COLLABORATION FOR ENVIRONMENTAL EVIDENCE

Systematic reviews for conservation and environmental management

CONTEXT

In cities, climate change may increase human exposure to high temperatures (including heat waves), **ground-level ozone and ultra-violet even more than in surrounding countryside. Could this be mitigated by greening urban areas (increasing the abundance and cover of vegetation)?**

*This question was addressed by a **systematic review** of the accessible scientific referenced and grey literature. The systematic review takes into account the quality of the research and possible biases, in order to provide a rigorous, transparent, replicable and updatable review of the scientific evidence .*

From the CEE Library

GREENING CITIES TO MITIGATE IMPACTS of CLIMATE CHANGE

POLICY BRIEF from Systematic Review
CEE 08-004

FINDINGS

On average, a park is 1°C cooler than a built-up area

Many factors can moderate this difference, such as the park size, proportion of paved areas, wind, irrigation, season and latitude, weather and surroundings.

3 studies report that the cooling effect extended beyond the boundaries of the park or trees, further studies are needed to confirm this result.

Attempts to use **greening to reduce ground-level Ozone must take into account possible counter-effects due to biogenic emissions of Volatile Organic Compounds** by some tree species.

There are too few studies on the impact of greening on UV penetration to report any reliable conclusion.

RECOMMENDATIONS

The diversity of methodologies and parameters measured across studies limits the potential for synthesis of findings.

To improve the evidence-base, standardised methodologies should be encouraged, with the recording of many parameters like temperature/ wind/humidity/shade… as long time-series measurements in a variety of green spaces and at different distances from them.

Funded by NATURAL ENGLAND

Conducted by CEBC

Methodology

What was studied?
Temperature, ground-level Ozone (O_3) and UV

What was compared?
The above parameters were compared between:
-an urban "green" area (park/green space, isolated or clustered trees, or ground vegetation) and an urban "non-green" area, either in the vicinity (<500m from the green area), or in another part of the city.
- a portion of roof that has been greened vs its non – greened counterpart.

What was measured?
The difference in temperature, O_3, and UV between the above comparators.
Methods used to measure the parameters were: remote sensing, modelling and direct ground-level data collection.

Protocol of the systematic review :

1. Accessible referenced and grey literature were **searched for to obtain the largest number** of articles addressing the question (based on their titles and abstract).
2. Articles relevant to the question were **appraised** according to the **quality of the methodology** (experimental design) **and the likelihood of biases, in order to take this into account when drawing conclusions.**
3. When included studies contained enough data of the same parameter (e.g. means and variance), a **meta-analysis** was conducted and provided a quantitative synthesis.
4. When this was not possible, a **narrative synthesis** was provided. Because they are based on fewer or more diverse studies, conclusions based on narrative synthesis must be examined with caution.

RESULTS

212 relevant studies were obtained.

No study reported measurements made before/after the creation of a green area. Most studies were thus observational rather than experimental (the exceptions being those on green roofs).

Methods of synthesis

TEMPERATURE ➡ META-ANALYSIS + NARRATIVE

OZONE ➡ NARRATIVE only

UV ➡ NARRATIVE only

OZONE O_3 (+its precursor VOC "Volatile Organic Compounds" and Nitrogen Oxides)

Single plants (7 studies)

All plants absorb O_3 and emit VOC in highly variable quantities. Causes of these variations are unclear. One study found that deciduous trees seem to absorb more O_3 than evergreens on a short term basis, but the leaves may not resist high O_3 concentrations long term, which would put a time-limit to absorption. Another study reported that emissions varied according to temperature and light. One study found that stress affects VOC emission, but with different results according to species. Two studies reported that rates of emission may be directly correlated to leaf development (thus higher during the period of the year corresponding to active growth).

