

# Where should we plant the trees: A case study in Cambridge



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# Social economic costs of tackling social problems in cities

- Social and economic cost of mental illness in UK is £ 119 billion\*.
- The total NHS and social care cost due to PM<sub>2.5</sub> and NO<sub>2</sub> estimated in 2017 was £42.88 million; the total cost between 2017 and 2025 would be £1.60 billion\*\*.

\* A Spending review for wellbeing. Centre for Mental Health, UK(2020)

\*\*Estimation of costs to the NHS and social care due to the health impacts of air pollution: summary report. Public Health England(2018)



# Impacts of urban forests

Research has found urban forests as one of the largest biomes in the cities are valuable.  
**e.g. the relationship between LST and green infrastructure and building**



From the results, we can see that NDVI which represent the green coverage in the land surface as well as tree canopy have strong negative correlation with land surface temperature



NDBI, which presents the impervious surface in the land surface such as building, concretes, show positive correlation with land surface temperature. This means the increasing areas of impervious surface impose higher risk of UHIs.

	NDVI	NDBI	Tree canopy
Coefficients	-3.433	5.721	-813.061
Intercepts	34.161	33.512	28043.289

# Benefits of urban forests

- **Social economic values**
  - reduce crime rate.
  - increase house price.
- **Health and well-being**
  - healing effects.
  - reduce stress.
  - encourage walking and cycling.
- **Environmental benefits**
  - mitigate surface water flooding, air pollution and heat islands.
  - Store carbon.
  - Improve biodiversity and ecological resilience.

**e.g. total annual benefits of London's Urban forest is estimated £132.7 million**



A woman wearing a traditional straw hat, a floral patterned shirt, and yellow gloves is kneeling in a field, planting a young tree. She is holding the tree's base in the soil. A blue plastic bucket is visible on the ground next to her. The background shows a lush green field with trees and a clear blue sky.

## Where should we encourage planting the trees in the city?

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When farmers plant a tree, what they consider

- Soil texture
- Soil fertility
- Water availability
- Sunlight
- Soil acidity
- Etc



## When this becomes a problem for urban planners

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- Whether the land is public or private
- Building density and population size
- Whether low income households have less disposable money and time for planting
- Whether there are community support for tree planting
- Etc.

# Challenges for urban planners

Tree canopy cover survey: 283 towns and cities in England

Canopy Cover	Number of Towns	Size of urban areas estimated(km2)			
		Mean	Median	25 <sup>th</sup> Percentile	75 <sup>th</sup> Percentile
Under 10%	40	11.6	8.3	5.0	15.7
10-20%	175	24.5	10.7	6.9	19.9
20-30%	60	26.9	10.2	7.0	16.4
over 30%	8	9.1	9	8.3	10.0

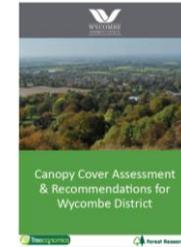
\* Doick et al(2018)

## ➤ UK setting

- UK tree strategy: minimum 20% of canopy cover target as national goal recommended. Cambridge has 17.3% in 2008.

## ➤ Where to plant trees in order to

- reduce social inequality.
- increase social capital and natural capital in poor areas across the city.



PERSPECTIVE | ECOLOGY

## The natural capital of city trees

Katherine J. Willis<sup>1,2</sup>, Gillian Petrokofsky<sup>2</sup>  
 + See all authors and affiliations

Science 28 Apr 2017:  
 Vol. 356, Issue 6336, pp. 374-376  
 DOI: 10.1126/science.aam9724





# Urban forest and house price

- **OLS (Ordinary Least Square): House price as an example**

$$\text{House price} = 0.097 * \text{Canopy Size} - 2.27e^{-05} * \text{Population density} - 0.018 * \text{Population with limited education} + 0.79 * \text{Income} + 3.98$$

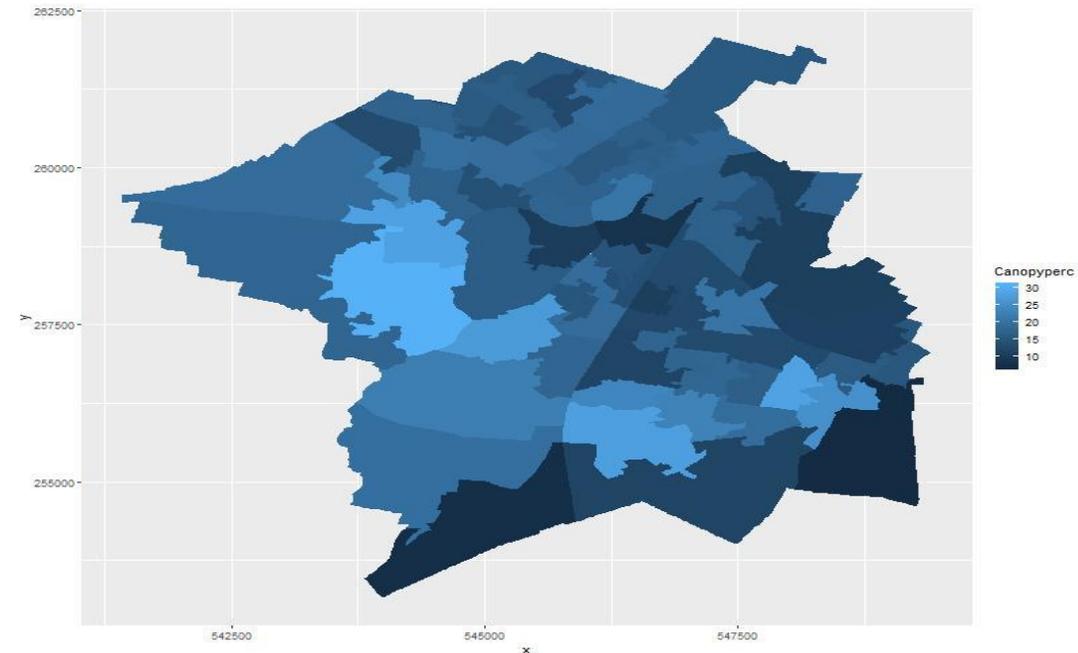
Coefficients	Value	Prob
Intercept	3.983e+00	0.0093 **
Canopy Size	9.762e-02	0.0131 *
Population density	-2.265e-05	0.0197 *
Population with limited education	-1.845e-02	0.0004 ***
Income	7.910e-01	1.05e-07 ***

