health', 0 else	0.385	0.49	0	1
Very good health	Health dummy; 1 if 'Very good health', 0 else	0.135	0.34	0	1
Basic education	Education dummy; 1 if education on ISCED level 1 or 2[a]; reference category	0.077	0.27	0	1
Secondary education	Education dummy; 1 if education on ISCED level 3 or 4[a]	0.459	0.50	0	1
Tertiary education	Education dummy; 1 if education on ISCED level 5 or 6[a]	0.464	0.50	0	1
Full-time employed	Occupation dummy; 1 if 'full-time employed', 0 else; reference category	0.491	0.50	0	1
Part-time employed	Occupation dummy; 1 if 'part-time employed', 0 else	0.129	0.34	0	1
Unemployed	Occupation dummy; 1 if 'unemployed', 0 else	0.061	0.24	0	1
Unable to work	Occupation dummy; 1 if 'unable to work', 0 else	0.034	0.18	0	1
Retired	Occupation dummy; 1 if 'retired', 0 else	0.132	0.34	0	1
Student	Occupation dummy; 1 if 'student', 0 else	0.095	0.29	0	1
Other occupation	Occupation dummy; 1 if 'other occupation', 0 else	0.061	0.24	0	1
Household characteristics (X_i)					
Child	Dummy variable; 1 if at least one child under the age of 12 is living in the household, 0 else	0.127	0.33	0	1
Detached, semi-detached, or terraced house	Housing dummy; 1 if 'detached, semi-detached or terraced house', 0 else; reference category	0.087	0.28	0	1
Small apartment building	Housing dummy; 1 if 'apartment building with 3 to 8 apartments', 0 else	0.301	0.46	0	1
Large apartment building	Housing dummy; 1 if 'apartment building with 9 or more apartments (but no high rise)', 0 else	0.522	0.50	0	1
High rise	Housing dummy; 1 if 'high rise', 0 else	0.088	0.29	0	1

All data is taken from the web survey. The number of observations included is 379 for all variables.

[a] For an overview of how the German educational achievements translate into the internationally comparable ISCED levels see Statistisches Bundesamt (2010).

3.4 Descriptive statistics of spatial and environmental variables

We used the self-reported information on residential address to locate respondents in the city of Berlin in a spatially explicit way using ArcGIS. Out of the final 379 respondents, 43 people indicated their full address, including name of the street and number. The rest of the respondents indicated less unambiguous addresses so that we had to proxy their location. Table 2 gives an overview of the type of information we gathered from the respondents, the way we located them in ArcGIS, and the location statuses we assigned to them based on decreasing level of precision. We will account for these different statuses in the life satisfaction regressions carried out in section 4 of this paper.

Table 2. Overview of different location statuses.

Location status	Description	Location	Number of observations
1	Full address	Precise address	43
2	Street without number	Middle of the street	262
3	ZIP code	Centroid of the ZIP code area[18]	44
4	District	Centroid of the district[19]	30

We use two different measures for urban green space that we include in the life satisfaction regressions in section 4. Table 3 displays the descriptions and summary statistics of these variables (and the control variables for the selected districts). The variable 'green area' captures the total size of green space in the vicinity of a respondent's home determined as described above. The spatial data on urban green spaces were taken from the Urban Atlas (EEA, 2012). This database provides pan-European comparable land use and land cover data for large urban areas with more than 100,000 inhabitants. We used the areas designated as "green urban areas" to create our variable 'green area'.[20]

To infer how much green space there is in the surrounding of the respondents' homes, we used a point layer created from locating the respondents' addresses. We then created buffers around the respondents' addresses, i.e. we laid circles with varying diameters around the respondents' homes. We used three buffers with a radius of 0.3, 0.5, and 1 km respectively. We then calculated the amount of green space within the buffer areas for each of the respondents. This gave us an individual measure of green space availability on the respondent level. However, we had to be aware of potential measurement errors in the green space variable due to the uncertainties related to the location of the respondents described above. For example, a point corresponding to a respondent could seem to be located in the middle of a park, if we don't observe the true address but have to proxy it with the centroid of a ZIP code area or district. The green space measure might then not reflect the true degree of green space availability. Thus, we excluded observations in the 2 and 98 percentile of the variable 'green area' from our sample to mitigate the influence of outliers. This led to an exclusion of 26 observations from the sample.

