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Natural capital accounts for public green space in London

Methodology document

: vivideconomics

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1 Introduction

This document lays out the proposed methodologies for estimating the various benefits generated by green space in London. There is a section for each benefit category with a brief literature review and suggested steps for calculations. The spatial aspects of calculations have not been discussed in this document and will be presented separately. The study will also indicate confidence levels – high, medium, low – for all methodologies used at a later stage. Table 1 summarises the calculations and presents potential sources for data.

TABLE 1

Equations for service from public green space in London

BENEFIT	CALCULATION	SOURCE
Mental health	area of influence of green space or proximity measure (ha) * population density (persons/ha) * improvement in mental health outcomes due to proximity to green space (%)* expenditure on mental health in London (£/person) OR density of green space in ward (%) * population of ward (persons) * improvement in mental health outcomes due to green space density (%)* expenditure on mental health in London (£/person)	White et. al. (2013) and Sturm and Cohen (2014) for dose response Centre for Mental Health (2010)
Physical health	area of green space catchment (ha) * contribution of green space to provision of physical activity in its catchment (%) *population density (persons/ha) * cost of physical inactivity for London (£/person) OR cost of diseases due to physical inactivity for London (£)*proportion of at-risk population going to parks for physical activity (%) * risk reduction for disease due to physical activity (%)	Bird (2004) for dose response relationship Chief Medical Officers (2011)
Property valuation	area of influence of green space or proximity measure (ha) * housing density (dwellings/ha) * property price uplift (%)* house price (£/dwelling) OR density of green space in ward (%) * number of dwellings (dwellings) * property price uplift (%)* house price (£/dwelling)	Smith/GLA (2010)
Air temperature	reduction in number of deaths * economic value of avoided premature death	Forestry Commission (2012) Department of Health
Carbon	carbon in soil: area of green spaces (ha) * carbon sequestered per hectare (tCO2/ha) * cost of carbon (£/tCO2) carbon in trees: from iTree study	Forestry Commission (2012) BIS (2017) iTree (2015)
Recreation	Estimated number of visitors valued by costs of travel according to varying socioeconomic and green space characteristics	Outdoor Recreation Valuation Tool (ORVal). Day and Smith (2016)

Source: Vivid Economics

2 Mental Health

2.1 Existing literature

This section assesses the evidence concerning the link between access to urban parks and mental health outcomes with the aim of identifying potential studies that could be used to quantify this impact.

First, a number of relevant studies that have been identified are discussed and assessed for their potential usefulness. Second, how these studies could be applied to study London parks is discussed.

At the end of this section there is a table detailing seven studies on this relationship. Relevant literature was identified using three primary means. First, a search was made using Google Scholar. This employed the following search terms: 'urban', 'parks', 'mental health', 'green space' and 'economic valuation'. Second, studies within relevant titles that were cited by identified literature were also shortlisted. Third, the potential studies were narrowed down by selecting studies that:

- estimate a specific parameter related to access to parks and mental health outcomes; and
- have relevance to mental health in the UK.

2.2 What do these studies say about the link between access to urban parks and mental health?

Is there agreement on the direction of the impact that urban parks have on mental health in the UK?

Yes, all seven studies conducted in the UK find a statistical association between greater access or use of green space and improvements in mental health outcomes.

Which aspects of mental health do these studies refer to?

All of the identified studies rely on self-reported evaluations of mental health. For instance, three studies rely on evaluations collected through the British Households Panel Survey, which asks respondents for their subjective assessment of their mental health. Respondents are asked how they have felt in the 'past few weeks' in relation to 12 different mood states, ranging from stress and lack of confidence to the ability to make decisions.

How many of these studies would provide a useable estimate of the effect that urban spaces have on mental health?

Three studies are immediately discounted since they are not immediately relevant for mental health, that is, they concern broader health outcomes. (Excluded – Dunstan et al. (2013), Mitchell & Popham (2008), Richardson & Mitchell (2010)).

