MEASURING TREE CANOPY COVER IN LONDON

An analysis using aerial imagery

MAYOR OF LONDON

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Executive Summary

This study estimates tree canopy cover in London using aerial imagery. Sample points across London were classified into land cover categories using aerial images from the summers of 2003, 2007, 2010 and 2013. The results provide a snapshot of tree cover for these years, as well as a baseline for comparison with future images. Classifications were made for tree canopy cover as well as other key land use categories using the London Tree Officer Association's Open Source Canopy Cover Audit (OSCCA) process[1]. The subjectivity of the classification process was managed using an accuracy assessment, whereby ten per cent of the sample points were reclassified and compared to the original results. Variations in classifications greater than 10 percent triggered complete reclassification of the image and a repeat of the quality control exercise.

The classification of 3,000 random points for each image estimated London to have over 50 percent of green cover (trees, woodland and other vegetation). This compares well with figures from Greenspace information for Greater London[2]. From 2007 to 2013 the classification of random points found total tree and woodland cover to be on average 19.5 percent of the total area of the Greater London Authority. This equates to just over 31,000 hectares.

Using aerial images provides a snapshot of tree cover each summer, and therefore indicates an estimation of the tree canopy cover rather than an absolute figure. Importantly, the method used here is low cost and easily repeatable. It does not, however, identify recently planted trees since they will predominantly have a canopy cover that is too small to be detected using aerial imagery. Taking into account this lag time for newly planted trees to reach a canopy size that can be easily identified, it is recommended that the Greater London Authority repeats and monitors aerial image analysis of canopy cover on at least a 5 year basis across London.

[1] http://www.ltoa.org.uk/resources/open-source-canopy-cover-audit-oscca
[2] http://www.gigl.org.uk/our-data-holdings/keyfigures/

CHAPTER 1: INTRODUCTION

1.1 Objective

This report aims to provide an assessment of tree canopy cover in London using a robust and repeatable methodology. We attempt to identify whether canopy cover has changed between 2003 and 2013 as well as providing a baseline for further research and monitoring of long term tree canopy cover targets.

1.2 Tree canopy cover

Trees in urban areas provide economic, environmental and social benefits. Trees remove pollutants from the air, improving air quality and absorbing carbon dioxide emissions and reduce noise pollution. By providing shading trees cool buildings and roads in the summer, reducing the temperatures during very warm periods. Tree cover reduces wind speed and intercepts rain, helping to reduce the risk of local flooding. They are important to Londoners socially by improving the appearance of an area and therefore creating focal points and landmarks, whilst also supporting a range of wildlife in the city. Trees can have a positive impact on health and wellbeing and can create a sense of identity and pride in a community.

Policies have been implemented in London to more fully realise the benefits tree cover provides to the city. The Mayor's urban greening programmes include protecting and increasing tree canopy cover; ensuring Londoners benefit economically, environmentally and socially. The RE:LEAF partnership[3] is helping to deliver the Mayor's target to increase tree cover across London by five percent by 2025, as stated in the London Plan. By creating or enhancing small outdoor spaces the Mayor's Pocket Parks[4] programme has helped increase green cover including trees. The Mayor's Street Tree Initiative[5] has delivered 20,000 street trees across London since 2009. The GLA have also supported 60 community projects through the Tree and Woodland Grant Scheme since 2012. This has helped green neighbourhoods and enhance London's identity as one of the greenest world cities.

1.3 Measuring tree canopy cover in London

The Mayor aims to increase tree canopy cover across London from a baseline of 20 percent of total land cover in 2008 to 25 percent by 2025. The 20 percent baseline is an estimate calculated by GLA in 2008 using a range of sources. For example, the results of the 1993 London Tree Survey provided an

[3] RE:LEAF is a partnership campaign led by the Mayor to protect the capital's trees and encourage individual Londoners, businesses and organisations to plant more trees. For more information please see www.london.gov.uk/priorities/environment/greening-london/re-leaf/releaf-partners

[4] Pocket parks are small areas of inviting public space for all people to enjoy, providing relief from the hustle and bustle of the city. These spaces should have trees and greenery; they should be open to all; they should have places to sit and relax and for people to come together; and they should contribute to making the city friendlier, greener and more resilient.

[5] During the Mayor of London's first term he fulfilled a commitment to plant 10,000 street trees in London. Following the success of this initiative the Mayor planted an additional 10,000 street trees by March 2015.

estimate of the number of individual trees in Greater London of 5,400,000 and further trees were documented in an estimated 400,000 cypress hedges. The study did not include woodland and therefore results from surveys of open space and wildlife habitat by the London Ecology Unit and Greater London Authority were also included in the headline figure. An estimated 1,900,000 trees in 'stands', most of which are in woodland, were added to create an approximation of 7,300,000 trees in London. The headline 'around 7,000,000 trees' is used because of the level of uncertainty associated with these sources of information.