Adjusted R-Squared : 0.724, Multiple R-squared: 0.740

\*\*\* Significant at 99%

\*\* Significant at 95%

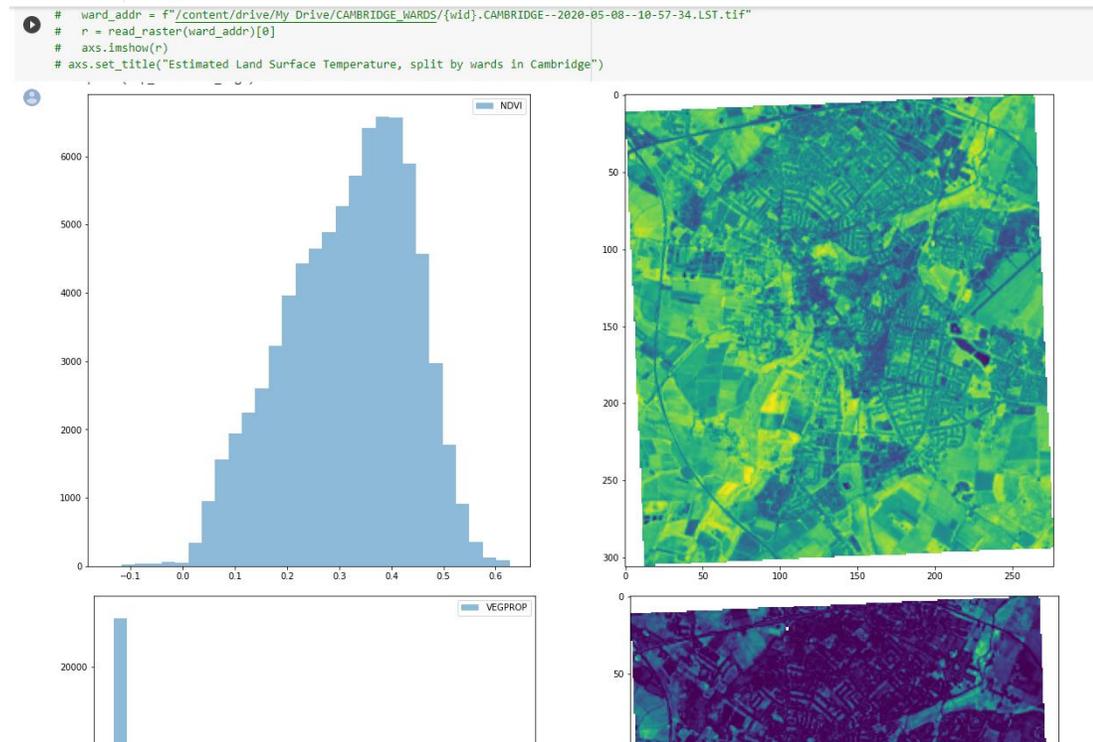
\* Significant at 90%



