Effects of Vegetation on Urban Air Pollution. *A report prepared by the UK Air Quality Expert Group*

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NERC SCIENCE OF THE ENVIRONMENT

Outline

- AQEG
- Principles
- Measurements and modelling
- The potential and reality
- Some conclusions

AQEG

- The Air Quality Expert Group (AQEG) is an Expert Committee for Defra that provides independent scientific advice on air quality
- Specifically AQEG gives advice on levels, sources and characteristics of air pollutants in the UK. It does not advise on health impacts or air quality standards.

AQEG Reports

- **December 2017:** AQEG advice on the use of 'low-cost' pollution sensors published
- **August 2017:** Impacts of shipping on UK Air Quality report published
- **August 2017:** The Potential Air Quality Impacts from Biomass Combustion report published
- **June 2016:** Appointment of experts to the Air Quality Expert Group (AQEG)
- **April 2016:** Paints and Surfaces for the Removal of Nitrogen Oxides report published
- **September 2015:** Evidential Value of Defra Air Quality Compliance Monitoring report published
- **August 2015:** Mitigation of UK $PM_{2.5}$ Concentrations report published
- **August 2015:** Linking Emission Inventories and Ambient Measurements report published

The questions on vegetation :

- *Is there definitive observational evidence of the effectiveness of urban vegetation in mitigating air pollution?*
- *What role does vegetation and its effects on air pollution play in integrated urban planning and policy?*
- *Are the data and models to quantify effects of urban planting schemes on air quality in the major cities of the UK generally available?*

The Pollutants

- Reactive gases NO_2, O_3, SO_2,….
- Particulate matter

Background

The urban landscape, buildings, roads, parkland, gardens….there are opportunities to change the surfaces

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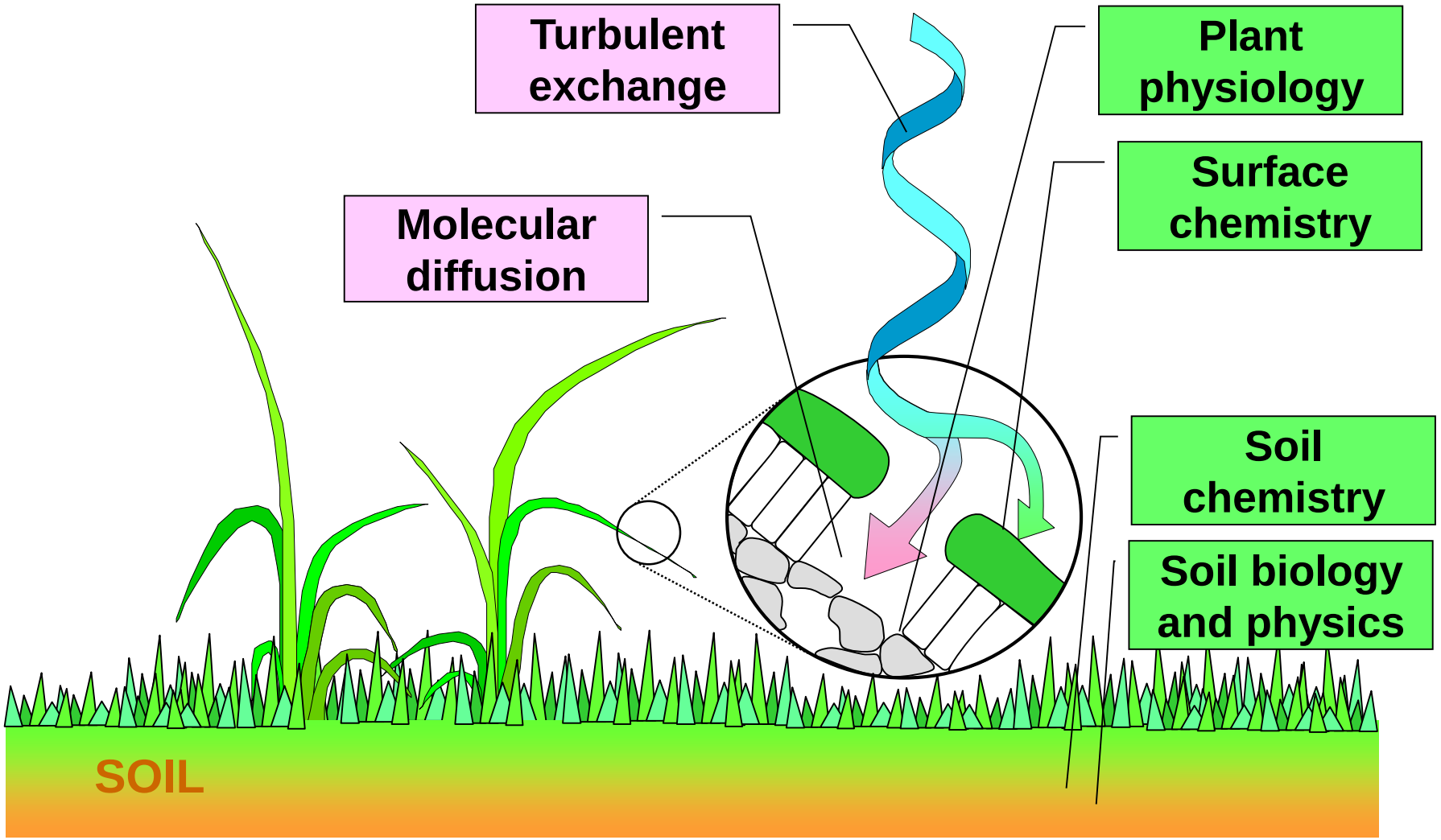
Background

But space is limited and in general the scope for additional vegetation in the urban setting varies hugely and maximizing the benefit for the population should be the objective