Having established the importance of tree canopy cover in London it is vital to have a robust baseline from which any changes in cover can be assessed. Mapping of tree cover using aerial imagery is relatively recent and therefore there is limited literature on mapping trees within an urban context. Automated analyses of aerial images can be used to estimate tree canopy cover. Such methods are particularly useful when attempting to create images of trees that can be presented in maps. However, such methods can be costly and also can underestimate tree cover where tree canopy is in the shadow of taller objects (such as other trees or buildings).

This report therefore focuses on using an easily repeatable and cost effective method to estimate tree cover in London.

1.4 Report structure

The method of using aerial imagery data is explained in chapter two including the accuracy assessment. Chapter three displays the results and chapter four discusses them in more detail to establish a baseline. The final chapter concludes the key findings and recommendations.

CHAPTER 2: METHODOLGY

2.1 Study area – Greater London Authority

As shown in figure 1 London is formed of 32 boroughs and the City of London and covers an area of around 1,600 km^2.

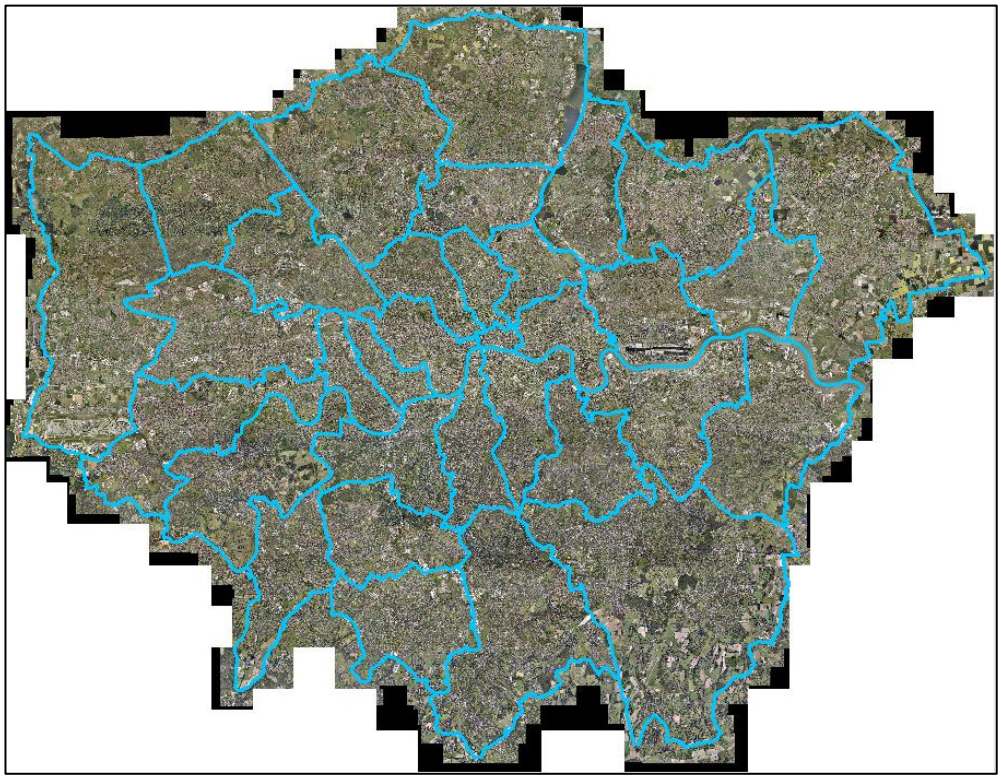

Figure 1: Map of London illustrating the borough boundaries (aerial image from The Geoinformation Group, 2011).

2.2 Mapping software - ArcMAP

The geographical information system ArcMAP was used to evaluate land cover (including tree cover) in London from 2003 to 2013. The method used to generate and then classify sample points is that used by the London Tree Officer Association's Open Source Canopy Cover Audit (OSCCA) process[6].

[6] http://www.ltoa.org.uk/resources/open-source-canopy-cover-audit-oscca

2.21 Datasets

To analyse tree canopy cover over a 10 year period, four aerial images were used (2003, 2007, 2010 and 2013). For each image 3000 random points were created to be classified by land cover type. Classifying the points is subjective and it should be noted tree canopies can cover a considerable proportion of areas of 'other vegetation' as well as roadways, footways, car parks and other such impermeable surfaces (but seldom buildings).