Green areas (10 studies)

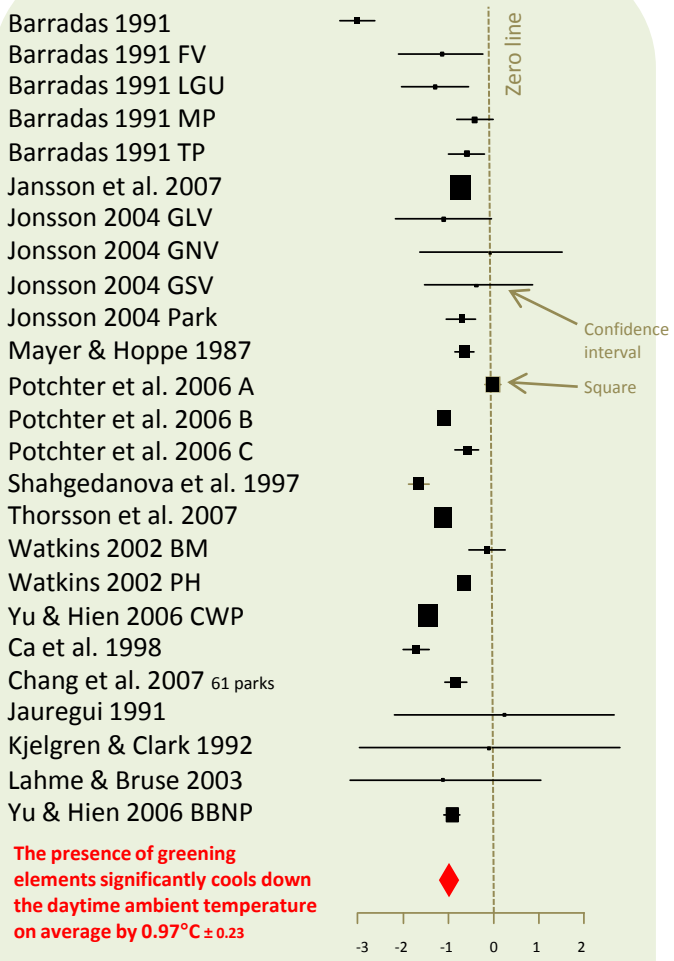
The overall **impact of green areas on ozone levels is unclear because they, in turn, are affected by traffic emission levels (7 studies)**. High levels of pollution in cities increase emissions of Nitrous Oxide (NO) which recombines with O_3 and thus decreases the level of ozone. Thus, it is possible to observe higher levels of O_3 in green areas when they are less affected by high levels of traffic emission.

ULTRA-VIOLET (3 studies , 1 model + a review with data)

Trees may limit UV penetration but the effectiveness is not directly correlated to the amount of shade (measured in most studies). Penetrance may be influenced by the permeability of the canopy (% sky visible) and by variation in leaf reflectance, but this parameter is rarely measured.

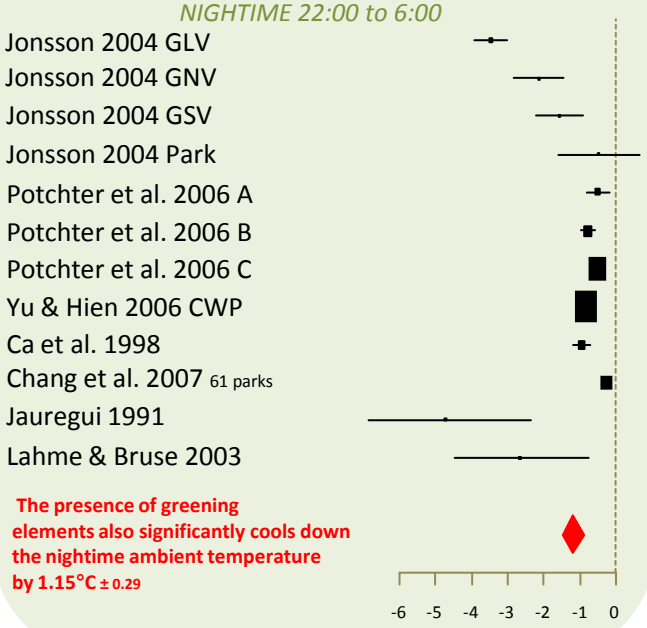
TEMPERATURE IN PARKS

DAYTIME 6:00 to 20:00



The presence of greening elements significantly cools down the daytime ambient temperature on average by 0.97°C ± 0.23

NIGHTIME 22:00 to 6:00



The presence of greening elements also significantly cools down the nightime ambient temperature by 1.15°C ± 0.29

Understanding the figures

- Each square ■ represents the standardised mean difference in temperature observed during the study.
- The zero line represents a null difference (no effect).
- The size of a square reflects the weight given to each study according to the size of the study sample (larger= result more reliable).
- The horizontal lines represent the 95% confidence interval (variability) around the means.