One study is omitted due to lack of a reasonable causal interpretation; it is highly questionable that the effect of access to green space on mental health is well-identified. (Excluded – Mitchell (2013)).

Further studies include:

Alcock et al. (2013) study the effect of moving to urban areas with more green space by means of a self-reported General Health Questionnaire (GHQ) form, which was devised to measure depression and anxiety based on British Households Panel Survey (BHPS) from 1991-2008. However, it is unclear how the authors define urban. In addition, the point estimates do not give a clear estimate of the effect of urban green space on mental health due to the way that green space is defined. In this study the focus is on the effect of moving to a 'more' green area (green space is a binary variable). This study, therefore, proved unsuitable due to its inadequate definition of green space which is only considered in terms of whether an individual has moved to a more or less green area.

White et al. (2013) study whether individuals in areas with different amounts of urban green space (defined as percentage of land covered in green space) have better mental health outcomes (controlling for individual fixed effects and other covariates). Data is taken from the BHPS from 1991-2008.

What's the nature of the estimated effect?

White et al. (2013) compare within-person differences in well being associated with living in urban areas containing different amounts of green space using BHPS. They find that for a one standard deviation increase in green space (equivalent to moving to an area with 48 per cent green space to area with 81per cent green space) leads to a reduction in 0.14 in GHQ and a 0.07 increase in life satisfaction (GHQ is measured on a scale of 0 to 12).

Methodological considerations: a crucial issue in estimating this effect is the range of factors, such as income and demographics that may correlate with access to green space that also affect an individual's mental health. These factors can potentially lead to omitted variable bias in the estimate. The study uses two strategies to isolate this effect:

Controls for individual fixed effects eliminate the influence that confounding individual characteristics, such as personality type, may have on the relationship between green space and mental health. For example, that people of a naturally happier disposition may be more likely to locate in areas with more green space.

Control variables at the area and individual level whilst controlling for individual fixed effects address the problem of omitted time invariant factors, do not take account of the fact that there may be factors that change over the sample period. For example, an individual could become long-term unemployed, which has been shown to significantly lower average mental health scores. If areas with different levels of green space experienced different changes in unemployment over the sample period, this would bias the estimated effect of green space.

The control variables included:

- age;
- education;
- marital status;
- children;
- household income;
- work-limiting health status;
- labour market status;
- residence type (flat, terrace, semi-detached, detached);
- household space;
- commuting time.

Limitations of this study

Note: excluding gardens from the classification of green space roughly halves the estimated effect of green space on mental health.

The mechanisms through which the effect of access to parks take place are not described; none of these studies provide an answer to this question.

2.3 Calculation

Step 1: Use dose-response relationship from White et al. (2013) between share of abundance of green space within a particular area and mental health outcome. This relates to the density approach, which assumes that the concentration of green space in near proximity to a given population is a good measure of access to green space. A crucial assumption to make here is function form of the relationship between share of green space and mental health. In White et al. (2013) it is assumed to be linear.

Step 2: Repeat the above calculation for each administrative area in London. In the study, LSOAs are used as the unit of analysis. Subsequently, the percentage of green space within each LSOA is assumed to be the relevant measure of access to green space.

Step 3: Attaching an economic value to reductions in mental health burden. This is monetised based on the benefits of avoided incidence of mental health due to green space in each administrative area.

A search for publicly available mental health expenditure data disaggregated by London boroughs or wards was not successful. Thus, mental health expenditure data is taken from estimates by the Centre for Mental Health (2010) who derive total economic costs for England. These total costs are estimated for London by calculating per person costs of mental illness in England and aggregating these up according to London's population.

Alternative methodology

The study by White et al. (2013) provides a point estimate that could be used to quantitatively link the *amount of green space* in an area to reductions in mental health burden. This method crucially relies on the assumption that the density of green space in an urban area is of key importance for mental health. This method precludes a *proximity*-based approach to measuring the welfare impact of parks, where only those individuals within a set distance from a park benefits from its welfare-improving impact. In order to understand the effect of this modelling, both methods are used to calculate benefits and then compared with each other.

