Mapping tree shade in Cambridge

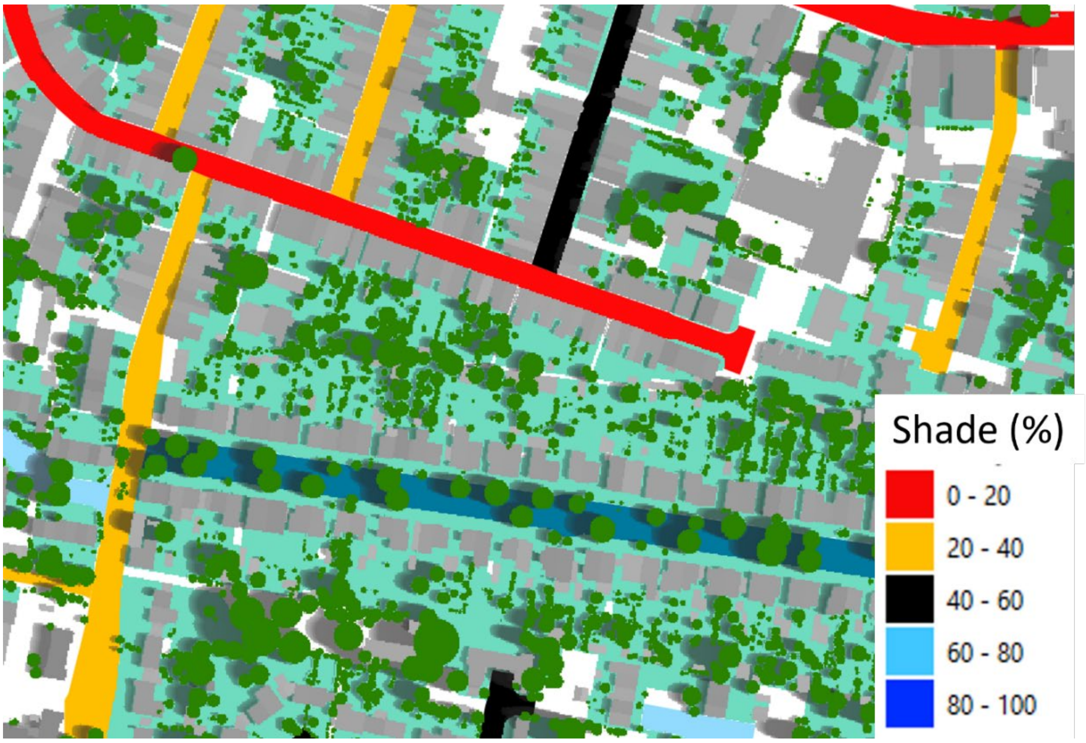

Figure 1 – Example of a map of tree shade in Cambridge

This report was produced by Dr Toby Jackson for Matthew Magrath, Cambridge City Council.
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Introduction

In summer, Cambridge is one of the hottest places in the UK. The shade provided by urban trees is therefore extremely valuable, especially to pedestrians and cyclists. Increasing this tree-shade will improve wellbeing for all inhabitants and encourage more active travel.

Tree planting and tree protection efforts should be focused in areas which currently have comparatively low levels of tree-shade. To target these efforts effectively, a city-wide assessment of the tree-shade is essential. It is also important to assess the opportunity for planting trees, whether on the highways themselves or in private gardens which border these streets. This proposal outlines how this can be achieved using existing data.

Aims

A. Map the spatial variation in road shade across the city, to identify streets for potential intervention and enable users to plan shaded routes across the city.
B. Estimate the changes in road shade throughout the day, and throughout the summer.
C. Quantify the proportion of each street which is bordered by private gardens, since they present a good opportunity for tree planting.
D. Count the number of council managed trees on each street and check whether this is associated with a higher level of shade.

Key findings

1. Shade varied dramatically with time of day, with most of the streets in Cambridge having more than 50 % shade at 0800, while many of the streets had less than 20 % shade at midday.
2. West Cambridge, particularly Castle and Newnham, had consistently the highest levels of shade across all dates and times. The spatial variation in shade levels was most striking at 1600, with many streets having extremely low levels of shade but some shaded routes through the city still possible with good route planning. We therefore suggest that the July 1st 1600 shade map be used for prioritizing streets for intervention.
3. We identified particular streets with extremely low levels of shade. Some of the least shaded streets were Hatherdene Close, Castle Street, Daisy Close, Kilmaine Close and Frank's Lane. The full list is provided as an excel file for the 1st July at 1600.
4. Surprisingly, road shade was not related to the proportion of the road bordered by gardens. This may signify an opportunity to increase tree planting and protection in private gardens to increase road shade. However, this could also be a methodological issue since we did not include parks and other green spaces, focusing solely on gardens.
5. Roads with more council managed street trees had higher levels of shade. This suggests that previous management of these trees has increased the shade on these roads, and that future protection of street trees is an effective strategy to increase shade.