# UHI and trees

- Spatial parameters

- a) NDVI
- b) NDBI
- c) Emissivity
- d) etc



# A snapshot of UHIs in Cambridge

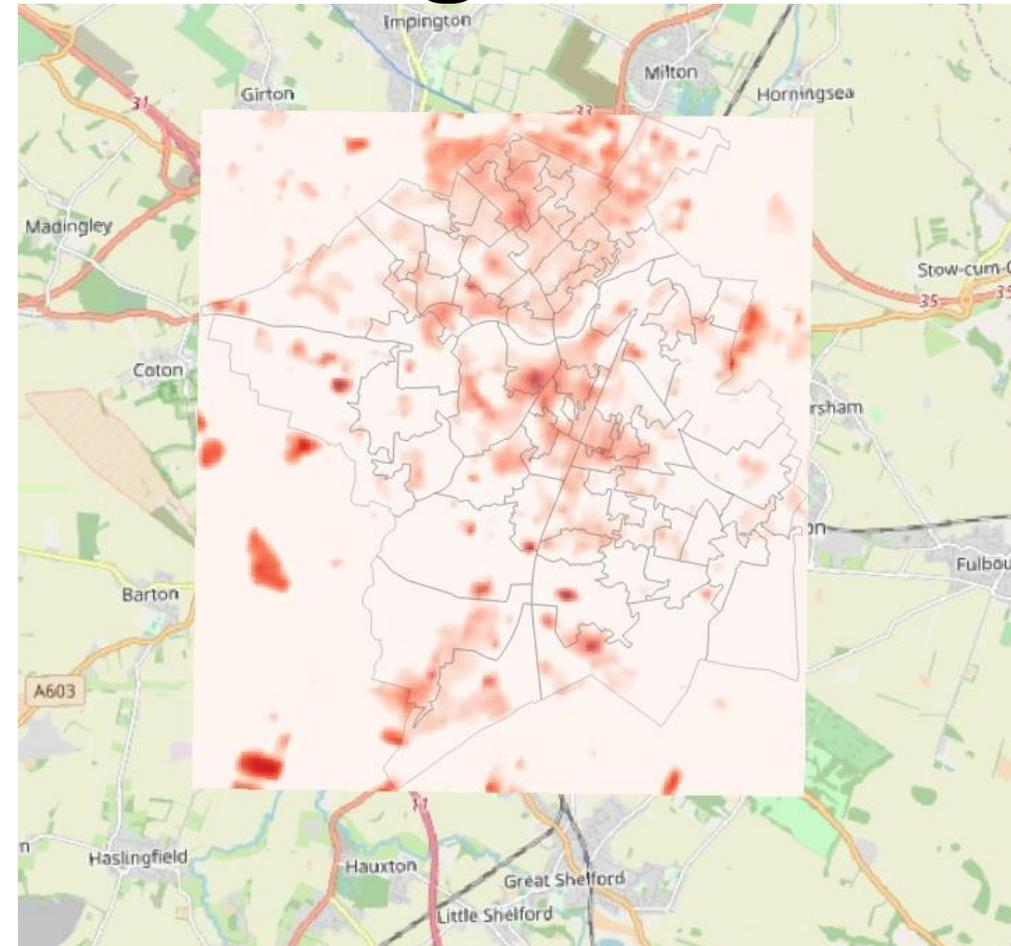
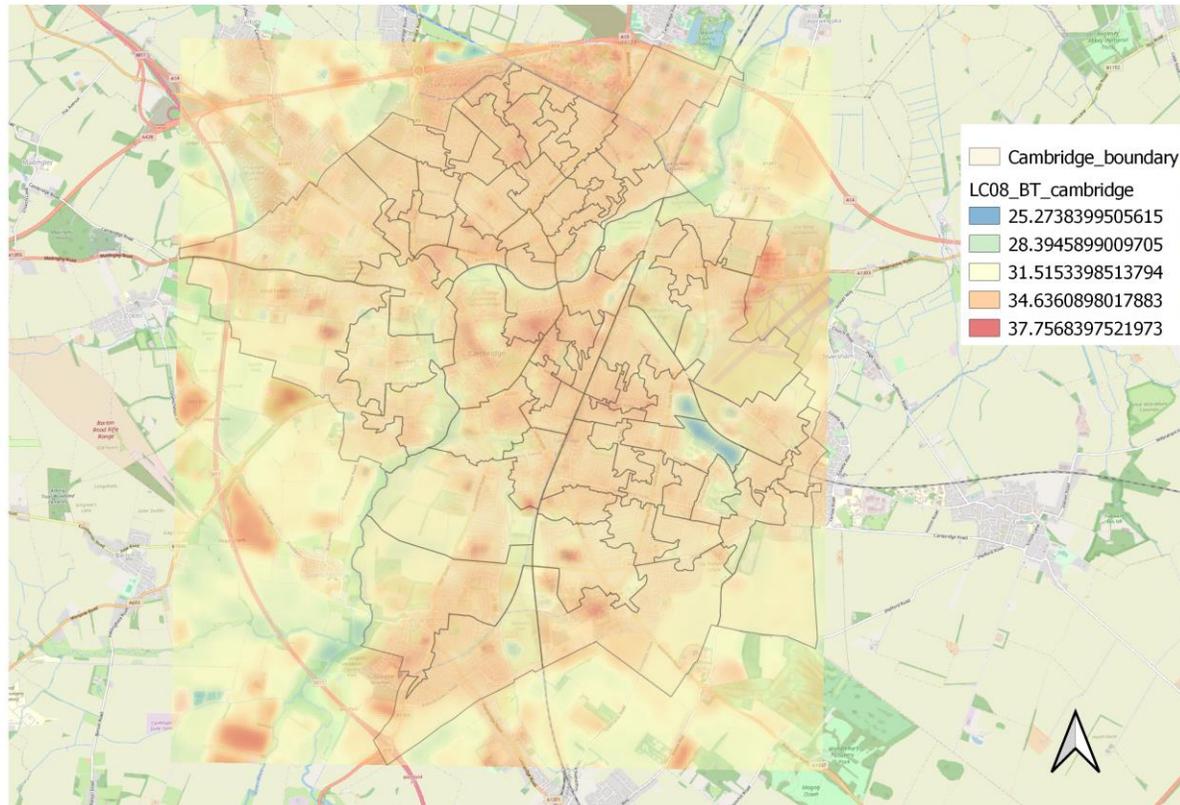