In the previous Sheffield Parks study by Vivid Economics, a proximity measure was used. This figure was taken from a study by Sturm and Cohen (2014) conducted in Los Angeles, which found that those within proximity of 400m from a park had 2 per cent better self-reported mental health scores.

In order to understand the effect that this modelling decision could have on the estimated effect of reduced mental health incidence due to parks, it is proposed that both methods are used to calculate benefits and then compared with each other.

TABLE 2

Selected studies exploring the link between access to green space and mental health outcomes

NO.	AUTHOR, DATE	TOPIC	AGGREGATION METHOD AND SAMPLING	REGION	QUANTITATIVE SCOPE	RESULTS
1	Alcock et al. (2013)	Impact of relocation to greener areas on mental health.	Adult samples were participants in the British Household Panel Survey for five consecutive years who reported mental health and relocated between second and third years (n = 1,064).	England	Panel data, fixed effects analysis. Mental health self-reported, measured on a 12-point scale where higher scores represent better health.	Movers to greener areas see, on average, an increase of 0.4 in their mental health score a year after the move. The new score is sustained for the subsequent sample years. Movers to less green areas see scores drop by 0.2 in the first year but adjust to the new setting two years after the move and go back to pre-move mental health levels. (95% C.I.).
2	Barton and Pretty (2010)	Impact of green exercise on self-esteem and mood.	Meta-analysis methodology using 10 UK studies involving 1,252 participants.	United Kingdom	Assessment of changes in self-esteem and mood pre- and post-green exercise interventions. Study used Rosenberg Self-Esteem Scale and Profile of Mood States. Dose responses assessed for exercise intensity and exposure duration.	The overall effect size for change in self-esteem due to green exercise was d=0.46, signifying an increase in self-esteem; and for total mood disturbance it was d=0,54, representing an improvement in mood (95% C.I.).
3	Dunstan et al. (2013)	Impact of quality of built environment i.e. presence of 'natural elements' on general health.	30,000 residents aged 18 or over from 777 post-codes. Built environment quality measured using Residential Environment Assessment Tool (REAT) at unit postcode level.	South Wales	Using a logistic model, with two possible outcomes (good/poor health), REAT score linked to residents' health, controlling for socio-economic and demographic characteristics.	Respondents 90 to 100% more likely to have good health if their neighbourhood has 'natural elements' as specified by the REAT.
4	Mitchell, (2013)	Use of green space and general/mental health.	Scottish Health Survey 2008 Respondents age: 16+ Sample size 1,860.	Scotland	Logistic regression to link self-reported general health and mental health (high vs. low health score) to proportion of green space in respondent's area of residence.	Regular use (at least once a week) of open space/park or woods/forest associated with a 43% lower risk of poor general health (95% C.I. 12 – 63%). Each additional use of any natural environment per week associated with 6% lower risk of poor mental health.

Continue on next page

TABLE 2 **(continued)**

Selected studies exploring the link between access to green space and mental health outcomes

