Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

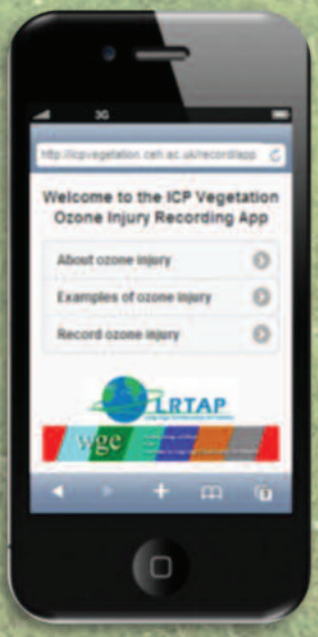
LRTAP
Long-range Transboundary Air Pollution



Have you seen these ozone injury symptoms?



If you have, let us know using our new smart-phone App and website
http://icpvegetation.ceh.ac.uk

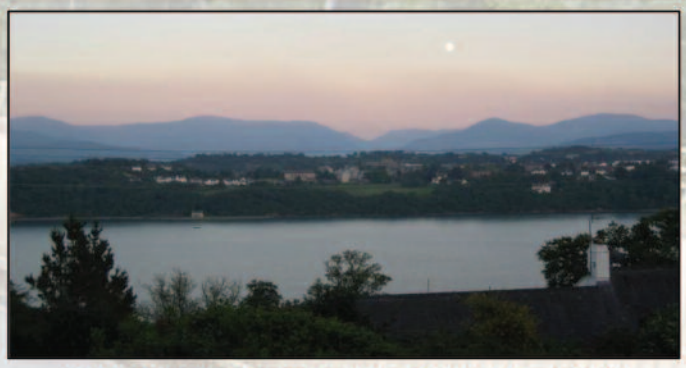


wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

Ozone pollution

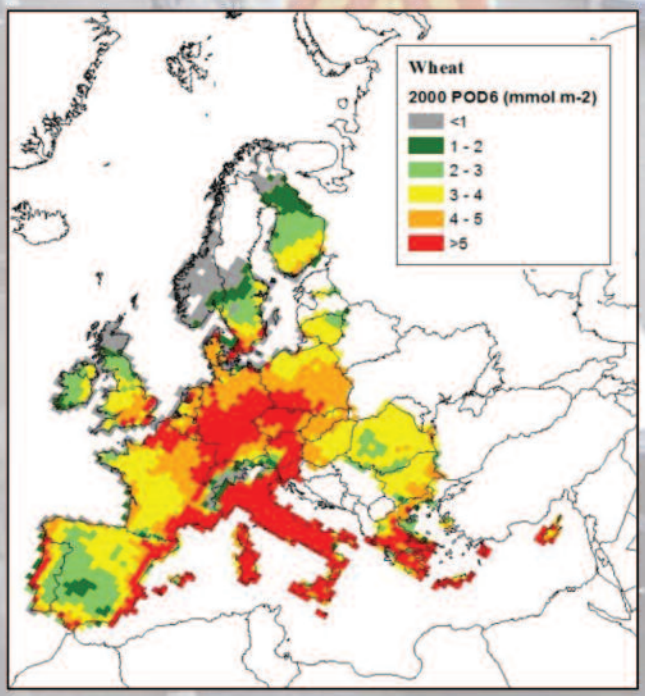
Ozone is a naturally occurring chemical and is present in the upper layer of the Earth's atmosphere, protecting us from harmful UV light from the sun. At ground-level, there is always a background concentration of ozone. In addition, more ozone is being formed from chemical reactions involving compounds emitted as a result of man's activities, for example, from vehicle exhausts and industry.

Industrial emissions, Castellon, Spain



Smog containing ozone over Snowdonia, Wales

At ground level, ozone is a damaging pollutant that can have negative effects on human health and the environment. Ozone concentrations tend to be highest in rural and upland areas, particularly downwind of major cities. The concentration of ozone is also strongly influenced by the weather, being higher on warm, dry sunny days. These conditions can lead to "ozone episodes" where concentrations peak at high levels for several days.