[18] The average area of the ZIP code areas in which the respondents live is 3 km^2.
[19] Average area of the selected districts is 54 km^2.
[20] The land use category "green urban areas" includes public green areas for predominantly recreational use such as gardens, zoos, parks, or castle parks. Not included are private gardens within housing areas, cemeteries, buildings within parks, such as castles or museums, patches of natural vegetation or agricultural areas enclosed by built-up areas without being managed as green urban areas (EU, 2011).

The total buffer area for the buffer with a 1 km radius is 314.2 ha (~3.14 km^2). Individual green space availability is between 0.4 and 26.1% of this buffer area, i.e. between 1.3 and 82.1 ha.[21] For comparison, the area of the selected districts in Berlin is between 2,034 ha in the case of Friedrichshain-Kreuzberg and 10,315 ha in the case of Pankow.[22] The mean area of green space in Berlin is 1,065.3 ha measured over all districts, with a minimum in Friedrichshain-Kreuzberg (324 ha) and a maximum in Pankow (1,617 ha) (Senatsverwaltung für Stadtentwicklung und Umwelt Berlin, 2012a).[23]

A second control for the effect of urban green on subjective well-being is the variable 'park view'. This dummy variable captures whether respondents have a view onto a park from their homes or not. 12.4% of the respondents report that they have a view onto a park from their home.

Table 3. Definitions and summary statistics of environmental and spatial variables.

Variable name	Definition	Mean	Std. dev.	Min	Max
Environmental variables (A_j)					
Green area	Hectars of green space in the surrounding of the respondent's home[a]	21.763	15.42	1.274	82.118
Park view	Dummy variable; 1 if respondent has a view on a park from her home, 0 else	0.124	0.33	0	1
District controls (S_j)					
Mitte	District dummy; 1 if respondent lives in this district, 0 else; reference category	0.158	0.37	0	1
Friedrichshain-Kreuzberg	District dummy; 1 if respondent lives in this district, 0 else	0.084	0.28	0	1
Pankow	District dummy; 1 if respondent lives in this district, 0 else	0.161	0.37	0	1
Charlottenburg-Wilmersdorf	District dummy; 1 if respondent lives in this district, 0 else	0.132	0.34	0	1
Tempelhof-Schöneberg	District dummy; 1 if respondent lives in this district, 0 else	0.179	0.38	0	1
Neukölln	District dummy; 1 if respondent lives in this district, 0 else	0.129	0.34	0	1
Lichtenberg	District dummy; 1 if respondent lives in this district, 0 else	0.156	0.36	0	1

[a] Green space is calculated using data provided by the Urban Atlas (EEA, 2012). The area that was considered in the regressions included a circle with a radius of 1 km around the respondents' residential addresses.

[21] For the 0.5 km buffer, total buffer area is 78.5 ha. Individual green space availability within this area is between 0 and 27.6%, i.e. between 0 and 21.7 ha. For the 0.3 km buffer, total buffer area is 28.3 ha. Individual green space availability within this area is between 0 and 31.3%, i.e. between 0 and 8.8 ha.

[22] For whole Berlin, only the district Köpenick is larger than Pankow with an area of 16,850 ha.

[23] Measured in percent of the district area the minimum amount of green space can be found in Treptow-Köpenick (3.0%) and the maximum amount can be found in Mitte (14.8%).