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Data sets used

1. ProximiTREE data sets © Bluesky International Limited.
    a. All tree canopies are assumed to be cylindrical. The height of the cylinder is fixed at the height provided in the ProximiTREE data set. This simplification slightly overestimates the amount of shade provided by the tree. However, our aim is to quantify the relative shadiness of different roads across the city, so this simplification will not affect our results.
2. Building height and footprint data from OS master map[1].
    a. Building height data were provided as csv files containing multiple measurements of building height. The measurement used for this project was the height of the roof from the ground (RelH2[2]) since this takes into account topography and doesn't overestimate height of buildings by including chimneys or pitched roofs. This measure may slightly underestimate the shade cast by some houses with steep pitched roofs at low sun angles. This bias will be consistent across the city so will not affect the relative shadiness of different roads.
    b. Building footprint maps were provided as GZ files and converted into shapefiles. These were then matched with the building height data using the TOID. The building map was then converted into raster format to calculate the shade.
3. Map of all highways in Cambridge ('City Area Highway Data' shapefile) provided by Cambridgeshire County Council.
    a. Some roads recorded in this file cover very small areas. These small roads are more likely to have extreme shade values. Some are completely covered by trees, whereas others have no shade at all. When prioritizing roads by shadiness, it is therefore important to consider the area of road itself, and use the map to ensure the road is large enough to be considered for some intervention.
4. Map of private gardens generated from OS Master Map 2018.
5. Map of council managed street trees (tspecies.shp) provided by Cambridge City Council

[1] https://www.data.gov.uk/dataset/7624f5d0-899e-4f38-93a6-22f6b915befe/os-mastermap-building-height-attribute
[2] https://www.ordnancesurvey.co.uk/documents/product-support/tech-spec/OS-MasterMap-Topography-Layer-Buidling-Height-Attribute-Technical-Specification.pdf

Methodology

Estimating amount of shade on each road.

- To calculate shade, we need information on the position of the sun, which varies with the date and time of day. To give a good overview of shade during the summer, we calculated shade for the dates and times in Table 1, using a freely available sun angle calculator[3].
- The shade cast by the trees and buildings was calculated separately using the QGIS plugin 'terrain shading'[4]. This was repeated for each date and time in Table 1. We decided to focus on the 1st day of each summer month. Within each day, we calculated the shade at 0800, representing the morning commute, at midday when the shade will be lowest, and at 1600. We chose 1600 as it represents a mid-point between school leaving time and afternoon commute. This also gives 4-hour intervals either side of midday. We calculated shade at each of these days and times, resulting in 15 rasters for tree shade and 15 rasters for building shade.
- These 30 shade rasters were overlaid onto the map of the roads in Cambridge. For each individual road the proportion of its area shaded was calculated for each of the 30 shade rasters.
- We also calculated the proportion of shade due to trees, compared to that of buildings.
- Our initial results showed that road shade varied much more over the course of the day than across the summer months (Figure 2). To simplify the results, we therefore decided to focus on a single day, July 1st, which had the lowest levels of shade in the summer. The results for July 1st are very similar to those of the other summer months, and shapefiles are provided for each month in as part of this project.

Calculating the proportion of each road bordered by gardens.

- For each individual road, we created a polygon representing a 1 m border around the edge of the road. This was done by buffering the road polygons by 1 m and subtracting the original road polygons.
- We then overlaid this road border polygon onto the gardens data and calculated the proportion of the road border covered by gardens. Note that we did not include green spaces such as parks in this proportion, as we are specifically aiming to encourage more tree planting in private gardens.

Finally, for each road, we counted the number of council owned street trees which fall within the road boundaries.

We note that our approach does not calculate the air temperature on each road. Shade is one of the drivers of local temperature variation, but other factors such as airflow and heating of buildings are also important. This report focuses only on shade levels.

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[3] https://www.omnicalculator.com/physics/sun-angle
[4] https://github.com/zoran-cuckovic/QGIS-terrain-shading