Map. Risk of adverse effects of ozone on wheat yield based on the ozone uptake by wheat in 2000.*

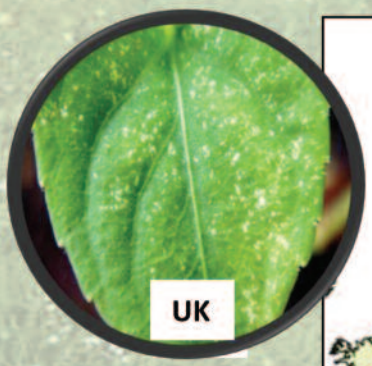
* Assumes adequate soil water supply

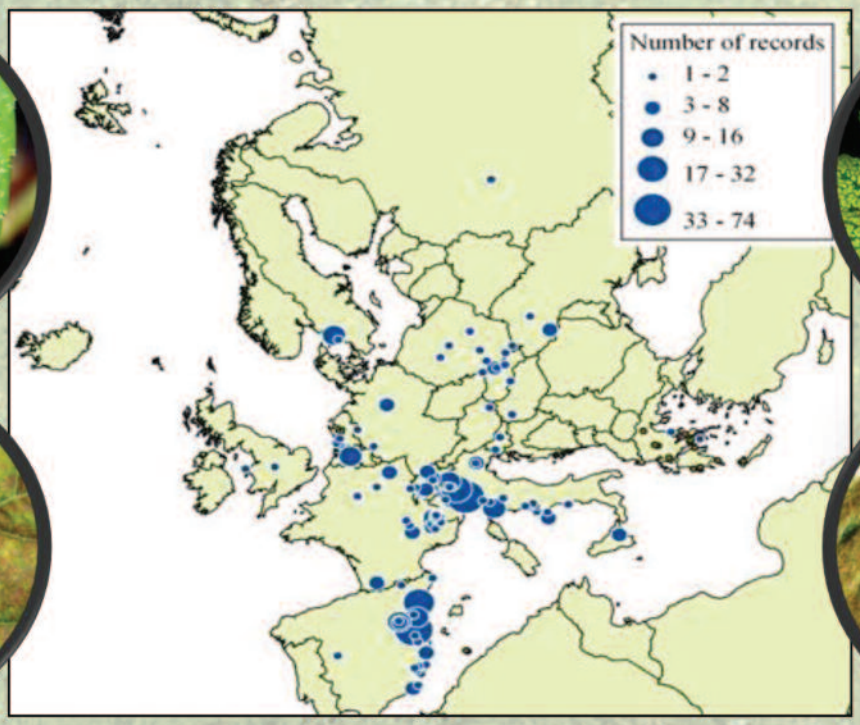
Ozone concentrations vary across Europe, being generally higher in the south. However, negative effects on vegetation are also found in central and northern Europe, where ozone concentrations are lower but climatic conditions lead to increased uptake of ozone by plants (see map).

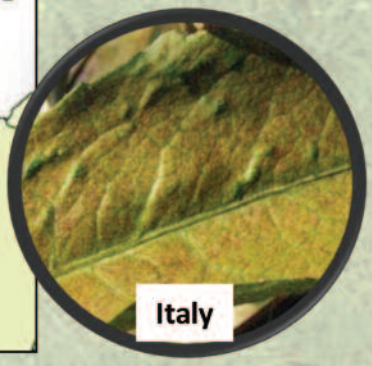
Ozone damage to vegetation

Ozone can be damaging to vegetation both at background levels and during ozone episodes. Negative effects include visible leaf injury, decreased growth and reductions in both yield quality and quantity. Ozone pollution does not result in a residue on the leaves, therefore visible leaf injury is the most easily detectable evidence of damage.

Over 30 species of crops, 90 species of grasses and forbs, and 80 species of trees and shrubs have been recorded as damaged by ozone in Europe. Between 1990 - 2006, the number of records of visible injury on crops, shrubs and (semi-)natural vegetation from 16 European countries exceeded 600 (see map).







