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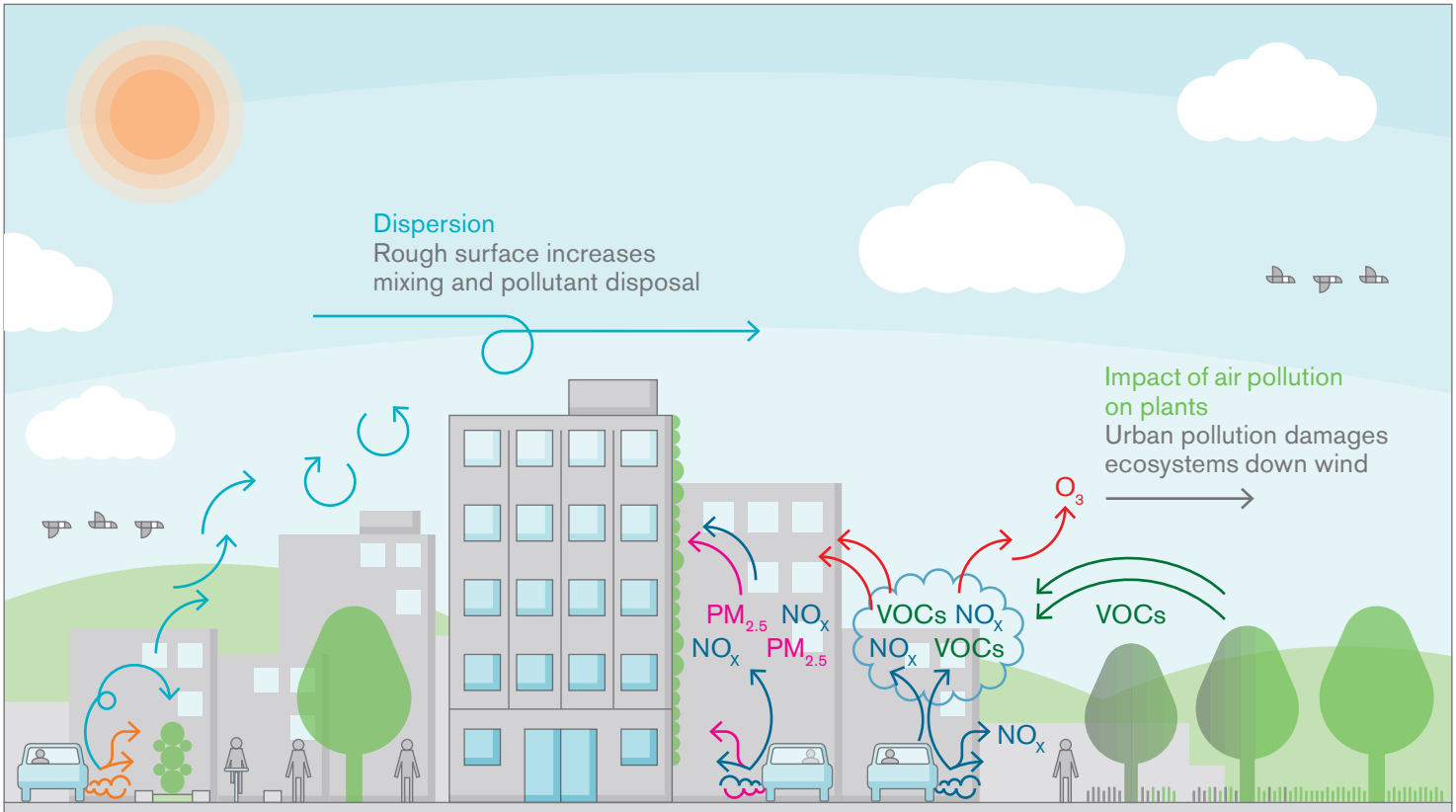
TREES AND URBAN AIR QUALITY: A BRIEFING NOTE

Key messages

1. Trees alone are not the solution to air pollution. They can create a localised positive benefit for air quality by changing the dispersion of pollution, but the amount of pollution deposited onto trees is not significant on an urban scale.
2. Air pollution can damage trees.
3. Emissions of VOCs from trees can, under the correct conditions, create ozone pollution. This is only relevant when creating new woodlands.