Results

Variation in road shade (%) over the summer

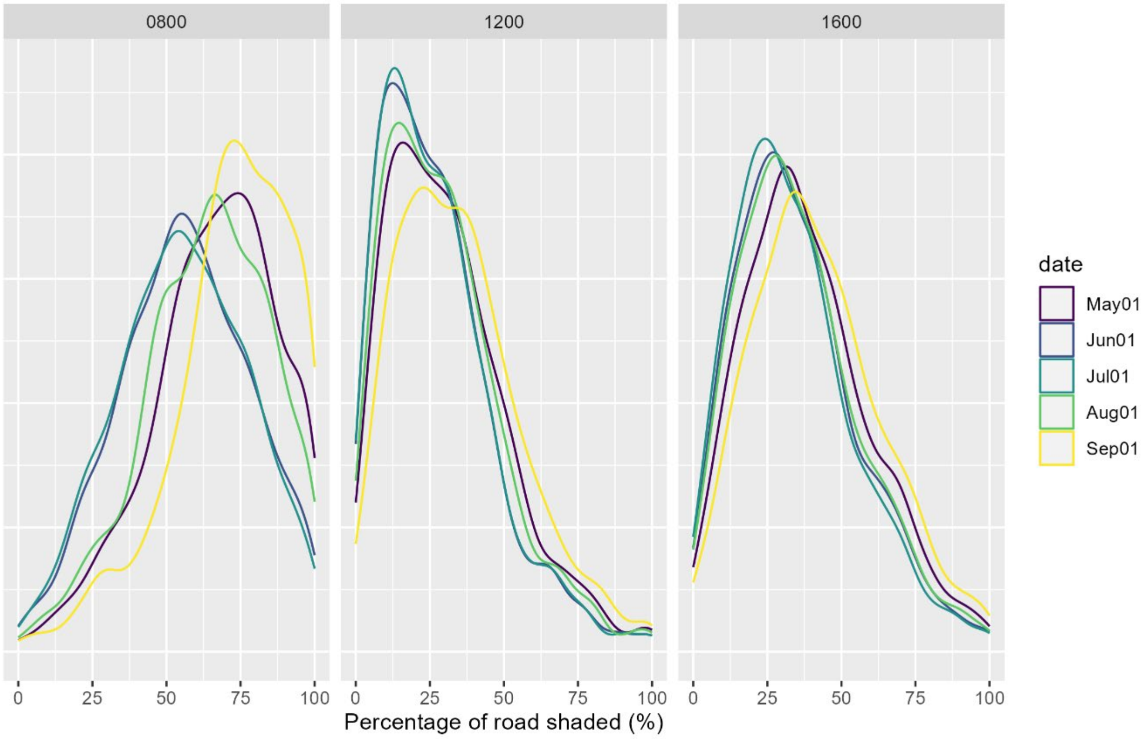

Figure 2 – Histograms showing the percentage of each road shaded at particular times (left panel = 0800, middle panel = 1200 and right panel = 1600) and months (colours).

We assessed the shade at three different times of day (0800, 1200 and 1600) for five different dates (1st May, 1st June, 1st July, 1st August and 1st September) spanning the summer months in Cambridge. The biggest difference in shade percentage was due to the time of day. At 0800 many of the roads had over 50 % shade due to the long shadows cast by trees while the sun is low in the sky. At midday and at 1600 most of the roads had less than 50 % shade. The difference with time of day was larger than the difference between summer months. In all cases, July was the month with the least shade. We therefore decided to use only data from July 1st to simplify the following analysis. Shade data for all remaining dates are provided as shapefiles.

Ward level variation in road shade (%)

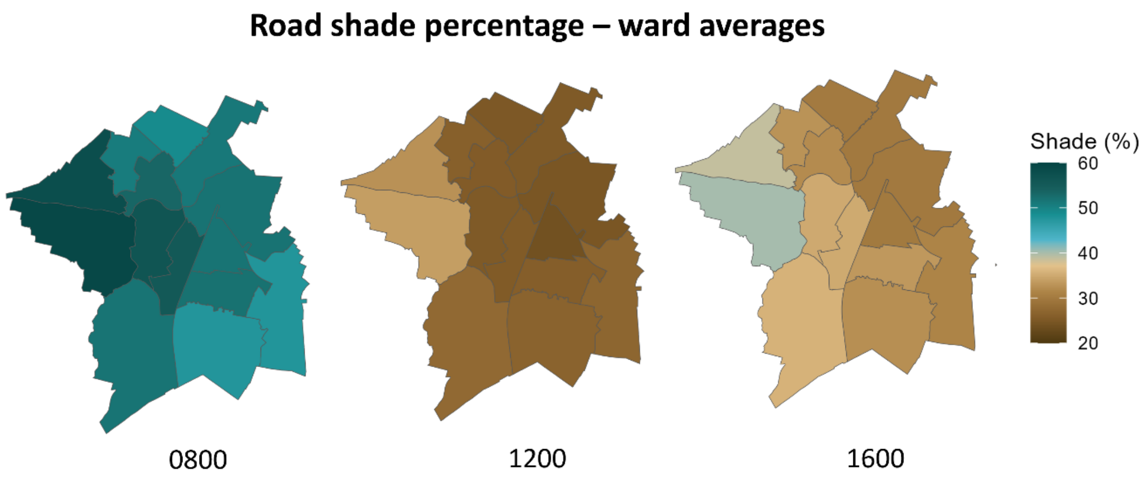

Figure 3 – Maps of ward average road shade (%) on July 1st at 0800, 1200, 1600.