2.22 Classification of land cover

Points were classified consistently across all the boroughs. Table 1 lists definitions of each classification. Classifications were made on what was directly under the sample point rather than what may surround the sample point.

Several land cover classifications were included alongside tree cover. This provides a good opportunity to use these classifications for future projects. Although subjective, a distinction between 'woodland' and 'tree' may be useful for future research and policy-making concerning individual tree cover. The two categories were combined to give an accurate estimate of total tree canopy cover.

Table 1: Description of classifications

Classification	Description
Building	To validate other figures - as buildings are easy to identify. This includes warehouses, sheds, greenhouses etc. There are figures already available for the built environment. A close correlation of results reinforces the accuracy of the canopy figures.
Flat roof	Flat roof
Green roof	Vegetated roof
Other manmade	Anything unclear or outside the remit of the survey. This may include things like a paved area of public realm which is not a footpath, a (non-grass) tennis court, a public square etc.
Other vegetation	Any vegetation that is not a tree i.e. grass, garden shrubs, trackside nettles, front garden hedges, farmland, scrub, etc. Analysis of shadow effects can help identify trees over smaller vegetation, or overlaying other useful datasets (OS Mastermap etc) can help put the area into context.
Tree	Individual or small groups of trees.
Woodland	Larger areas of continuous tree canopy cover. For the avoidance of doubt this means "predominantly tree covered land whether in large tracts or small blocks (e.g. coverts, woods, shelterbelts, copse, cars, railway banks, waterway banks)".
Water	Any surface water body (river, lake, canal, reservoir, pond, swimming pool)

Transport	Including any impermeable surfaces on which people walk, drive, ride and park (NB in this study canal is classed as 'Water'). Please note that train depots etc. are classed as buildings, but track would count as transport. If the classification point falls on top of a vehicle on a piece of transport infrastructure, then classify as 'Transport'. Private driveways would also be classed as 'Transport'. Impermeable surfaces used for pedestrians to travel along e.g. pavements, walkways, footbridges etc. have been classed as Transport but public squares, patios or desire lines through parks have not.

2.3 Classification accuracy assessment

Data quality analysis is important in this project given the subjectivity of classifying the points. Within the 3000 points for each image, 300 were randomly selected for re-analysis and classification by another user. The 300 re-sampled points were compared to the original classifications and reasons for discrepancies in classification were investigated and noted. If the difference between total number of trees and woodland classified between the two samples of 300 points was larger than 10 percent then the 3000 points were classified again.

2.4 Summarising classifications

Total percentages were calculated for all classifications as well as tree and woodland combined. Green cover comprises tree, woodland and other vegetation combined. The main aim is to study total tree canopy cover and therefore a graph is produced illustrating the trend with standard error. Using a method consistent with the i-Tree (2011) approach, standard error and confidence intervals are calculated using the formula below:

Standard Error = $\sqrt{(pq/N)}$

Where
N = total number of sampled points
n = total number of points classified as tree
p = n/N
q = 1 – p

In the case above, a 95 percent confidence interval can be calculated:

If N>=30 the SE x 1.96 is added to and subtracted from the estimate.

CHAPTER 3: RESULTS

3.1 Study area

Four aerial images were used to classify the random points using the mapping software ArcMAP. The exact timings of image acquisition varied between the years, although all are summer images. As mentioned previously the images are a snapshot of the study area.

3.2 Sample points

Figure 2 shows the location of the random points for each year of study - 12,000 points in total – covering the whole of London.