NO.	AUTHOR, DATE	TOPIC	AGGREGATION METHOD AND SAMPLING	REGION	QUANTITATIVE SCOPE	RESULTS
5	Mitchell and Popham (2008)*	Percentage of green space in an area and rate of self-reported 'not good' health.	All residents of England as per 2001 Census.	England	Linear regression model.	For a percentage point increase in green space, the likelihood of poor health falls by 2%.
6	Richardson and Mitchell, (2010)*	Percentage of green space in an area and health outcomes by gender.	UK Census and Generalised Land Use Database. 6,432 urban wards with total population of 28.6 million adults aged 16 to 64, 2001.	UK	Negative binomial regression models.	Men living in the greenest urban wards in the UK have a 5% lower risk of cardiovascular disease mortality and 11% lower risk of respiratory disease mortality than men in the least green wards. No significant effects found for women.
7	White et al. (2013)	Effect of living in areas with urban green space on life satisfaction and mental distress.	Use British Household Panel Survey of 10,000 individuals between 1991 and 2008.	England	Individual fixed effects over 18-12 waves of the survey. Use the British Households Panel Survey.	Individuals living in areas with more green space have better life satisfaction and mental distress scores. Compared with living in an LSOA with green space 1 standard deviation below the mean (48% green space), living in an LSOA with green space 1 standard deviation above the mean (81% green space) was associated with a 0.14 reduction in GHQ (variables ranges from 1-12) and a 0.07 increase in life satisfaction (variable ranges from 1-7).
9	Gascon et al. (2016)	Systematic review long term health benefits of green space.	28 studies reviewed.	Global	65 chosen for full-text evaluation and 28 finally included. 6 were panel, one was ecological and 21 cross-sectional. 19 conducted in Europe (8 in UK).	Classify the evidence of causal relationship between surrounding greenness and mental health and related disorders as limited. Also study access to green spaces (i.e. only those in direct proximity to green space). Classify evidence between proximity and mental health as inadequate.

Source: Vivid Economics

3 Physical Health

3.1 Existing literature

There is lack of peer reviewed literature that assesses the economic health value of green infrastructure but there are several studies in the international grey literature that estimate this value. No single prevailing methodological framework is used in these studies, however the general approach has been to estimate the potential healthcare savings that result from improved physical health due to presence of increased levels of green infrastructure.

Bowen and Parry (2015): collate and review existing literature on links between green infrastructure (defined as green and natural spaces) and health

Health and economic burden of physical activity:

- physical inactivity is the main cause for 21-25 per cent of breast and colon cancers, 27 per cent of diabetes and 30 per cent of ischaemic heart disease burden (World Health Organization, 2016);
- health economics model from the Chief Medical Officers (2011) calculates that inactivity in England costs £8.2 billion (£1.7 billion for the NHS, £5.4 billion for work absence and £1 billion for early mortality) (Bird, 2004).

Relationship between physical activity and green infrastructure:

- considerable amount of evidence showing that provision of open green spaces influences the amount of physical activity that individuals engage in;
- odds of achieving recommended amount of physical activity was 1.27 for people living in greenest quintile in England compared to those living in least green quintile after controlling for individual and environmental factors (Mytton, Townsend, Rutter, & Foster, 2012);
- provision of green spaces is important for children. Each additional 5 per cent increase in proportion of neighbourhood land covered by treed areas leads to 5 per cent increase in free time physical activity outside school hours and grounds (Janssen & Rosu, 2015).

Estimation of health benefits of green space:

- CJC Consulting (2005): cost savings associated with improved physical health due to reduced physical inactivity as a result of changes in green space in the UK. The report estimates that if green space facilitates physical exercise such that the proportion of sedentary males and females in the UK fell by 1 per cent, this would result in a saving of £1.4 billion per annum. This value is close to the lower estimate from Vivid Economics' Sheffield study (2016) scaled up for the UK (£1.7 billion/annum).
- Bird (2004): costs saved from avoided physical inactivity – estimated for a number of cities in the UK including London. The author estimates the proportion of physical activity that an urban park can contribute to the total amount of physical activity undertaken using survey results - current contribution from an urban park to its catchment population's physical activity is 20 per cent. Calculations are not adjusted for age, sex and socio-economic profiles. National level savings estimates from this study are extremely small, £2-£8 million per year, compared to £15-45 million per year for Sheffield calculated by Vivid Economics (2016). A detailed review of this study to needs to be conducted to determine the reliability of these estimates.

- Mourato et al. (2010): economic value of improved physical and mental health derived from increased physical activity created by provision of natural habitats and green spaces in the UK. Estimated the probability of additional exercise with changes in green space and then measured the physical and mental health impact of physical activity. The authors looked at reductions in number of deaths due to increase in physical activity and used the value of QUALYs to arrive at a monetary estimate. Estimated that changes in natural and green space that resulted in 1 per cent decrease in sedentary behaviour in the UK population would provide an economic health benefit of £2 billion per annum.

