Participatory system dynamics and health impact modelling for green infrastructure in London

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On behalf of the CUSSH consortium

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Complex Urban Systems for Sustainability and Health

GREEN INFRASTRUCTURE

Healthy City Design, 16-17 October 2018

Overview of CUSSH

- Four-year research project funded by the Wellcome Trust (2018-2022)
- Support cities in bringing about **city-wide changes** with the aim of transforming environmental quality, sustainability, population health and health equity
- Multi-partner consortium with six partner cities

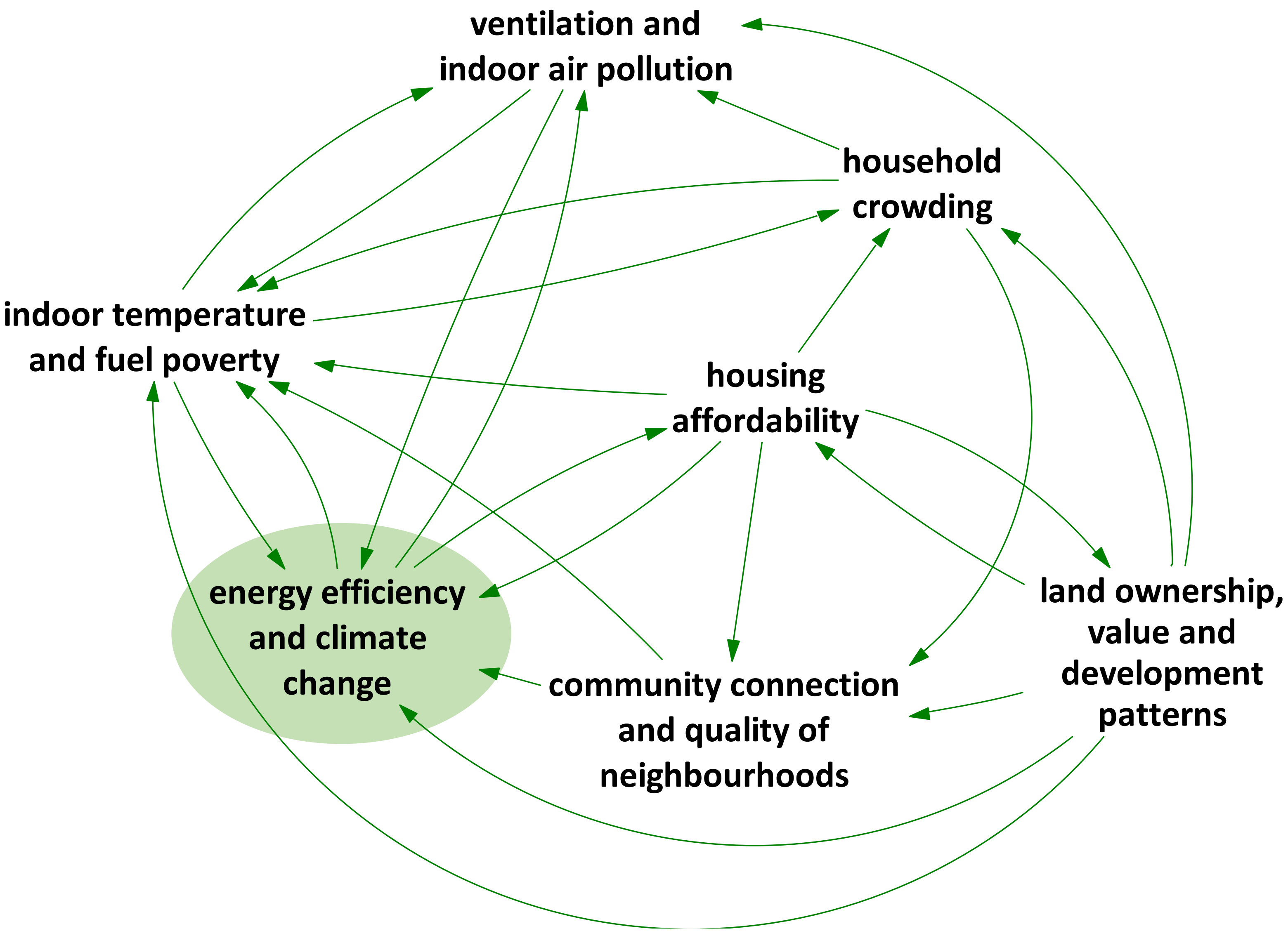
3 main components

- Cutting edge scientific evidence
- Framework of participatory research
- Complex systems approach to transformation

Systems thinking

energy efficiency and climate change

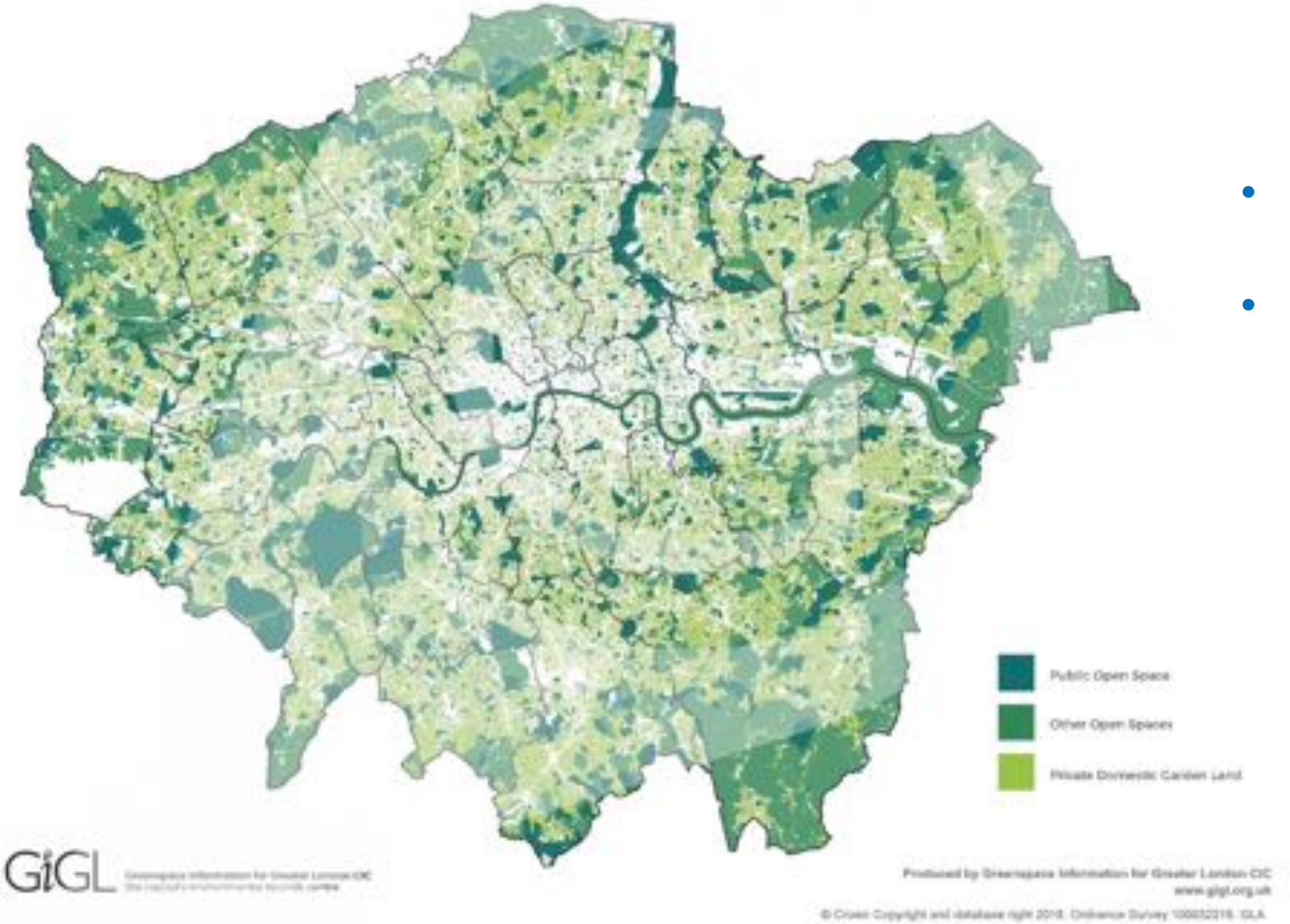
Systems thinking



The London Environment Strategy

Aims to make London into a National Park City and has the objectives to:

‘MAKE MORE THAN HALF OF LONDON’S AREA GREEN BY 2050’



- 10% increase in tree canopy cover until 2050
- 10% increase in urban forest, (current, urban forest covers 20% of London's land area) - target 22% by 2050

Background

Complex Urban Systems for Sustainability and Health

- ~47% of Greater London is already considered ‘green space’
- London is limited with space for housing and other services with the population projected to rise to 13 Million by 2050
- This raises several questions for policy makers & town planners:
    - What types of green space are most beneficial for sustainability and health?
    - Where would benefit most from increases/changes in green space?
    - How do we avoid unintended consequences such as gentrification?