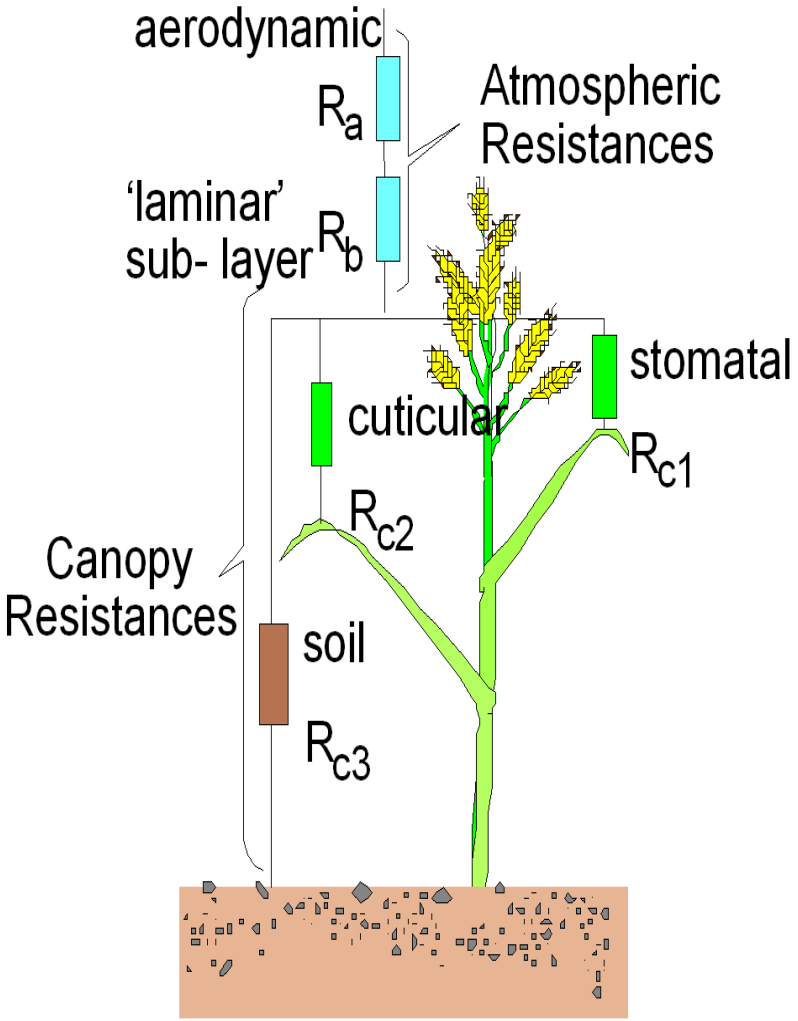
Principles

- Vegetation presents additional surfaces for the capture of reactive gases and particles
- It also offers a potential barrier and influences dispersion

Dry deposition



The resistance analogy



$$v_d = \frac{\text{flux}}{\text{concentration}} = \frac{1}{R_t}$$

$$R_t = R_a + R_b + (1/R_{c1} + 1/R_{c2} + 1/R_{c3})^{-1}$$

Principles

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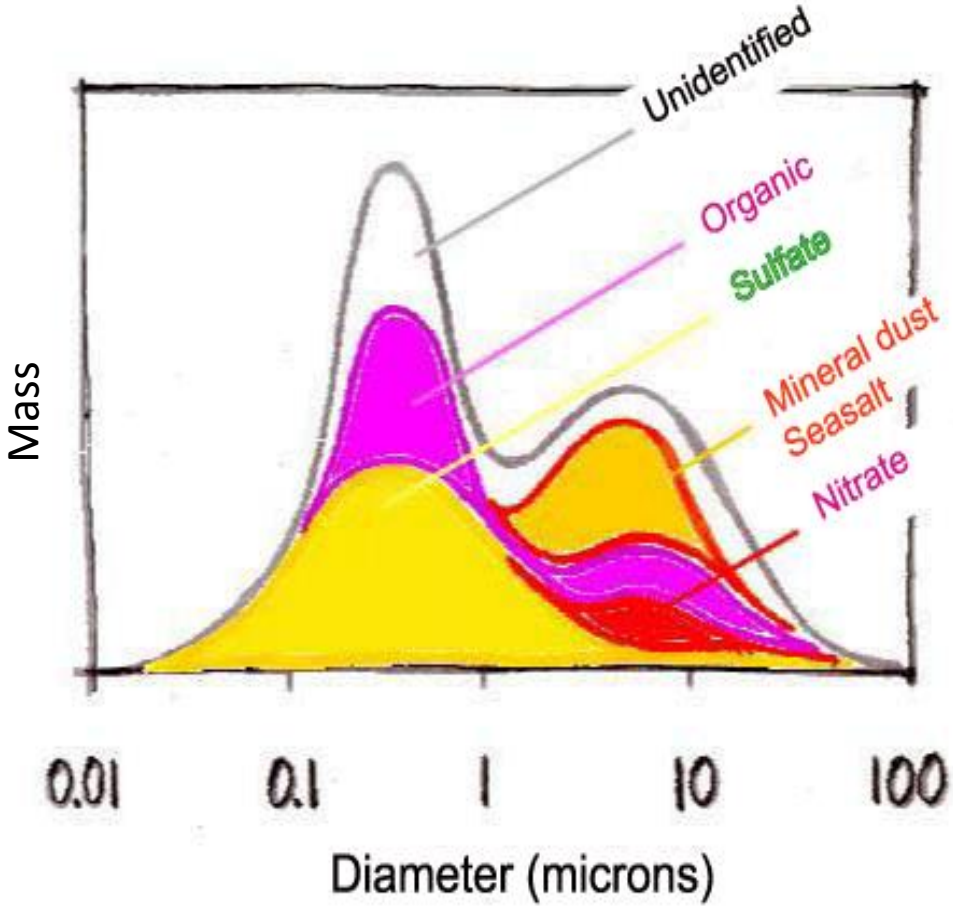
The chemical perspective ... a chemical size distribution

1. chemical size distributions resemble mass, not number

2. sulfate and organics dominate the accumulation mode, but there's a surprising amount of seasalt

3. there are a lot of unidentified organics

4. the coarse mode has the expected mechanically generated aerosols, but also nitrate and sometimes sulfate