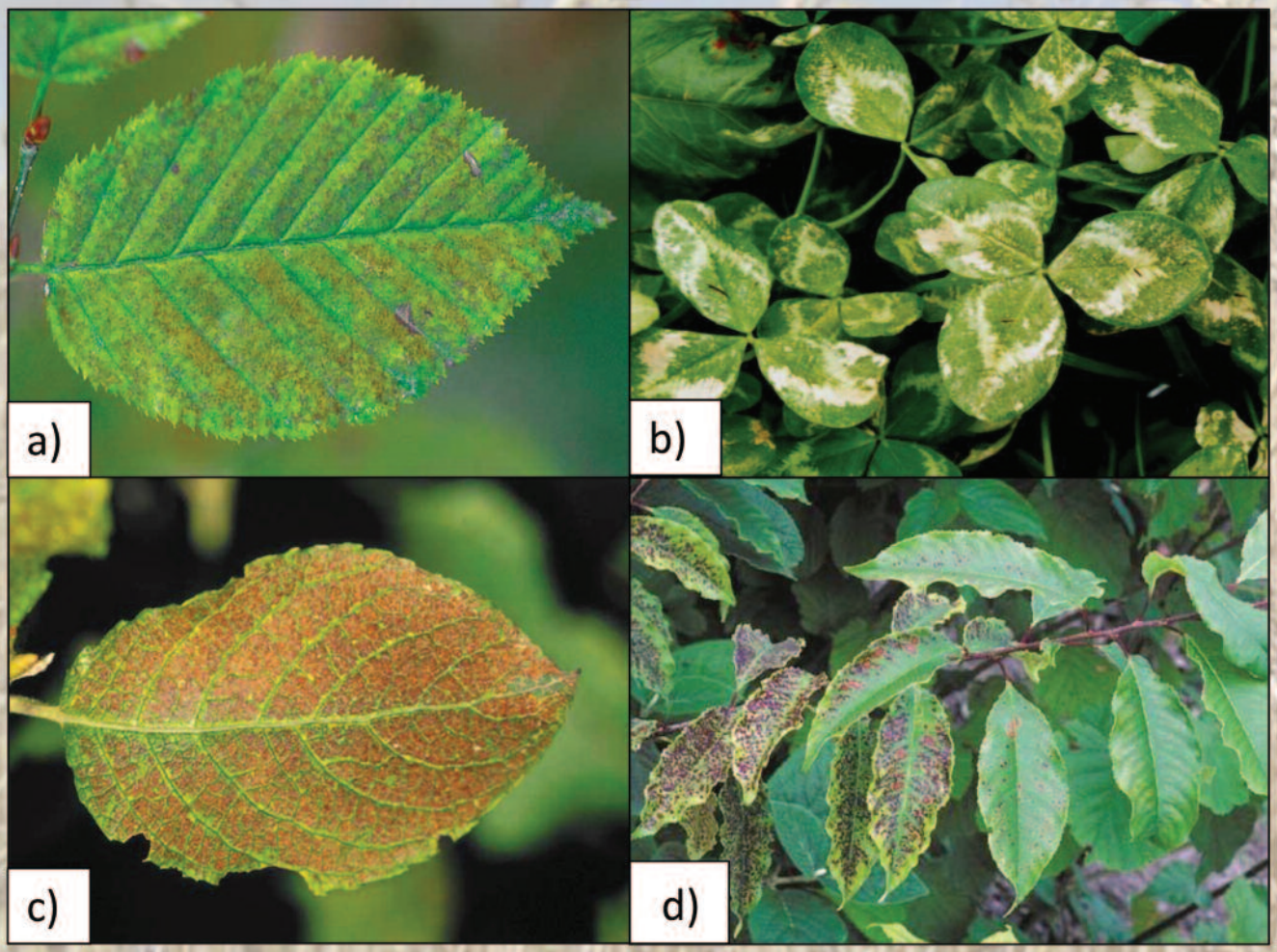
Map. Locations of records of visible injury attributed to ozone on crops, shrubs and (semi-)natural vegetation (Hayes et al., 2007*).

*Hayes, F., Mills, G., Harmens, H., Norris, D. (2007). Evidence of widespread ozone damage to vegetation in Europe (1990 – 2006). ICP Vegetation Programme Coordination Centre, CEH Bangor, UK. ISBN 978-0-9557672-1-0. Available at http://icpvegetation.ceh.ac.uk.

Visible symptoms of ozone injury

When ozone enters a leaf, it is transformed into cell-damaging compounds causing localised cell death. This becomes visible on the leaf surface as small pale yellow, cream or bronze pin-head sized blotches. In severe cases, these spots (known as stipples) can join together to cover large areas of the leaf surface.

Spots on the leaves occur between leaf veins, appearing first on the upper leaf surface and then spreading to both sides as damage worsens. Leaves towards the base of stems and branches (older leaves) are usually more affected than younger leaves. Overlapping leaves may protect those underneath from damage.



Photos. a) Bronze spots between veins in Hornbeam (*Carpinus betulus);* b) Pale cream spotting in White clover (*Trifolium repens)* ; c) Severe stippling on leaves of Goat willow (*Salix caprea)*; d) More severe symptoms on older leaves in Black cherry (*Prunus serotina).*

Symptoms similar to ozone damage

It is important to remember that there can be other causes of leaf damage that can be mistaken for ozone-induced damage, for example, leaf biting insects can create holes in the leaf surface; red spider mites (pin-head sized insects) cause pale spots and can be seen crawling on the leaves; leaf viruses can cause regular-shaped injury between veins and leaf diseases can cause yellow or dark patches and/or signs of powder on the leaf surface.

Ozone leaf damage on agricultural crops

Almost all of Europe's important agricultural crops can be negatively affected by ozone pollution. Crops can be classed as sensitive (including wheat, soybean and beans), moderately sensitive (including potato, barley, maize) and tolerant (including oats). Visible ozone damage to crops may be an indicator that biochemical changes have occurred within the plant, which may lead to a reduction in yield quality and/or quantity. Yield can also be negatively affected by ozone without the presence of visible injury.