3.2 Calculation

Method:

Estimate the savings in costs of physical inactivity for London due to green spaces, such as cardiovascular disease, diabetes, obesity, colon and breast cancer due to availability of green spaces as carried out in Vivid Economics (2016).

Step 1: estimate catchment area for each park (area)

Step 2: estimate the contribution of parks to physical activity in terms of population in the catchment area (Bird, 2004) (population density*area of catchment* percentage contribution to physical activity)

Step 3: estimate cost of physical inactivity for London per person by pro-rata scaling down the costs for England/UK (£/person)

Step 4: estimate savings in health expenditures per person for London (£/person * number of persons with increased physical activity from step 2)

There remain significant uncertainties in this relationship owing to a lack of evidence linking variation in access to parks to physical activity. To account for this, sensitivity analysis is performed in the report around this figure.

4 Property Valuation

4.1 Existing literature

Property prices are commonly used as a means to estimate the economic value of green space. This is commonly done using the hedonic pricing (HP) framework. This approach assumes that property prices are a function of various observable characteristics such as property type, socioeconomic variables and locational factors, such as access to amenities. Using variation of property prices across these different characteristics, it is then possible to estimate the willingness to pay for each characteristic.

Previous estimates

A sizeable number of empirical studies have used the HP approach to estimate the value of green space on property prices. In order to understand the size of this effect, two studies that review these sets of studies are summarised.

First, Konijnendijk et al. (2013) conduct a systematic, qualitative review of the benefit categories associated with urban parks. They identify 19 studies that are of high enough quality globally. Examining the findings of these studies, they conclude that there is moderate to strong evidence that urban parks have a positive effect on house prices. Parks have a stronger impact on property prices than other types of green space, such as agricultural land. There is general agreement that there is a non-linear relationship between property value and distance to park, although there are no agreement bounds for this relationship, no agreed threshold beyond which proximity to park begins to have a positive effect on house prices. Other findings suggest that other mediating factors may be important in determining whether or not parks have a positive effect on value. For instance, parks do not have a significant impact on prices in high crime areas: crime rates in an area need to be below a certain threshold. There are also large regional differences in the size of the effect. This makes it hard to generalise about impact of distance on property values across different space.

A second review paper by Brander & Koetse (2011) involves a meta-analysis of 12 hedonic studies identified as suitable, of which eight specifically relate to parks. The authors conclude that distance from green space is the most commonly used metric to assess values. The average effect size from these studies is estimated to be: for each 10m increase in proximity to an urban green space, property values increase by 0.1 per cent. There is also evidence of a declining effect of green space as distance increases, although this effect is less well understood. The reviewed studies point to evidence of large regional differences in effect size in the USA, implying that value transfer may be difficult.

Methodological issues

The review studies highlight a number of empirical issues that may limit the applicability of previous HP studies to estimate urban parks benefits. These relate to concerns over relevant omitted variables, the type of value that households derive from parks, and issues about value transfer across contexts.

- Risk of omitted variable bias – most HP studies exploit variation in property prices using cross-sectional data. This makes it difficult to use methods to reduce the potential bias caused by omitted variables. For instance, in estimating the value of green space on property prices, omission of a variable that is correlated with both green space and property prices would lead to a biased estimated effect of green space on prices.

- Not possible to ascertain mechanism behind value of green space on property – there may be a number of ways that households derive value from being located near to a green space. One possibility is that households primarily derive value from recreation amenity provided by proximity to parks. Another possibility is that households primarily value aesthetic features of parks, such as views.
- Value transfer – previous reviews of the literature have highlighted substantial differences in effect size. The use of estimated effects from dissimilar contexts should be avoided if possible.

How do other urban park studies estimate this effect?