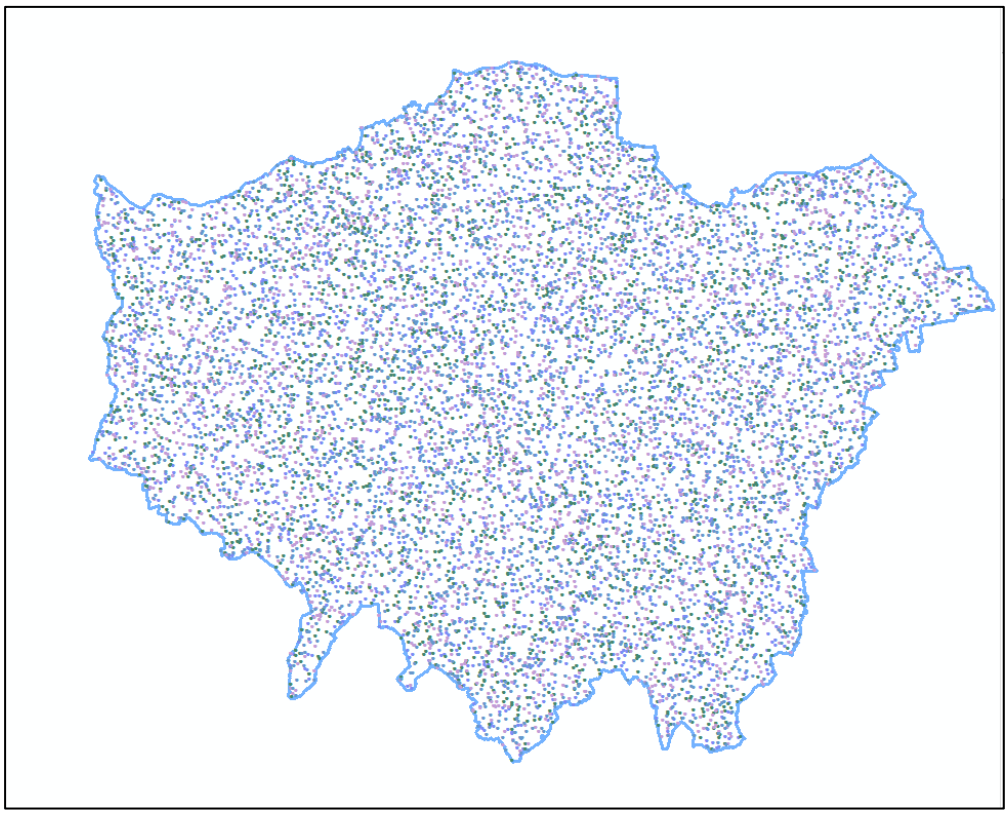

Figure 2: Map illustrating 12,000 random points for all 4 images.

3.3 Classification accuracy assessment

The aim of the classification accuracy assessment was to ascertain the difference in in total woodland and trees classifications between two users. If the difference was larger than the threshold of 10%, then the points were classified again. Re-classification was required for 2010 only. Table 2 shows the results of accuracy assessments for the categories of both trees and woodlands (combined) and other vegetation. Trees and woodland were combined because of the highly subjective nature of the descriptions.

Table 2: Accuracy assessment on tree and vegetation cover for all years

Year	Difference between sample 1 & 2 (trees + woodland)	Difference between sample 1 & 2 (other vegetation)
2003	4.4%	4.7%
2007	6.9%	1.8%
2010	2.9%	3.9%
2013	1.5%	3.1%

The percentage difference between all samples is under seven percent indicating close agreement between the two users classifying the random points.

3.4 Summarising classifications

Table 3 suggests that between 2003 and 2013 total woodland and tree cover has increased (from 18.2 to 19.5 percent) - however the percentage in 2003 is significantly lower than the other years, which will be explored in more detail later in this report. The total green (vegetated) area of London is just over 50 percent throughout the 10 years.

Table 3: Percentage of tree and other vegetation cover

Year	Total woodland and trees	Other vegetation	Total woodland, trees and other vegetation
2003	18.2%	34.4%	52.5%
2007	19.5%	33.7%	53.2%
2010	19.4%	33.6%	53.0%
2013	19.5%	32.5%	52.0%

Table 4 displays the other classifications showing similar percentages over the 10 years with no clear increasing or decreasing trend. We would expect building cover to remain fairly consistent over the study period - please note that building and flat roof cover should be combined to produce total building cover values.

Table 4: Percentage of other land cover

Year	Building	Flat roof	Other manmade	Transport	Water
2003	12.4%	3.9%	17.4%	11.6%	2.1%
2007	11.2%	4.4%	15.7%	12.8%	2.6%
2010	13.6%	2.4%	17.5%	12.2%	1.3%
2013	11.4%	4.7%	16.0%	13.8%	2.1%

Figure 3 demonstrates the small percentage differences in tree and woodland cover over the study period, indicating that despite variables that would have affected canopy cover such as weather conditions, date of image acquisition etc. tree cover appears to have remained fairly constant. It should be noted that trees planted recently are often difficult to identify on aerial images due to their small canopy.

Figure 3 suggests a baseline which is averaged to 19.1 percent with a confidence interval between 17.7 and 20.5 percent. Removing the probable anomaly of 2003, in which extreme warm and arid conditions were experienced, current canopy cover can be estimated to be around 19.5% of London's total area (+/- 1.4% using a 95% confidence level).

