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# 1 Introduction

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**J.N.B. BELL AND M. TRESHOW**

It is 18 years since the first edition of this book was produced. Now we have reached the millennium it is timely to produce a new totally revised second edition. Since 1984 massive changes have occurred in the areas of concern in the general field of air pollution impacts on plant life, with a range of new issues appearing on the research agenda. Furthermore, over the same period there has been a major expansion of higher education in the general field of environmental science, at both undergraduate and postgraduate levels. Thus we felt that it was highly opportune to produce a new edition which is aimed primarily at final year undergraduates and Masters students, as well as providing a comprehensive introduction for PhD students and other research workers entering this field for the first time. We were also very keen to produce a publication with a purchase price within the average student's pocket. Over the last 10 years or so a number of books on air pollution effects on vegetation have been published. However, these all tend either to contain a series of chapters on particular specialist topics or are strongly biased towards certain aspects of the field, and thus we believe this second edition fills a niche in the market and hope that it will prove as popular as its predecessor.

At the time of the publication of the first edition, the great bulk of research was concerned with impacts of SO<sub>2</sub>, NO<sub>2</sub> and O<sub>3</sub> on crop productivity in the developed world, particularly North America. Thus the National Crop Loss Assessment Network (NCLAN) programme was in full swing, utilising open-top chambers and dose/response and economic models to attempt an assessment of monetary losses arising from air pollutant induced reductions of major crops across the USA as a whole. At the same time much of the research into effects on crops in Europe was piecemeal with a lack of international, and in most cases, national integration. It was not until a year or two later that the European equivalent of NCLAN emerged, in the form of the European Open-Top Chambers Network (EOTCN). In fact the latter coincided with a general fall in interest in most European countries as well as in North America on the subject of air pollution impacts on agricultural crops: in the USA the NCLAN programme had cost a lot of money but produced some definitive results, while agricultural surpluses in western Europe doubtless mitigated against much concern for this problem.

As interest in crops declined, it was more than counteracted by a massive increase into research on the effects of air pollutants on forest trees. This had been the subject of some of the earliest research on air pollution impacts on vegetation in Germany in the nineteenth century (see Chapter 2) and continued over the first three-quarters of the

twentieth century in both Europe and North America. However, much of this research was largely devoted to problems around point sources or very close to industrial areas, with the exception of the growing concerns from the 1960s onwards of widespread oxidant damage to forests in the USA, particularly in California. The appearance of a mysterious apparent decline in forest health in Germany, followed by elsewhere in Europe, and also in North America resulted in a massive switch towards research into impacts of air pollution on trees. Large research programmes were inaugurated in both continents, accompanied by a concomitant decline in crop research. This issue was driven by powerful political forces, not the least in Europe and the issue remains far from resolved and it has been argued strongly that a non-existent problem was being addressed (see Chapter 15). An examination of our first edition indicates a low profile for this issue: there was one chapter on 'long range transport of air pollutants and acid precipitation', otherwise no further indication of the subject. Thus in this new edition we have attempted to address this important subject via Chapter 16, covering acidification effects on aquatic vegetation and Chapter 15 on 'Forest Decline'. In the most recent years attention has moved on to some extent from trees to other forms of natural vegetation. This is primarily concerned with ozone in view of its widespread rural distribution, this being covered in Chapter 6, and with excess nitrogen deposition (Chapter 12).

As an overview of the book, we will now put the other chapters in context, particularly with respect to developments since 1984. Chapter 2 provides a historical overview of the development of our understanding of air pollution impacts both pre-1984 and up to the present day. Since the first edition the vast bulk of research efforts into air pollution have not been concerned with impacts on vegetation or, at least until recently, on human health. Indeed they have been concerned with the identification, elucidation and quantification of emissions sources and the subsequent dispersion and atmospheric transformation of the pollutants concerned. These subjects are covered in Chapter 3, where the enormous strides in understanding air pollutant pathways and transformations that have taken place in the last 17 years are covered in some depth. These have been driven primarily by concerns over long-distance transboundary air pollution and the requirement to understand who produces what, where it goes to and in what form it reaches sensitive receptors. Equally important is the subject of Chapter 4, which received scant recognition in the first edition. The link between atmospheric burdens and deposition to surfaces, particularly uptake into vegetation, has been subject to major investigation over these years, with new understanding developing on issues such as co-deposition of  $\text{NH}_3$  and acid gases, and the importance of determining fluxes rather than atmospheric concentrations, when developing dose/response models for effects on plants.