A report from the WM-Air project
Contacts: wmair@contacts.bham.ac.uk; https://wm-air.org.uk



Vegetation and particularly trees interact with air quality in three ways; increasing dispersion, deposition of pollutants to vegetation surfaces and emitting VOCs

Trees and urban air quality

Trees can play an important role in addressing many environmental challenges and tree-planting is high on the political agenda in the UK. The total area of UK woodland is estimated to be 3.23 million hectares[1] and all major political parties have set tree-planting targets with the UK government aiming to plant 7,000 hectares of woodlands a year by the end of the current Parliament (May 2024)[2].

Trees can act as a carbon sink and native trees particularly benefit biodiversity, while green spaces can support the physical and mental wellbeing of local residents, provide shade and help regulate temperature. Here we provide an overview of the **impact and benefits of trees on urban air quality** specifically.

Urban air quality

Air quality can be impacted by pollutants which are directly emitted, for example from cars, (e.g. nitrogen dioxide (NO_2) and primary particulates) and pollutants which form in the atmosphere (e.g. ozone and secondary particulates). The impact of air pollution on health depends on the pollutant and the concentration to which an individual or community is exposed.

Air quality in urban environments is determined by the pollution sources present, and the local design and layout of roads, buildings and other features, including vegetation. Air movement within an area, and therefore the movement of air pollutants, is affected by both the weather (e.g. prevailing wind and rainfall), and the physical characteristics of the locality (e.g. building size and density). Vegetation and particularly trees have three main impacts on local air quality: increasing dispersion, deposition of pollutants to vegetation surfaces and emitting volatile organic compounds (VOCs – gases given off by the tree). Action to improve air quality can be summarised in three key concepts: **1. Reduce, 2. Extend and 3. Protect**. Reducing emissions of pollutants is the most effective way of improving air quality. Extending the distance between pollution sources and human receptors allows for dispersion and dilution of pollutants. Finally, protecting vulnerable populations through direct interventions to reduce concentrations at specific sites. Trees and green infrastructure contribute to "extend" and "protect" but have little impact on the source of emissions. **Trees alone cannot address poor urban air quality and must form part of a wider solution addressing pollution sources**.

Dispersion

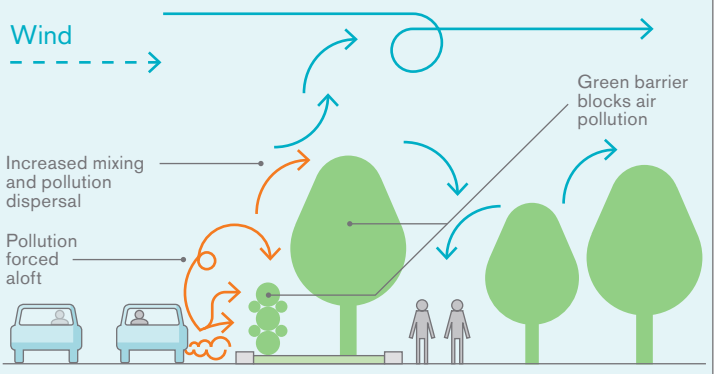
The concentration of directly emitted pollutants is usually highest at the source (e.g. vehicle exhaust or chimney) and falls as the pollutant disperses from this point. Trees can impact the flow of air across a landscape, increasing turbulence and thus diluting pollutants between the emission source and individuals. Where vegetation acts as a barrier close to a pollution source studies have shown that concentrations of pollutants immediately downwind of the barrier, over distances of a few metres, can be reduced by up to a factor of two[3].

However, in street canyons (areas where tall terraced buildings alongside a road form an artificial "canyon") air flow can be limited, resulting in pollutants from traffic becoming trapped. Studies have shown that in these environments tree canopies further limit air flow preventing the release of pollutants into the atmosphere above the canopy. This can lead to increased pollutant concentrations at a street level[3,4].

The impact of planting on dispersion will depend on the species selected and the chosen environment. Careful consideration of local pollution sources and meteorology is necessary to ensure the maximum positive benefit. Tools such as the GI4RAQ platform[5] can aid this decision making.

— Trees can increase the dispersion of pollutants, reducing pollutant concentrations.
— In urban environments the impact of tree canopies on air flow should be considered.