Participatory System Dynamics

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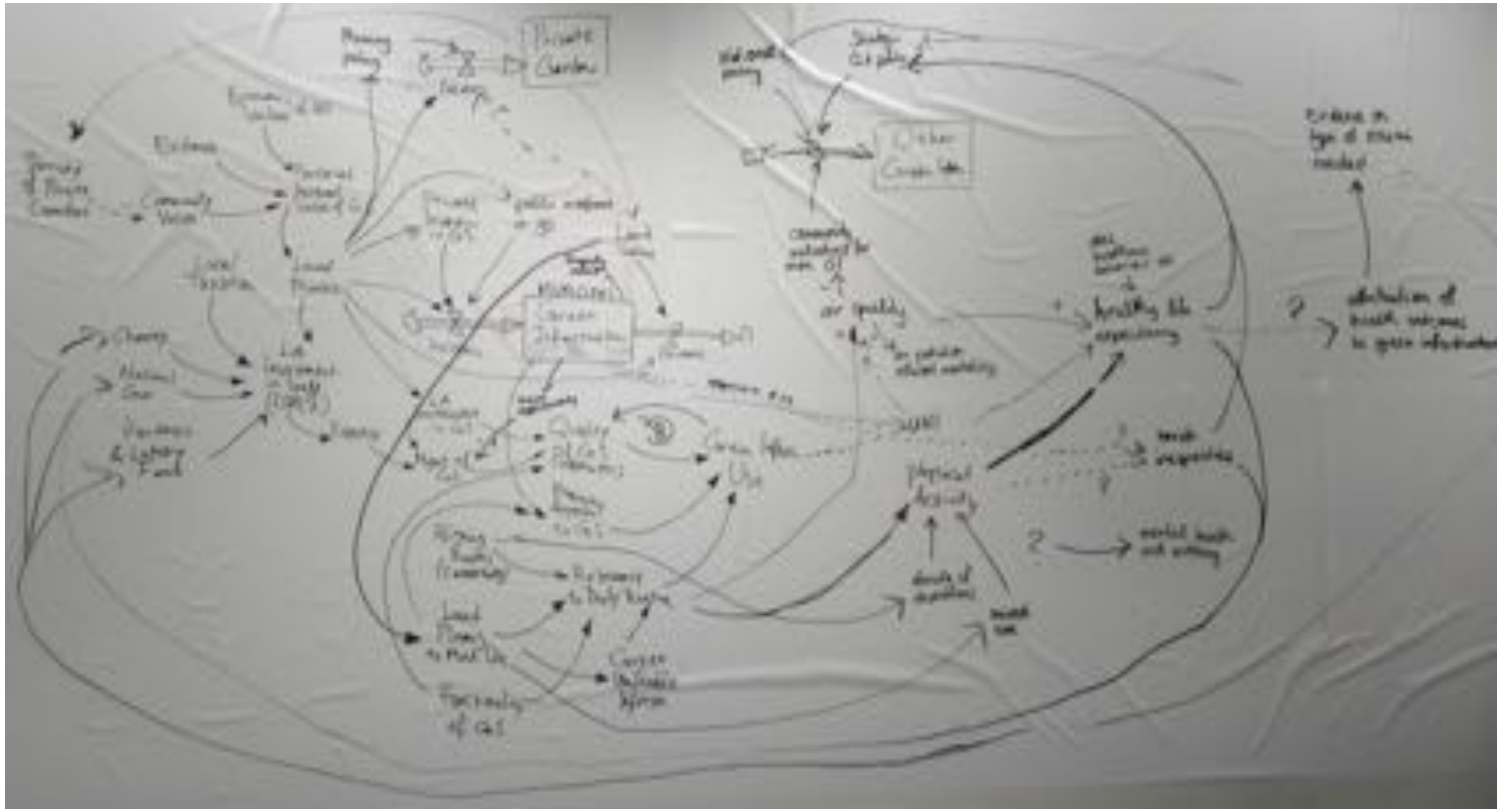
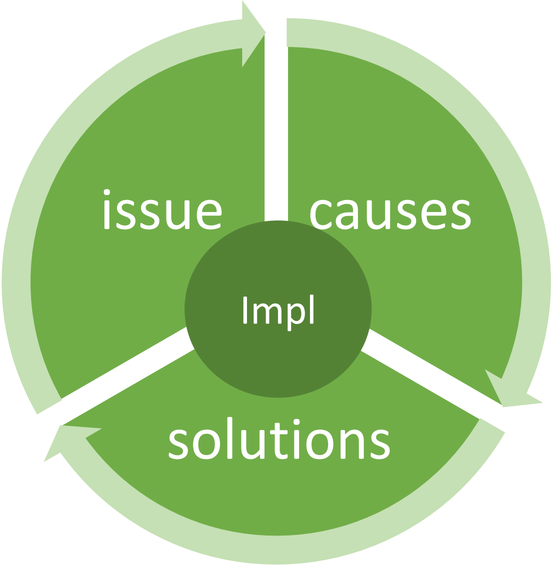
Co-creation with city

2 participatory modelling workshops with environment and health experts (February and September 2018)





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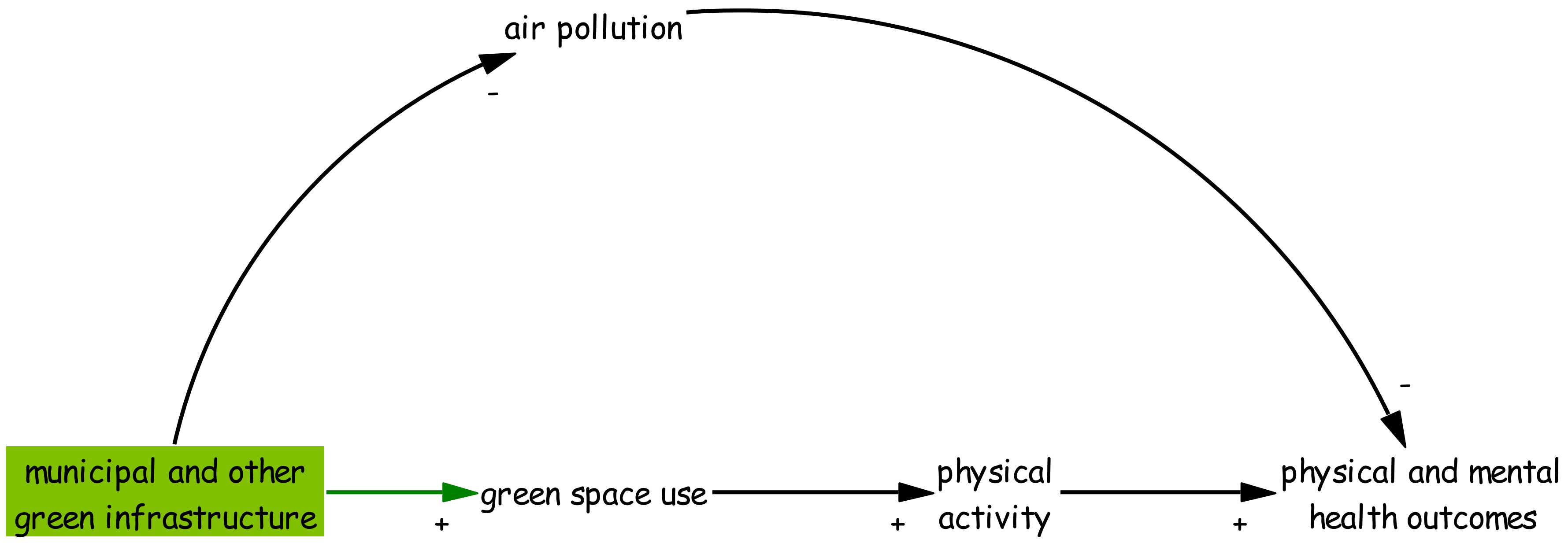
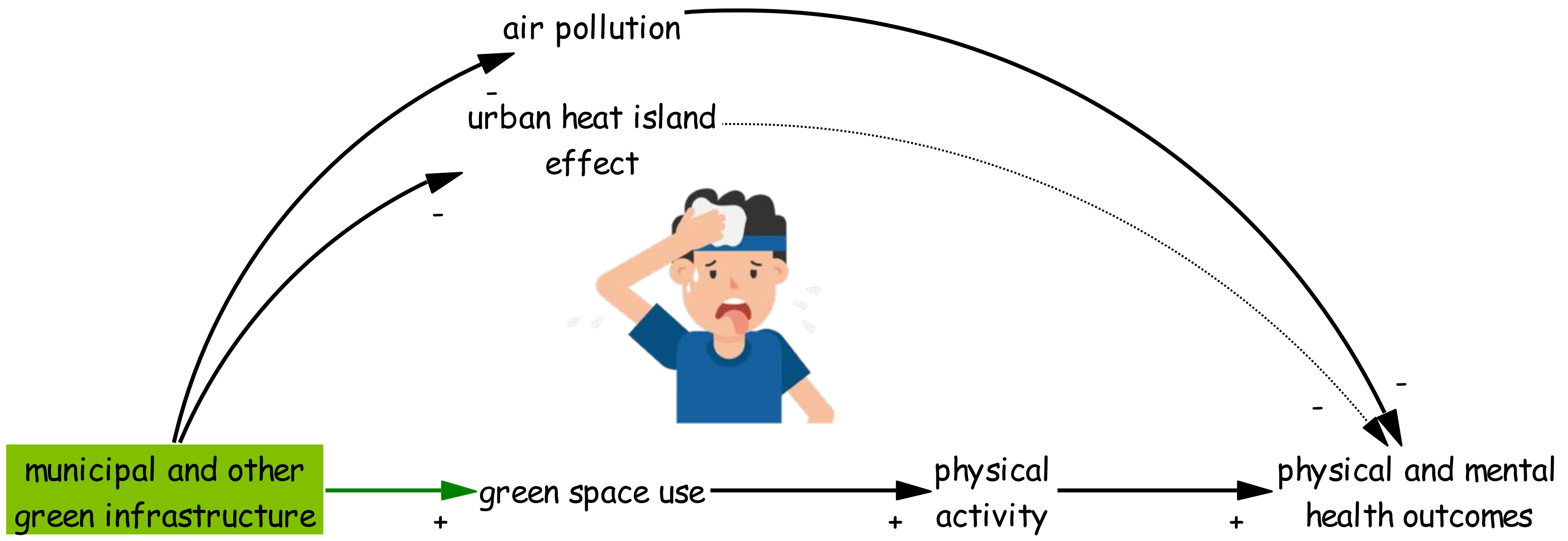
System Dynamics model

municipal and other green infrastructure $\xrightarrow{+}$ green space use $\xrightarrow{+}$ physical activity $\xrightarrow{+}$ physical and mental health outcomes