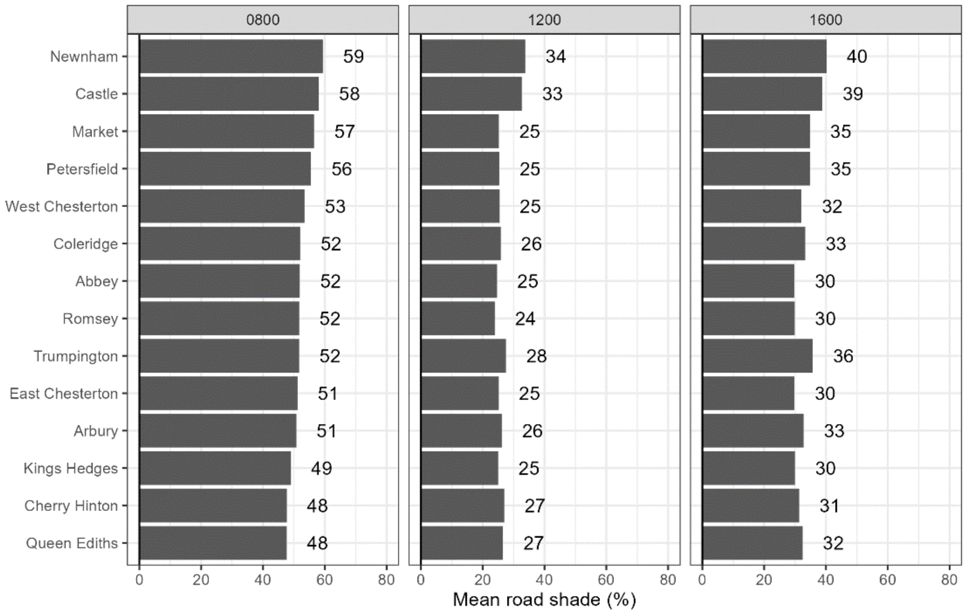

Figure 4 – Bar charts showing ward average road shade (%) on July 1st at 0800, 1200, 1600.

West Cambridge, particularly Castle and Newnham had the highest levels of shade at all times of day. North-east Cambridge had the lowest levels of shade.

Note that these ward level averages give a useful summary of the spatial variation, but should not be used for planning interventions because the street level variation in shade is extremely important.

Street level variation in road shade (%)

This section provides detailed maps of road shade for each street in Cambridge. We also include tables for the ten most shaded and ten least shaded streets in the city. The maps and tables were created using the sun angles on July 1st at 0800 (Figure 5, Table 1), 1200 (Figure 6, Table 2), and 1600 (Figure 7, Table 3). These maps are also available as shapefiles, to enable users to plan a shaded route through the city.

During the morning commute (0800) most of the streets in Cambridge have over 50% shade at 0800. However, there are many areas for improvement, especially in north east Cambridge, where many roads have 20-40% shade.

By midday, very few of the major roads have 50% shade and many have less than 20% shade. This makes walking and cycling difficult during the middle of a hot summer's day. This map of 1200 on July 1st represents the lowest level of shade out of all the dates and times tested in this study (Figure 2).

In the afternoon (1600) the spatial variation in road shade is particularly important. West Cambridge contains the majority of the roads with 60-80 % shade. For example, Green Park and Madingley Road have the consistently high levels of shade. Many of the roads in east Cambridge still have 20-40 % shade, for example Hatherdene Close, Castle Street, Daisy Close, Kilmaine Close and Frank's Lane all have consistently very low levels of shade. However, there are shaded routes throughout the city with reasonable levels of shade throughout. This demonstrates the importance of good route planning and prioritizing roads for intervention which link up these shaded routes.