Fig 1. **Dispersion – Increased surface roughness causes pollutants to disperse into the atmosphere**



Increased surface roughness causes pollutants to be dispersed into the atmosphere reducing surface concentrations

References

1. Forest Research: Provisional Woodland Statistics: 2021 Edition. Forest Research, 2021. Accessed 22/07/2021. Available at: https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/woodland-statistics/

2. DEFRA: Press release: Tree planting rates to treble by end of this Parliament, DEFRA 2021. Available at: https://www.gov.uk/government/news/tree-planting-rates-to-treble-by-end-of-this-parliament

3. Air Quality Expert Group: Impacts of Vegetation on Urban Air Pollution. Prepared for the Department for Environment, Food and Rural Affairs; Scottish Government; Welsh Government; and Department of the Environment in Northern Ireland, 2018. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1807251306_180509_Effects_of_vegetation_on_urban_air_pollution_v12_final.pdf

4. Ferranti, E.J.S., MacKenzie, A.R., Levine, J.G., Ashworth K., and Hewitt C.N.: First Steps in Urban Air Quality. Second Edition. A Trees and Design Action Group (TDAG) Guidance Document. UK: London, 2019. Available at: http://epapers.bham.ac.uk/3069/

5. Pearce H., Levine J.G., Cai X. and MacKenzie A.R.: Introducing the Green Infrastructure for Roadside Air Quality (GI4RAQ) Platform: Estimating Site-Specific Changes in the Dispersion of Vehicular Pollution Close to Source. Forests, 12, 769, 2021. GI4RAQ platform available at: https://gi4raq.ac.uk/pages/login

Deposition

Pollutants are removed from the atmosphere through deposition onto surfaces, this is the reason stone buildings turn black and have to be cleaned. This can occur by dry deposition or wet deposition (through rain or snow). Trees and other vegetation greatly increase the surface area of a landscape providing a greater surface onto which deposition can occur[3,4]. Plants have also been shown to take up NO_x directly. However, the rate of deposition is limited by the total volume of air coming into contact with the plant surface. Therefore, simply increasing vegetation cover is likely to have little impact on the concentration of pollutants overall in the local ambient air; as most of it is not coming into direct contact with the leaves.

— The removal of pollution from the atmosphere via deposition on plants is minimal, and is unlikely to make any measurable difference to air quality.

'Vegetation and particularly trees interact with air quality in three ways; increasing dispersion, deposition of pollutants to vegetation surfaces and emitting VOCs.'

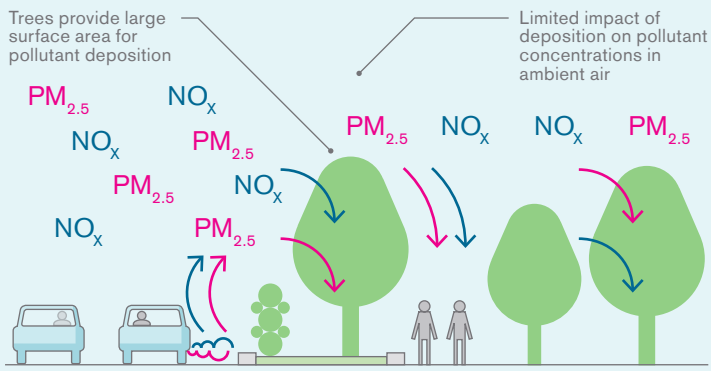
Volatile Organic Compound (VOC) emissions

VOCs are reactive compounds emitted into the atmosphere and are produced by many natural and human-made sources. At a global scale plants are one of the largest sources of these compounds. Vegetation-derived VOCs are not harmful directly, at the levels found in ambient air, but their reactions with other air pollutants (NO_x) form ozone and particles, which are harmful to people and reduce crop yields. Many VOCs emitted by plants are familiar in everyday life e.g. the smell of cut grass or pine and citrus fragrances, but from an air quality perspective isoprene is the most important VOC emitted by trees. Isoprene emission is highly species-dependent with some common native tree species emitting large amounts of isoprene (e.g. oak and poplar) and others (e.g. beech and ash) emitting very little.

In NO_x-polluted urban environments the naturally produced VOCs can react with the human-made pollution to form ozone and particulates. The impact of VOC emission is often felt tens of miles downwind of the source as it takes some time for ozone formation to occur. As isoprene emission is highly species dependent where large scale tree-planting is being considered (changing regional tree production >10%[6]). It may be wise to consider isoprene emission potential when selecting species to be planted in or immediately upwind of urban environments. The isoprene emission potential of tree species can be calculated using tools such as iTree[7] and is widely available in scientific literature[8].