Deposition velocity and particle size

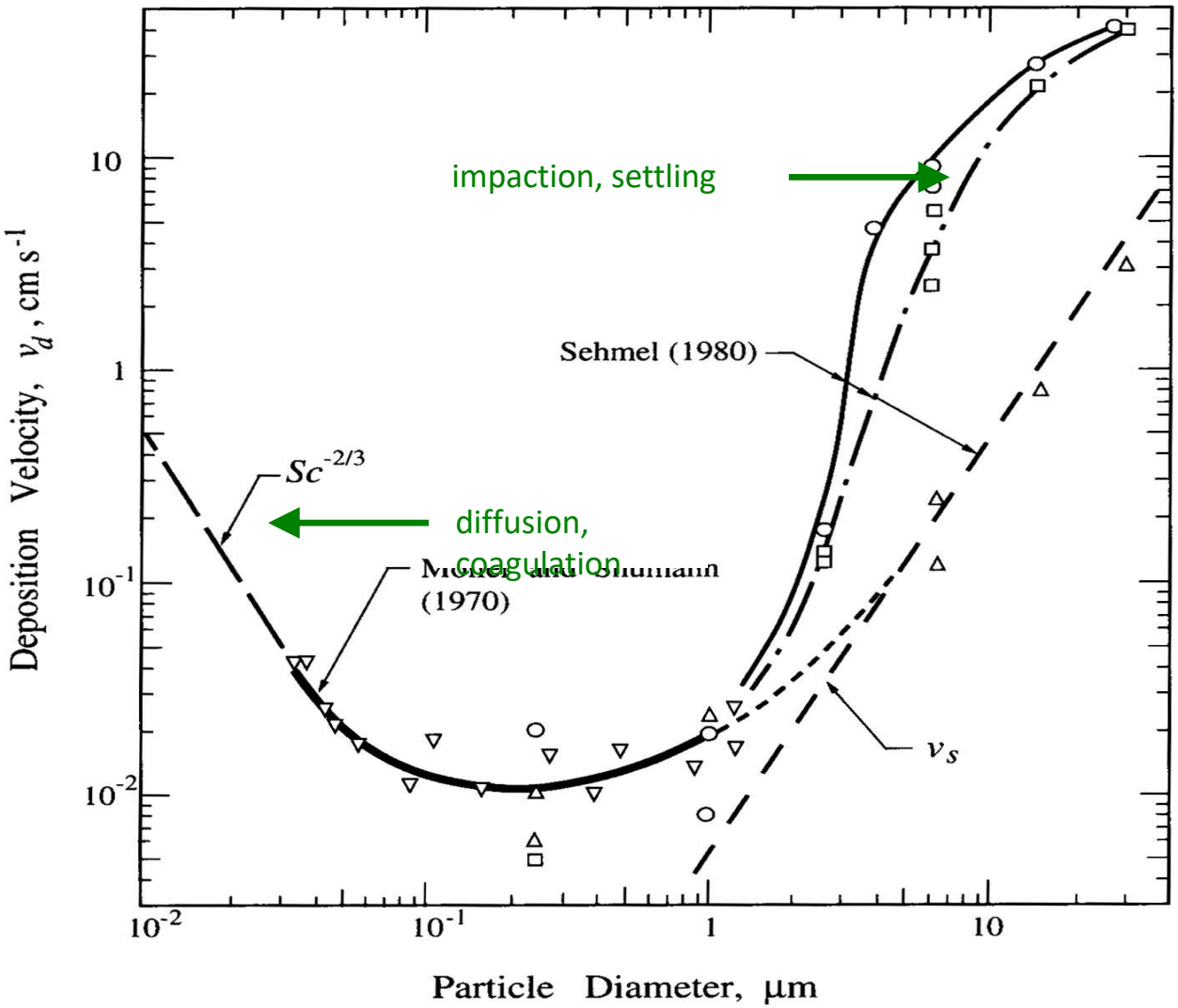
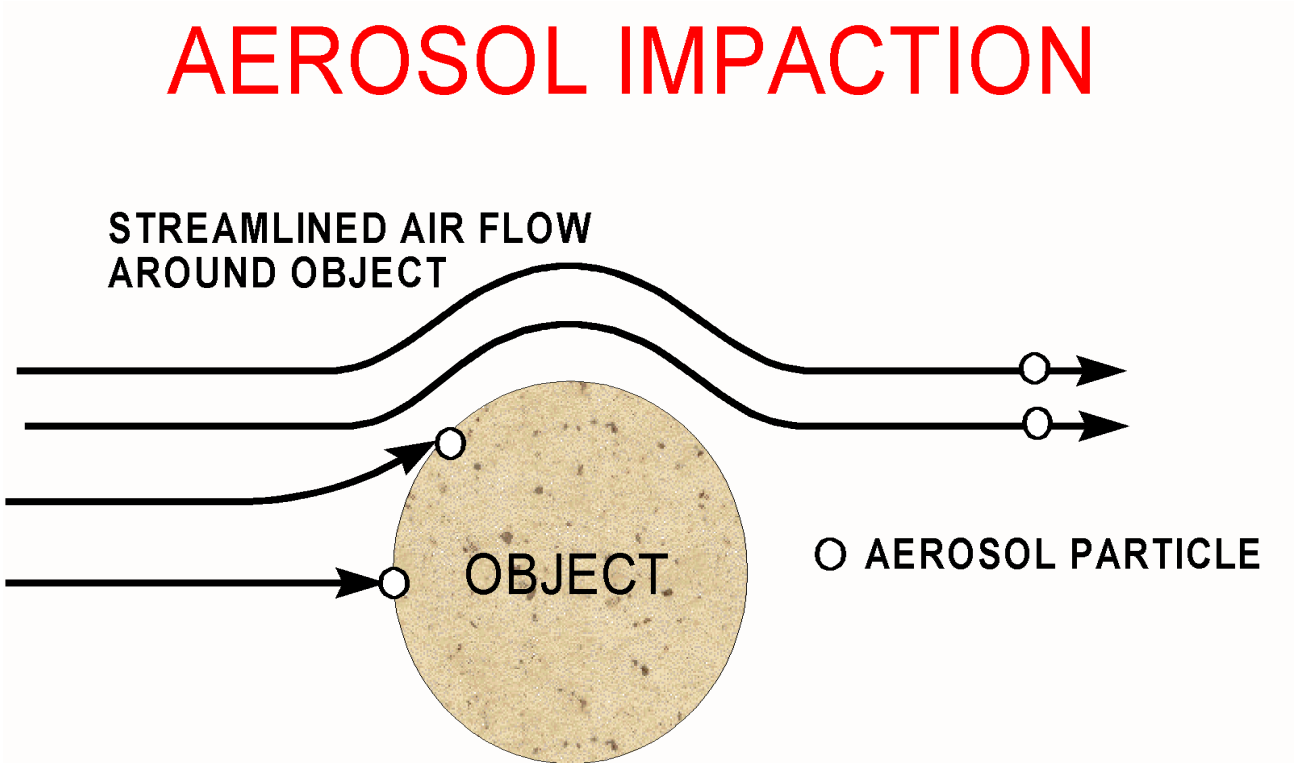
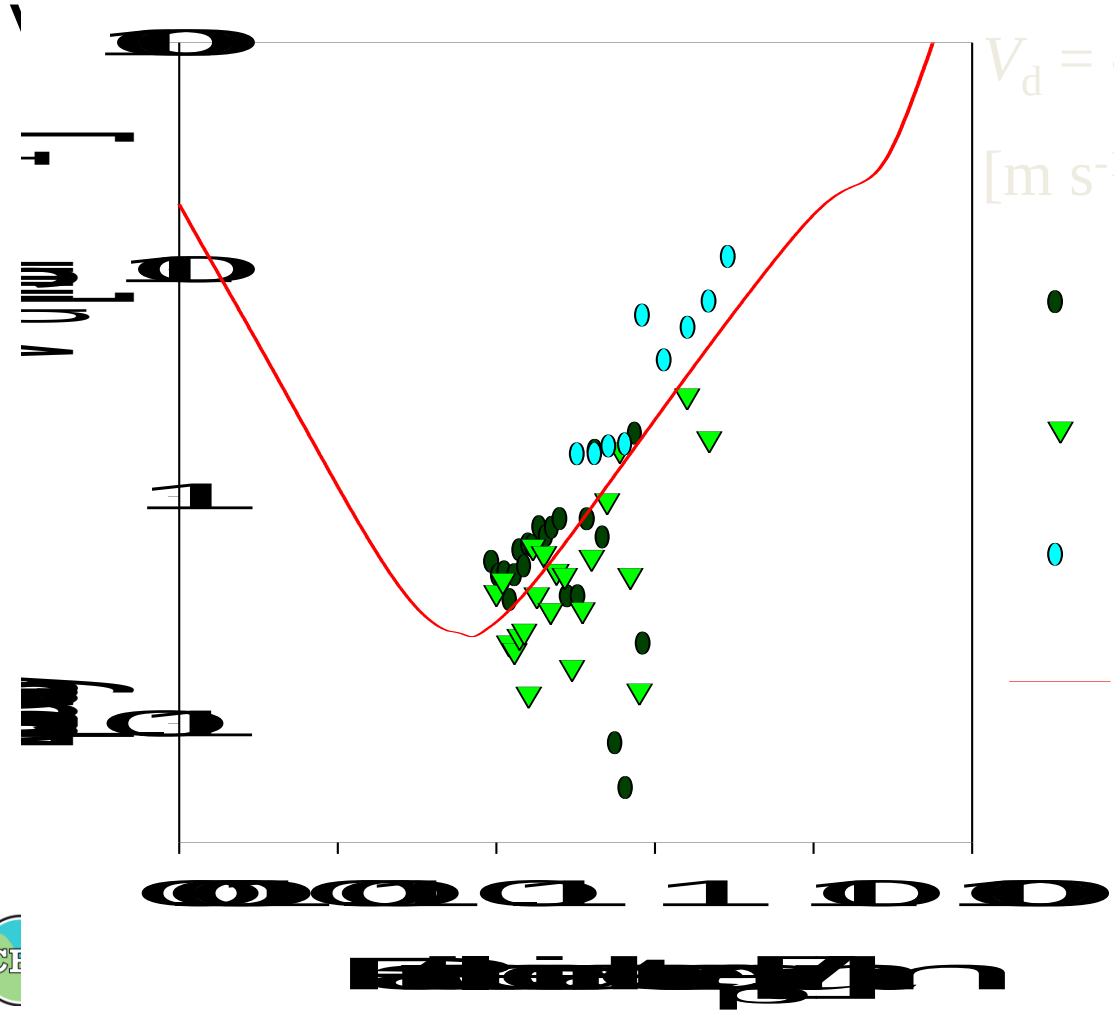