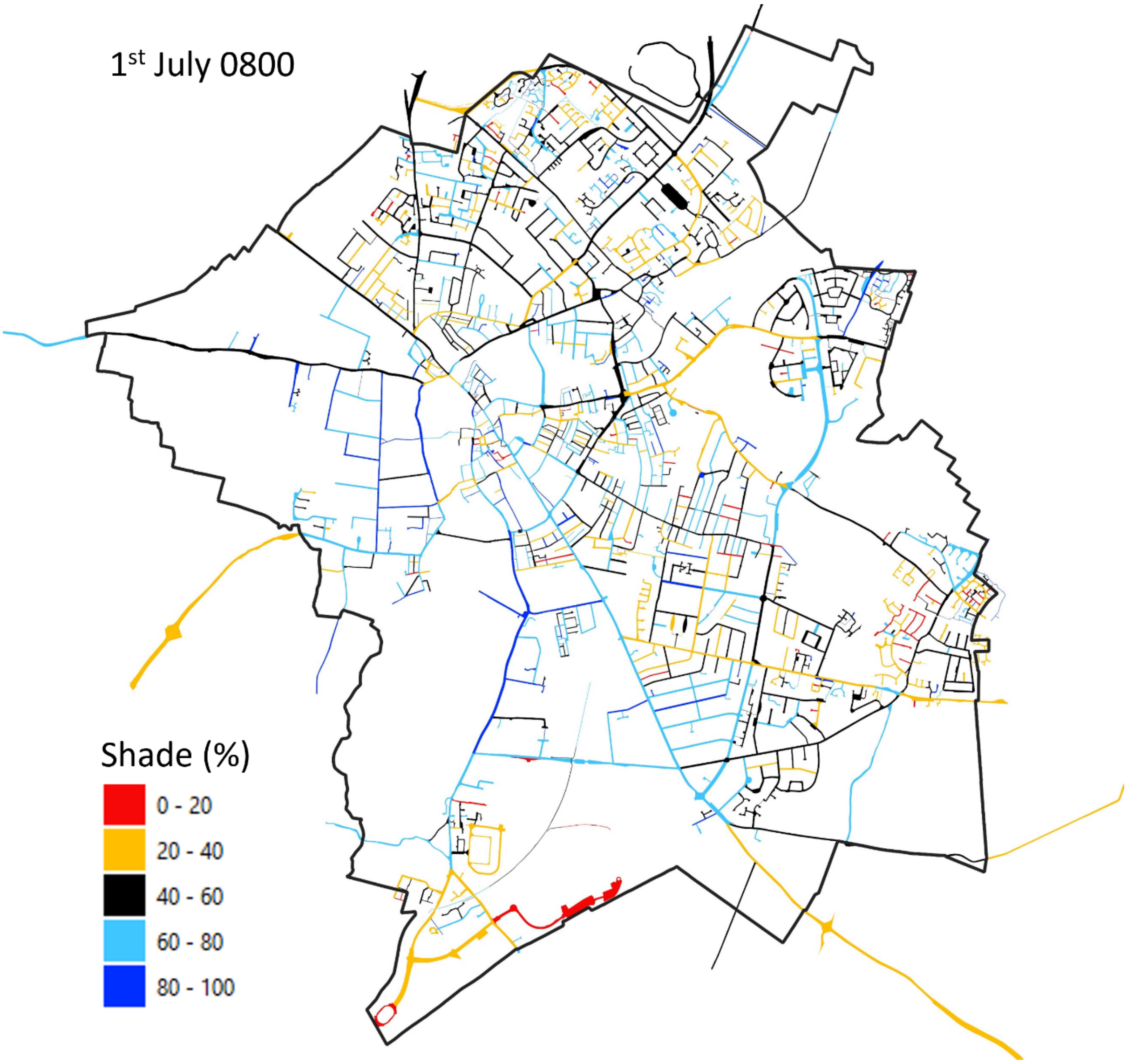

Figure 5 – Map of the roads in Cambridge coloured by their level of tree shade at 0800 on 1st July

	Street	Area (%)	Shade (%)	# Street trees	Bordered by gardens (%)
Roads with most shade	Pikes Walk	84.8	99.7	0	10.0
	Green Park	248.2	99.5	0	0.0
	Madingley Road	550.7	98.6	0	0.0
	Malting Lane	591.2	97.8	0	19.6
	Burnside	1379.8	97.4	0	35.6
	Arbury Road	798.8	96.8	15	49.8
	George IV Street	690.4	96.4	0	0.0
	Herschel Road	3884.5	96.3	0	29.9
	Dundee Close	963.4	96.0	2	27.7
	Guildhall Street	620.7	95.9	3	0.0
Roads with most shade	Swann’s Terrace	170.7	7.3	0	43.8
	Brothers Place	530.9	6.0	0	39.1
	Chigwell Court	483.2	5.0	0	74.0
	Burnham Close	1393.9	4.9	0	58.5
	Elfleda Road	2704.4	4.4	0	86.8
	Hatherdene Close	904.4	4.2	0	42.6
	Ditton Lane	236.6	4.0	0	64.8
	Natal Road	608.2	3.2	0	93.1
	Salmon Lane	381.0	3.2	0	8.5
	St Mary’s Road	438.3	2.0	0	0.0