4 Empirical valuation of urban green using the life-satisfaction approach

4.1 Regressions on the role of urban green space for human well-being

4.1.2 Methodological approach and estimation strategy

We estimate the effects of different demographic, socio-economic, and environmental variables on life satisfaction using the following regression equation:

$$LS_{ij} = \beta_0 + \beta_1 \ln(Y_i) + \beta_2 X_i + \beta_3 A_i + \beta_4 \, S_j + \varepsilon_{ij} \;\; \forall \;\; i = 1, \ldots, 379 \; and \; j = 1, \ldots, 7 \qquad (1)$$

The dependent variable, LS_{ij}, is the life satisfaction of respondent *i* living in district *j* measured on an 11-point Likert scale. Explanatory variables include Y_i which is the individual net monthly income of respondent *i* measured in Euros and calculated as described in section 3.3. Income enters the regression equation in its natural logarithm to account for the declining marginal utility of income. Further explanatory variables are captured in the vector X_i which contains other demographic and socio-economic characteristics of the respondent *i* and her household (see Table 1 for a description of these variables). A_i is a vector of environmental variables, characterizing the degree to which there is green space in the living environment of respondent *i* and whether respondent *i* has a view onto a park from her home (see Table 3 and section 3.4 for details). S_j captures dummy variables for each district *j* to control for district-specific effects (also see Table 3). As we include variables on the individual level and on the district level in our data, we cluster the error terms on the district level to calculate robust estimates (Moulton, 1990).

Following the standard approach in the literature, we use ordinary least squares (OLS) to estimate the effects although the dependent variable 'life satisfaction' is an ordinal variable. Ferrer-i-Carbonell and Frijters (2004) analyze different estimation strategies and compare results for panel data. They provide evidence that assuming cardinality and using OLS make little difference for estimation results, while accounting for individual heterogeneity in panel models makes a large difference. Several studies using (repeated) cross-section data confirm that there are little differences between OLS and ordered probit or logit estimations (see e.g. Ferreira and Moro, 2010 or Brereton et al., 2008). Thus, we only show OLS estimation results in this paper.[24]

[24] We also carried out ordered logit and probit estimations for robustness checks. In accordance with the literature, we find that they yield very similar results compared to OLS although significance levels are generally slightly lower in OLS specifications. The results of ordered logit or probit estimations are available from the authors on request.

4.1.2 Regression results

Results of the estimation of equation (1) using OLS can be found in Table 4. Model 1 represents the baseline specification which includes the whole sample of 379 observations. Models 2 and 3 represent specifications with only a subset of the respondents, selected via their location status to account for potential measurement errors in the environmental variables. See below for an interpretation and discussion of the results.

Table 4. Results of life satisfaction regressions (OLS).

Life satisfaction (LS_{ij})	Model 1	Model 2	Model 3
Individual demographic and socio-economic characteristics (Y_i, X_i)			
Log individual income	**0.696*** **	**0.756*** **	**0.691*** **
	(0.13)	**(0.16)**	**(0.15)**
Gender	-0.275	-0.183	-0.095
	(0.16)	(0.18)	(0.20)
Age	-0.073*	-0.060	-0.076
	(0.03)	(0.04)	(0.05)
Age squared	0.001*	0.001	0.001
	(0.00)	(0.00)	(0.00)
Migration background	-0.143	-0.118	-0.107
	(0.16)	(0.17)	(0.21)
Lifetime	0.616**	0.661**	0.600**
	(0.17)	(0.18)	(0.21)
Single	reference	reference	reference
Married	0.482***	0.406***	0.443***
	(0.11)	(0.07)	(0.09)
Partner	0.359	0.304	0.332*
	(0.19)	(0.18)	(0.13)
Separated	-1.059	-1.492	-2.031
	(0.94)	(1.12)	(1.25)
Widowed	1.150	1.215*	1.343*
	(0.60)	(0.55)	(0.58)
Very bad health	reference	reference	reference
Bad health	0.476	0.214	0.194
	(0.62)	(0.52)	(0.48)
Fair health	1.672**	1.364**	1.424**
	(0.56)	(0.46)	(0.39)
Good health	2.646***	2.317***	2.345***
	(0.61)	(0.59)	(0.56)
Very good health	3.385***	3.115***	3.096***
	(0.65)	(0.56)	(0.56)
Basic education	reference	reference	reference
Secondary education	1.131*	1.112*	1.122*
	(0.54)	(0.54)	(0.49)
Tertiary education	1.118*	1.151*	1.181*
	(0.53)	(0.52)	(0.54)
Full-time employed	reference	reference	reference
Part-time employed	0.882**	0.807***	0.686**
	(0.25)	(0.18)	(0.25)
Unemployed	-0.038	-0.019	-0.190

