Ecosystem services: air pollution mitigation

Purpose

The objective of the mapping is:

- to apportion a relative value across mainland Cornwall corresponding to landscape's contribution to the removal of air pollution under existing conditions;
- to apportion a relative value across mainland Cornwall indicting the potential air pollution benefits of woodland or heathland creation.

Background

Poor air quality is estimated to result in 40,000 (+/-25%) equivalent attributable deaths in the UK every year and is a major cause of morbidity (RCPCH 2020). It also negatively affects habitat function and species survival. Although some atmospheric pollutants have reduced over recent years, particulate matter (PM10 and PM2.5) and ozone remain a considerable concern (Jones et al 2017).

Among those pollutants most regularly monitored and modelled, PM2.5 is widely considered the most harmful (COMPEAP 2010) with no recognized safe level and has been estimated to account for nearly 90% of the estimated monetary value of air pollutant filtration by vegetation results in the UK even though this pollutant accounts for less than 2% of the physical volume of pollution removed from the atmosphere (Jones et al 2017). Most PM2.5 is man-made, and is emitted during the combustion of solid and liquid fuels, such as from diesel and petrol cars, power plants and domestic heating. PM2.5 includes the aerosol fraction that derives from NH3 and is the most damaging component of PM10.

Vegetation provides an air quality regulating service (UKNEA, 2011) by capturing airborne pollutants and removing them from the atmosphere. Although Cornwall has relatively low air pollution compared with many urban regions of the United Kingdom, model estimates of the amount of pollution removed by vegetation (kg/ha) (ONS 2019), found that Cornwall and Isles of Scilly was the second UK highest region (66kg/ha compared with lowest region of Tower Hamlets at 2kg/ha) due to high vegetative cover and relatively high background levels due to pollutant transport from mainland Europe.

Key factors that can determine the value of the air quality regulation service provided by vegetation are:

- **Ambient air quality:** vegetation will remove more pollutant in those areas with the highest levels of pollution;
- **The amount and type of vegetation:** the capacity of vegetation to remove pollutants is generally associated with the total biomass and the canopy area and structure. In general, woodland removes far more pollutants per hectare than other kinds of natural or semi-natural habitat.
- **Meteorology:** wind speed and, to a lesser extent, precipitation play a significant role in moderating the deposition velocity at any point in time;
- **Pollutant transport:** the health benefits resulting from pollutant removal can be experienced in a different location to where the removal happens. For example, a large forested area upwind of London might provide substantial pollutant removal, thereby lowering the background levels of pollution that people in London are exposed to. This 'transported benefit' is not captured in static assessment methods.

Methodology

General approach

The approach estimates the quantity of PM2.5 removed by vegetation on a grid cell basis by assigning a deposition velocity to each habitat type that is further moderated by wind speed. PM2.5 is considered indicative of the overall level of air pollutants damaging to health.

This approach can represent the relative ***quantity*** of pollutant removed by each vegetation type. The approach does not consider atmospheric transport and so cannot assign a relative ***value*** to the amount of pollutant removed as it does identify the locations where the benefits of improved air quality are realised.

To assess the locations where the benefits of improved air quality are realised would require dynamic modelling (such as the EMEP4UK model) to estimate the change in pollutant concentration as well as the quantity of pollutant removed by each vegetation type. Whereas this approach has been applied to assign total benefit values to different vegetation types (Jones et al 2017) it is not readily applied to detailed spatial mapping.

Air pollution data

Information from two modelled sources of pollution data were used (see figure 1):

Pollution Climate Mapping Model outputs – a methodology based on the UK Pollution Climate Mapping (PCM) approach, was used to model the annual mean background and roadside concentrations for the UK as a whole and provide 1 x 1 km background maps of NOx, NO2, PM10 and PM2.5 levels for the years 2008 – 2019 (Defra 2019). The mapping does not capture the transport of pollution from remote sources such as Europe.

EMEP4UK dynamic modelling outputs- the EMEP4UK atmospheric chemistry and transport model (Vieno et al. 2007, 2015, Simpson et al 2012) generates pollutant concentrations directly from emissions, and dynamically calculates pollutant transport and deposition. In the EMEP4UK model, PM2.5 concentrations from both primary and secondary sources are calculated from primary industrial and agricultural emissions of precursor compounds within the UK and the import of precursors from abroad. The change in pollutant concentration at a location is an outcome of vegetation and meteorology-pollutant interactions that have occurred in the parcel of air before reaching that location. Model outputs were used to capture the transport of pollution precursors from outside of the county of Cornwall, in particular Northern Europe.

Air pollution removal by vegetation

Dry deposition is the removal mechanism for trace materials (gases as well as particles) carried by the wind and is considered the primary mechanism by which vegetation will mitigate air pollutants. A strong positive correlation exists between dry deposition velocity and wind speed. Higher the wind speed, higher is the friction velocity which accelerates transport of particulate matter (Mohan 2016).