Table 1 - Roads with highest and lowest amounts of shade on July 1st at 0800

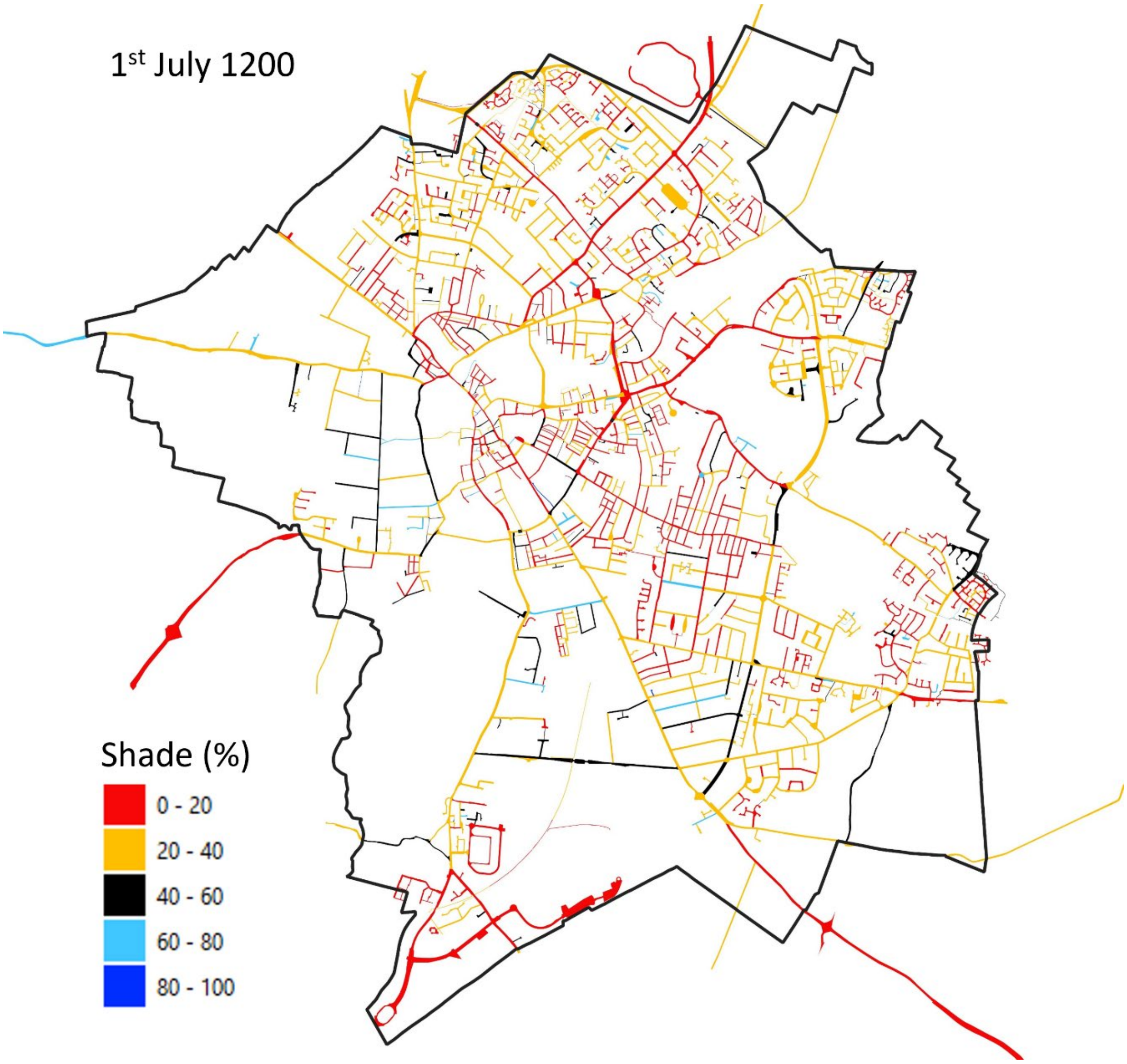

Figure 6 – Map of the roads in Cambridge coloured by their level of tree shade at midday on 1st July.

	Street name	Area (m^2)	Shade (%)	# Street trees	Bordered by gardens (%)
Roads with most shade	All Saints Passage	399.4	91.3	0	5.1
	Madingley Road	550.7	90.6	0	0.0
	Church Road	299.5	90.2	0	78.5
	Lady Jane Court	561.8	89.6	0	29.5
	Green Park	248.2	89.2	0	0.0
	Regent Terrace	1634.5	85.9	0	11.3
	Little Street	605.0	79.7	1	2.2
	Emperor Court	221.1	79.3	2	26.4
	Red Cross Lane	2352.8	79.3	0	65.0
	Sidgwick Avenue	6016.9	79.0	36	13.8
Roads with least shade	Hertford Heath	2934.0	1.3	0	79.3
	Henley Way	989.2	0.9	0	0.0
	York Street	2582.3	0.7	0	2.4
	Hatherdene Close	904.4	0.5	0	42.6
	Kings Lane	389.5	0.3	0	0.0
	Castle Street	1562.9	0.3	0	0.5
	Daisy Close	1089.9	0.1	0	0.2
	Parson’s Close	183.5	0.0	0	0.0
	Kilmaine Close	1214.0	0.0	0	0.0
	Frank’s Lane	44.5	0.0	0	82.4

Table 2 - Roads with highest and lowest amounts of shade on July 1st at midday.