System Dynamics model



System Dynamics model



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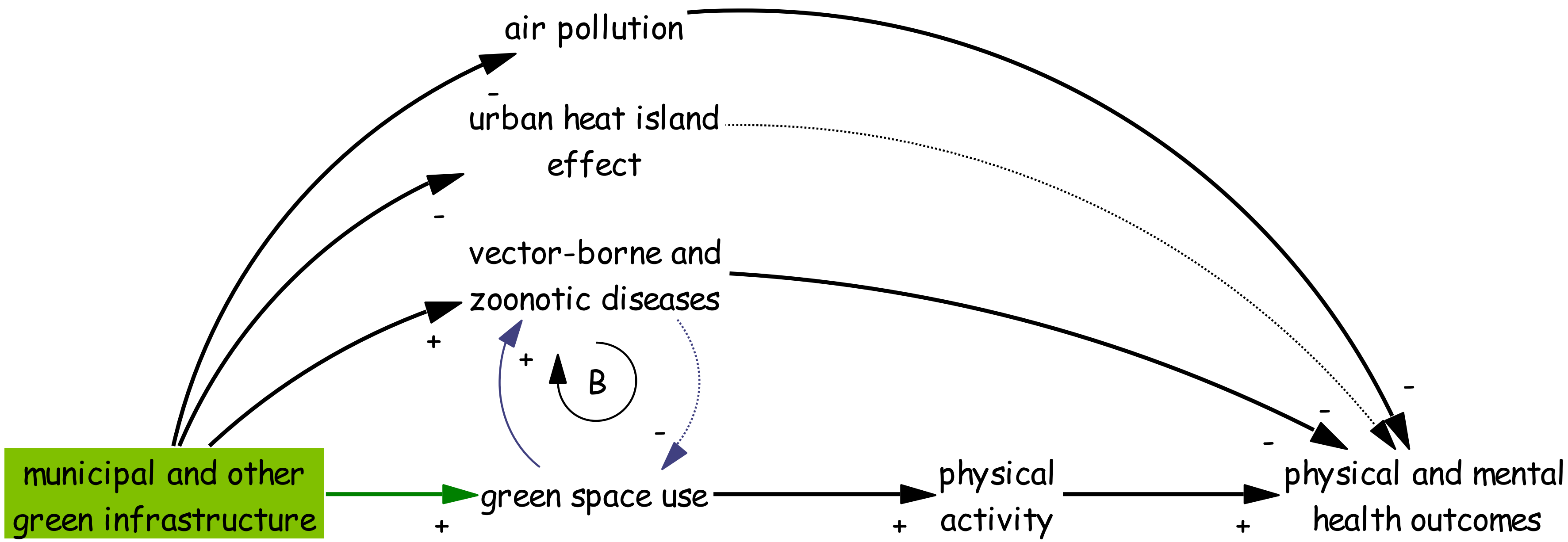

System Dynamics model

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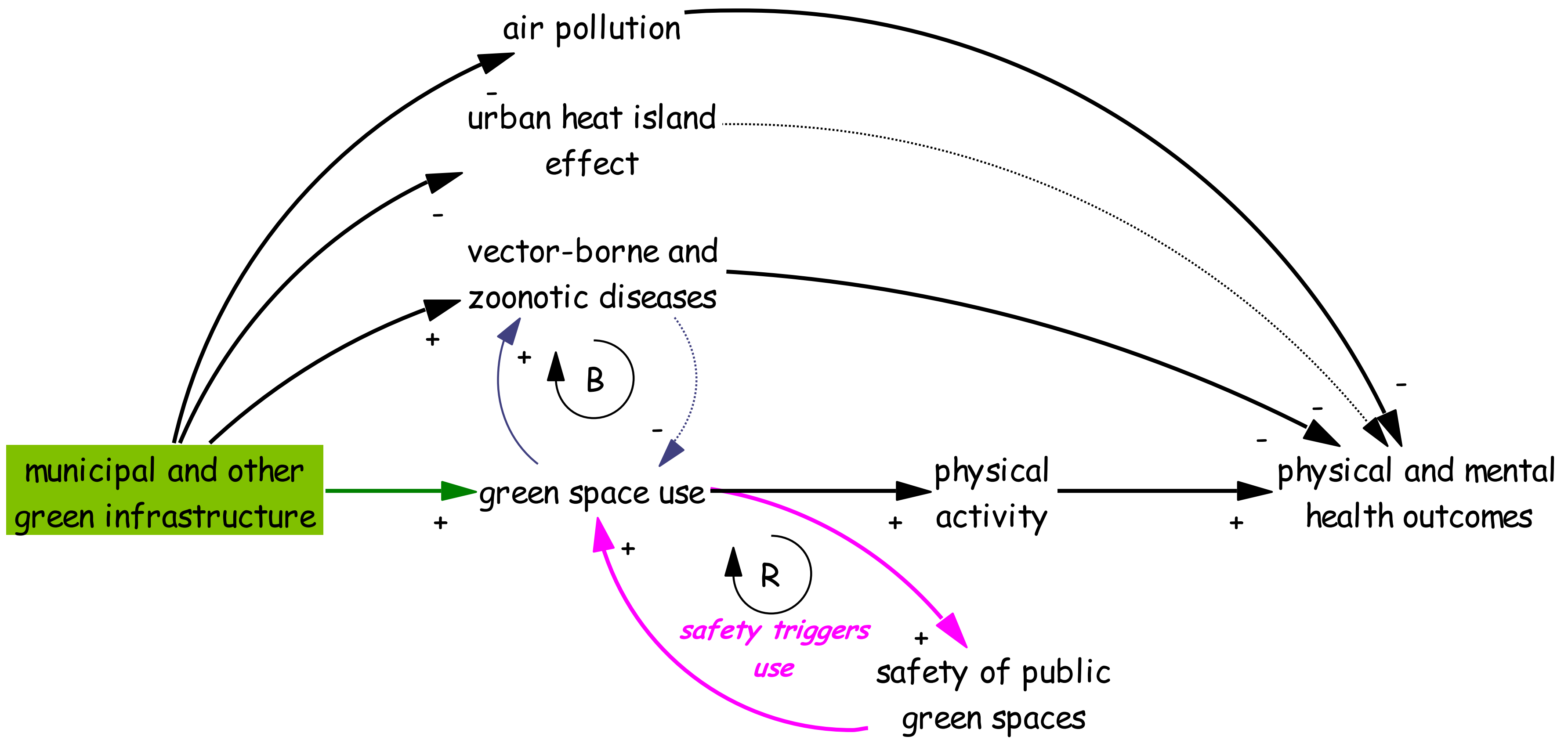

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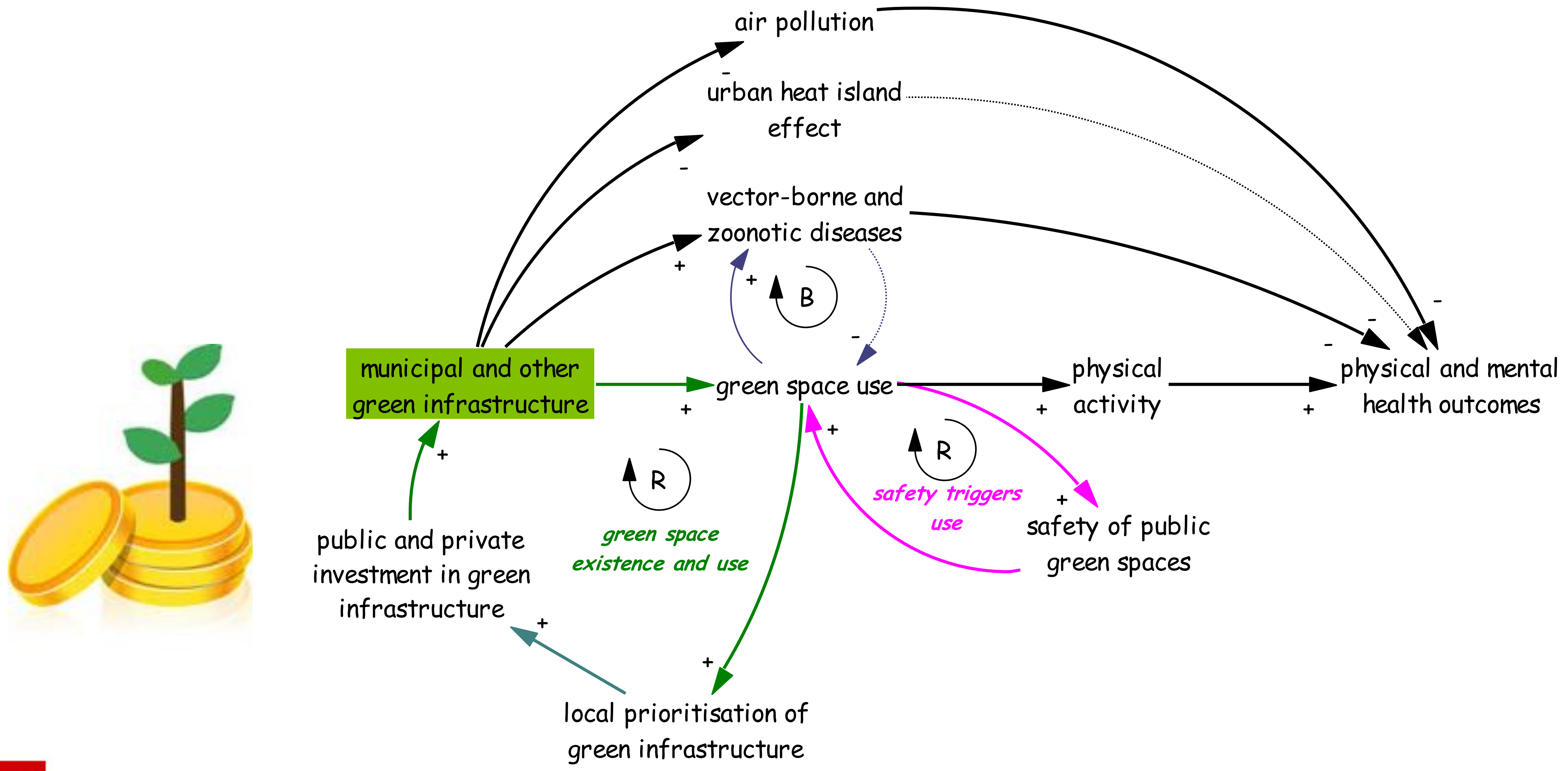

