# 4 Services provided by nature

4.1 This section provides evidence about the different services provided by nature. Specific services may be of interest to different policy makers and practitioners, so you may choose to focus just on those. Alternatively, you may be interested in overarching themes such as economic competitiveness, so **Chapter 2** and **Chapter 3** may be useful in identifying how the environment contributes to those themes.

4.2 It is important to note that not all services provided by nature are included here. The ones chosen are the ones which on the basis of current evidence are most important in the context of environmental projects. The ones selected are also those for which we have available scientific and economic evidence.

# 4a Air quality

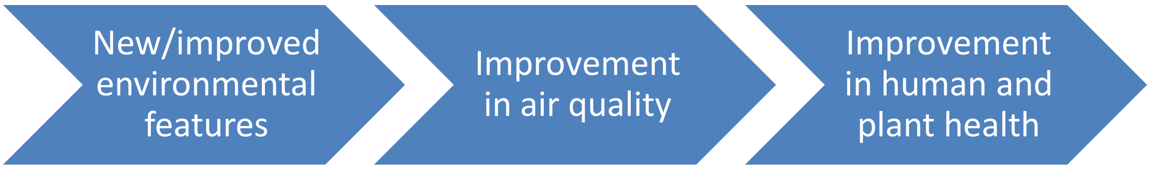
*Air quality issues can pose significant risks to human and plant health. There is strong evidence that vegetation, particularly trees, can contribute to air quality improvements.*

## Introduction

4.3 This section reviews the evidence that the natural environment can improve air quality. There is a clear link with Section 4l **Temperature regulation**, because some air quality problems are worse at high temperatures. Although air quality has improved, this trend is flattening or even reversing in some locations (Tiwary, Sinnett et al. 2009). It remains a significant problem, particularly in urban areas.

4.4 Air quality has important implications for human and plant health, and also affects the provision of a wide range of other ecosystem services.

## Theory of change




## Can the benefit be quantified?

4.5 Yes, the relationships can be quantified but the exact effects will be influenced by local contextual factors. Therefore modeling relies on reasonable average assumptions.

## How strong is the evidence?

4.6 Research has shown a strong link between vegetation and air pollution, but the strength of the effect depends importantly on the vegetation type and the context. The evidence presented illustrates the links between the first two links in the theory of change, and then the second two. Very few studies link all three parts of the theory of change, with Tiwary, Sinnett et al (2009) being an exception. However, it is highly plausible to expect that an improvement in air quality caused by the natural environment would result in an improvement in human, plant and/or ecosystem health.

**Evidence of environmental features affecting air quality**

- Saebo, Popek et al. (2012) found that in field trials of common European trees and shrubs there was a strong correlation between PM accumulation, leaf hair density and waxiness of the leaves. There were 10-20 fold differences in the level of accumulation between species. The most effective PM accumulating species were found to be mountain pine, silver birch, stephanandra, skimmia, grey willow and Scots pine (Saebo, Popek et al. 2012) [37].
- Modeling of removal of pollution by trees across the urban areas of the United States estimated that they remove 711,000 tonnes of pollution from the air per year. This could be increased through increasing the density of tree cover – with 100% tree cover (i.e completely forested) providing 16% improvement in short term levels of ozone ($0_3$) and sulphur dioxide

[37] What is not clear from this study is exactly how much PM is removed over a given time period, as the study sampled leaves only once each year, and examined the PM on the leaf at that point in time.

($SO_2$), 9% for nitrogen dioxide ($NO_2$) and 8% of particulate matter ($PM_{10}$) (Nowak, Crane et al. 2006)[38].

- A study in Chicago found that 19.8 hectares of green roofs (predominantly extensive, rather than intensive roofs) removed 1675kg of air pollutants, including 52% $O_3$, 27% $NO_2$, 14% $PM_{10}$ and 7% $SO_2$ over the space of a year (Yang, Yu et al. 2008)[39]. This averages out at around 85kg per hectare of green roof per year. Similarly, Speak and colleagues found that 50 hectares of extensive sedum green roof in Manchester city centre could remove 0.21 tonnes of PM per year (Speak, Rothwell et al. 2012). They also found that alternative grass species could remove over three times more PM than the common sedum varieties used.
- Green walls were found to potentially reduce the concentration of $NO_2$ and PM in city streets surrounded by high rise buildings by as much as 15% and 23% respectively, and to be even more effective at low wind speeds. They were also found to be more effective than green roofs in street canyons due to the nature of air flows in the street (Pugh, MacKenzie et al. 2012)[40].
- Some trees release Volatile Organic Compounds, which can contribute to the production of $O_3$. However, they also intercept ultraviolet light, reduce temperature through shading and remove pollutants when they are deposited on tree surfaces. A modeling study from the North East of the United States found that urban forests will on balance reduce $O_3$ pollution (Nowak, Civerolo et al. 2000)[41].

**Evidence of air quality affecting human health**

- Within high income countries, 2.5 percent of all deaths are estimated to be attributable to urban outdoor air pollution, specifically particulate matter (PM). This is due to PM causing an increased risk of cardiopulmonary conditions, respiratory infections and lung cancer (World Health Organization 2009)[42]. There is also growing evidence linking air pollution with pre-term births, reduced birth weight, lowered immune response and the development of conditions such as asthma in children (European Environment Agency 2013).
- Modeling found that 547 ha. of mixed greenspace within a 10 x 10 km square of East London (i.e. 5% of 100 square kilometres) could significantly reduce pollution with an estimated effect of two deaths and two hospital admissions avoided per year (Tiwary, Sinnett et al. 2009)[43].