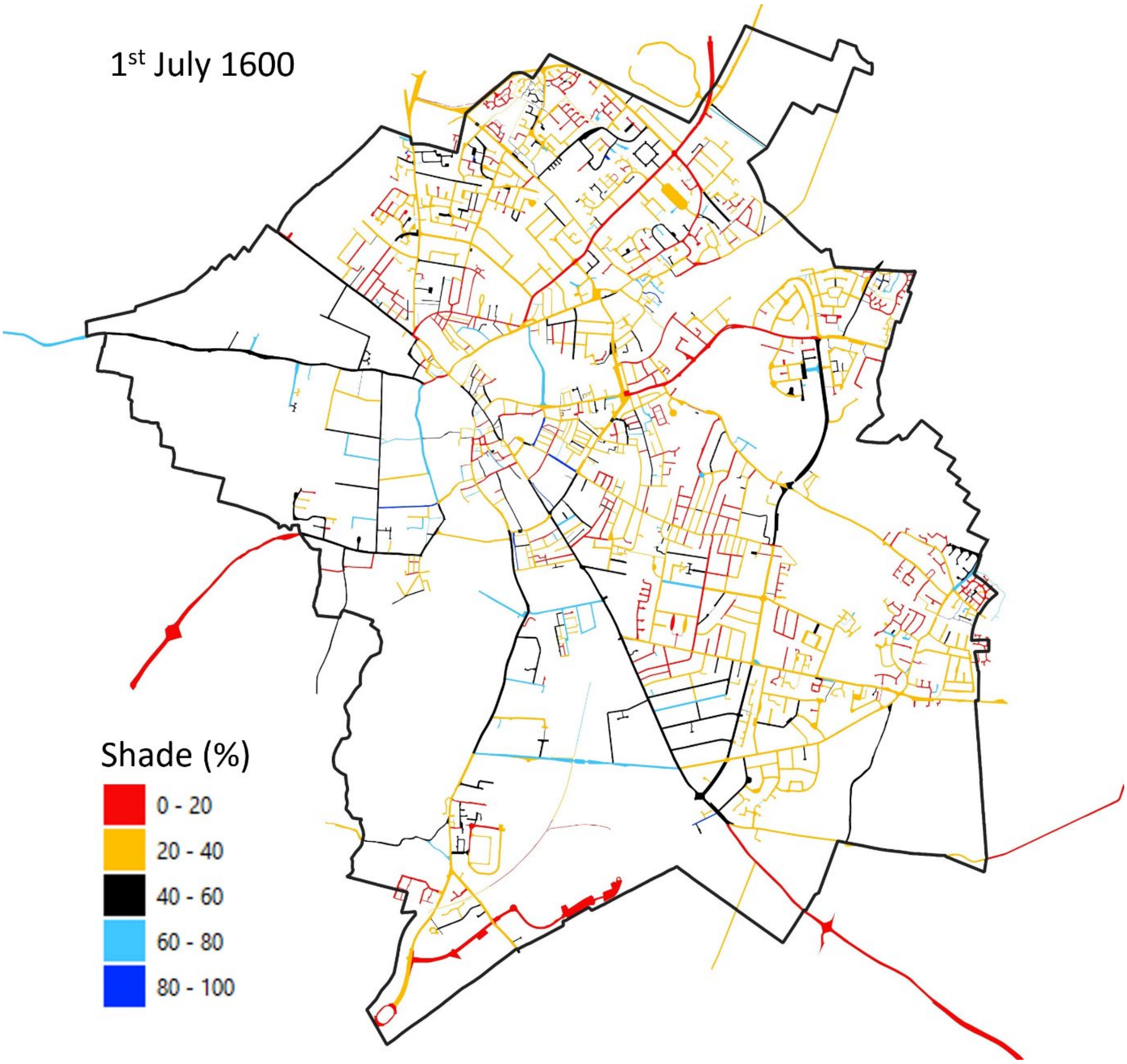

Figure 7 - Map of the roads in Cambridge coloured by their level of tree shade at 1600 on 1st July.

	Street	Area (m^2)	Shade (%)	# Street trees	Bordered by gardens (%)
Roads with most shade	Huntingdon Road	49.1	100.0	0	77.3
	Parkside	4812.6	93.6	0	16.7
	Red Cross Lane	2352.8	91.7	0	65.0
	Madingley Road	550.7	90.8	0	0.0
	Regents Terrace	1634.5	89.0	0	11.3
	Kinross Road	240.6	88.8	0	40.8
	Sidgwick Avenue	6016.9	88.7	36	13.8
	Larkin Close	980.5	88.1	9	0.0
	Portico Way	219.1	87.4	1	67.7
	Parsons Close	183.5	87.0	0	0.0
Roads with least shade	Henley Way	989.2	1.4	0	0.0
	Grand Arcade	2369.9	0.9	0	0.0
	Christ's Lane	408.4	0.7	0	0.0
	Castle Street	1562.9	0.2	0	0.5
	Brentwood Close	563.7	0.2	0	76.4
	Staffordshire Street	691.8	0.1	0	0.0
	Daisy Close	1089.9	0.0	0	0.2
	Moyne Close	659.4	0.0	0	70.0
	Kilmaine Close	1214.0	0.0	0	0.0
	Frank's Lane	44.5	0.0	0	82.4

Table 3 - Roads with highest and lowest amounts of shade on July 1st at 1600.