In the Philadelphia parks study, the authors impose a limit for the effect of parks on property prices to 500 metres from a park. They do not discuss the empirical validity of this threshold, however. Additionally, the authors assume that within this boundary, property prices experience a 5 per cent value uplift. This assumption is not referenced.

A similar methodology is used in the Beam Parklands study. Here, the authors assume that green space has a 3 per cent effect on property prices for properties within 300 metres. As with the previous study, the empirical validity of these assumptions is not documented.[1]

4.2 Calculation

The methodology proposed lists the source that the estimated effect is taken from, the precise methodology employed, the dose-response relationship, and potential criticisms.

Method 1

Estimate property price uplift based on density of green spaces in a previous study commissioned by Greater London Authority.

Source:

Smith (2010).

Methodology:

Estimates the value of green space in London using the HP method. For the dependent variable, the average house price in each 'lower super output area (LSOA)' of Greater London (there are over 20,000 LSOAs in London as opposed to around 600 wards) is used. The metric of green space relates to the percentage of green space within 1km of a 'lower super output area'.

Dose-response relationship:

For each hectare of green space within 1km of a locality, average house prices in London increase by 0.08 per cent (0.077-0.083 95 per cent confidence interval).

Potential benefits of using this figure:

- criticisms of value transfer across different contexts are avoided;
- uses a straightforward methodology to estimate access to green space that can easily be applied using GiGL data.

[1] The authors do argue that this figure tallies with the result that would be achieved by using the Smith (2010) estimate for London. They calculate that based on GLA's estimate of an uplift of 0.08 per cent per hectare of green space within 1km of a park, the 53 hectares extent of Beam Parklands implies an uplift of 4.3 per cent for properties within 1km.

Potential disadvantages of using this figure:

A key methodological difference between this study and those reviewed by Konijnendijk et al. (2013) and Brander and Koetse (2011) is the specification of the metric of proximity or access to green space. Whereas the review articles focus on estimating the effect of distance away from green space as a measure of access, Smith (2010) use the density of green space within 1 km as the metric. Effect is estimated at the LSOA level. Whether this effect can be generalised for administrative areas of lower resolution, such as wards, can be debated.

Double counting of benefits – since it is not possible to ascertain which specific aspects of urban green space are priced into property, there is the risk of double counting (to attempt to reduce this problem, health benefits of green spaces have been subtracted from the hedonic estimates).

Method 2

Estimate property price uplift based on proximity to green spaces as in Brander and Koetse (2011). A figure of 5 per cent uplift for properties within 300m was used, analogous to the figure used in the Philadelphia study. Along with assuming a buffer around parks of 300m, the estimation was run only for properties within 100m of a park boundary to provide a set of lower bound estimates. Given uncertainty about the size of green space that is sufficient for people to be willing to pay to live in closer proximity, estimates are also calculated assuming that only parks above 2 ha are sufficient to lead to property price uplift.

Step 1: estimate the number of dwellings experiencing uplift by using dwelling density (dwellings/ha) and area of influence of green space (ha) by ward.

Step 2: apply this uplift to house prices (£/dwelling) by ward to calculate the total benefit (£).

Step 3: estimate uplift assuming variable buffers (300m,100m) and park size sufficient to cause uplift (no limit, only parks >2 ha).

5 Air Temperature

5.1 Existing literature

Areas of green space generally have lower temperatures compared to urban areas. This is owing to the cooling effect that vegetation and open space has relative to built environments that can lead to urban heat island effects due to heat absorption, density of energy intensive activities, and lack of spacing between buildings.

What is the strength of empirical evidence for this effect?

A significant number of studies have specifically considered the role that urban parks play in temperature regulation. A systematic review of the literature in this area is provided by Bowler et al. (2010), who conduct a meta-analysis of urban green space heat effects by reviewing studies that compared temperatures at green sites with non-green sites.