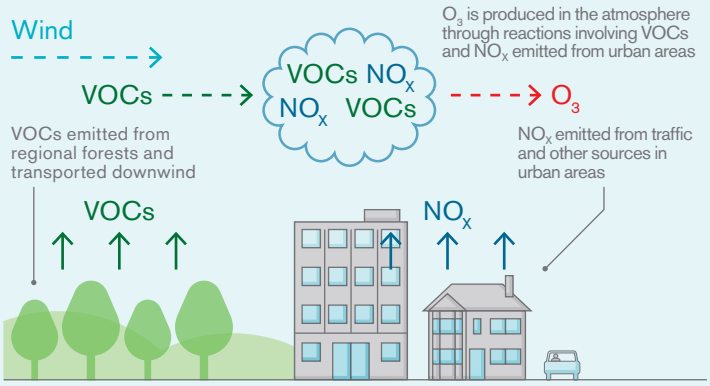
— In NO_x-polluted environments, and upwind of these environments, consider planting low isoprene emitting species when planning mass tree-planting schemes (changing regional tree production >10%).

Fig 2. **Deposition – Pollutants are removed from the atmosphere through deposition to plant surfaces**



Pollutants such as nitrogen oxides (NO_x) and fine particulates ($PM_{2.5}$) can be deposited to plant surfaces

Fig 3. **VOCs – Ozone formation in the lower atmosphere**



Volatile organic compounds (VOCs) released by forests can react with NO_x pollution from vehicles leading to ozone (O_3) formation in the lower atmosphere

References

3. Air Quality Expert Group: Impacts of Vegetation on Urban Air Pollution. Prepared for the Department for Environment, Food and Rural Affairs; Scottish Government; Welsh Government; and Department of the Environment in Northern Ireland, 2018. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1807251306_180509_Effects_of_vegetation_on_urban_air_pollution_v12_final.pdf

4. Ferranti, E.J.S., MacKenzie, A.R., Levine, J.G., Ashworth K., and Hewitt C.N.: First Steps in Urban Air Quality. Second Edition. A Trees and Design Action Group (TDAG) Guidance Document. UK: London, 2019. Available at: http://epapers.bham.ac.uk/3069/

6. Hewitt C.N., Ashworth K. & MacKenzie A.R. Using green infrastructure to improve urban air quality (GI4AQ). Ambio 49, 62–73, 2020.

7. i-Tree Canopy. i-Tree Software Suite v6.0. Web. Accessed 22/07/2021. Available at: http://www.itreetools.org

8. Karl M., Guenther A., Köble R., Leip A. and Seufert G.: A new European plant-specific emission inventory of biogenic volatile organic compounds for use in atmospheric transport models. Biogeosciences, 6, 1059–1087, 2009.

Impact of air pollution on plants

While trees can impact air pollution through dispersion, deposition and emission of VOCs, air pollution can also impact the health of plants and their ecosystems. Exposure to air pollution has three main impacts on plants: direct harm caused by the pollution, disrupting plant signalling and changing the nutrient balance of ecosystems.

Exposure to pollutants can directly damage trees and other plants. Sulfur dioxide and nitrogen oxides can react with water in the atmosphere to form acids. The dry or wet (acid rain) deposition of these acids onto trees and plants can cause significant damage to trees and ecosystems. Gas phase pollutants such as ozone have been shown to directly harm plants causing visible damage and reducing yields[9].

Many plants rely on pollinators for fertilisation. Alongside visual cues pollinators often rely on floral odours to locate flowers. These floral odours are made up of VOCs which can react with ozone and other pollutants in the atmosphere disrupting, changing and degrading these floral odours. A recent study demonstrated that in field studies exposure to ozone and diesel fumes reduced flower visits by pollinators by 83-90%[10].

The deposition of nitrogen, especially in nitrogen poor ecosystems, can change the nutrient balance of ecosystems reducing plant species richness. In wetlands this nitrogen fertilisation can lead to eutrophication, where increased nutrients lead to algal blooms which deplete dissolved oxygen leading to the loss of aquatic plants and animals.

— Air pollution can damage ecosystems and reduce crop yields.