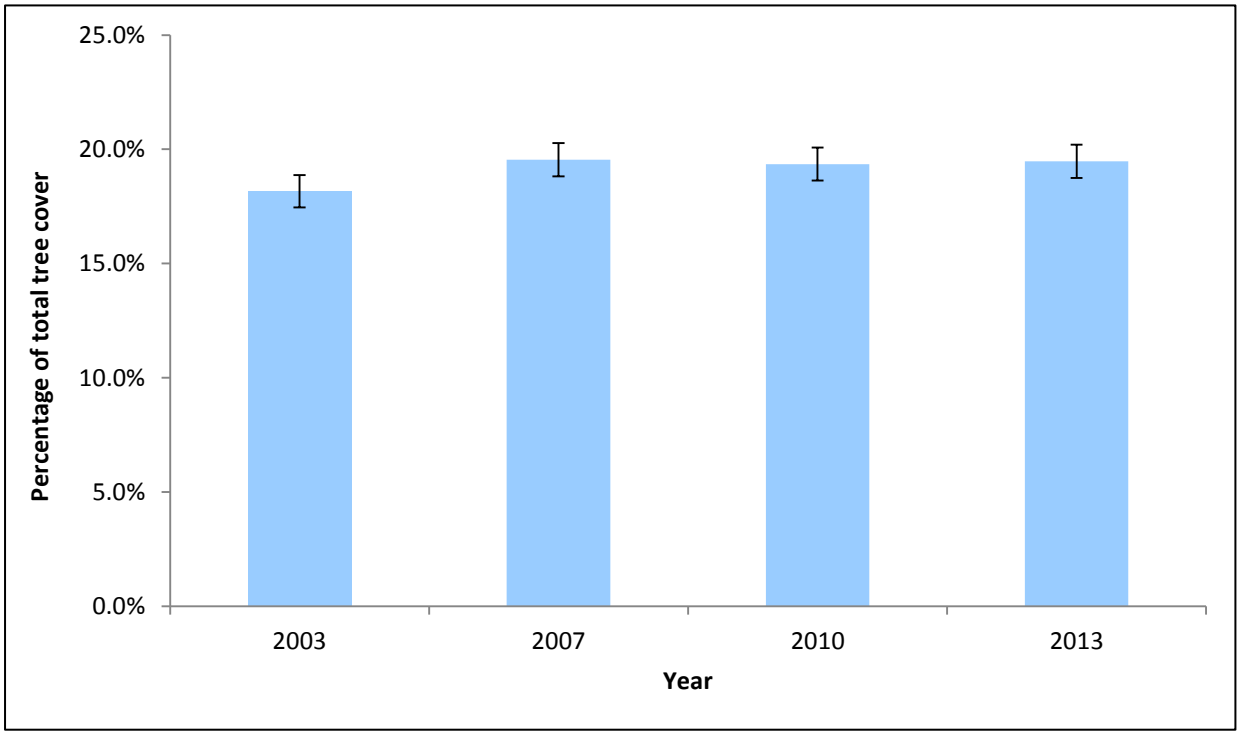

Figure 3: Percentage of total tree canopy cover, with confidence intervals.

CHAPTER 4: DISCUSSION

4.1 Study area

The images of London represent a snapshot taken during summer for all four years, but not necessarily the same week. Therefore for all years analysed the tree canopy cover could be higher or lower during different times of the year depending upon tree maintenance cycles or prevalent weather conditions. Therefore the results analysed indicate an estimation of the tree canopy cover rather than an absolute figure.

4.2 Tree canopy classification

Originally 'woodland' and 'tree' were classified separately to examine the potential use of the aerial imagery method to evaluate individual tree cover. Unfortunately classifying between 'tree' and 'woodland' was found to be very subjective and therefore the results were not reliable individually. The main reason for difference in trend between the two categories is misclassification, illustrating the challenges of identifying between the two categories. Therefore in this study tree and woodland cover were combined into one category of tree canopy cover.

4.21 Tree Canopy Cover

Over the decade covered by the aerial images the total tree cover in 2003 appears to be an anomaly - it is unlikely a large increase of trees were planted prior to 2007 to explain the apparent increase in cover between these images, since trees take several years to mature and develop a canopy noticeable on aerial imagery. During the summer of 2003 when the images were taken, London was suffering a heat wave which in August reached temperatures of around 38°C, creating dry conditions and water shortages. It is assumed the summer heat wave of 2003 influenced the low canopy cover estimate for this image, although this study does not investigate the potential impacts of heat and water stress on tree canopies.