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[38] $0_3$, $PM_{10}$, $NO_2$ and $SO_2$ and $CO_2$ were modeled and Hawaii and Alaska were excluded. Due to the assumptions made the figures are offered as a first order approximation. It is important to note that although the figures sound large they were typically only 1% air quality improvements during the day time during the in-leaf season. The US wide modeling shows the strongest benefits for areas with long in-leaf seasons and low rainfall – rather different circumstances to the UK.

[39] Extensive green roofs are relatively shallow and support mostly grasses, whilst intensive green roofs have deeper soils and can support small shrubs. The authors note that the values produced should be taken as approximations only, due to uncertainty surrounding some of the assumptions used.

[40] This study was produced using the atmospheric chemistry model CiTTyCAT, and includes a range of assumptions including local wind speeds and deposition rates to vegetation. Results should therefore be taken as suggestive of the likely benefits, but not as definitive results as they are not based on scientific observations.

[41] The modeling exercise is necessarily built on simplified assumptions, but is detailed and carried in a peer-referenced journal. Although there are important differences, the climate of the North East United States is in many ways similar to that of the UK.

[42] Predominantly countries in western Europe, including the UK. For a full list of countries, see WHO 2009. The estimate does not include those who are chronically ill due to air pollution, nor does it include the impacts of air pollutants other than PM.

[43] The modeling assumed that 75% of its green area was grassland, 20% Sycamore maple and 5% Douglas fir. It should be noted that a study comparing the method used in Tiwary et al 2009 and an alternative pollution flux method found that the Tiwary method produced results that were 2.5 times higher than the alternative method – for details see Tallis, M., G. Taylor, et al. (2011). "Estimating the removal of atmospheric particulate pollution by the

- A major piece of research on the Global Burden of Disease for the World Health Organization found that in 2010, there were 48,016 deaths in the UK attributed to air pollution. By comparison, there were 52,490 attributed to physical inactivity, and 18,833 attributed to alcohol and drug use (Murray, Vos et al. 2012)[44].
- The Department for Environment, Food and Rural Affairs estimates that air pollution (specifically PM) reduces the average life expectancy by 6 months and that this equates to a value of between £8.6 and £18.6 million per year, with a central estimate of around £16.4 million per year. This includes the amount people would be willing to pay to avoid the reduction in life expectancy, and the cost of additional hospital admissions (Department for Environment Food and Rural Affairs 2010)[45].

### Evidence of air quality affecting plant and ecosystem health

- Air pollution can also impact on plant health and agricultural productivity. Evidence suggests that ozone pollution is a particular problem, with detrimental effects observed across Europe in most years. Within the Greater Thessaloniki area in Greece, crop losses due to ozone pollution were estimated at €42.5 million in 2002 (approximately £35 million), with particularly affected crops being cotton, spring wheat, sunflower, lettuce and tomatoes (Vlachokostas, Nastis et al. 2010)[46].
- In the UK, wheat crop losses due to ozone pollution were estimated at £90 million in 2000 (7 per cent of national wheat production), with East Anglia being most affected. For potatoes, the loss was estimated at £12 million (2 per cent of national potato production), with southwest England and Northern Ireland being most affected (RoTAP 2012)[47].
- Nitrogen deposition due to air pollution can increase crop growth, however it may also lead to plant nutrient imbalances and increased susceptibility to disease or pest attack (RoTAP 2012)
- Acid rain caused by sulphur dioxide and nitrogen dioxide emissions has been a major environmental problem for UK inland waters, however the situation is now improving (Kernan, Battarbee et al. 2010).
- Changes in soil acidity and chemical composition due to air pollution can have far-ranging effects on ecosystem services such as climate regulation, nutrient cycling, biodiversity support and regulation of water quality and quantity (RoTAP 2012).
- Nitrogen deposition has resulted in loss of plant diversity in sensitive priority habitats for conservation. By 2020 it is estimated that 48 per cent of the UK’s sensitive habitats will exceed critical loads for nitrogen deposition (RoTAP 2012).

## Link with climate change

- Higher temperatures lead to an earlier start and an increase in length and intensity of the pollen season (D'Amato and Cecchi 2008). They also lead to increased pollutant levels, increased long distance transportation of pollutants, and increased heavy precipitation events (which are associated with significant increased asthma) (D'Amato and Cecchi 2008).

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urban tree canopy of London, under current and future environments." Landscape and Urban Planning **103**: 129-138.

[44] The authors note that there are many uncertainties associated with these estimates. They estimate a 95% probability that the actual number of deaths attributed to air pollution in 2010 lies somewhere between 38,507 and 58,608 (approximately +/- 10,000 deaths).

[45] Notice that this is an average figure so some communities will be affected much more strongly than others.

[46] The economic loss has been estimated as the value of the reduced yield, at producer prices. The authors note that this is a simplistic approach which does not account for the impact on consumers, nor the potential for farmers to adapt and change their crop composition to more ozone resistant crops.

[47] This particular analysis is subject to a range of uncertainties, including the difference in ozone tolerance between different crop cultivars, and the extent to which the quantity of lost production may be offset by higher ozone levels contributing to improvements in grain quality.

- Ground-level ozone pollution is worse at higher temperatures due to increased chemical reactions leading to its formation (US Environmental Protection Agency 2003). With constant emissions levels this can be expected to lead to increased illness and premature deaths (Ebi and McGregor 2009).
- However, warming temperatures could also lead to reduced susceptibility to upper respiratory infections due to warmer winters (D'Amato and Cecchi 2008).

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