Figure: LST from LandSat 8 extracted from 25 July 2019

# Assessing heat risks in Cambridge



High heat risk due to high density of residential area

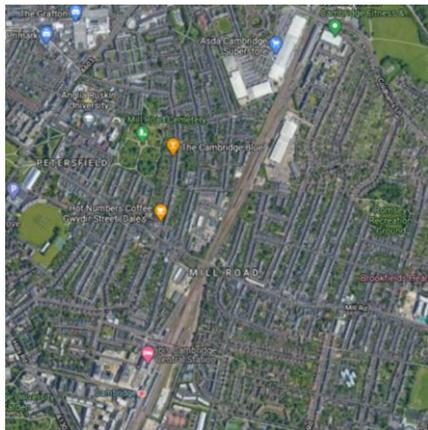
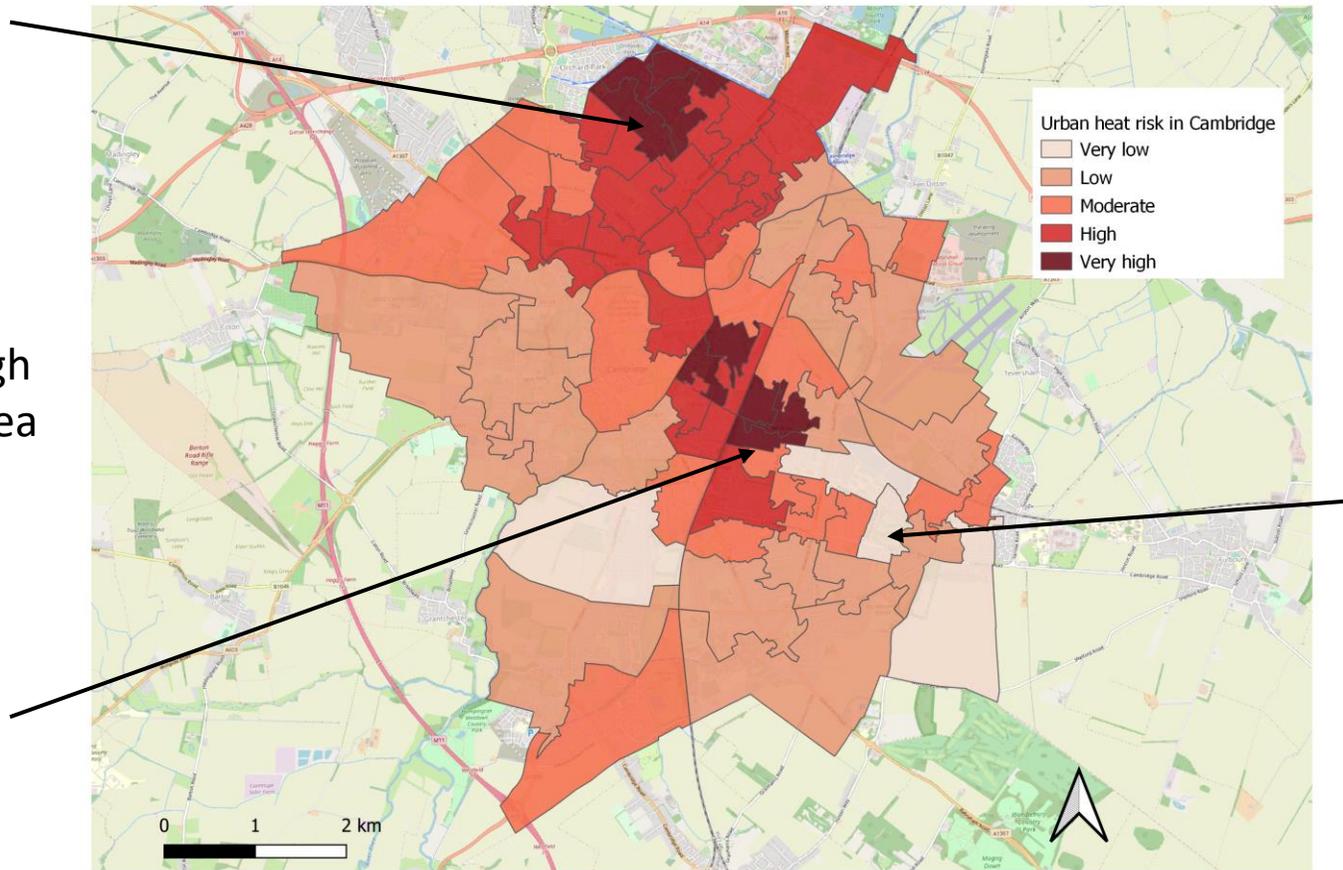


Figure: UHIs under heat wave conditions at LSOA level in Cambridge



Low heat risk due to high density of green coverage and the presence of water bodies.

# Risk assessment mapping:

combining the vulnerability groups and heat hazard map to create a final heat vulnerability risk map