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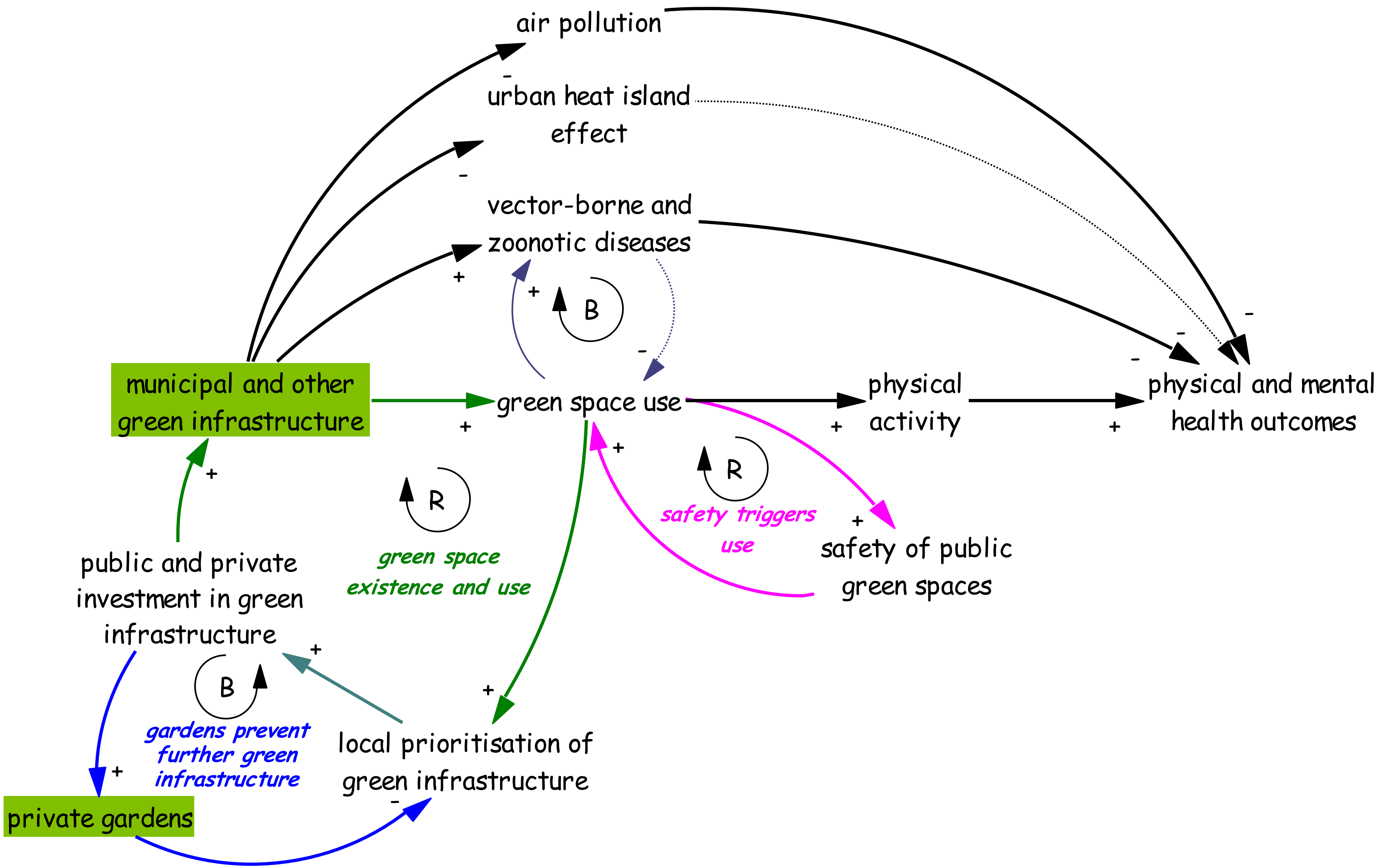

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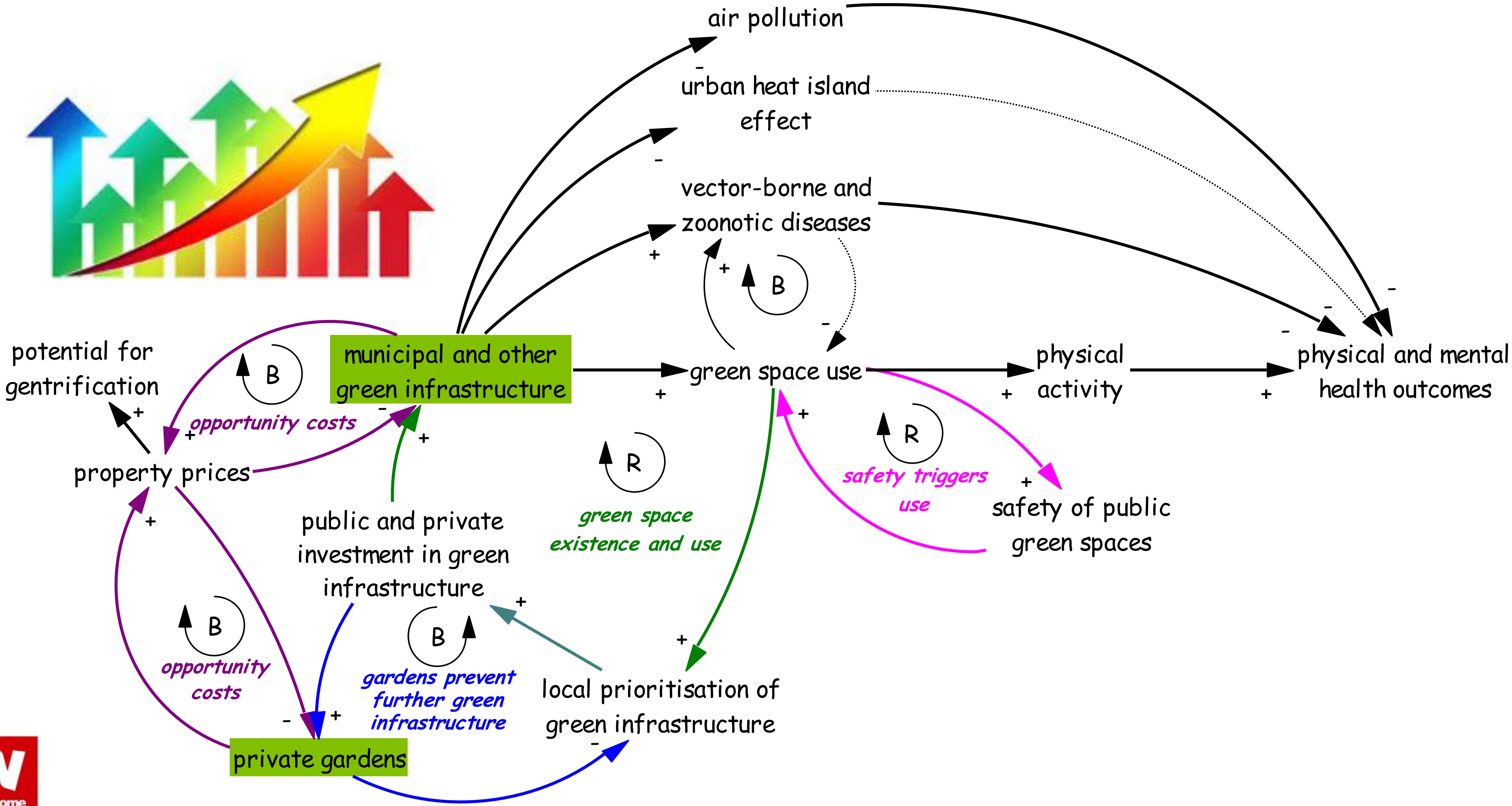
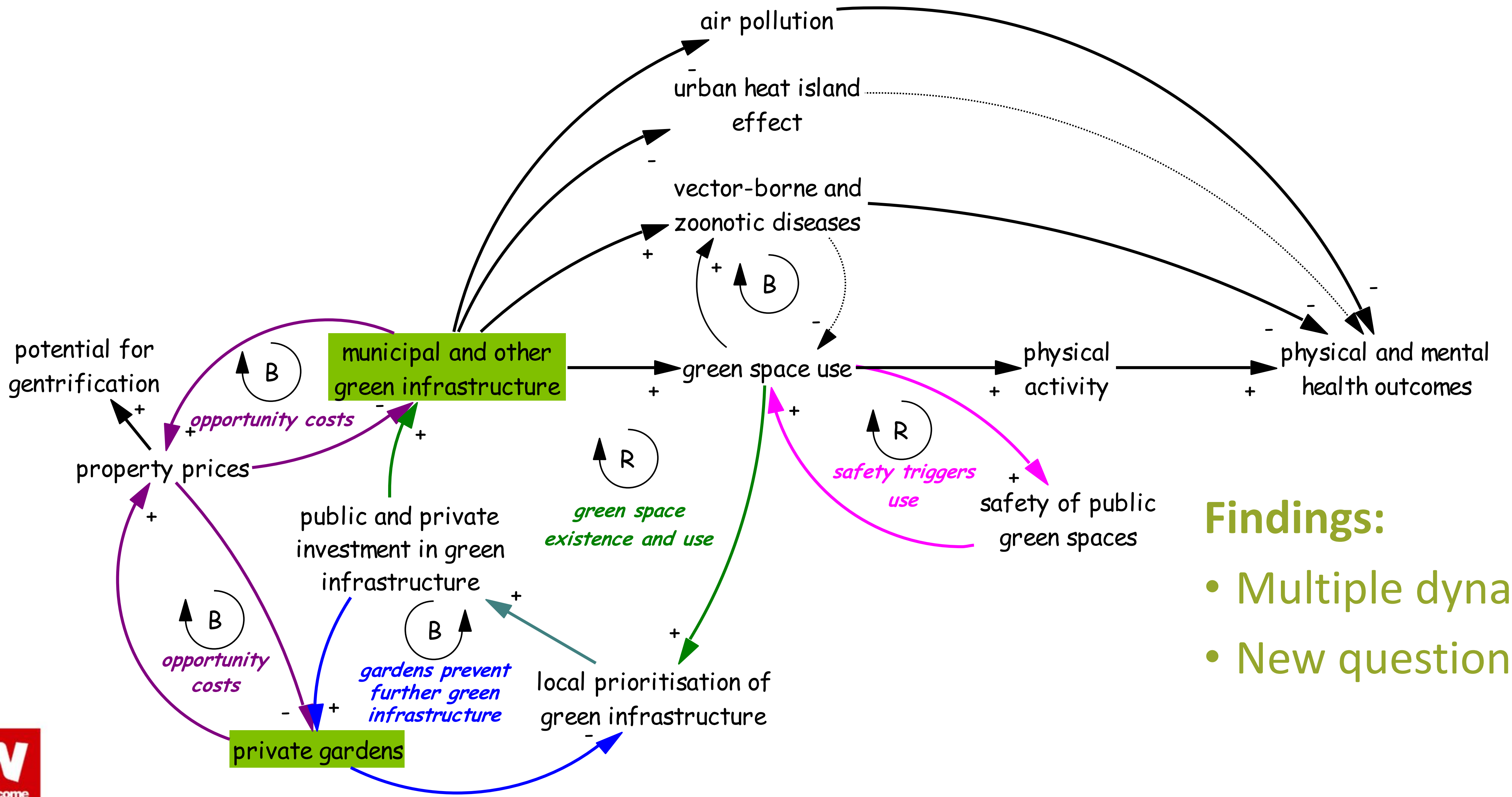