Estimating tree cover is important for many reasons, one of them being where to focus planting new trees. Studying tree cover using this method can help determine where cover has increased on a local level as well as the constituent gaps. Figure 4 suggests a concentration of tree cover in outer London especially near the south-east and north-west of London. Outer London is less densely populated and therefore there are generally larger green spaces and more woodland. Towards the centre of London tree cover decreases, as one would expect as the density of the built environment increases.

It is unlikely polices in place now to increase tree cover will be represented by tree cover analyses in this report because of the time lag for newly planted trees to mature and become noticeable in aerial imagery. This raises an important point on how to analyse the implementation of the policies to increase tree cover. It is difficult to disaggregate the impact of policies and other factors affecting canopy growth, and whether tree planting is the sole answer to reach the canopy cover target. This report aims to establish a baseline to provide a foundation for future research. Recommendations on the next steps and taking this report forward are discussed in the next chapter.

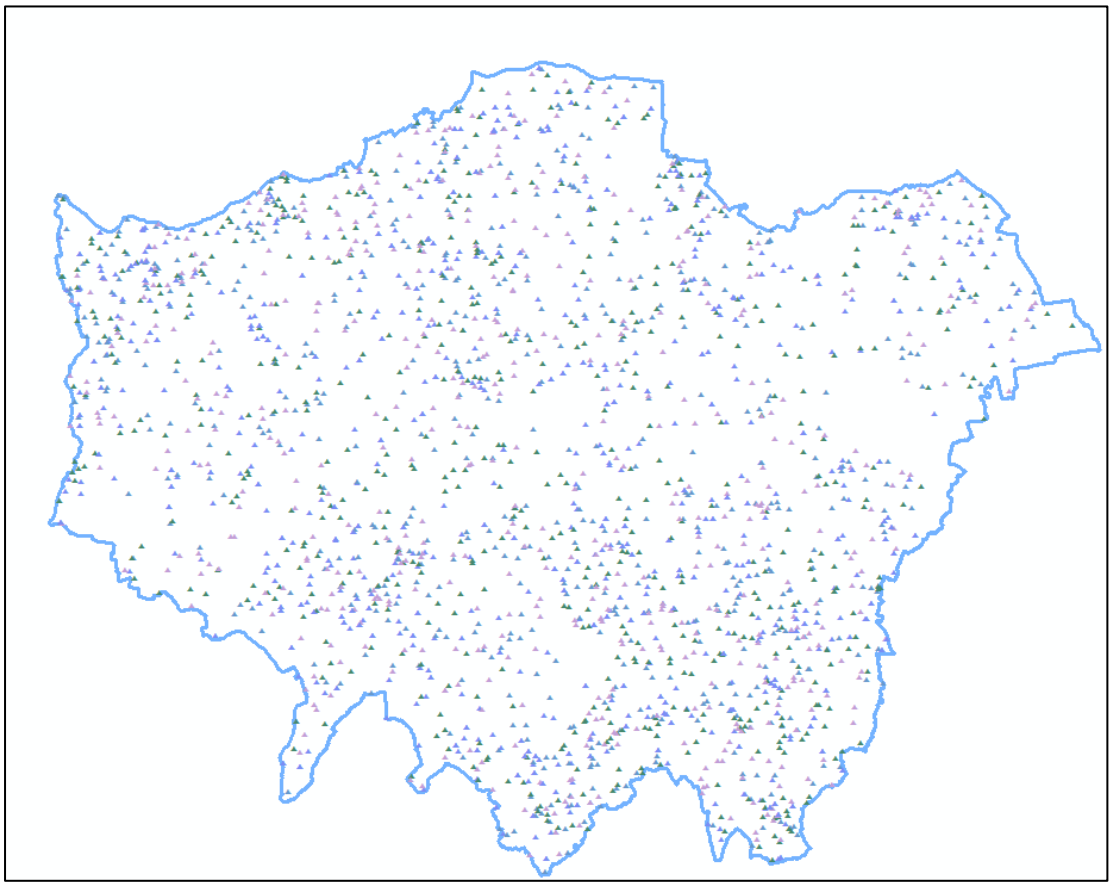

Figure 4: Tree and woodland cover for all years.

4.22 Total vegetation cover

Figure 5 illustrates the total vegetated area of London (woodland, trees and other vegetation) is just over 50 percent throughout the 10 years. The main gaps in random points classified as vegetated cover are around central London and along the River Thames.