FIGURE 19.3 Particle dry deposition velocity data for deposition on a water surface in a wind tunnel (Slinn et al., 1978).

Particle capture



AEROSOL DEPOSITION VELOCITIES AS A FUNCTION OF SIZE TO MOORLAND



V_d = - flux / concentration

[m s^{-1}] = [# m^{-2} s^{-1}] / [# m^{-3}]

Principles

- Deposition velocities for $PM_{2.5}$ on urban vegetation are not very large (<5 mm s^{-1})for short vegetation and 10 mm $s^{-1}$for mature trees.
- And it is the differential cf building surfaces or short vegetation that matters (a few additional mm s^{-1})
- But the effects depend greatly on particle size

Measurements of fluxes over cities

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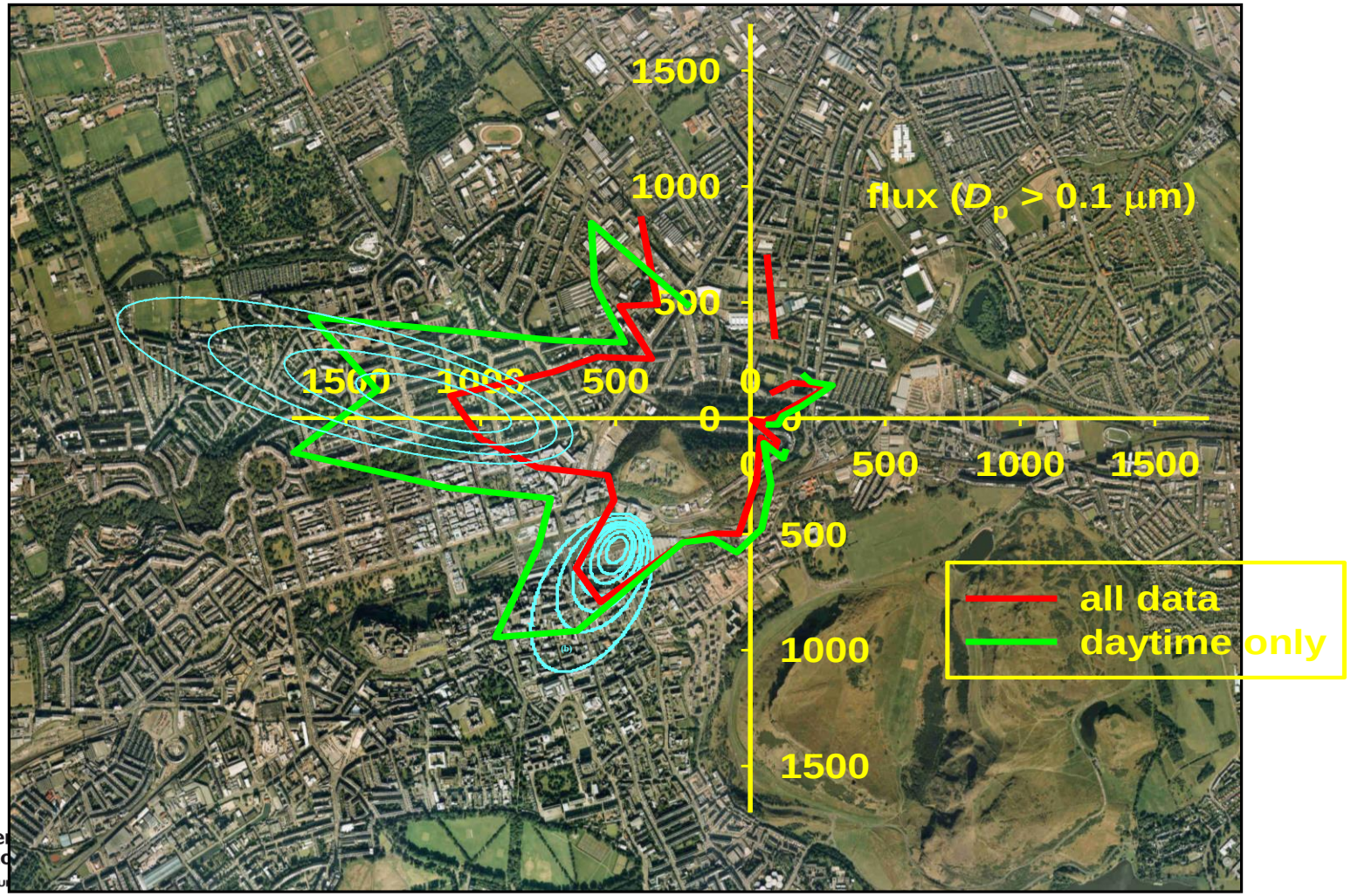