	(0.68)	(0.71)	(0.79)
Unable to work	1.081	0.966	0.945
	(0.81)	(0.80)	(0.85)
Retired	0.266	0.322	0.320
	(0.49)	(0.53)	(0.57)
Student	0.404	0.303	0.107
	(0.28)	(0.29)	(0.40)
Other occupation	-0.634	-0.491	-0.500
	(0.55)	(0.55)	(0.62)
Household characteristics			
Child	0.085	0.094	-0.025
	(0.26)	(0.24)	(0.32)
Detached, semi-detached, or terraced house	reference	reference	reference
Small apartment building	-0.463*	-0.374*	-0.216
	(0.19)	(0.16)	(0.21)
Large apartment building	-0.370	-0.209	-0.072
	(0.22)	(0.29)	(0.33)
High rise	-1.166**	-1.126**	-1.061**
	(0.33)	(0.41)	(0.35)
Environmental variables (A_i)			
Green area	**0.034****	**0.037****	**0.037****
	(0.01)	**(0.01)**	**(0.01)**
Green area squared	**-0.000****	**-0.000****	**-0.000****
	(0.00)	**(0.00)**	**(0.00)**
Park view	**0.667****	**0.689****	**0.695****
	(0.24)	**(0.23)**	**(0.24)**
District controls (S_j)			
Mitte	reference	reference	reference
Friedrichshain-Kreuzberg	-0.269*	-0.178	-0.252**
	(0.12)	(0.10)	(0.09)
Pankow	-0.021	-0.047	0.046
	(0.10)	(0.12)	(0.14)
Charlottenburg-Wilmersdorf	0.434**	0.289*	0.118
	(0.13)	(0.13)	(0.17)
Tempelhof-Schönefeld	0.322*	0.334*	0.308
	(0.15)	(0.17)	(0.23)
Neukölln	-0.046	-0.033	-0.306
	(0.13)	(0.15)	(0.17)
Lichtenberg	-0.069	-0.070	-0.156*
	(0.06)	(0.07)	(0.07)
Constant	-0.368	-0.876	0.143
	(1.06)	(1.43)	(1.66)
Sample Size	379	349	305
R^2	0.4626	0.4647	0.4663
Standard errors in parentheses * p<0.1, ** p<0.05, *** p<0.01	All location statuses	Location status < 4	Location status < 3

Focusing on the results of Model 1, including all observations, we are able to reproduce standard findings of the life satisfaction literature regarding the effects of socio-economic and demographic variables on life satisfaction (see Blanchflower (2008) for a comprehensive review). We find that income has a significantly positive effect on life satisfaction. Other positive effects on life satisfaction that are significant include the effect of being married as opposed to being single, and the effect of being employed part-time as opposed to being employed full-time. We do not find a negative effect for being unemployed (as e.g. in Clark and Oswald, 1994), which might be due to the fact that there are very few unemployed people in our sample (6.1% of those that stated their occupation status). Self-reported health also has a strongly positive and monotonously increasing impact on life satisfaction. Age displays the usual negative u-shaped relationship with life satisfaction (Blanchflower and Oswald, 2004), but is not significant in all specifications. Also, the impact of education is significantly positive for secondary and tertiary education. In Model 1, the effect for secondary education is slightly bigger than for tertiary education, which is a pattern well-observed in the literature.