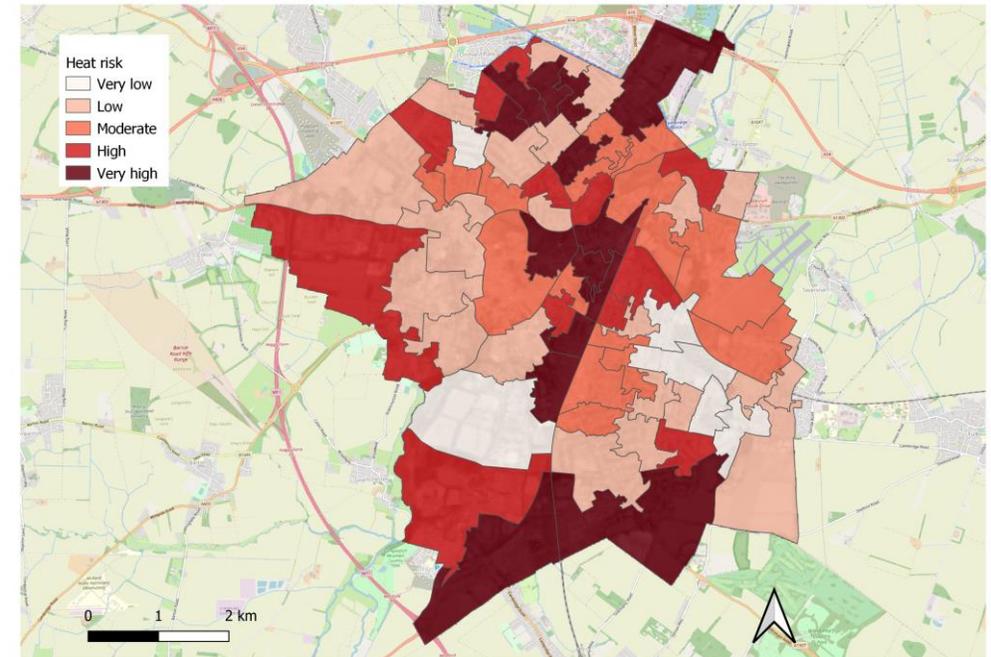
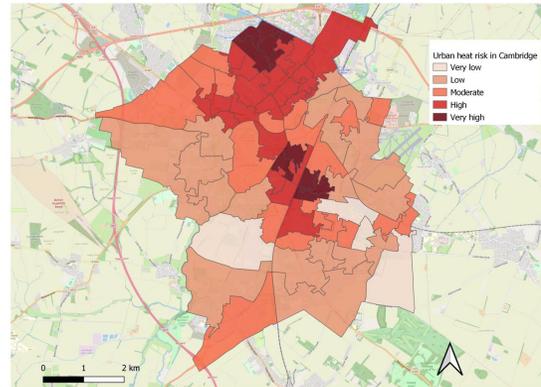
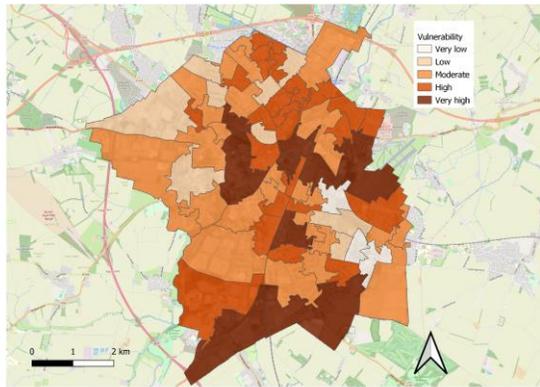


Figure: heat vulnerability risk map

# Matching OAC groups with heat vulnerable areas

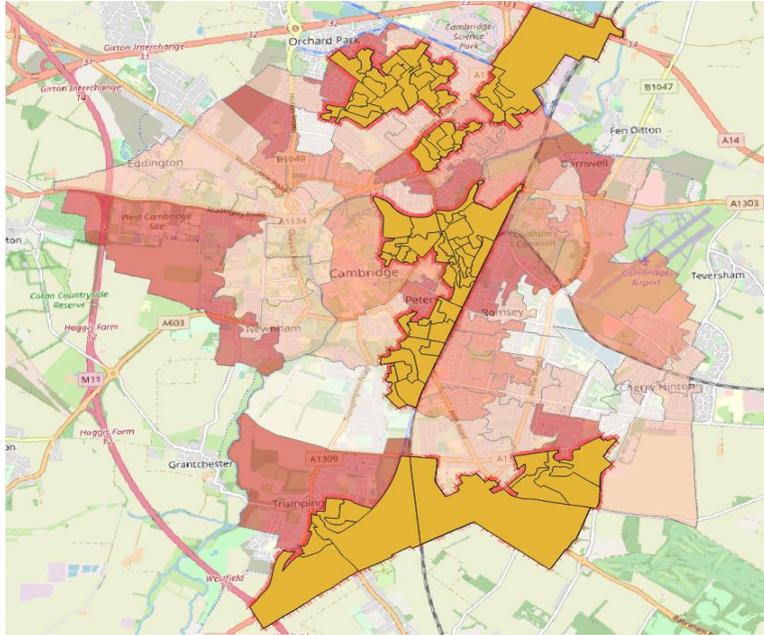


Figure a: heat vulnerable areas with very high risks

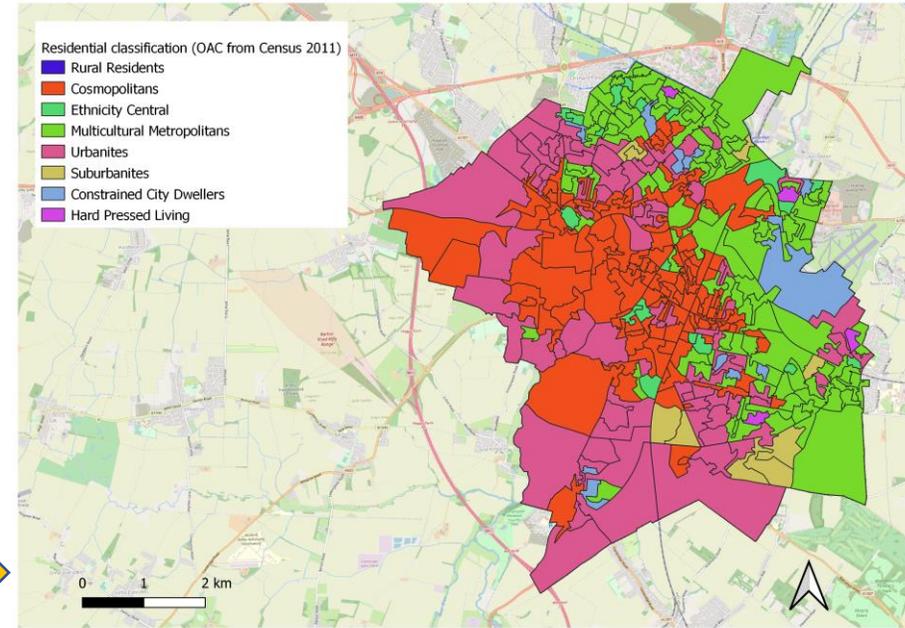
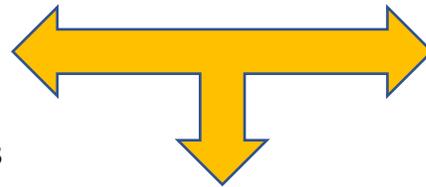


Figure b: OAC groups from census 2011.