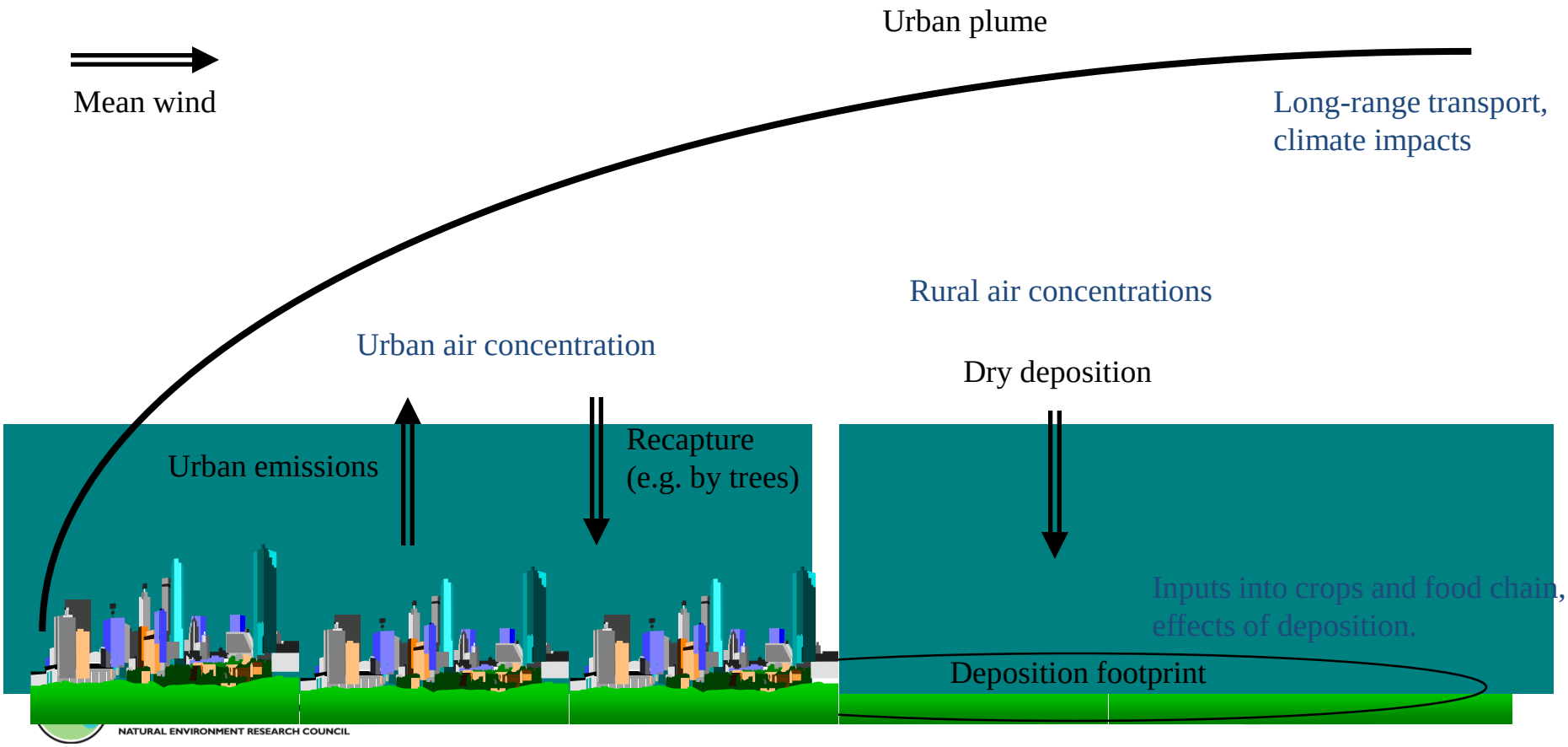
Urban plume
Mean wind
Long-range transport,
climate impacts
Rural air concentrations
Urban air concentration
Dry deposition
Urban emissions
Recapture
(e.g. by trees)
Inputs into crops and food chain,
effects of deposition.
Deposition footprint
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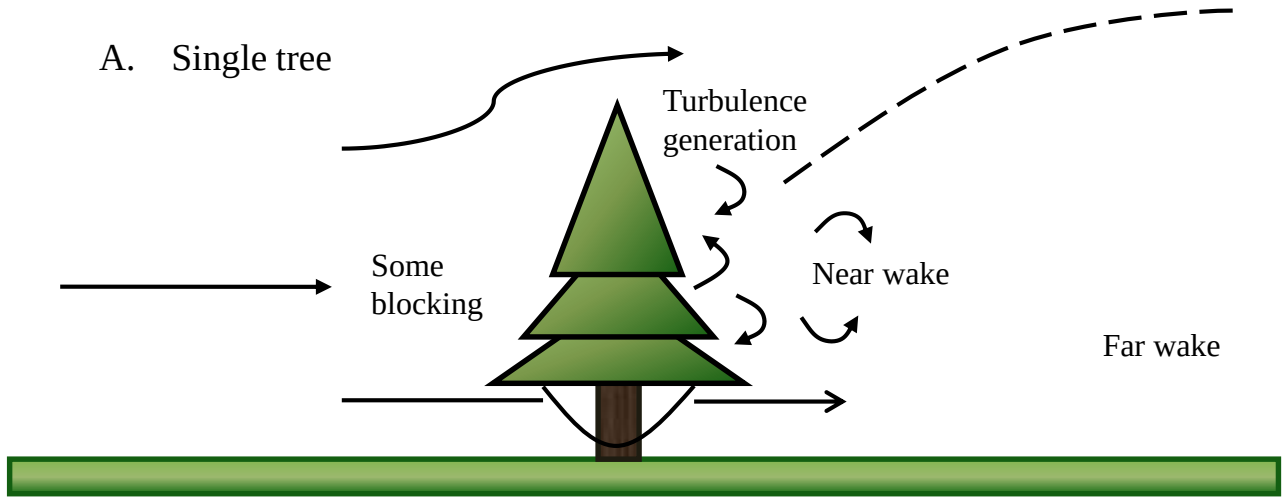
Airflow and Dispersion