Regarding the variables that address the living environment of the respondents, interestingly, we find that respondents who have lived in a certain district for their whole lives report significantly higher levels of life satisfaction than others. Moreover, we also find strong evidence that the respondents' housing conditions affect their well-being. People living in a high-rise building, for example, are significantly less satisfied with their lives compared to those living in detached, semi-detached, or terraced houses. Regarding the environmental and spatial variables, we find that, ceteris paribus, the amount of urban green space in the vicinity of a respondent's home significantly positively influences life satisfaction. Moreover, there is evidence that the marginal utility of green space is decreasing as the squared value of green space has a significantly negative effect on well-being even though the size of the effect is fairly small.[25] We also find evidence that the view onto a park from home increases a respondents' life satisfaction positively.

These results are interesting as they seem to support the findings from psychological and medical research that there are different transmission channels for the positive effects of urban green space on well-being and health. The amounts of green space in the vicinity of a respondent's home and the distance to it are the two most important determinants of park use (Schipperijn et al., 2010). Our variable green area combines distance and amount of green space in one variable and may thus serve as a good proxy for a determinant of park use. In addition, however, we find a positive effect of park view on life satisfaction. This supports psychological findings on the positive effects of natural window views on well-being (Kaplan, 2001).

[25] Using a t-test, both variables together are significant on the 5%-level.

4.1.3 Sensitivity analyses and discussion of the results

The three model specifications presented in section 4.1.2 use different subsets of observations selected via their location status to account for potential measurement errors in the environmental variables. While Model 1 encompasses the whole sample, Model 2 only encompasses observations with a location status smaller than 4 and Model 3 encompasses observations with a location status smaller than 3. This means that, on the one hand, the precision of the spatial points associated with the single respondents increases, but that, on the other hand, sample size decreases considerably. The smaller sample size might be one reason for the fact that age is no longer significant in model specifications 2 and 3, while being a widow is positively significant in specifications 2 and 3. However, it can also be inferred from Table 3 that the size and significance of the variable 'green area' does not change for the different specifications. This indicates that the spatial location of the respondents is sufficiently accurate to capture the effect of green space on life satisfaction.

Replacing the 1 km buffer with the 0.5 or 0.3 km buffers, however, leads to insignificant results regarding the effect of the variable 'green area' on life satisfaction. In these cases, the buffer areas are getting much smaller, decreasing from 3.14 km^2 for the 1 km buffer to 0.78 km^2 for the 0.5 km buffer and 0.28 km^2 for the 0.3 km buffer. Overall, these smaller buffer areas seem to be too small to capture the characteristics of a neighborhood. For example, a respondent might have a park within 500 m of her home but if the park only starts there, the true extent of green space availability would not be captured in the green space variable for smaller buffer areas. For this reason, we decided to include the 1 km buffer in our preferred model specification.[26] In addition, we would like to underline that the variable 'park view' is strongly positively significant in all model specifications. This also holds true for the ordered probit and logit specifications that we ran for robustness checks. This suggests that urban green spaces do not only increase well-being if they are easily accessible by city inhabitants but that also passive views onto green spaces increase well-being, independently of whether people actually go there or not.

For sensitivity analysis, we also carried out regressions including district-specific variables such as average household income or population density per district in addition to the district dummies. However, these variables were highly correlated with the district dummies and did not add explanatory power to the estimation so that we decided to drop them in the final specifications.

[26] We did not include more than one green space variable in our regressions because they are to some extent pairwise correlated which could induce multi-collinearity and bias estimates.