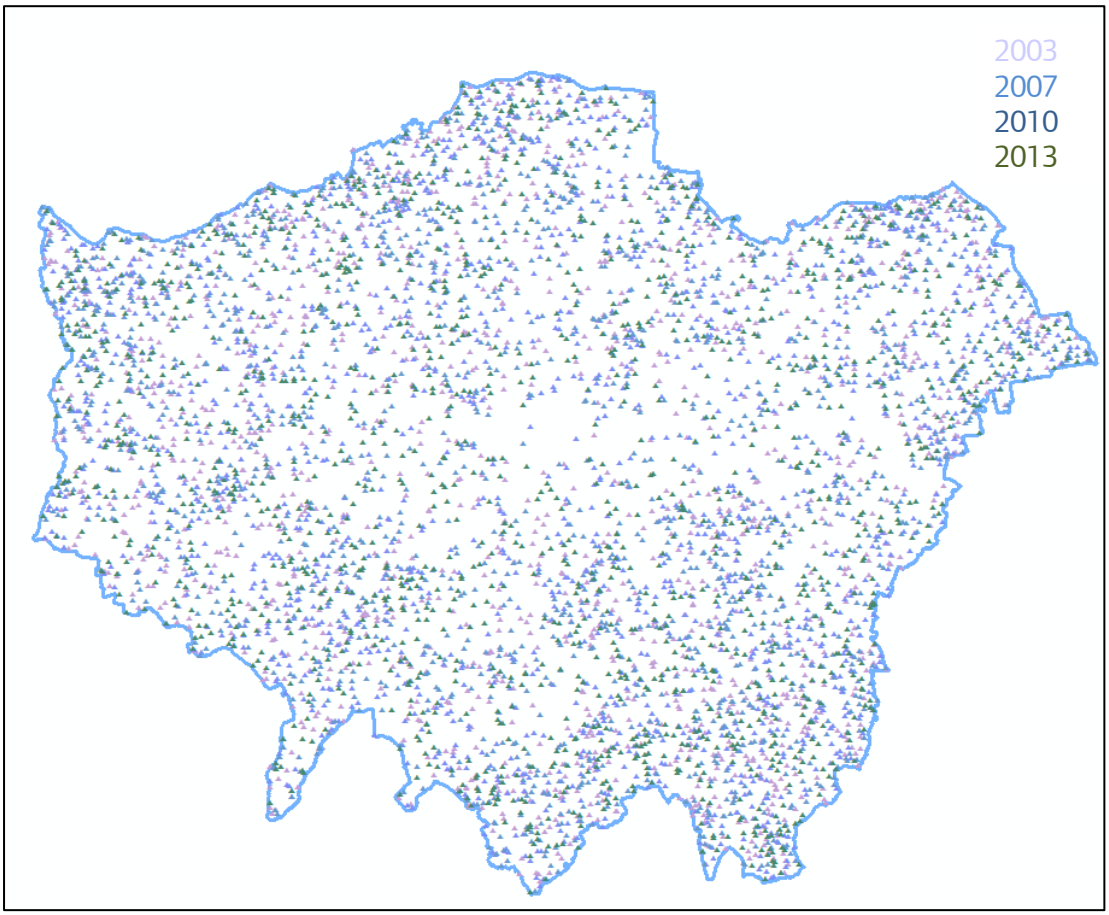

Figure 5: Tree, woodland and other vegetation for all years.

4.3 Classification accuracy assessment

Table 5: Percentage out of total sample for border or edge and misclassification

Year	Borderline/edge	Misclassification
2003	5.3%	4.0%
2007	3.7%	7.3%
2010	4.7%	2.3%
2013	5.0%	7.0%

The accuracy assessment reveals that predominantly classifications differed between users due to the point being located on a border or edge of a land cover type, or misclassification due to human error.

It is difficult to improve on the accuracy when the points are located between two classifications as the outcome will vary by individual points, with the user's experience and interpretation and image clarity. In this study we opted against creating an 'unclassified' category for such difficult points.

From other studies misclassification is known to be common (e.g. Myeong *et al* 2001). Human error, which is unavoidable to a certain extent, can certainly be reduced. Other misclassifications were caused by subjective matters – for example whether graveyards were other vegetation or other manmade. Another common subjective issue was whether private roads/driveways were other manmade or transport. As this is the first time this research has been conducted the misclassification on certain points was unavoidable and influenced the classification descriptions for future use. The quality of imagery did vary for different years and causes problems especially in 2003 and 2010. Reasons for this included localised blurry and unclear images as well as shadows which made it difficult to identify the land cover under the sample point.

CHAPTER 5: CONCLUSION

5.1 Summary

This study establishes a baseline of tree canopy cover in London to be used for further research. Omitting 2003 as an anomaly, between 2007 and 2013 this value is estimated at 19.5 percent (+/- 1.4% using a 95% confidence level). An estimated baseline of 20 percent was previously calculated by Greater London Authority using other data sources.