LSOA examples	LSOA Name	Residential Classification (OAC)	Main Group
E01017995	Cambridge 013D	5b,6a	Aging urban living, suburban achievers
E01017983	Cambridge 007C	2a,2d,5a	Students, aspiring and affluents, urban professional and families
E01017978	Cambridge 001D	4a	Rented family living

In sum, the main groups who are exposed to high risk of heats are composed of rented family and families who tend to live in flats, students, Asian traits, ethnical families.



# Neural network(NN) modelling for tree planting

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# Challenges and features in Cambridge



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## Four problems in Cambridge

- 1) Population growth and migration beyond the capacity of the city.
- 2) Increasing transport pressure asks for new planning for more transport routes.
- 3) Urban expansion works hard to meet the housing pressure.
- 4) Inequality goes deeper due to polarization of income within the city.

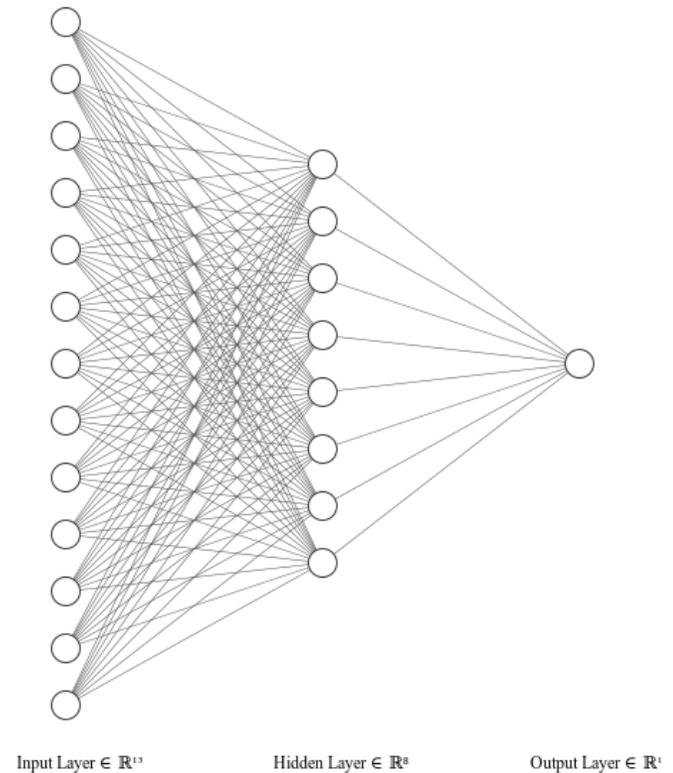
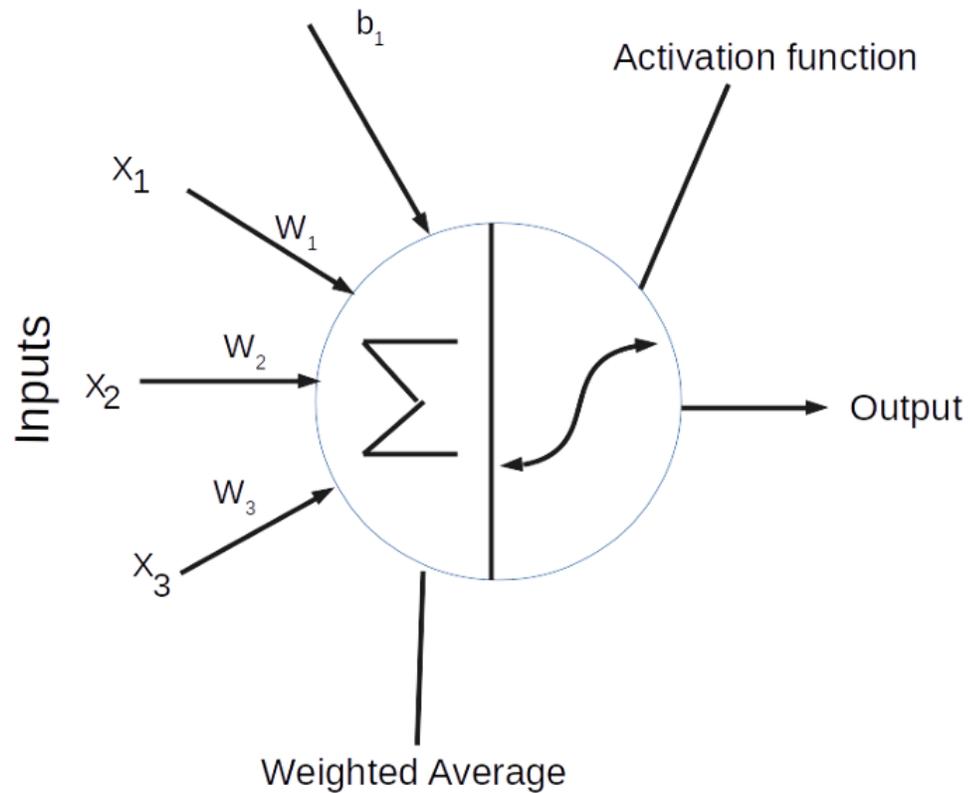
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Increasing demand for green infrastructure to cope with city development. This is particularly reflected during the lockdown of COVID-19.