4.2. Monetary valuation of urban green using the life satisfaction approach

4.2.1 Implicit marginal rates of substitution

Following Welsch (2002, 2006) the MRS between income and green space can be computed by dividing the absolute value of the derivative of life satisfaction (LS_{ij}) with respect to green space (GA_i) by the derivative of life satisfaction with respect to income (Y_i). In the case of the semi-logarithmic regression equation (1) including both the level of the variable 'green area' and its squared value, this would yield:

$$MRS = \left. \frac{\partial LS_{ij} / \partial GA_i}{\partial LS_{ij} / \partial Y_i} \right|_{dLS_{ij}=0} = \frac{\beta_{a1} + 2\,\beta_{a2}\,\overline{GA}}{\beta_1}\,\overline{Y} \qquad (2)$$

In this case, β_{a1} is the estimated coefficient of the level of the variable 'green area' (GA_i) while β_{a2} is the estimated coefficient of the squared value of the variable 'green area'. The MRS is evaluated at the mean values of the variables 'income' and 'green area'.

Turning to the calculation of the MRS between income and green space as described in equation (2), we find that, in the standard specification (Model 1) the WTP for an increase of 1 ha in green space in the vicinity of a respondent's home is approximately 37 Euros per person per month (see Table 5).

Table 5. Marginal rates of substitution (MRS) between green space and income.

	Model 1	Model 2	Model 3
Mean individual income (Euros)	1,426	1,441	1,441
MRS (Euros/ha)	37.09	35.14	40.54
Sample Size	379	349	305
	All location statuses	Location status < 4	Location status < 3

Using log household income in the regressions instead of individual income calculated as described in section 3.3, WTP would be 52.28 Euros/ha per household per month or 627.42 Euros/ha per household per year for the baseline specification Model 1. Compared to Ambrey and Fleming (2012a), our WTP estimates are significantly smaller. They find an average WTP of AUD 1,168 per household per year for a 143 m^2 increase in green space in the respondent’s CD. This would translate into AUD 81,678.32 (or ~63,400 Euros[27]) per household per year for a 1 ha increase in green space. Thus, our estimates are about ten times smaller than those of Ambrey and Fleming (2012a).

5 Discussion and conclusion

We used two individual green space measures to explore how urban green spaces affect the well-being of the residents of Berlin, Germany. We combined spatially explicit data derived in a customized web survey with spatially highly disaggregated GIS data on urban green spaces to carry out our analyses. The first green space measure captured the area of green space in a pre-defined buffer area surrounding a respondent’s home. In addition, we investigated if the view onto a park from a respondent’s home influences overall well-being. Our results support findings from psychological and medical research that there are different transmission channels for the positive effects of urban green space on well-being. On the one hand, green space availability, which may also serve as a proxy for park use, influences well-being positively. On the other hand, we also find a positive effect of park view on life satisfaction. Moreover, there is evidence that the marginal utility of green space is decreasing

When carrying out life satisfaction regressions, some issues arise that may bias the estimated coefficients of income and the environmental variable. These need to be discussed as they may influence the magnitude of the estimated implicit MRS and thus of the calculated WTP.

Firstly, endogeneity of income may be one potential issue. In principle, the observed relationship between economic conditions and well-being could be explained by reverse causation. It seems plausible that, on average, happier individuals tend to lose their job less often, to be re-employed more easily, or to find jobs that are better paid (see Frey and Stutzer (2002) for a discussion). This might bias the income coefficient downwards and thus WTP upwards. Studies instrumenting for income find that the income coefficients estimated using instrumental variable (IV) approaches are twice to three times as large compared to usual OLS specifications (Powdthavee, 2010; Dolan and Metcalfe, 2008).

Secondly, in addition to income endogeneity, there is evidence that there may be an omitted variable bias if personality traits are not considered as control variables in the life satisfaction regression (Diener and Lucas, 1999; Boyce, 2010). Introducing such character trait controls may increase the income coefficient and even increase explanatory power of the model as it captures significant sources of otherwise unobserved heterogeneity (Ambrey and Fleming, 2011). Unfortunately, it was outside the scope of our survey to include questions on character traits so that we cannot control for unobserved individual

[27] Converted with an exchange rate of 0.77621 Euros/AUD as of 30 January 2013.

heterogeneity in our cross-section data set. Thus, it may well be that the WTP results presented in section 4.2.1 are overestimated.