The authors find that, on average, temperature reduction was 0.94°C during the day based on 26 estimates from 16 studies. At night, the temperature difference was 1.15. They find limited evidence that parks had any effect on temperature on a wider surrounding area.

There are other studies however that suggest that parks affect temperatures in surrounding areas such as (Doick et al. (2014). A 111-hectare park in London (Kensington Gardens), England, generated an evening cooling effect from 20 metres to up 440 metres beyond the park. Statistical modelling displayed an exponential decay in the extent of cooling with increased distance from the green space. The mean temperature reduction over these distances was 1.1°C in the summer months, with a maximum of 4°C cooling observed on some nights.

Uncertainties in this relationship

According to Bowler et al. (2010), there are a number of empirical uncertainties that make it difficult to ascertain the temperature regulation effects for a specific green space.

- Size – uncertainty about the area of green space that is necessary to lower temperatures. For instance, how would the cooling effects of a park that was one hectare in size differ from a 50 hectare park?
- Effect on surrounding areas – although it is generally agreed that cooling effects from green space are greater closer to a park, the exact cooling effects for surrounding areas or threshold values are not known. Later evidence reviewed by Zupanic et al. (2015) finds a maximum cooling distance of 224 metres.
- Park type – a number of studies have identified that vegetation type is an important factor in determining the cooling effect of parks. Trees are generally considered more important than other types of vegetation.

5.2 Calculation

The literature identifies two economic benefits of the cooling effects of urban green space.

1. Report by(Doick & Hutchings (2013) for the Forestry Commission estimates value of avoided health costs in London. The author follows a basic methodology that attaches a value to the health costs of extreme heat;
   - Assume that London's green infrastructure reduces the urban heat island (UHI) effect by 2°C;
   - Link this to effect of reducing deaths on very hot days by 16-22;
   - Link this to Department of Health's value for economic value of avoided premature death (1.7 million);
   - Total value is £26.4-26.4 million. Note: not clear whether this is a daily 'hot days' figure or a total figure.

2. Previous Vivid Economics study of Sheffield Parks quantifies benefits of urban cooling as a reduction in air conditioning costs

This study will estimate the benefit of air temperature regulation as the value of avoided health costs in London.

It will also calculate the reduction in air conditioning costs but this value will not be reported in the accounts as enough evidence is not available to determine whether green spaces also lead to additional heating costs due to lowering of temperatures in the surrounding areas.

6 Carbon

6.1 Existing literature

The relationship between parks, which contain large amounts of organic matter in trees and soil, and the amount of carbon stored is fairly well understood. This is because carbon in trees and soil is easily measurable.

Two studies form the basis for the calculation of the amount of carbon stored in London parks.

The first is taken from the iTree study (Rogers et al. 2015) for London. This project estimated the number of trees in the city and the amount of carbon stored by these trees. Although the iTree study does present very credible estimates of tree numbers for London as a whole, one downside of this study is that it is not clear how many trees are located within London's publicly accessible green space. In the absence of this data, the total trees for carbon sequestration in London is used.

The second source, used to estimate the amount of carbon in soil, is taken from the Forestry Commission (2011). This source gives a per hectare amount of carbon stored in soil. It is important to note that only soil in woodland is included in this number. This decision is taken since wooded areas are much more substantial stores of carbon than other green areas, such as grassland. The area of woodland is calculated using GiGL's open space categorisations.

6.2 Calculation

Method

Estimate the value of carbon in trees and carbon in soil.

Carbon in trees

Value taken from iTree study.

Carbon in soil

Area of wooded green spaces (ha) * carbon sequestered per hectare (tCO2/ha) * cost of carbon (£/tCO2).

Cost of untraded carbon dioxide (£63/tCO2e) figure is taken from figures published by Department for Business, Energy and Industrial Strategy (2017).

7 Recreation

7.1 Existing literature

Data on visitor numbers is collected annually by Sport England, Visit Britain and Royal Parks. However, this data is typically of a limited spatial extent and not suitable for aggregation of all types of green space across London.