1. **Effects of trees on airflow and turbulence.**
2. **Effects of Trees on Dispersion**
3. **Tree Barriers**
4. **Trees within street canyons**


A. Single tree
Turbulence generation
Some blocking
Near wake
Far wake

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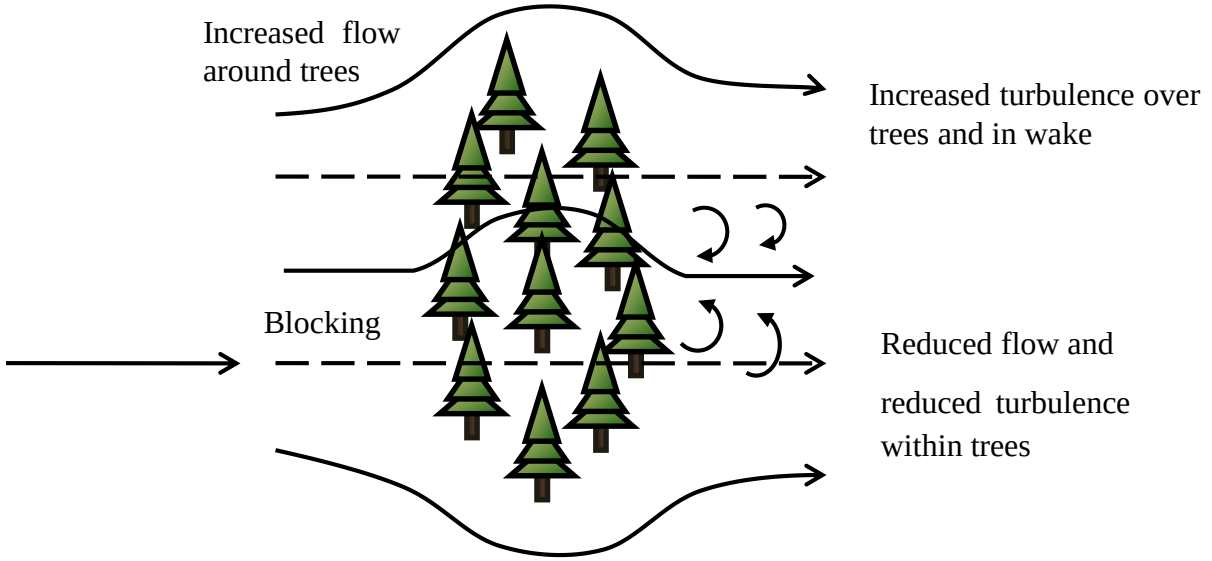
C. Moderate density tree array



Vegetation and dispersion

- Locally (tens to hundreds of square metres) tree planting may enhance or reduce dispersion; this redistributes pollution but does not remove it
- Where vegetation acts as a barrier close to a source, concentrations immediately behind the barrier owing to that source are reduced typically by a factor of about 2 relative to those which would occur without the barrier,
- whereas on the source side of the barrier concentrations are increased.
- Tree planting may also exacerbate the build-up of pollution within street canyons by reducing air-flow

Deposition

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Moseley and Edgbaston Golf Course and woodland

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^{210}Pb INVENTORY METHOD

RADIOACTIVE DECAY → ^{210}Pb PARTICLE → ATTACHED TO ATMOSPHERIC AEROSOLS SO_4^{2-}, NO_3^-, H^+, NH_4^+

↓

WASHED OUT BY PRECIPITATION

↓

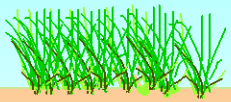
^{210}Pb

↓

ORGANIC MATTER

Dry deposited to terrestrial surfaces

↓



RADON GAS

↑

Soil

$t^{1/2}$ ~ 22 years

Soil should be undisturbed for ~4 half lives

Aerosol deposition rates

	Sutton Park	Edgbaston	Moseley	Average
Grass				
Total dep. (Bq m^{-2} y^{-1})	89	86.3	82.5	
Dry dep.	24	21	17.5	
V_d (mm s^{-1})	**3.8**	**3.3**	**2.8**	**3.3**
Woodland				
Total dep. (Bq m^{-2} y^{-1})	108.9	124.6	132.4	
Dry dep.	44.9	59.6	67.4	
V_d (m s^{-1})	**7**	**9.4**	**10.7**	**9**