A further issue that might bias the estimated coefficient of the environmental variable ‘green area’ upwards is that there may be preference heterogeneity and self-selection in the choice of the residential location, such that individuals with higher preferences for green spaces and parks would move to greener areas of the city. However, as Ambrey and Fleming (2012a) note, though the evidence seems to be mixed, several authors find that this selection bias is rather small (e.g. Chay and Greenstone, 2005).

Appendix 1.

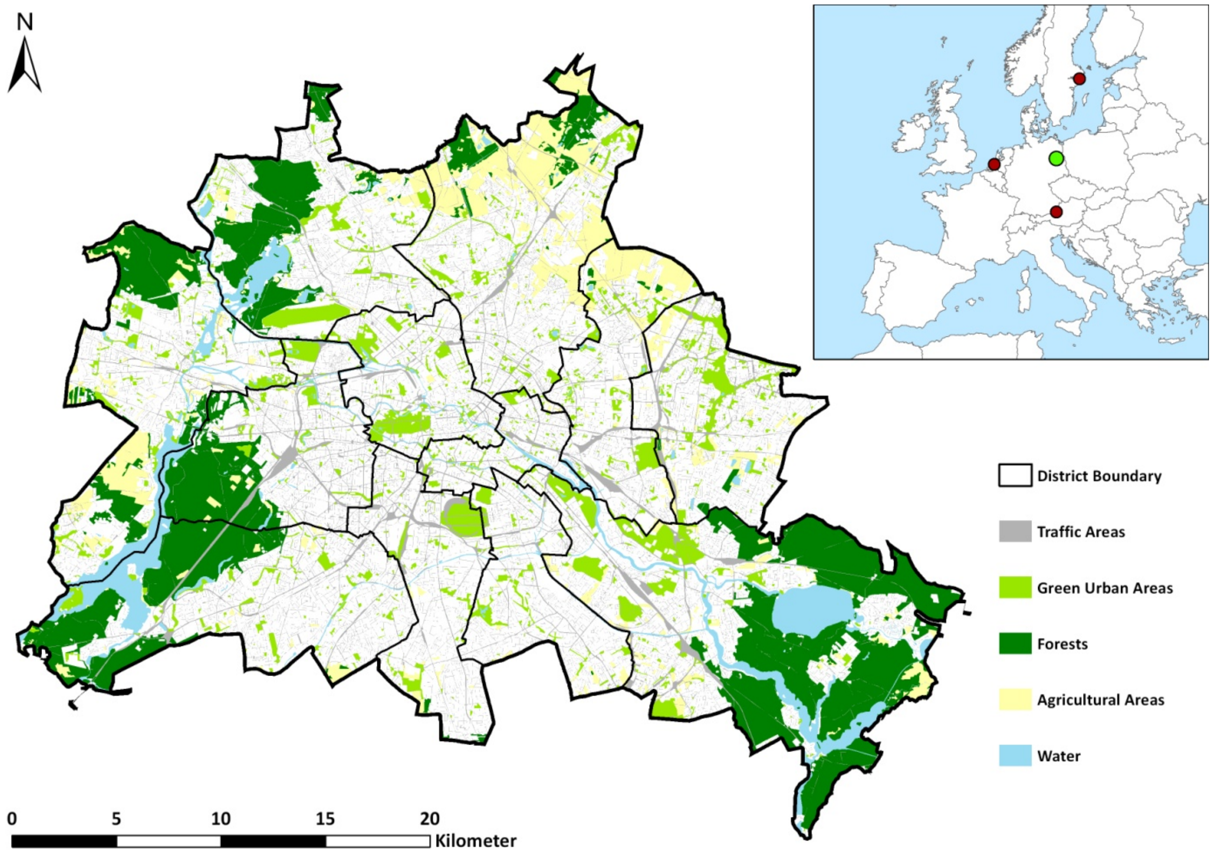

Figure A1. Distribution of green urban areas in the city of Berlin. Own presentation based on data from EEA (2012).

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