One previous study on the economic value of urban parks has used estimated recreational use values by combining telephone surveys with estimates of the value of different types of recreational activity. A report by the Philadelphia Parks Alliance (2008) surveyed 600 people on their use of the city's parks and used economic values from the U.S. Army Corps on the 'Unit Day Value' of different types of activity. This method was judged as unsuitable for application in London owing to lack of reliable survey data on activities conducted in London's parks and caution on transferring estimated benefits from the U.S. to the U.K. context.

7.2 Calculation

To estimate the value of recreation provided by London's parks, the Outdoor Recreation Value (ORVal) tool devised by Day & Smith (2016) is used. To address uncertainties and lack of data concerning the value placed on recreation values in the UK, the ORVal tool uses an econometric model of recreational demand. The model is supported by data from the Monitor of Engagement in the Natural Environment (MENE) survey, which asks people about the amount of time spent in different types of green space and the activities they conduct in these areas. These are restricted to day trips and only for adults residing in England.

Using this model, the ORVal tool is able to estimate values of recreational activities based on the costs borne by respondents in travelling to each type of green space. These estimates are available at the local authority level, so are available for each borough and the City of London.

8 Air Quality (not included in account)

8.1 Existing literature

Konijnendijk et al. (2013) conduct a systematic review of the benefit categories associated with urban parks. It concludes that most studies evaluate the effect of urban vegetation on air quality with the majority using the density of urban trees as relevant measure. The paper identifies seven studies examining effect of urban parks on air pollution. Five studies found that parks reduced particulate matter and reduced other pollutants (NOx and SOx). A regression study by Yin et al. (2011) found that urban parks in China reduce total suspended particles (TSP) by 9.1 per cent, SO2 by 5.3 per cent and NO2 by 2.6 per cent within parks. A study by (Lam et al. (2005) looks at differences in air quality in parks and in surrounding areas. They found that for 70 parks in Hong Kong, air quality was not substantially better than in surrounding areas. The conclusion of the authors is that there is weak to moderate evidence that urban parks improve air quality through removing pollutants. Several studies highlight the role of trees in particular.

An additional review by Zupancic et al. (2015) concluded that for studies comparing the effects of small and large parks on air quality, the evidence base was poor.

A key problem identified by both reviews was that for many studies examining the link between air pollution and urban green space, modelling is often used in absence of empirical, on-site measurements. This leads to a number of assumptions being made about a park's mitigating effect on air pollution that may or may not be empirically valid.

What is known about the economic burden of air pollution in London?

A 2015 report by Kings College, commissioned by TfL and GLA estimated the mortality burden of 2010 levels of air pollution (PM2.5 and NO2) in London expressing this in terms of life years lost. Although this report contains damage costs per tonne of air pollution in London (Walton et al., 2015), it is unclear whether parks and green space have any role to play.

8.2 Calculations

There is lack of reliable evidence on the dose response relationship between green spaces and impacts on air quality. The most relevant study available is Yin et al. (2011) which is a peer reviewed paper, experimentally estimating the air pollution impacts within urban parks in Shanghai, China. The study uses seasonal monitoring data of TSP, SO2 and NO2 for outside and inside six parks in Pudong District, Shanghai, China. A crown volume cover (CVC) variable was used to characterise vegetation conditions in parks, and CVC along with pollution diffusion distance were key predictors influencing pollutant removal rate. Pollutant removal rates within parks were then estimated for each park. The paper indicates that if normally all the ground-level air pollutants could diffuse through a 50-m-wide vegetation patch with the CVC of 0.488 m3/m2 in urban area, the hypothetical average percentage air quality improvements within parks were 9.1 per cent for TSP removal, 5.3 per cent for SO2 and 2.6 per cent for NO2. The relationship between urban vegetation and air pollutant removal outside of the vegetation patch can be affected by multiple factors such as land use and spatial heterogeneity and therefore caution may be needed when upscaling these findings.

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