Wheat (*Triticum aestivum*)

Soybean (*Glycine max*)

Potato (*Solanum tuberosum*)

Grape (*Vitis vinifera*)

Maize (*Zea mays*)

French bean (*Phaseolus vulgaris*)

Ozone leaf damage on horticultural crops

Many horticultural crops are also sensitive to ozone. Ozone pollution can lead to reduced yield (e.g. tomato, watermelon) and/or cause visible damage to leafy crops (e.g. lettuce, spinach, chicory), which may reduce market value. It has occasionally been reported that the leaf damage following ozone episodes has led to farmers losing entire crops of leafy vegetables.

Lettuce (*Lactuca sativa*)

Chard (*Beta vulgaris*)

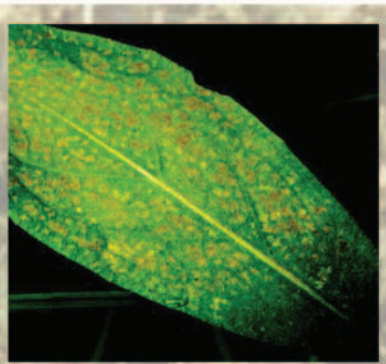
Onion (*Allium cepa*)

Parsley (*Petroselinum crispum*)

Ozone leaf damage on natural vegetation

Over 90 species of (semi-)natural vegetation in Europe have shown visible symptoms of ozone damage, including both forbs and grasses. Studies have shown that ozone pollution can also have invisible impacts on grassland species, such as a decreased tolerance to drought stress. The response to ozone can vary between species, possibly leading to shifts in species composition of grassland and pasture communities and a potential reduction in biodiversity.

Subterranean clover
(T*rifolium subterraneum*)



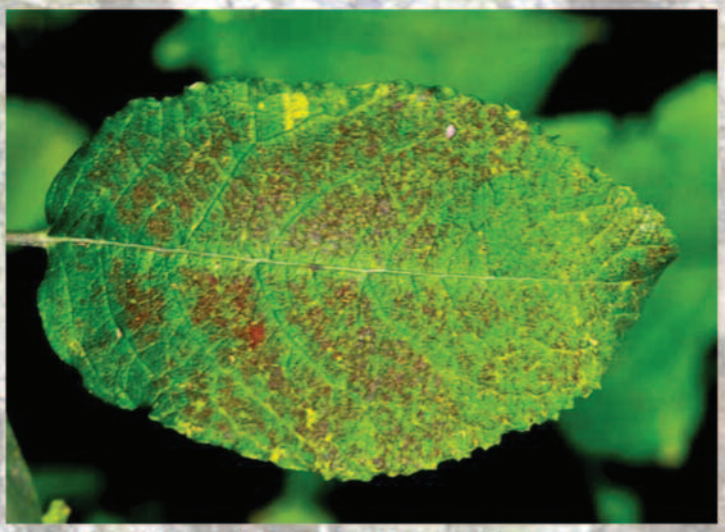
Brown knapweed
(Centaurea jacea)

Blackberry
(Rubus fruticosus)

Ozone leaf damage on trees and shrubs

Tree and shrub species show the same key symptoms of visible ozone injury as crops and (semi-)natural vegetation, with circa 80 woody species (both coniferous and deciduous) reported as ozone sensitive. As a consequence of visible injury, ozone damage leads to early leaf senescence and premature leaf loss in woody species. The severity of injury varies between species and depends on the age of the tree as well as on the microclimatic conditions.

Eastern white pine *(Pinus strobus)*



Goat willow *(Salix caprea* L.)

Wayfaring tree *(Viburnum lantana)*

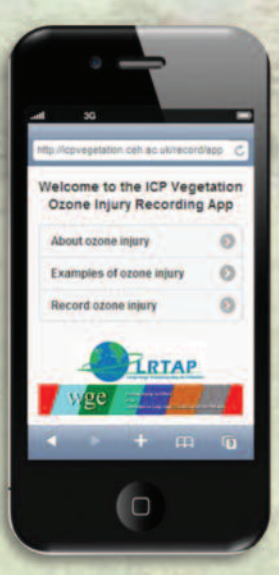
Ash *(Fraxinus excelsior)*

Sycamore *(Acer pseudoplatanus)*

Common Alder *(Alnus glutinosa)*

Recording incidences of ozone injury

We have created a new way of recording visible ozone injury on vegetation. The ozone injury smart-phone App (available for i-phones and android phones) allows users to upload photographs of ozone injury and location co-ordinates as soon as damage is observed. The App also gathers details on the level of experience of users, ozone injury symptoms and recent weather conditions. Use of the App will enable us to collect widespread information on ozone damage to vegetation across Europe (and potentially the rest of the world). Information on how to download the App together with a web-based recording facility can be found on the ICP Vegetation website:



http://icpvegetation.ceh.ac.uk

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Photos:
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