System Dynamics model



Findings:

- Multiple dynamics
- New questions

System Dynamics model

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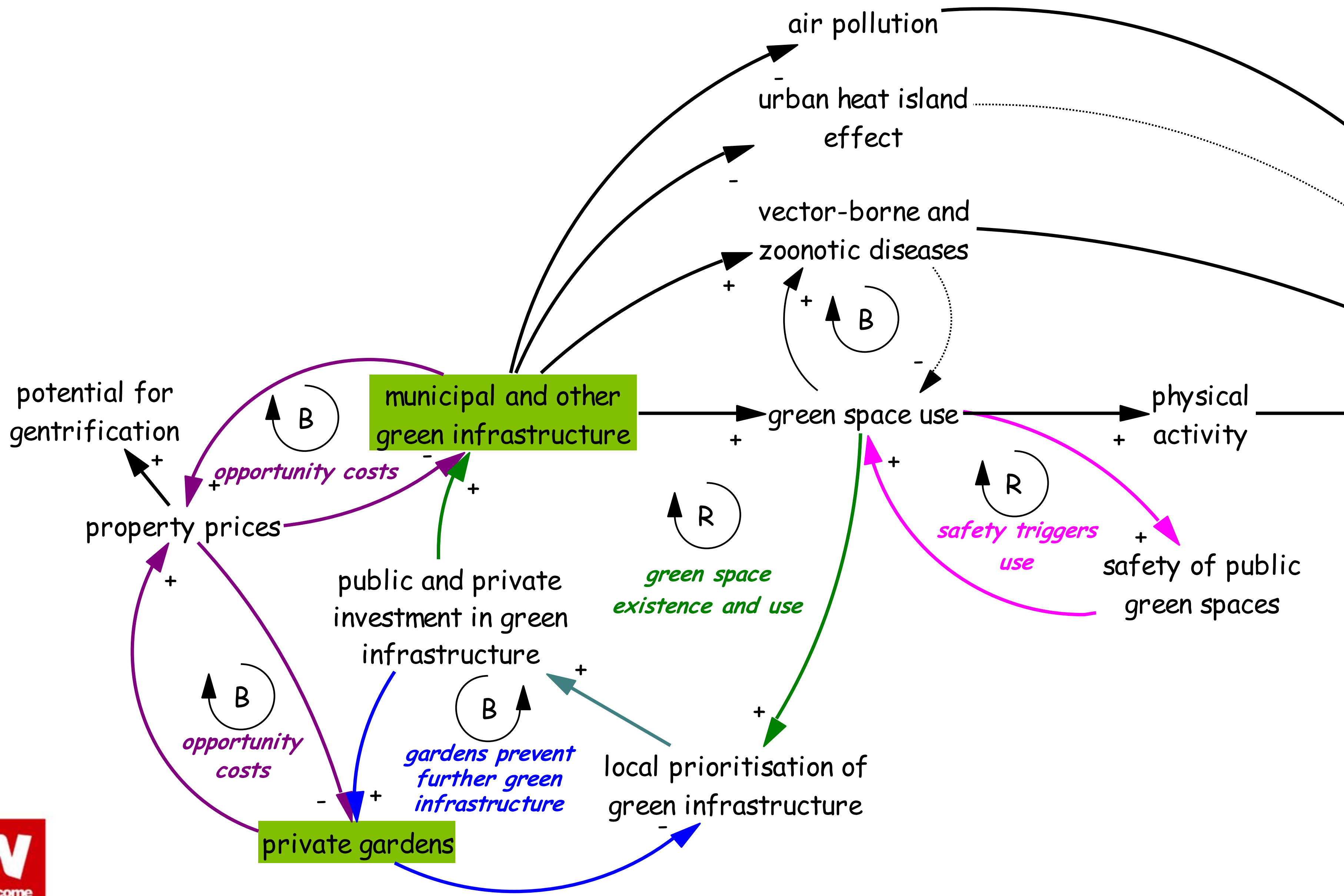

Limitations:

- Spatially aggregated
- High-level view

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System Dynamics model

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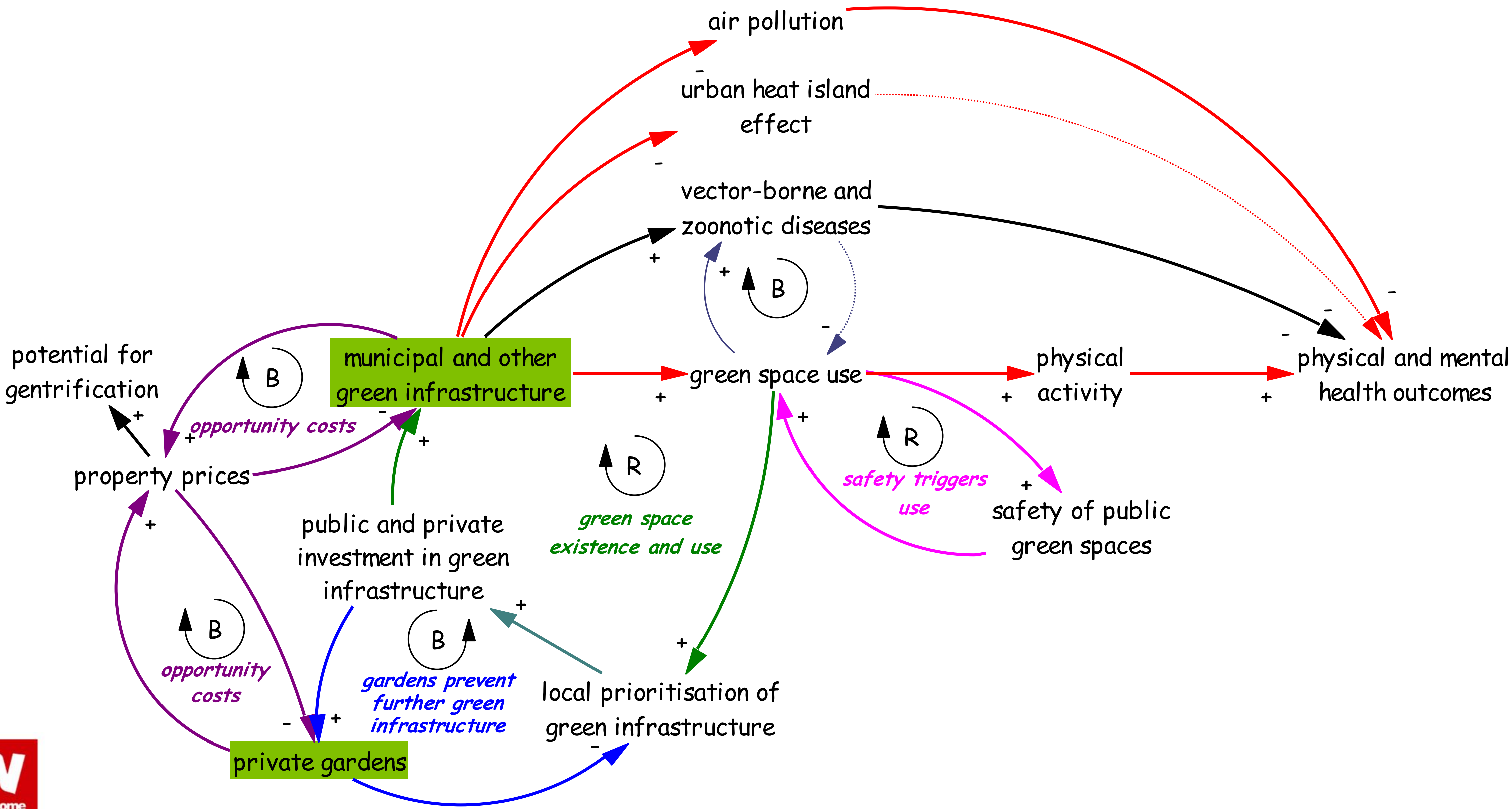

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What impact does GI have on health?

