European Commission

Science for Environment Policy

Effects of air pollution on Mediterranean plants could be studied with reflectance spectroscopy

A technique called reflectance spectroscopy is the subject of a new literature review focusing on the use of this tool to study the effects of air pollution on vegetation. In particular, the researchers suggest that the technique could be more widely applied in the Mediterranean region, to study the effects of climate change and air pollution, which will be detrimental to crop growth as well as other vegetation. It could also be used as a more general biomonitoring technique for assessing pollutant levels in the environment.

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The impact of climate change in the Mediterranean is expected to be particularly severe due to the area's sensitivity to minor changes in atmospheric dynamics. Climatic models indicate that the Mediterranean basin will experience drastic reductions in precipitation (rain and snow) of up to 25–30% by the end of the 21st century and an increase in air temperature of 2–3 °C by 2050. Combined with stressors such as air pollution, human population growth and urbanisation, ecosystems in the region are vulnerable to negative impacts, note the researchers.

As well as investigating how air pollution and other stressors will affect plants and ecosystems in the Mediterranean, in the changing climate, they argue that monitoring is also needed to evaluate the effect of environmental policies. Optical remote sensing (a range of imaging techniques that can differentiate targets or surfaces) is ideal for this purpose, as it can be used to rapidly give information about a large area, including the functioning of plants. In particular, one of these techniques, known as reflectance spectroscopy, could be an excellent method of monitoring vegetation responses to air pollution, propose the researchers. This publication reviews its use for detecting and evaluating the effects of air pollution on plants, beginning with a history of reflectance spectroscopy and then summarising relevant studies using the technique.

Spectroscopy is a branch of physics dealing with electromagnetic spectra (the range of wavelengths of electromagnetic radiation; the ones that are visible when reflected are commonly known as colours!). Radiation may be reflected, transmitted through or absorbed by the surface of vegetation. Spectroscopic devices can be used to measure reflectance — the ratio of radiation reflected from a surface to the amount of radiation hitting the surface. Plant properties such as physical structure, water content and stress responses can be inferred from reflectance, though subject to some inaccuracy.

Spectroscopy offers an alternative to biochemical analysis, where plant tissue is collected and investigated in a laboratory. The advantages of spectroscopy over this standard type of analysis are that it is rapid, taking only seconds; it is non-destructive — it leaves plants intact — allowing repeated measurements on the same tissue; and is relatively inexpensive. It can be used on a large scale, on many plants, and can be scaled up to study whole landscapes (though this process is imperfect; for example remote sensing may not detect hidden vegetation).

As early as the 1960s, laboratory-based studies using spectroscopy were able to predict the protein, fat and carbohydrate content of grains. Indeed, the majority of work up to the 1990s focused on agronomic applications and dried plant material. Ecological applications in forest and grassland species were introduced in the late 1980s, advanced by the development of airborne devices which could estimate nitrogen and lignin (an organic polymer found in plant tissue) content in tree canopies. The emergence of sophisticated portable devices drove further growth in its application to understand plant end ecosystem functions.

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Spectroscopy has been used to assess the impact of air pollution since the 1980s, with pivotal studies in German and US sites[1]. The ability of spectroscopy to detect the influence on plant function of all major and minor Mediterranean pollutants has been evaluated, argue the researchers. Ozone and its interaction with other gases (carbon dioxide, nitrogen oxides, and sulfur dioxide) have been the most studied, whereas air pollutants, such as particulate matter (PM), nitrogen deposition, and heavy metals, have drawn attention in the recent years.

Ozone pollution is of particular concern as it can affect plant development. Ground levels of this gas are expected to rise in the Mediterranean region due to climate change, as its formation is linked to solar radiation, high temperatures and high atmospheric pressure (associated with weather patterns under predicted climate change). Using simple spectral indices, or spectra-derived leaf traits, spectroscopy has been used for early detection and monitoring of plant responses to ozone. Research studies have even shown the possibility of identifying genotypes (strains of a plant) that have higher degrees of tolerance to ozone, which could be useful in breeding pollution tolerant crops and other plants.

Particulate matter is another atmospheric pollutant that could impact on plant (as well as human) health. Spectroscopy can be used to monitor the accumulation of PM on leaf surfaces and offer an indication of PM levels in the environment. It could also be used to monitor the deposition of nitrogen at the landscape scale, suggest the researchers, who note that ecosystems formerly limited by low availability of nitrogen are now being enriched by atmospheric deposition of this chemical, with unknown consequences.

The effects of other pollutants, such as heavy metals, can also be detected using spectroscopy, highlighting the further possibility of using the technique for biomonitoring of heavy metals in the environment.

The researchers conclude that that there is increasing interest in the use of reflectance spectroscopy as an approach for evaluating the impact of air pollution on vegetation. However, although various vegetation types have been studied, few of these species are representative of the Mediterranean environment. Thus, more emphasis on typical Mediterranean vegetation could be applied in future to help monitor the effects of climate change and air-quality decline in this region.

1. e.g. Rock, B.N., Vogelmann, J.E., Williams, D.L., Vogelmann, A.F. & Hoshizaki, T. (1986). Remote detection of forest damage. *Bioscience,* 36: 439–445