From the aerial imagery classified there is little change over the decade. However this does not necessarily mean that the rate of tree planting has not increased over the last decade. Recently planted trees will take several years to mature and for their canopies to be detectable on aerial imagery. This highlights the importance of repeating the process to estimate tree canopy cover, recording trends over an appropriate timescale to evaluate the impact of policies to increase tree canopy cover.

5.2 Recommendations

It is recommended that the GLA repeats this exercise on a regular basis to identify any trends in canopy cover. Due to the time taken for recently planted trees to develop canopies detectable through aerial imagery it is suggested that aerial image analysis of canopy cover is undertaken on at least a 5 year basis across London.

In this report the percentage of tree cover for each borough has not been calculated due to the relatively low count of samples per borough. This signifies the importance of undertaking a detailed analysis of each borough using this method of classifying aerial imagery. The Open Source Canopy Cover Audit (OSCCA)[7] provides a tool allowing London's tree officers to estimate local tree canopy cover, to improve knowledge of tree canopy cover and help identify priority areas for tree planting. The aggregation of more detailed local studies will help provide the most accurate picture of tree canopy cover in London.

5.3 Further research

Analysing the impact of policies to increase tree canopy cover by 2025 is a long term process, requiring a method that is repeatable and results that are reproducible. This study establishes a more accurate baseline for tree canopy cover across London than we have previously had.

Using aerial imagery is a time-consuming method of identifying land cover in an urban area. However, it is effective and accurate and does not require specialist processing or software. Few studies utilise aerial imagery to classify urban environments and this report contributes to the wider research on the best methods to analyse urban land cover. It would be useful to compare the findings produced by random point classification of aerial imagery to more automated methods.

[7] http://www.ltoa.org.uk/resources/open-source-canopy-cover-audit-oscca

The results suggest that weather can impact canopy cover of individual trees and woodland in London, for example the heatwave in 2003. Exploring the relationships between such events and their impact on vegetation in London will become increasingly important given the increased frequency of extreme events projected as a result of a warming climate.

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Chinese
如果需要您母語版本的此文件，
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Hindi
यदि आप इस दस्तावेज की प्रति अपनी भाषा में चाहते हैं, तो कृपया निम्नलिखित नंबर पर फोन करें अथवा नीचे दिये गये पते पर संपर्क करें

Vietnamese
Nếu bạn muốn có văn bản tài liệu này bằng ngôn ngữ của mình, hãy liên hệ theo số điện thoại hoặc địa chỉ dưới đây.

Bengali
আপনি যদি আপনার ভাষায় এই দলিলের প্রতিলিপি (কপি) চান, তা হলে নীচের ফোন্ নম্বরে বা ঠিকানায় অনুগ্রহ করে যোগাযোগ করুন।

Greek
Αν θέλετε να αποκτήσετε αντίγραφο του παρόντος εγγράφου στη δική σας γλώσσα, παρακαλείστε να επικοινωνήσετε τηλεφωνικά στον αριθμό αυτό ή ταχυδρομικά στην παρακάτω διεύθυνση.

Urdu
اگر آپ اِس دستاویز کی نقل اپنی زبان میں چاھتے ھیں، تو براہ کرم نیچے دئے گئے نمبر پر فون کریں یا دیئے گئے پتے پر رابطہ کریں

Turkish
Bu belgenin kendi dilinizde hazırlanmış bir nüshasını edinmek için, lütfen aşağıdaki telefon numarasını arayınız veya adrese başvurunuz.

Arabic
إذا أردت نسخة من هذه الوثيقة بلغتك، يرجى الاتصال برقم الهاتف أو مراسلة العنوان أدناه

Punjabi
ਜੇ ਤੁਹਾਨੂੰ ਇਸ ਦਸਤਾਵੇਜ਼ ਦੀ ਕਾਪੀ ਤੁਹਾਡੀ ਆਪਣੀ ਭਾਸ਼ਾ ਵਿਚ ਚਾਹੀਦੀ ਹੈ, ਤਾਂ ਹੇਠ ਲਿਖੇ ਨੰਬਰ 'ਤੇ ਫ਼ੋਨ ਕਰੋ ਜਾਂ ਹੇਠ ਲਿਖੇ ਪਤੇ 'ਤੇ ਰਾਬਤਾ ਕਰੋ:

Gujarati
જો તમને આ દસ્તાવેજની નકલ તમારી ભાષામાં જોઈતી હોય તો, કૃપા કરી આપેલ નંબર ઉપર ફોન કરો અથવા નીચેના સરનામે સંપર્ક સાધો.