Interpreting the figures

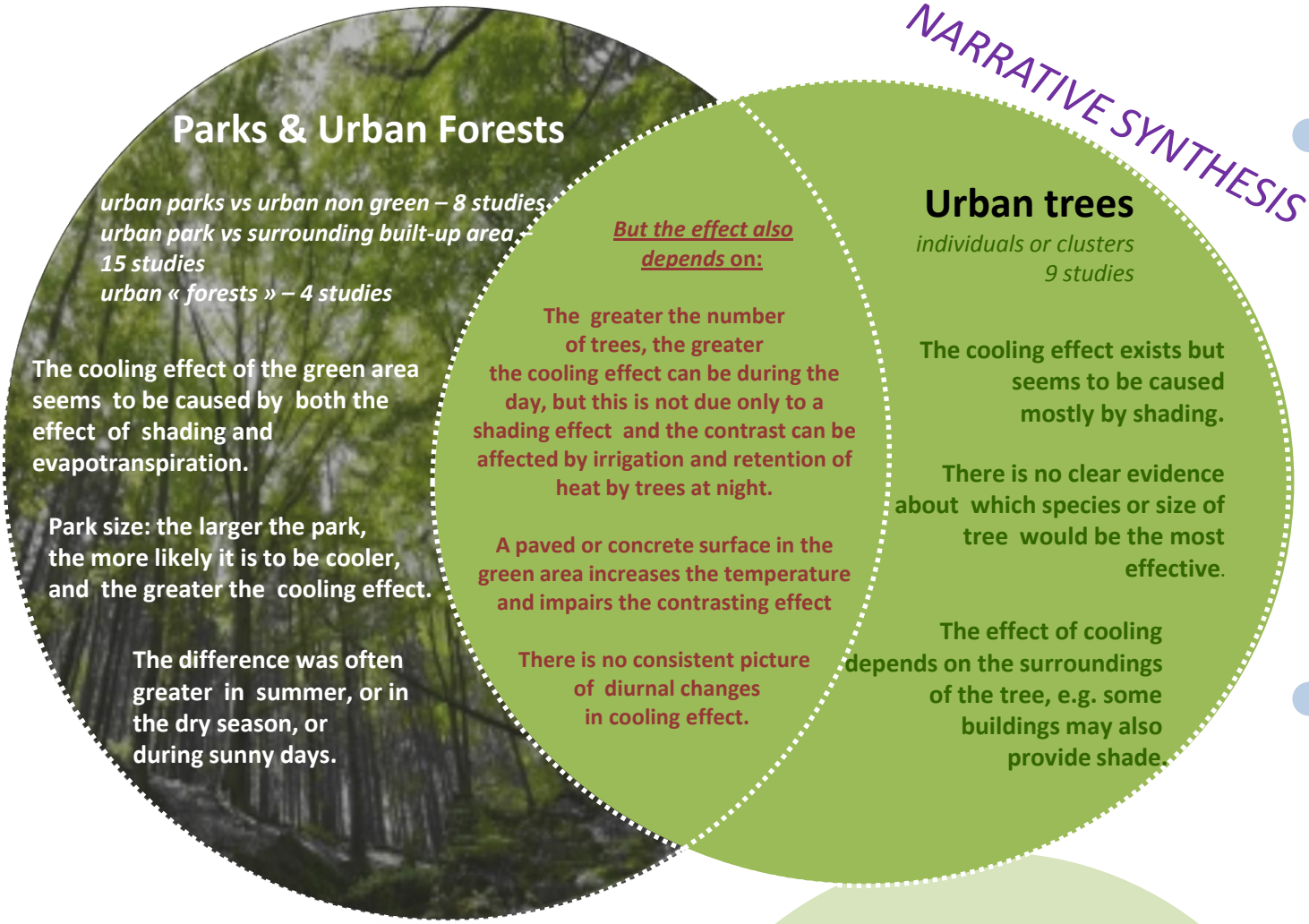
Most of the squares are on the left side of the zero line, which means that the results consistently show a decrease in temperature in the parks compared to non green areas. But there is variability in these results (indicated by the confidence interval), so that the average effect ♦ shows evidence of a somewhat small cooling effect (about 1°C).