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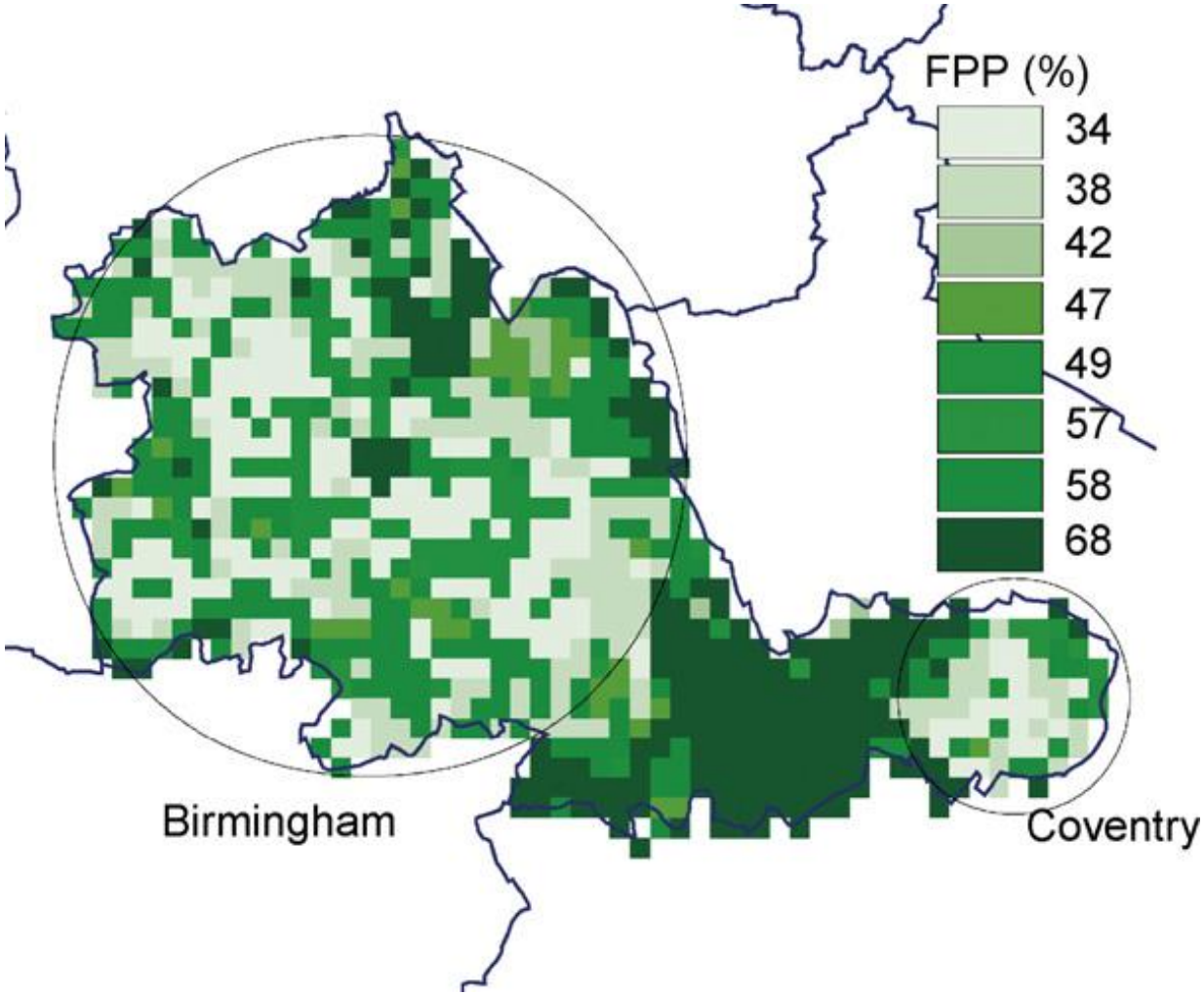
Modelling the effect of tree planting on PM_{10} in the West Midlands conurbation

- dispersion model
- Entire West Midlands conurbation ..Coventry Birmingham
- An extensive survey of vegetation

- FPP……..Future planting potential
- Removal of existing trees
- Planting 25% of available space
- 50%
- 75%
- 100%……..all gardens, parks, verges, green space, sports grounds.

Potential tree planting in the West Midlands



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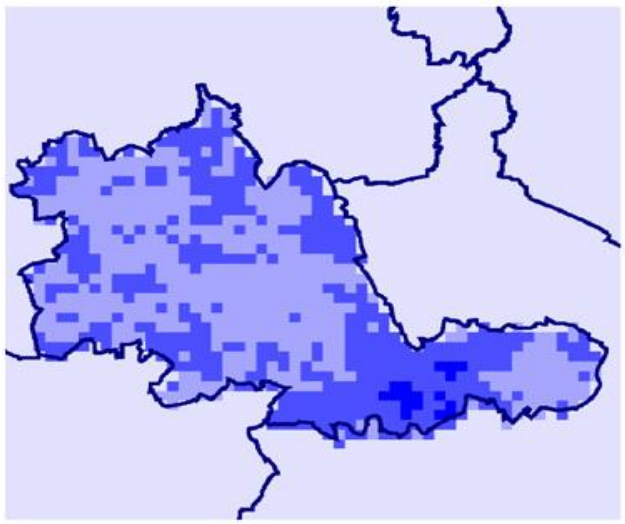
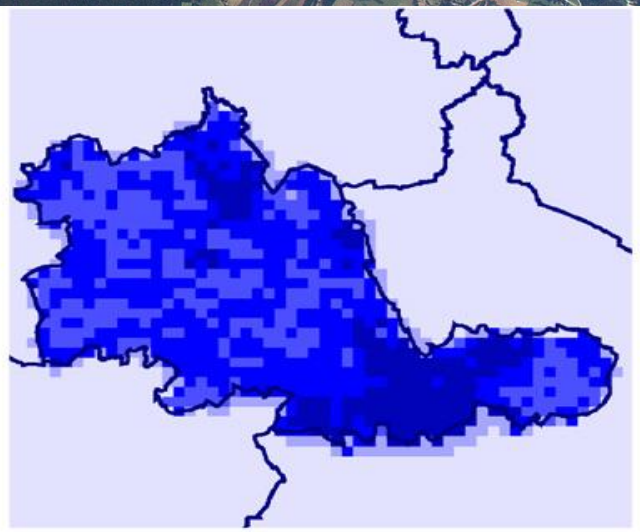
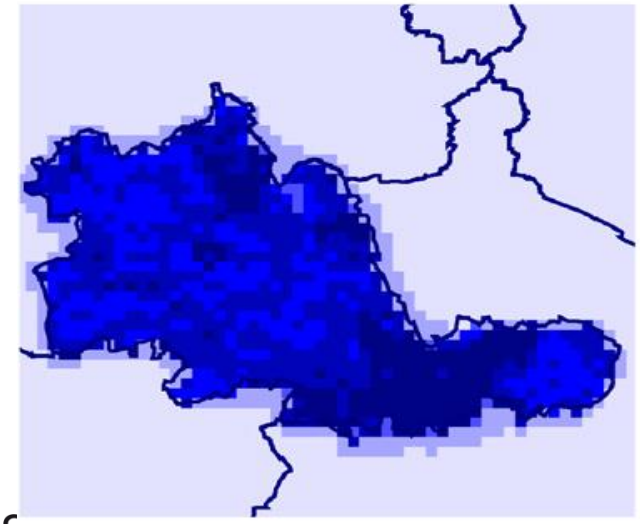
PM_{10} reductions for 4 planting scenarios



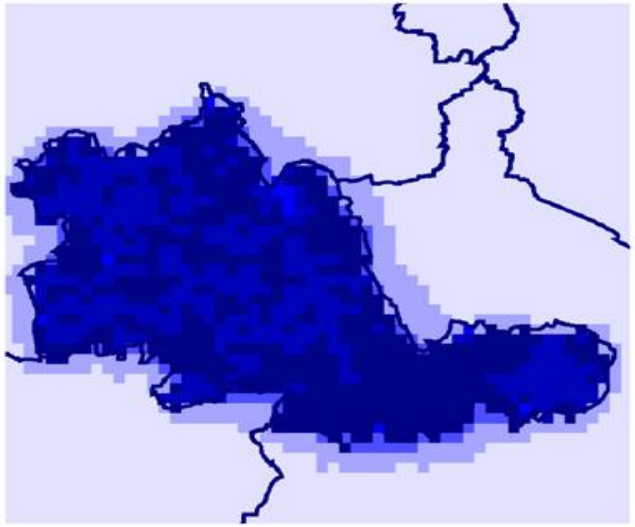
FPP25



FPP50



FPP75



FPP100

Percentage Reductions

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 40

McDonald et al 2007 Atmos Envirn

Modelled concentration and deposition changes due to tree planting for the West Midlands

