Preface

The Earth's climate is continuously changing and has always changed through time. These changes are based on complex, oscillating cycles that occur on decadal, century, and millennial time scales. Climate shifts are common, marked by ice ages as well as long, warm periods.

There is by now overwhelming evidence that human activities have altered natural climatic cycles (Stocker et al. 2013). Although atmospheric chemistry changes (in CO_2, CO, O_3, CH_4) have occurred in the past due to natural causes, the current and expected future atmospheric composition is unlike any in the past due to anthropogenically generated air pollution (in addition to the above: NO_x and tropospheric O_3, double the concentration of the pre-industrial era).

In computer-based models (general circulation models, GCMs), rising concentrations of greenhouse gases have resulted in an increase in air temperature and instabilities in weather. Warmer air holds more water, and it evaporates from all surfaces: soil, vegetation, and open water. In other areas, there will be flooding, just as deleterious as drought to maladapted species. Because every component of ecosystems responds to temperature and water, current ecosystems are and will continue to change in response to increases in temperature, increases in evaporation, and weather instabilities (extremes in temperature and precipitation, its form, and when the extremes occur). Evidence for climate change has already been reported in thousands of publications, in locations distributed throughout the globe. These changes, as well as predicted future changes, are predicted with high confidence on a global scale, yet may differ considerably from place to place (Stocker et al. 2013).

An increase in air temperature of 1–1.5 °C above the mean for 1850–1900 is highly likely by mid-century. In addition to the direct effect of increasing air temperature on water balance, global circulation models predict different amounts of precipitation (Stocker et al. 2013). The greatest threat to ecosystems is increased frequency, duration, and extremity of water availability (from drought to flooding) and temperature (unusual timing and duration of cold snaps, prolonged heat spells) that will disrupt function, survival, and distribution of plants, animals, insects, and pathogens adapted to a past, or at best the current environment. In addition, air pollution effects on ecosystems need to be considered over the long term, especially with regard to the fertilizing effects of CO_2 and nitrogen deposition, and the deleterious and CO_2-negating effects of tropospheric O_3 on carbon uptake and its allocation. Although generalized approaches to managing ecosystems for climate change may be developed, the novel combinations of atmospheric chemistry, temperature, water availability, and the instabilities and extremities in weather will require novel, place-based land management approaches for ecosystems.

At a time when much of the world seems to be discussing climate change, one might ask, 'why another book anticipating effects of climate change?' Firstly, because trees are such long-lived organisms they depend on the acclimation potential of the individuals throughout their lifetime for their survival. Adaptive evolutionary change is slow in species with long generation cycles; hence trees are particularly vulnerable to rapid environmental changes. It is therefore even more important to understand the life functions of trees and the function of forests to underpin possible adaptive management strategies, and these will most likely be different from strategies under consideration for annual or short cycle natural or cropping systems. Secondly, most treatises on climate change effects on biological systems are CO_2-centric: they emphasize CO_2 fertilization and CO_2-induced increased temperatures, accompanying decreases in water availability (in general), but increased plant water use efficiency. We have included the interactive effects of elevated CO_2, the physical environmental effects of greenhouse gas accumulation, and the *source* of the CO_2: atmospheric chemical changes of air pollution (CO_2, O_3, NO_x, and nitrogen deposition). This is a fundamental consideration that many of the discussions on climate change have ignored, or considered only in isolation (with some noted exceptions, see Emberson et al. 2000, who advocated integration of the effects of these components in a process-based model). Due to the difficulty and the magnitude of experimental studies with multiple factors, there are few field studies that have accomplished two abiotic interactive factors (such as CO_2 x temperature, Kellomäki et al. 2000, CO_2 x N amendment, Pääkkönen and Holopainen 1995, O_3 x CO_2 Karnosky et al. 2003, or O_3 x N amendment, Watanabe et al. 2006), let alone many environmental and biological factors over the lifetime of trees and within the complexity of forest ecosystems. Some studies along environmental gradients with carefully matched sites (e.g., high N deposition, drought stress, and moderate O_3 exposure vs. high N deposition and moderate O_3 exposure alone, Miller and McBride 1999) can provide an insight into multiplicative effects. However, we are still restricted to the *current* range in conditions and responses of extant trees that established in a past climate: 80–250+ years ago. The future holds an unprecedented combination and quantity of atmospheric chemicals, and it is as yet unclear whether and which current species or populations of trees are sufficiently equipped to cope with such conditions.

Our ecosystems are already and unequivocally (Stocker et al. 2013) experiencing environmental and climate change, and forests and other tree dominated ecosystems are likely to be severely affected. In this book, the authors have thoughtfully reviewed and described constituent functions and processes that will help us understand tree responses to the complex, concurrent effects of environmental stresses imposed by climate change, and its ultimate source, air pollution. In many cases they have challenged current theory on expected responses, and in all cases they have contributed their expert knowledge on tree and forest ecosystem response to environmental change: an integrated, qualitative assessment. We offer this comprehensive analysis of tree responses and their capacity to respond to environmental changes to give us better insight as to how to plan for the future.

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