The relative amount of pollution removed for each grid cell is therefore considered a function of:

i. Mean wind speed: estimated at 100 metre resolution after accounting for topographical shelter effects (Maclean et al 2019).
ii. Land cover: deposition velocities reported from theoretical models and field observations for particles <10um diameter typically vary by three to six-fold between woodland and grassland (e.g. Pistocchi et al 2006, Marner & Harrison 2004). Values in Jones et al (2017) are derived from national accounting and so reflect differences in the meteorological conditions associated with those habitats as well as vegetative factors, so these are adapted for use. Table 1 describes the deposition values assigned to different land cover types.
iii. Pollutant concentrations: derived from estimates of background levels and yearly pollutant concentrations from dynamic modelling (as described above)

Table 1: Relative deposition velocity values by habitat type used for the relative estimation of air pollution removal in mainland Cornwall.

Habitat / Land cover	Deposition velocity
Broadleaf woodland	4
Coniferous woodland	5
Heath/Moor	2
Wetland	2
Grassland (semi-natural and improved)	1
Arable	0.6
Water, Rock	0.5

Types of map

Map of the **air pollution mitigation value** of each cell is calculated from the product of wind speed, existing land cover and pollutant concentrations, and is used to provide a relative air pollution mitigation service ecosystem value across Cornwall (figure 2a).

For use in the creation of habitat opportunity maps, the potential air pollution mitigation service that could be provided is equated to the product of wind speed and pollutant concentrations (figure 2 b).

For mapping purposes both existing and potential mitigation values are normalised to a range between 0 and 100.

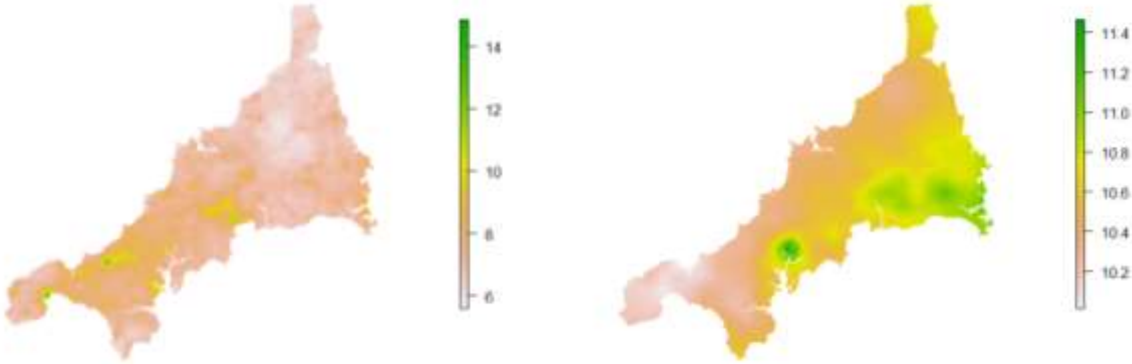

Figure 1: Air pollution (P2.5 μg m^{-3}) concentrations from background levels (left) and dynamic modelling outputs (right) – different scaling for each figure.

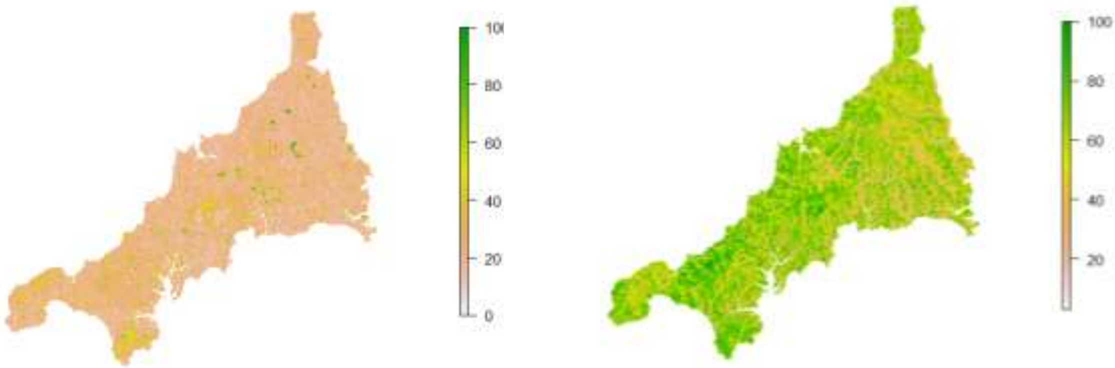

Figure 2: Relative values of a) existing (left) and b) potential (right) air pollution mitigation.

Uses and Applications

- **Maps are indicative of variation in the relative amount of P2.5 air pollution likely to be removed by vegetation.**
- **The maps are subject to a high level of uncertainty** that in part reflects the continued disparity observed between model predictions and field observations, particularly for heavily vegetated canopies (Hicks et al 2016).
- **Spatial variation only reflects variation in the amount of pollution removed** not variation in the 'benefit' realised.
- High variation in the amount of pollutants removed by different tree species has been reported.
- No account of vegetative shelter is made in the use of wind speeds, only topographical shelter.
- The effect of the temporal variation of many factors, such as seasonal fluctuation of both canopy and air pollution levels, has not been captured in the methods
- Other meteorological factors such as precipitation and temperature. Uptake by vegetation through stomatal deposition is a strong function of temperature, humidity, and sunlight.

References

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Data sources – use and copyright

Data used in the creation of this and the other ecosystem service maps on Lagas are listed here.