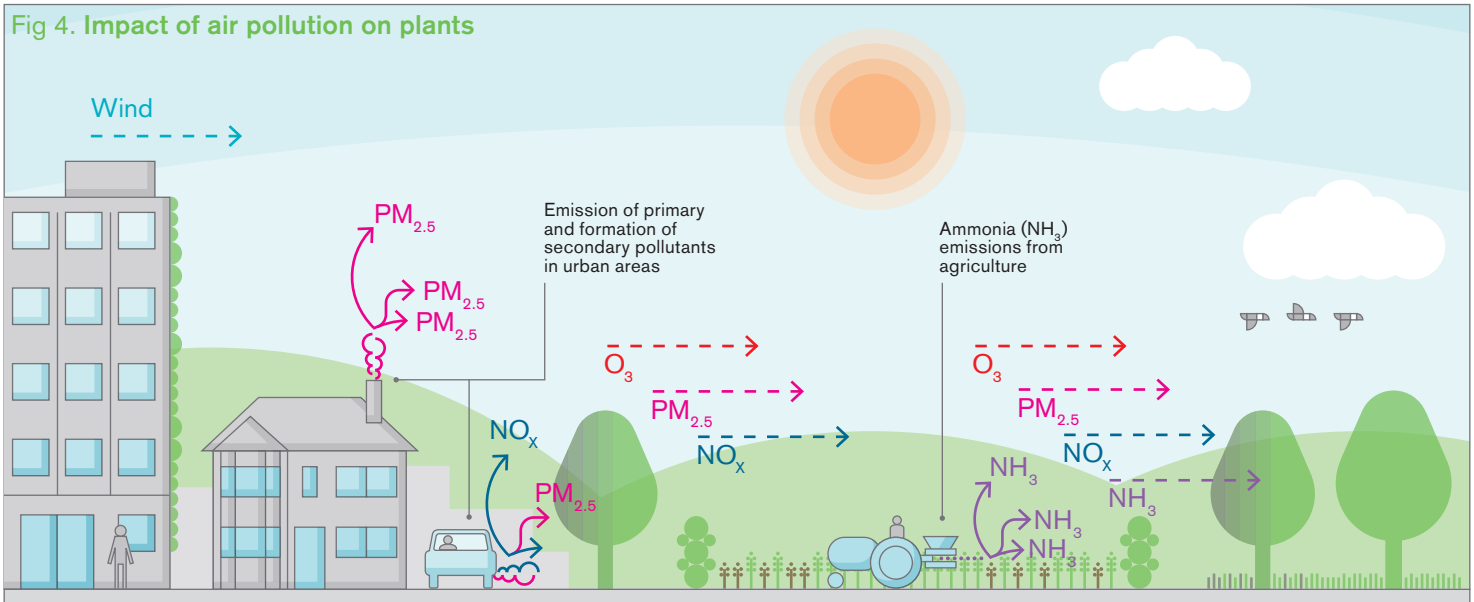
NEXT STEPS

Trees and green infrastructure can have a positive impact on air quality. However, if improving air quality is the primary policy objective then reducing the source of emissions should be prioritised. When considering the impact of tree planting on air quality it's important to ask the following questions:

Your Assessment Checklist

- What is the problem you are trying to fix?
- If it's local air pollution, can the point source be reduced before you consider planting?
- If you believe planting will help, what will be the best location and form to address your local concerns?
- Are you looking for dispersion or deposition from the vegetation?
- At what scale do you wish to plant? If planting on a large scale then do you need to consider the VOC's production and species choice?
- Once planted, what can you justifiably claim to be the main impacts of your planting?

Fig 4. **Impact of air pollution on plants**



Urban areas
Direct damage to plants through exposure to pollutants

Agriculture
Reduced crop yields caused by poor air quality

Natural environment
Nutrient balance of ecosystem changed by nitrogen deposition

Air pollution can directly harm plants, reduce crop yields and disrupt ecosystems downwind of the pollution source

References

9. Stevens, C.J., Bell, J.N.B., Brimblecombe, P., Clark, C.M., Dise, N.B., Fowler, D., Lovett, G.M. and Wolseley, P.A.: The impact of air pollution on terrestrial managed and natural vegetation. Phil. Trans. R. Soc. A 378: 20190317, 2020.

10. Ryalls, J.M.W., Langford, B., Mullinger, N.J., Bromfield, L.M., Nemitz, E., Pfrang, C. and Girling, R.D.: Anthropogenic air pollutants reduce insect-mediated pollination services. Environmental Pollution, 297, 118847, 2022.