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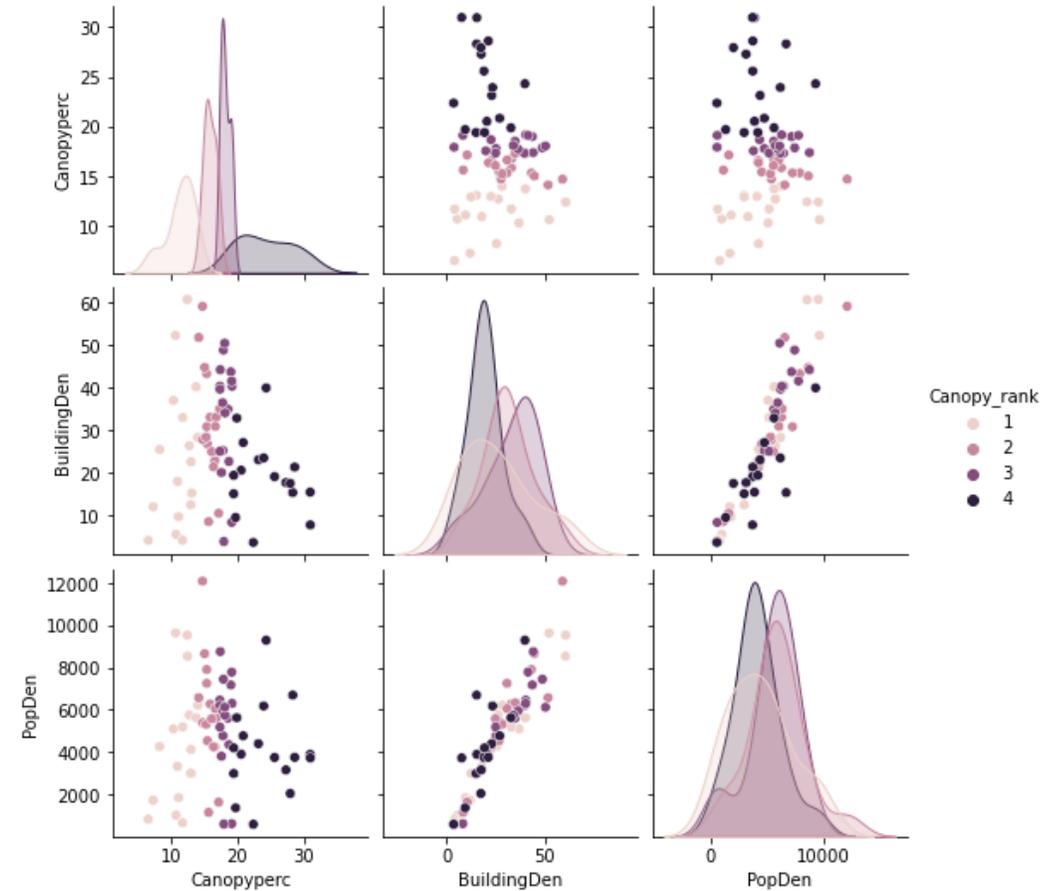
Thanks for the evolution of machine learning, statistical analysis, GIS technology, which make policy making more scientific. The fast development of location intelligence allows us to precisely work out the urban areas with problems.

# Basics of NN (Neural Network)



# Application of NN to optimise planting location

- Multiple social economic values to consider in urban environment, instead of considering where physical environment is suitable for tree growth or not.
- Set a management target as a layer output