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- Two recent meta-analyses produce different Risk Ratio (RRs)/Odds Ratios (ORs)

ELSEVIER

Environment International
Volume 86, January 2016, Pages 60-67

Review article

Residential green spaces and mortality: A systematic review

Mireia Gascon[a, b, c, d], Margarita Triguero-Mas[b, c, d], David Martínez[b, c, d], Payam Dadvand[b, c, d], David Rojas-Rueda[b, c, d], Antoni Plasència[a], Mark J. Nieuwenhuijsen[b, c, d]

ELSEVIER

Environmental Research
Volume 166, October 2018, Pages 628-637

The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes

Caoimhe Twohig-Bennett, Andy Jones

RR(all-cause) = **0.92** (95% CI: 0.87, 0.97)
RR(cardiovascular) = **0.96** (95% CI: 0.94, 0.97)

OR(all-cause) = **0.69** (95% CI: 0.55, 0.87)
OR(cardiovascular) = **0.84** (95% CI: 0.76, 0.93)

8% reduction in all-cause mortality if…

31% reduction in all-cause mortality if…

…live in **high** vs **low** green space exposure categories

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Simple Health Impact Assessment Methodology

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% Local green space data

Apply Risk factor

Population health data (age/gender specific mortality rates)

Local population data

Population health outcome

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Simple Health Impact Assessment Methodology

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% Local green space data

% Local green space data ↑

Apply Risk factor

Population health data (age/gender specific mortality rates)

Local population data

lag

Population health outcome

New population health outcome

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Intermediate Variables

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Wellbeing

Green Space
- Public (%)
- Private (%)
- Tree canopy cover (%)

Physical activity

Intermediate Environmental Variables
- **Air Pollution (PM2.5, etc…)**
- **Urban Heat Island (UHI) intensity (°C)**
- Noise pollution (db)

Health Outcomes
- Childhood Obesity
- Diabetes
- Mental disorders
- Air pollution and heat related mortality
- Life expectancy
- Health Inequalities

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Intermediate Variables

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1

Modelling/ monitoring

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1

Modelling/ monitoring

Intermediate Environmental Variables
- **Air Pollution (PM2.5, etc…)**
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- Noise pollution (db)

2

Epidemiological evidence

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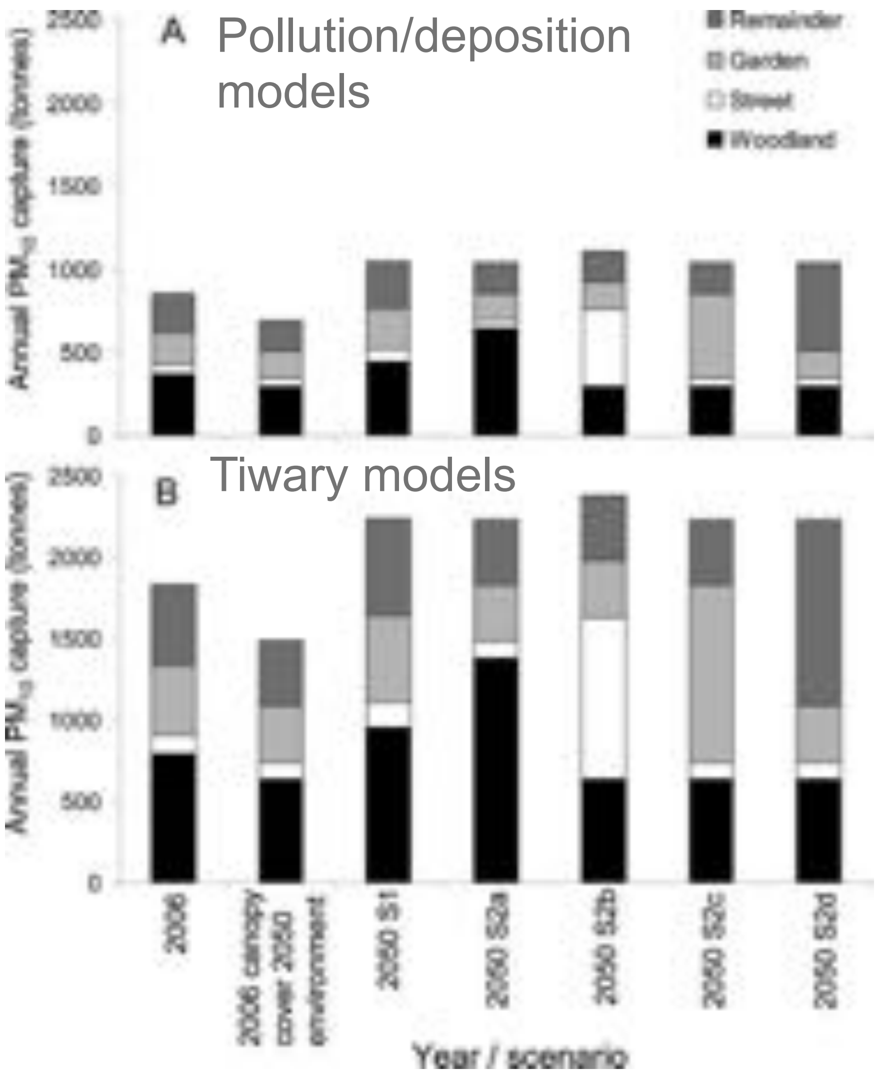
1. Impact of green space on environmental variables

- Tallis et al. employed a deposition model using the Urban Forest Effects Model (UFORE)
- 5 planting scenarios were assessed under future climate and PM_{10} emissions
- Results: current urban canopy of the Greater London estimated to remove between **0.7% and 1.4%** of PM_{10} from the urban boundary layer

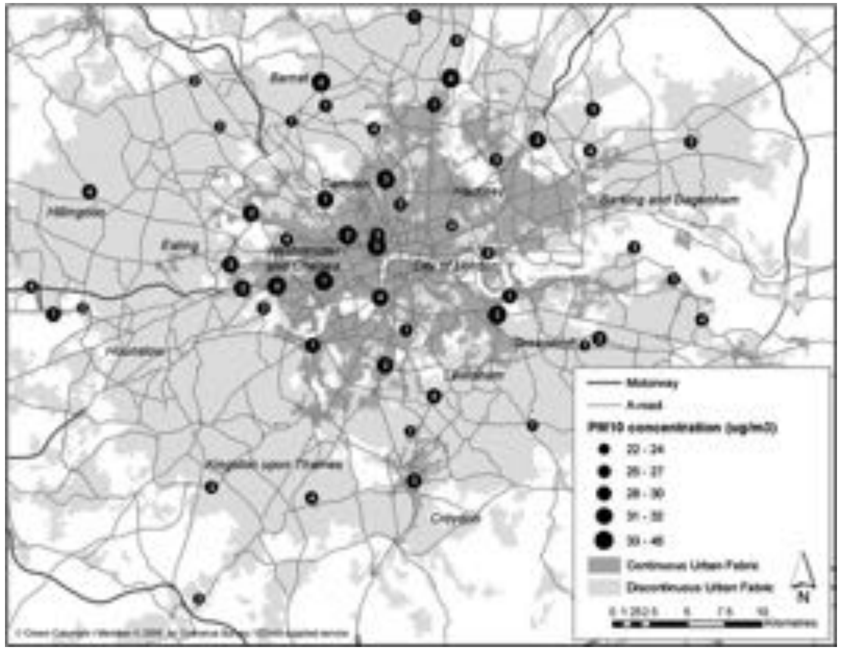


Source: Tallis et al. Landscape and Planning. 2011

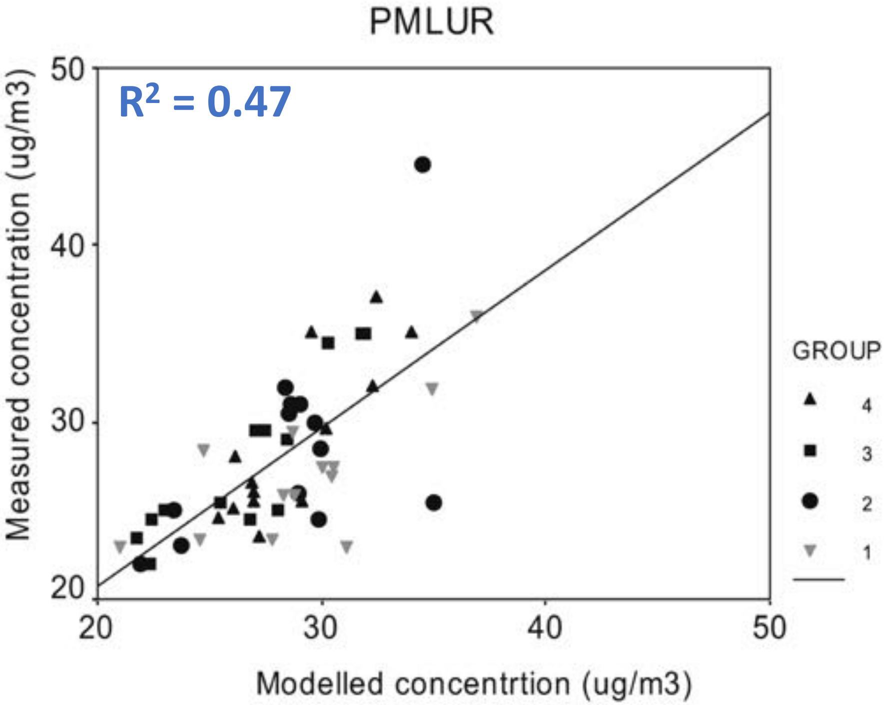
1. Impact of green space on environmental variables

Monitoring combined with **statistical** methods can be used to assess the impact of green space on environmental variables

Monitoring data



- Kriging
- Nearest neighbor
- Dispersion model
- **Land use regression (LUR) models**



Modelled versus observed concentrations at the 52 monitoring sites, based on the four calibration models.