The large number of studies enabled exploration of the reasons for variation in study findings, such as the effect of **park size; study type** (park/within 500m-surroundings vs park/urban-site-elsewhere) ; **data availability in article** (all data versus subset of data); **control for shade/sun between sites** (controlled vs not mentioned); **temperate versus tropical** (18 zones studied) , but none of these explained the observed variation, when analysed using meta-regression or sub-group analysis .

There were however, some indications that **the cooling effect extended beyond the physical boundaries of the park itself**, in that the contrast in temperatures at night was smaller in studies comparing the difference between a park and its surroundings (usually within 500 m) (mean difference= 0.65°C ±0.22) than in studies where the temperature of the park was compared with an urban site elsewhere in the city (mean difference= 2.26°C ±1.12). There was also some indication that **the night-time cooling effect was greater in parks in the tropical zone (Mean difference= 1.61°C ± 0.60) compared to those in the temperate zones (Mean difference= 0.70°C ± 0.25).** However many of these data come from a limited number of studies and are often not independent thus these results will need to be confirmed by further research.

The research included in this review covered a diversity of contexts and methods. None of the studies mentioned on the following page reported data that could be used in a meta-analysis and their findings are therefore only presented as a narrative synthesis.
This narrative synthesis differs from a traditional literature review because it benefits from the previous steps (systematic and explicit search, objective and transparent application of inclusion criteria) of a systematic review as set out in the systematic review protocol (for more details read the full Review (references on the last page), or refer to the CEE Guidelines (www.environmentalevidence.org/Authors.htm).

NARRATIVE SYNTHESIS



Parks & Urban Forests

urban parks vs urban non green – 8 studies
urban park vs surrounding built-up area – 15 studies
urban « forests » – 4 studies

The cooling effect of the green area seems to be caused by both the effect of shading and evapotranspiration.

Park size: the larger the park, the more likely it is to be cooler, and the greater the cooling effect.

The difference was often greater in summer, or in the dry season, or during sunny days.

But the effect also depends on:

The greater the number of trees, the greater the cooling effect can be during the day, but this is not due only to a shading effect and the contrast can be affected by irrigation and retention of heat by trees at night.

A paved or concrete surface in the green area increases the temperature and impairs the contrasting effect

There is no consistent picture of diurnal changes in cooling effect.

Urban trees

individuals or clusters
9 studies

The cooling effect exists but seems to be caused mostly by shading.

There is no clear evidence about which species or size of tree would be the most effective.

The effect of cooling depends on the surroundings of the tree, e.g. some buildings may also provide shade.

Green Roofs

(6 experimental studies)

The results are inconclusive for air temperature, but are suggestive that the surface temperature could be cooler than that of non-green roofs.

Ground Vegetation

(6 experimental studies)

Air temperature seems cooler above a green surface than a concrete surface and measuring surface temperature showed that grass was cooler than urban surfaces (concrete, asphalt)

Proportion of Vegetation Coverage

(10 observational studies)

These studies were variable in terms of methodology, nature of site and type of vegetation. None of them reported a minimum amount of vegetation coverage required to obtain a cooling effect, although negative correlations were observed between the percentage of coverage and the cooling effect.

Factors such as wind speed, cloud cover, rainfall or solar radiations affected this correlation.

MORE INFORMATION …

About this review: Bowler, D., Buyung-Ali, L., Knight, T., Pullin, A.S., 2010. How effective is 'greening' of urban areas in reducing human exposure to ground level ozone concentrations, UV exposure and the 'urban heat island effect'? *Environmental Evidence (ref CEE 08-004)*
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