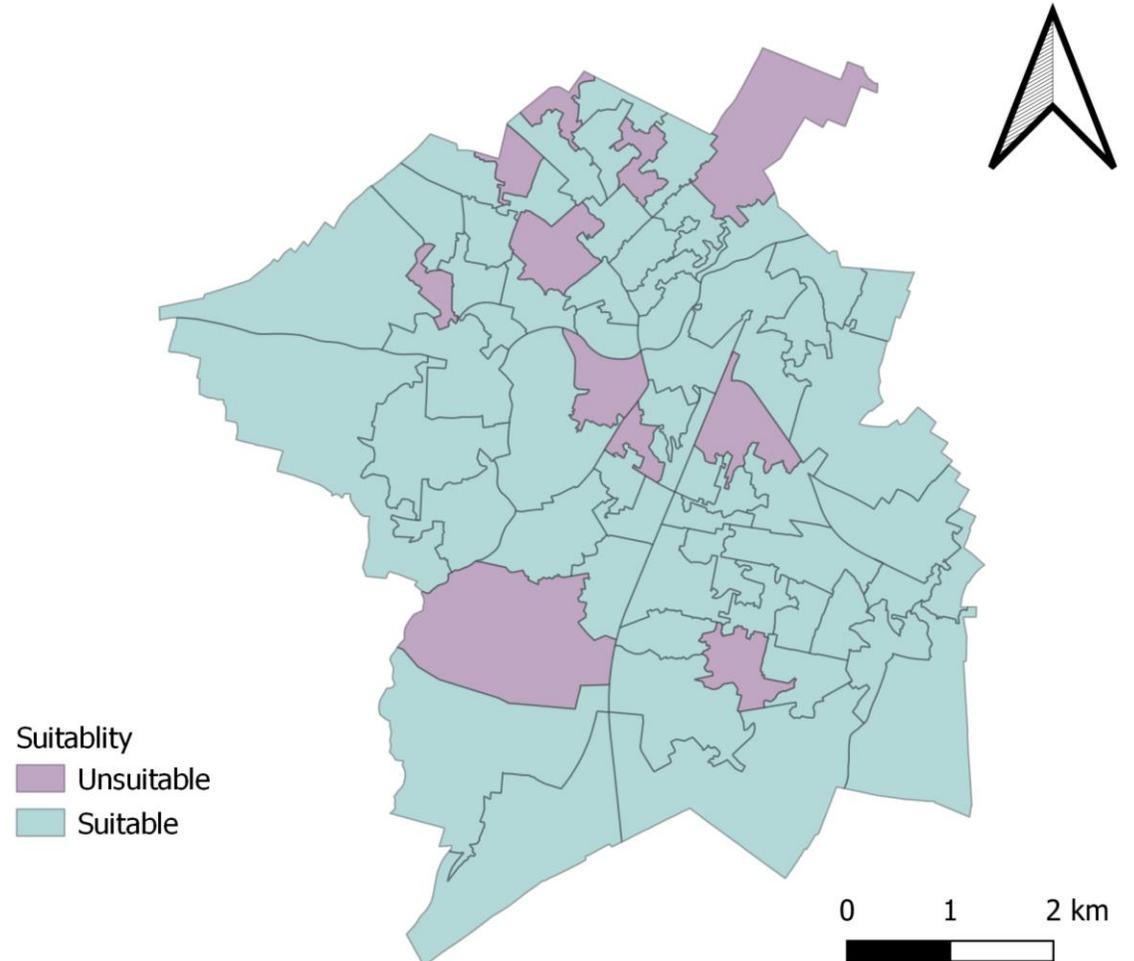


Inputs: Building density, population density, green space provision, crime rate etc.

# Simple decision model



Tree coverage	Suitability
$\geq 20\%$	Not suitable
$< 20\%$	Suitable



# More classification to aid decision

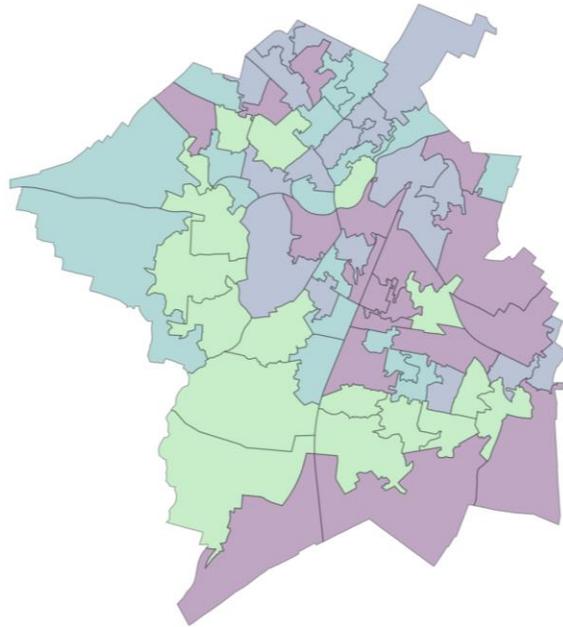


Ranking		Coverage
Highly Suitable	1	Under 10%
Moderately Suitable	2	10-20%
Marginally Suitable	3	20-30%
Not Suitable	4	Over 30%

Epoch=600, batch=10, accuracy>80%

Epoch=1500, batch=10, accuracy>90%

# Real vs Prediction

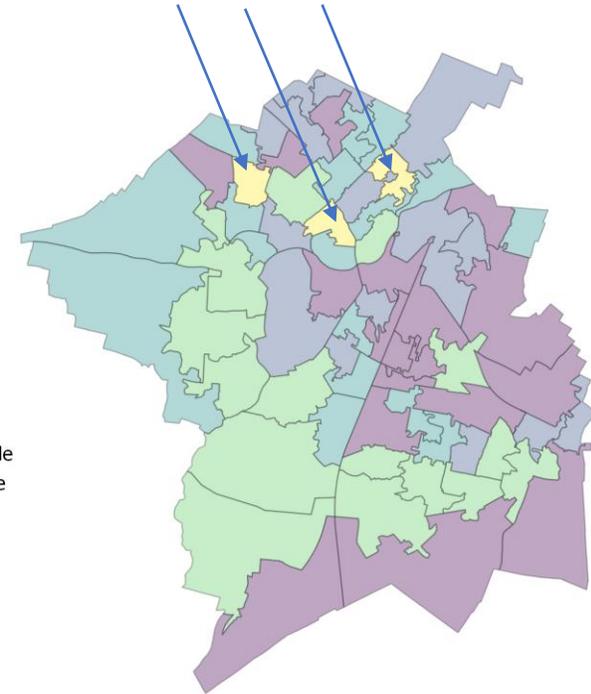


0 1 2 km

Suitability

- Highly suitable
- Moderately Suitable
- Marginally Suitable
- Not Suitable

Prediction error



0 1 2 km

Suitability

- Highly Suitable
- Moderately Suitable
- Marginally Suitable
- Not Suitable
- Not Sure



# NN predictive model for management and budgeting

- The model prediction will help urban planners to target problematic areas and optimise the green infrastructure.
- When conditions change over time  
e.g Urban expansion will reduce green space over years. House prices changes among LSOAs. The model can justify the target areas.
- Facilitate community engagement and development for social problems, e.g. walking routes planning, tree planting activities

Thank you!

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