Variation in road shade (%) with gardens and street trees

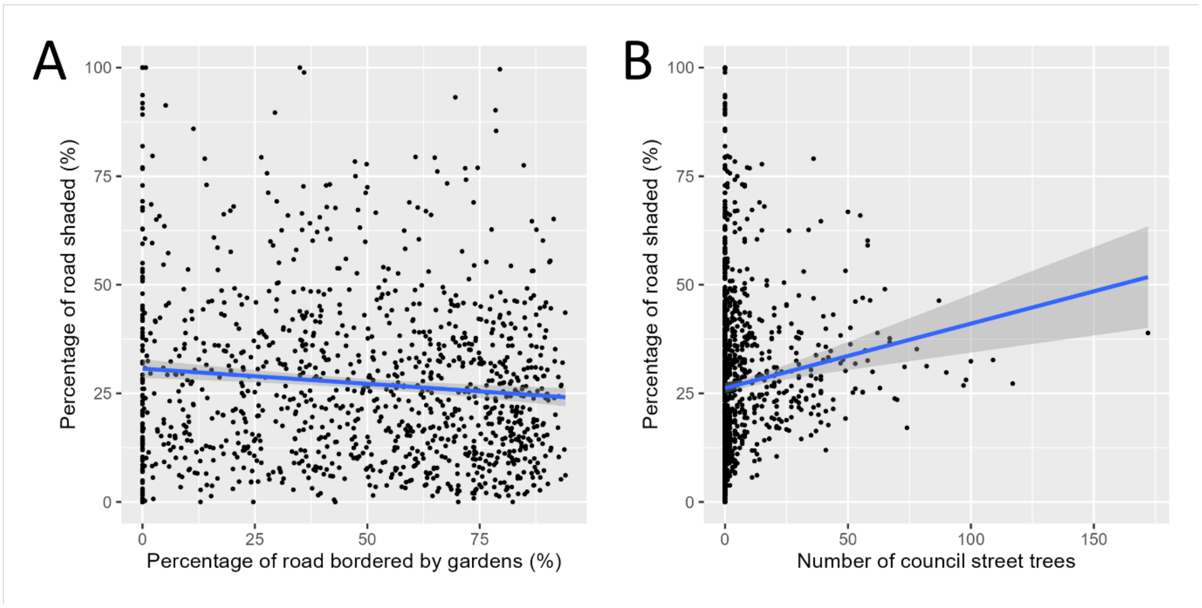

Figure 8 – Variation in percentage of road shaded with (A) percentage of road bordered by gardens and (B) number of council street trees. These figures were calculated with the shade at midday on July 1st, but the general trends are similar regardless of the date and time chosen. The blue lines show a linear regression and the grey shading represents the 95th percentile confidence interval around that regression line.

We assessed the percentage of each road bordered by gardens. Many roads were not bordered by any gardens, while others had up to 90% of their border covered by gardens. However, this variation in proximity to gardens was not related to the amount of shade on the roads. Figure 8A shows this variation for the 1st July at midday, and similar results was found for all times we assessed.

We also assessed the number of council managed street trees on each road. We found that streets with more street trees tended to have more shade (positive correlation) as shown in Figure 8B. This was expected as streets with more trees tend to have more shade, and it suggests that previous council interventions have increased the level of shade on these roads.

Deliverables

Shapefiles showing the road maps with the following fields are provided:

- Pct_shd = The percentage of the road which is shaded
- Prp_tree = The proportion of this shade which is due to trees
- Pct_gdn = The percentage of the road which is bordered by gardens.
- N_trees = The number of council managed street trees on the road.

The date and time of the shade calculation are given in the shapefiles name, for example: 'Shadeways/Deliverables/road_map_with_shadows_01May_0800.shp'

We also provide an excel file with the full list of roads and their shade percentage for July 1st at 1600. This list contains the same field names as the shapefiles (given above).

Appendix 1 – sun angles

Date	Time (BST)	Sun angle	Sun direction
1st May	0800	22	93
	1200	51	158
	1600	38	242
1st June	0800	27	88
	1200	58	154
	1600	44	247
1st July	0800	27	86
	1200	58	151
	1600	46	246
1st August	0800	22	89
	1200	53	153
	1600	42	242
1st September	0800	16	97
	1200	44	159
	1600	33	236

Table 4 – Times and dates for which shade was calculated, including the sun angles.