Source: Gulliver et al. Atmospheric Environment. 2011

1. Impact of green space on environmental variables

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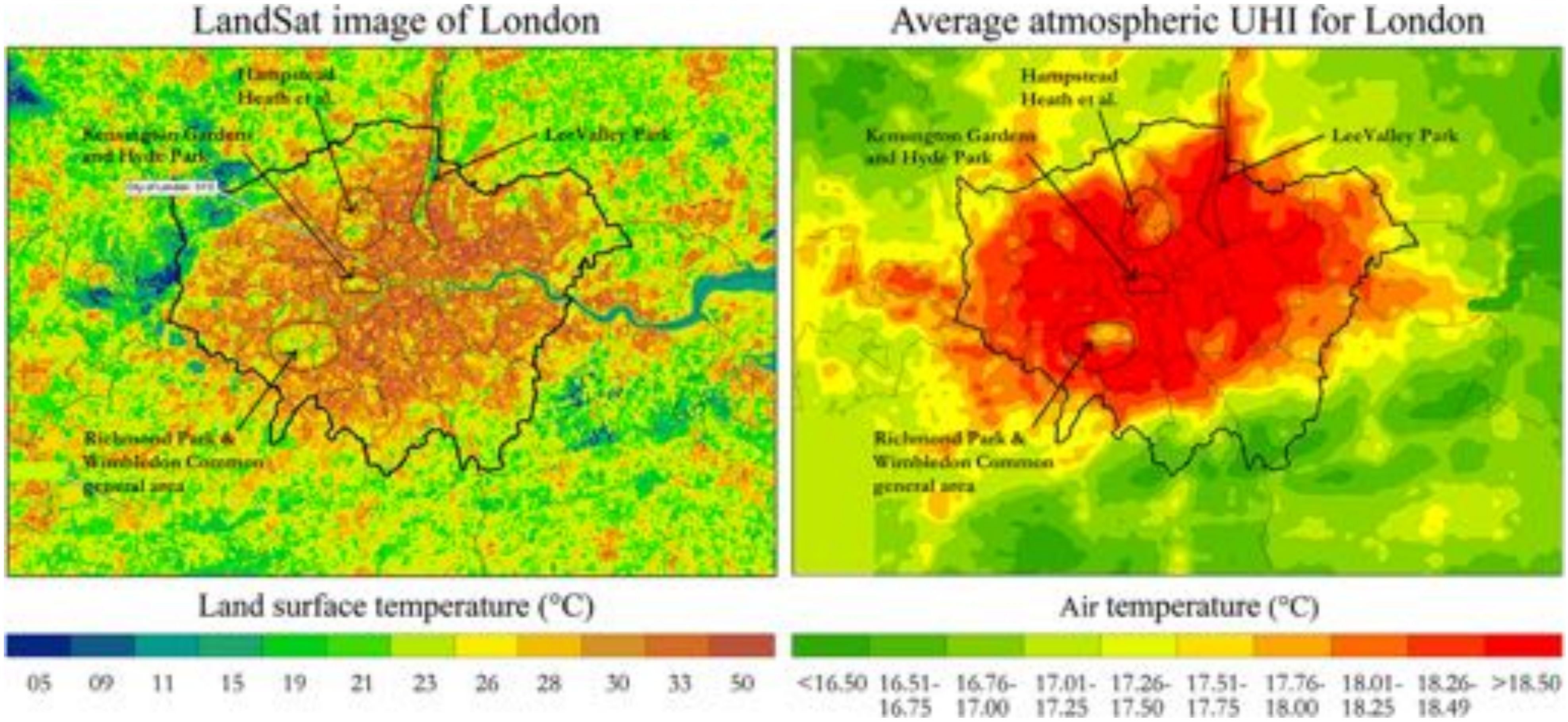
- …or **remote sensing data** can be used (e.g. to estimate the UHI)



Source: Gunawardena et al. STOTEN. 2017 (The LUCID project)

2. Impact of environmental variables on health

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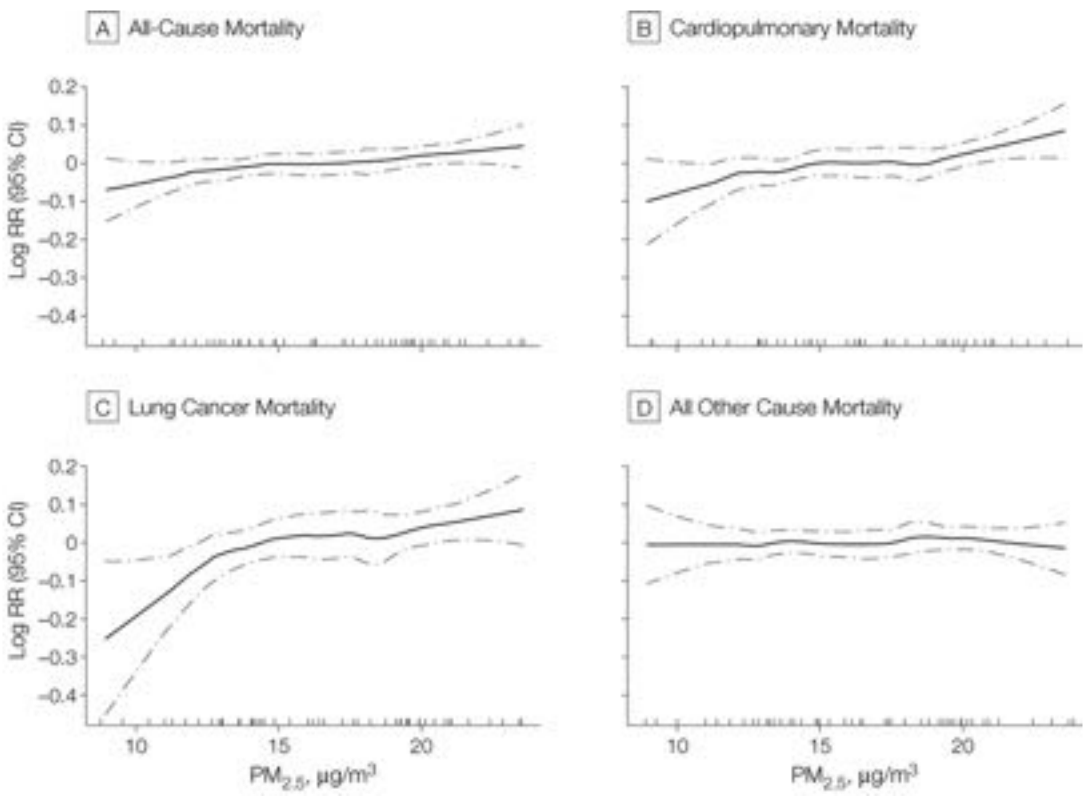
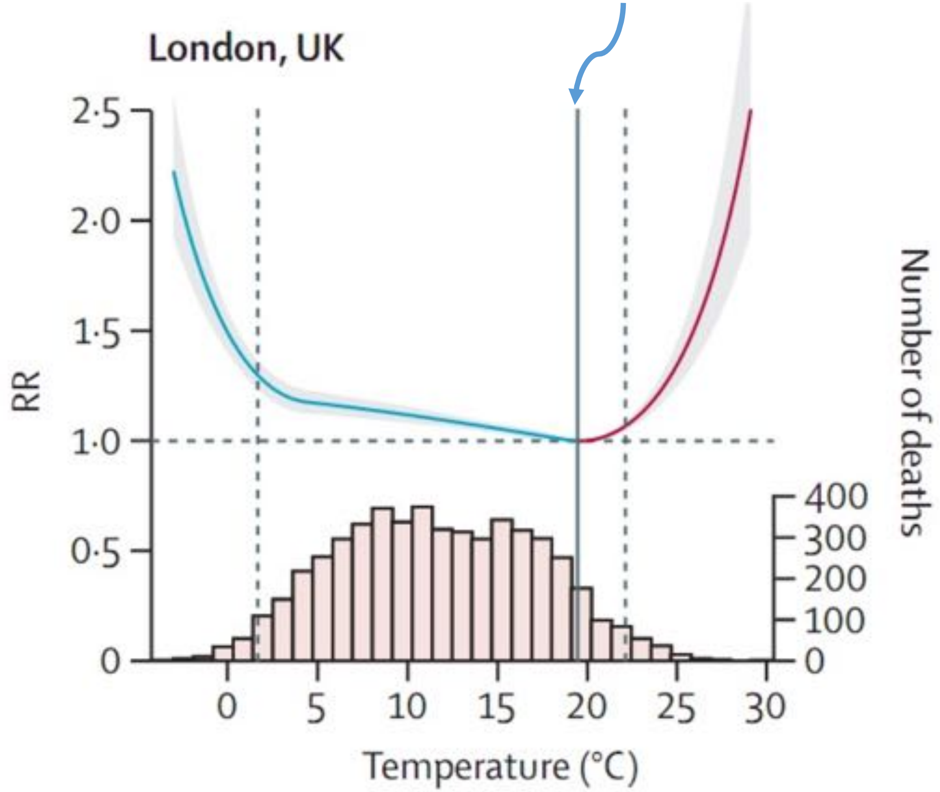
PM2.5:
6% increase in all-cause mortality per 10ug/m3