	Concentration		Deposition	
	Average ug m^{-3} Primary PM_{10}	% change of Primary PM_{10}	Primary PM_{10} tonnes	% change
Status Quo	2.3	n/a	575	n/a
No trees	2.4	4	536	-7
FPP_{25}	2.1	-10	685	19
FPP_{50}	1.9	-17	747	30
FPP_{75}	1.8	-22	773	34
FPP_{100}	1.7	-26	774	35

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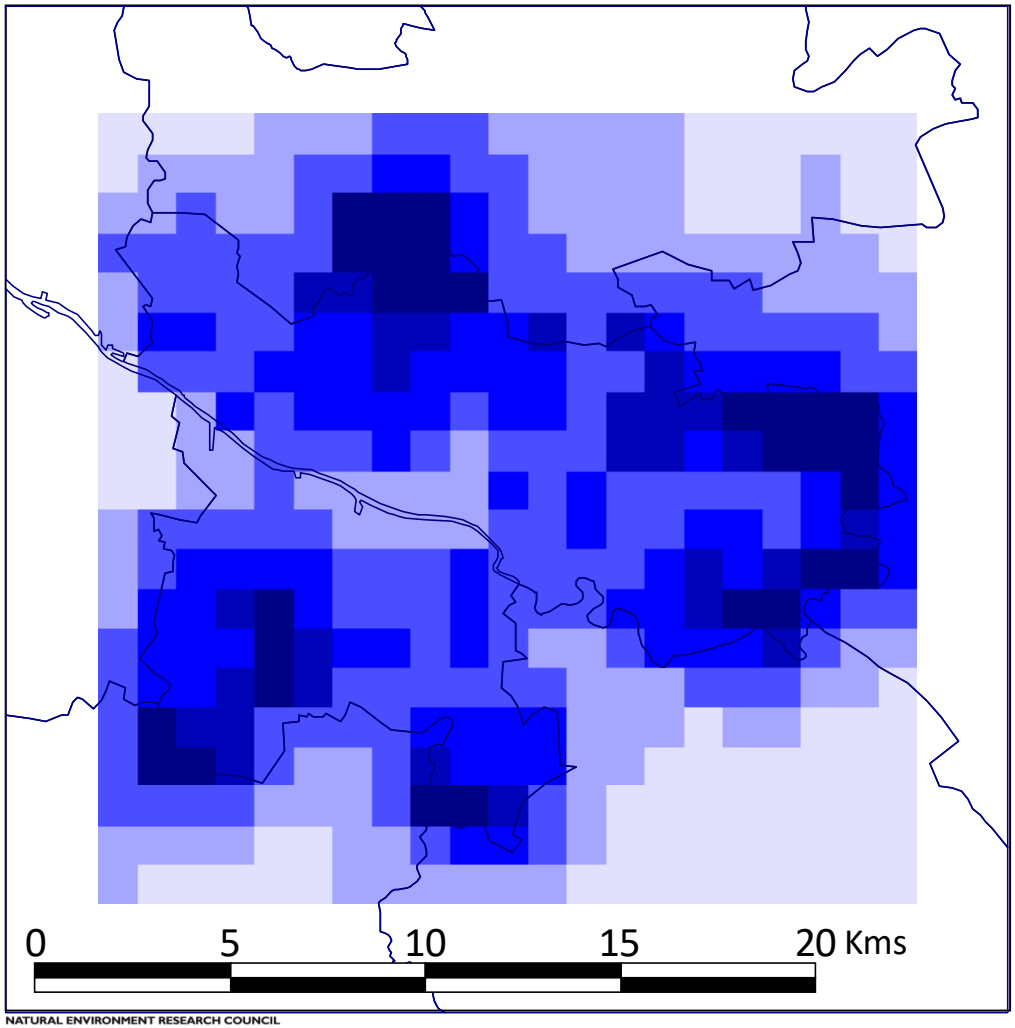
A similar study for Glasgow

Reductions in concentration due to 100% tree planting



Percentage reduction in PM_{10} concentrations

- 0-1 %
- 1-2 %
- 2-5 %
- 5-10 %
- 10-15 %
- 15-30 %

Maximum decrease: 29.4%
Average decrease: 7.7%

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A similar study for Glasgow

- for Glasgow, increasing tree cover from 3.6% to 8% reduces primary PM10 concentrations by 2%
- Increasing tree cover to 21% would reduce primary PM10 air concentrations by 7%, removing 13 ton of primary PM10 per year.

Returning to the AQEG questions

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The questions on vegetation :

- *Is there definitive observational evidence of the effectiveness of urban vegetation in mitigating air pollution?*

Conclusions

- Overall, vegetation and trees in particular are regarded as beneficial for air quality, but they are not a solution to the air quality problems at a city scale.
- it is unlikely that large reductions in concentration (>20% for $PM_{2.5}$) could be achieved using vegetation to enhance deposition over a substantial area.
- For nitrogen dioxide (NO_2), vegetation is, generally speaking, of little benefit; it is not a very efficient sink. The deposition occurs in daytime, and primarily in the warmer months, when NO_2 is less of a problem.

The questions on vegetation :

- *What role does vegetation and its effects on air pollution play in integrated urban planning and policy?*
- *Are the data and models to quantify effects of urban planting schemes on air quality in the major cities of the UK generally available?*

- The use of trees to improve air quality is not without negative impacts as some tree species are important sources of biogenic volatile organic compounds (BVOCs), notably isoprene.
- However, BVOC emissions could be avoided by selecting low emitting species.
- Similarly, the choice of plant species which are known sources of aeroallergens should be avoided.

- Compared with emissions control at source, removing pollutants once diluted into the atmosphere is challenging because of the large volume of air into which the pollutants have been dispersed compared to the surface area to which any potential abatement technology may be applied

- It is important in communicating the potential benefits of vegetation in mitigating urban air pollution problems to provide quantitative estimates, supported by measurement and modelling and their uncertainties, and avoid the campaigning zeal, which is commonly associated with popular publications on the subject.

The report has been published and is available on line

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