Unlike the first edition we have followed these initial chapters with a consideration of impacts of individual major pollutant categories. The realisation since 1984 that oxidants are the major pollutants of concern not only in North America, but also in Europe, as well as increasingly in developing countries (Chapter 21) is reflected in the number of pages devoted to this topic in Chapters 5 and 6, covering physiological/biochemical and whole plant/community effects, respectively. These chapters are followed by one on nitrogen oxides (Chapter 7), where much of the concern is involved

with mixtures with other pollutants (Chapter 14), and on sulphur dioxide (Chapter 8), which many view as a past or minimal problem in the developed world, but is becoming a very serious issue in many developing countries (Chapter 21). Chapter 9 covers fluorides, a topic of considerable concern around specific industries and again, particularly in the developing world, where much of the problem lies in poisoning of herbivorous animals. Since 1984 there has been a spectacular upsurge in research into environmental aspects of volatile organic compounds (VOCs), yet little on their direct effects on vegetation, which may be greater than realised, this subject being covered in Chapter 10. Another little understood area is covered in Chapter 11 – the effects of particulates. This is a topic which has turned full wheel in terms of human health, with a return to the concerns of the 1950s over coal smoke being replaced by those with vehicle emissions and other forms of PM<sub>10</sub> (<10 μ), but advances in terms of vegetation impacts are minimal. Chapter 12 addresses an issue which has grown out of all proportion since 1984: this is the deposition of N in both oxidised and reduced forms, with indications of widespread impacts on (semi-)natural ecosystems, amounting to a problem of eutrophication in addition to acidification, which was the matter of concern in the past. Chapter 13 covers impacts of wet deposited acidity: at the time of the first edition this had been the subject of intensive investigation in terms of acid rain (*sensu stricto*) effects on agricultural crops; subsequently interest switched to a possible role in forest decline, with identification of the potential importance of the hitherto neglected occult deposition in the form of fog, mist and cloud.

Chapter 14 follows on directly from Vic Runeckles' 1984 chapter on effects of pollutant combinations – a subject still relatively unexplored, but of immense importance if the real effects of air pollutants in the field are to be elucidated and quantified. The next two chapters have already been discussed with respect to their importance for long-distance transport of pollutants. Probably the most severe and widespread effects of air pollution on plants, in the developed world at least, occur on bryophytes and lichens. Yet, this topic has generally received scant attention, except in their use as bioindicators of air quality. Chapter 17 covers this issue, with some emphasis on the pitfalls of biomonitoring. The interpretation of field and quasi-field (e.g. open-top chamber) studies has always been fraught with difficulty as a result of the interactions that can occur with environmental conditions prevailing at the time. This important subject is covered in Chapter 18. Since the first edition, an equally or more important topic has emerged in that air pollution can predispose plants to damage by other, more familiar, environmental stresses and, indeed it has been argued that such impacts could be more important than the direct impacts of air pollutants on plant performance. The major advances in recent years in these subjects are discussed in Chapters 19 and 20, for abiotic and biotic stresses, respectively. Perhaps of greatest concern for the topic of this book is the growing evidence that the most serious impacts may be taking place in the developing world, notably on agricultural productivity. This subject was effectively ignored in the first edition, but Chapter 21 in this book addresses the subject, reviewing the evidence that air pollution presents a threat to food security in developing countries, where agricultural surpluses are most definitely not a problem!

Ultimately, the vast bulk of research into air pollutant impacts on vegetation is aimed at generating data which can be employed in the formulation of pollution control

policy, whether at national or international levels. This important issue is covered in Chapter 22, which includes a description of a range of air quality standards and guidelines, and the way in which vegetation studies have been used to develop these. The most intransigent of all air pollution issues are those that are truly global, notably in the form of increasing concentrations of greenhouse gases, and perhaps now to a lesser extent stratospheric O<sub>3</sub> depletion. When planning this book we deliberated for some time whether or not to include a substantial element on the effects of rising CO<sub>2</sub> levels and increased ultra-violet radiation on vegetation. In the event we decided that these subjects were so vast that they warranted a separate book and that their inclusion would seriously dilute the main theme, which is the same as that of the first edition. However, we felt that this topic deserved inclusion in the form of the interactions of CO<sub>2</sub> and ultra-violet radiation with the pollutants covered in this book, and this is covered in Chapter 23. Finally, in Chapter 24 we have included a concluding chapter which draws on the individual contributions, pointing towards future research priorities and directions of this massive environmental issue which is certainly not going to be resolved in the near future.

We hope that this updated edition of Mike Treshow's 1984 edition will prove useful to students, teachers and research workers for a good many years. All the contributors are top international scientists, carefully chosen for their expertise in the subject area covered by their chapters.