Source: Pope et al. JAMA. 2002

Heat/Cold:
~3.8% increase per °C above threshold of 24.8 C

Minimum mortality temperature



Source: Gasparrini et al. The Lancet. 2015

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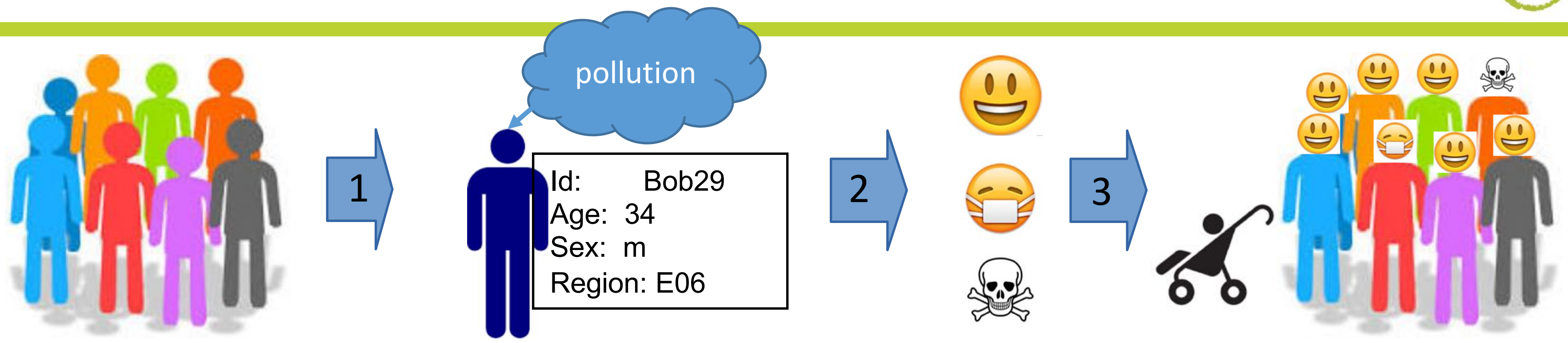
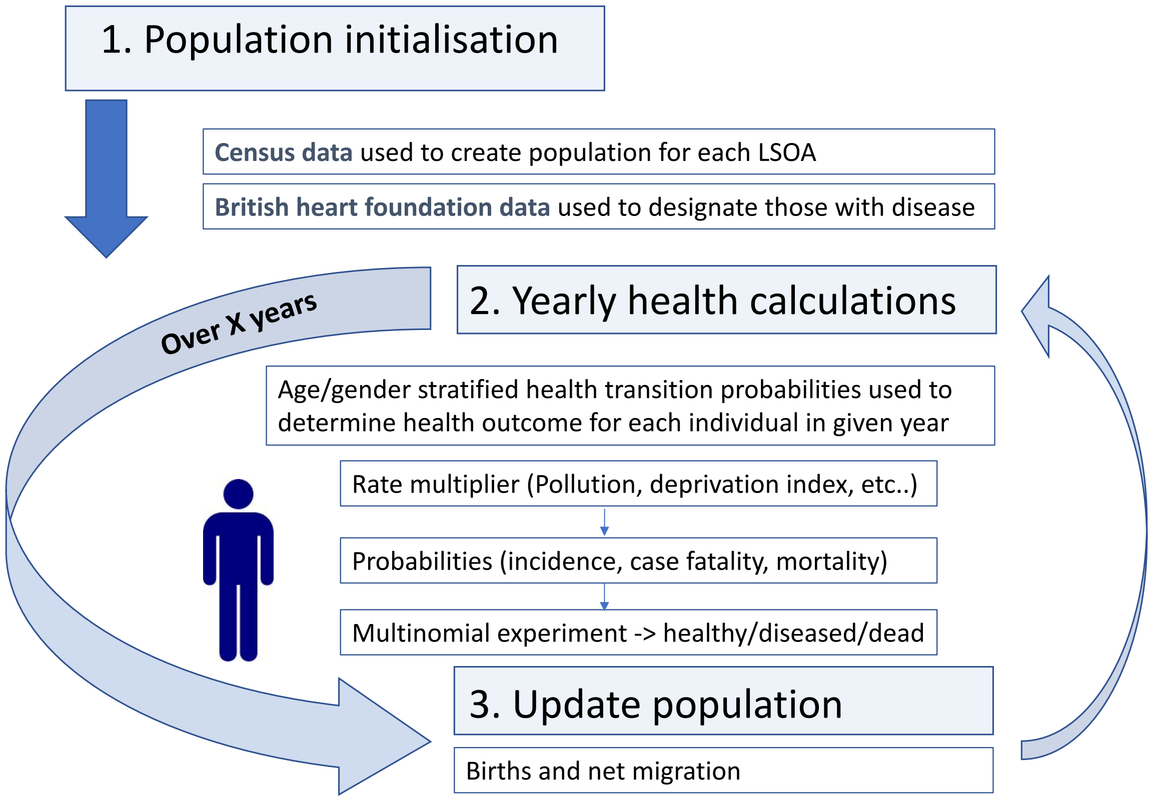
Health Impact Assessment



- **Microsimulation** provides a method to assess impact of air pollution and hot/cold exposures on health
- Currently being used to asses impact of air pollution on **cardiovascular morbidity**
- Can add additional layers such as green space and feedback mechanisms



Summary

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- Simple questions such as:

'What is the influence of green infrastructure on health/wellbeing?'

- can often lead to more complex questions when considering competing objectives
- There is a need to think futuristically

- **System Dynamics** takes a broad view the problem and identifies unintended consequences
- **Epidemiology methods** such as microsimulation allow health impacts to be quantified

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Thanks for your attention!

References

Gascon et al. (2016). Residential green spaces and mortality: A systematic review. Environ Int. 2016;86:60-7. doi: 10.1016/j.envint.2015.10.013

Twohig-Bennett C, Jones A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environ Res. 2018 Oct;166:628-637. doi: 10.1016/j.envres.2018.06.030

Tallisa M, Taylor G, Sinnett D, Freer-Smith P. (2011). Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. Landscape and Urban Planning; 103 (2):129-138. doi.org/10.1016/j.landurbplan.2011.07.003

Gulliver J et al. (2011). Comparative assessment of GIS-based methods and metrics for estimating long-term exposures to air pollution. Atmospheric Environment; 45 (39):7072-7080. doi.org/10.1016/j.atmosenv.2011.09.042

Gunawardena K.R., Wells M.J., Kershaw T. (2017). Utilising green and bluespace to mitigate urban heat island intensity. Science of The Total Environment; 584–585:1040-1055. doi.org/10.1016/j.scitotenv.2017.01.158

Pope C.A. et al. (2002). Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution. JAMA. 2002;287(9):1132-1141. doi:10.1001/jama.287.9.1132

Gasparrini et al. (2015). Mortality risk attributable to high and low ambient temperature: a multicountry observational study. The Lancet. 386 (9991): 369-375. doi.org/10.1016/S0140-6736(14)62114-0

Pictures freely availably from pixaby

Thanks for your attention!

Backup slides

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- Meta-analysis forest plots

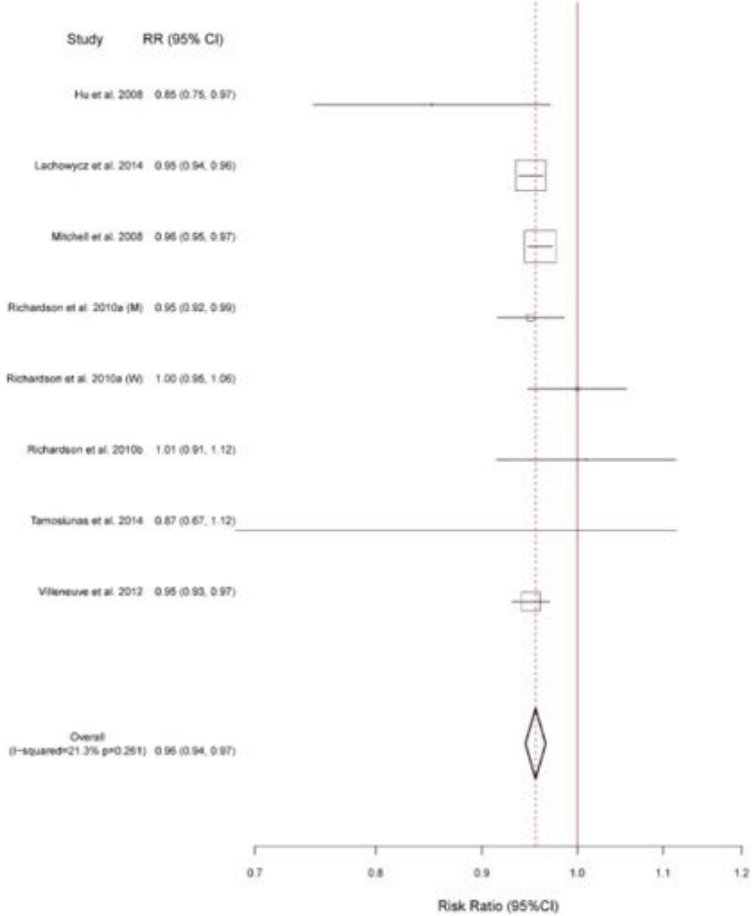
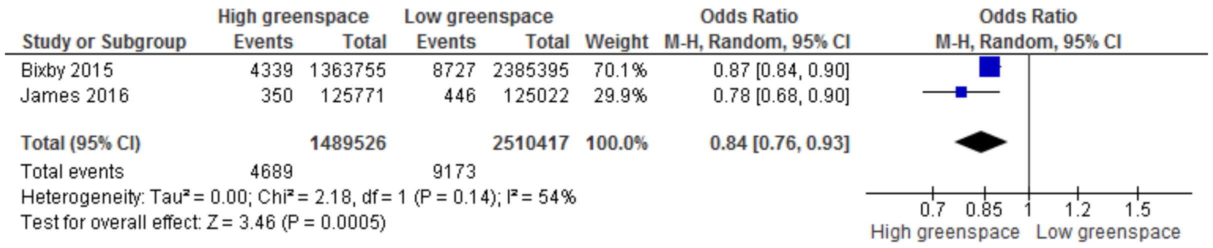


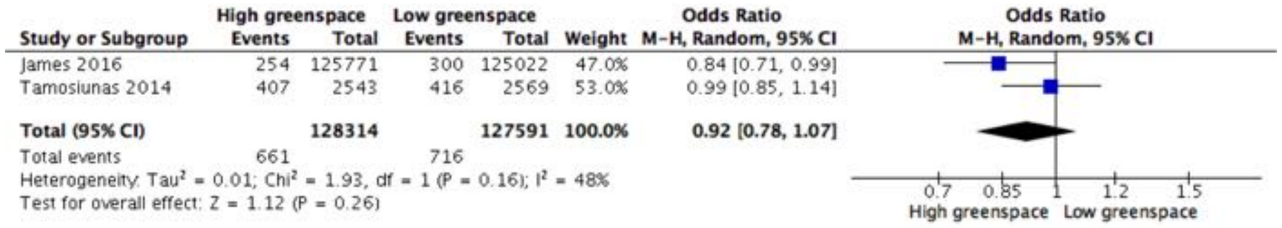
Figure S24: Cardiovascular mortality



	High greenspace		Low greenspace			Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI
Bixby 2015	4339	1363755	8727	2385395	70.1%	0.87 [0.84, 0.90]
James 2016	350	125771	446	125022	29.9%	0.78 [0.68, 0.90]
Total (95% CI)		**1489526**		**2510417**	**100.0%**	**0.84 [0.76, 0.93]**
Total events	4689		9173			

Heterogeneity: Tau² = 0.00; Chi² = 2.18, df = 1 (P = 0.14); I² = 54%
Test for overall effect: Z = 3.46 (P = 0.0005)

Figure S25: Coronary heart disease



	High greenspace		Low greenspace			Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% CI
James 2016	254	125771	300	125022	47.0%	0.84 [0.71, 0.99]
Tamosiunas 2014	407	2543	416	2569	53.0%	0.99 [0.85, 1.14]
Total (95% CI)		**128314**		**127591**	**100.0%**	**0.92 [0.78, 1.07]**
Total events	661		716			

Heterogeneity: Tau² = 0.01; Chi² = 1.93, df = 1 (P = 0.16); I² = 48%
Test for overall effect: Z = 1.12 (P = 0.26)

Fig. A1. Meta-analysis of the association between greenness (high vs low categories) and cardiovascular diseases (CVD) mortality. M (men), W (women) (Gascon et al. 2016).

Fig. A2. Meta-analysis of the association between greenness (high vs low categories) and cardiovascular diseases (CVD) mortality. (Twohig & Jones 2018).

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