

Foreword

Measuring impacts of climate change on plants

‘... change is constant. Change is inevitable.’

Benjamin Disraeli (1867), British Prime Minister and FRS

In Australia, the world's most arid and nutrient-poor continent, we are keenly aware of the critical role of resources in supporting the livelihood of our native plants and ecosystems as well as our primary industries of agriculture and forestry. However, recent trends, such as an extended decade-long drought in eastern Australia, increases in atmospheric CO₂ concentration exceeding 1.9 ppm per year from global CO₂ emissions (Raupach *et al.* 2007), and increasing N deposition in the meteorological footprint of northern hemisphere cities (Gruber and Galloway 2008), have generated scientific concern over the impacts of these changes on the plants and associated ecosystem services. In fact, our current era of anthropogenic change has been described by some as the Anthropocene to identify the major putative source of climate perturbations. It's important to recognise that these changes have progressed through the 19th and 20th century's industrialisation and land-use changes in Europe, the Americas and Australia, and which is rapidly proceeding in east Asia on a large scale. Whether change is considered ‘constant’, and aside from our value judgments concerning the change, we are now highly aware of recent changes in climate and its variability. Importantly, we are now realising the larger implications of climate change as evidence mounts regarding how not only plant processes, but globe-wide system processes, may be affected (Falkowski *et al.* 2000; Field 2001).

In recognition of the scientific importance of climate change in contemporary society, the central theme of the EcoFIZZ 2007 meeting held at the University of Western Sydney (UWS), Hawkesbury campus in Richmond, New South Wales on 27–28 September 2007 was concerned with the impacts of global climate change on plants and ecosystems. Four interrelated facets of this theme were topics for this meeting — water, carbon, nutrients, and growth and productivity — which addressed the three major resources that regulate plant response to climate change (Field *et al.* 1992; Reich *et al.* 2006) and their impact on the central plant processes leading to growth. This special issue of *Functional Plant Biology* highlights eight selected papers from amongst the 45 papers presented at the conference, many addressing aspects of how the availability of key resources for plant growth (carbon, nitrogen and water) affect the impact of climate change on plants and ecosystems.

Carbon has been long-recognised as a major common currency for ecophysiological comparisons among plants, and the balance between photosynthesis and respiration is central to achieving carbon balance under different environmental conditions. However, the photosynthesis–respiration balance in plants is also highly sensitive to environmental conditions that differentially force changes in either photosynthesis or respiration. This balance is highlighted in the contribution by O'Grady *et al.* (2008) on vertical patterns of photosynthesis and respiration in a Tasmanian *Eucalyptus* stand, as they show that

the carbon economy of shaded, suppressed trees within a forest stand is much reduced relative to more dominant neighbouring trees. Temperature can also have a strong forcing effect on this photosynthesis–respiration balance, and Ow *et al.* (2008) addressed this balance for controlled environment-grown *Pinus radiata* seedlings under different temperature regimes.

The importance of plant nutrition and nutrient relations in regulating growth as well as regrowth following defoliation was considered by Thomas *et al.* (2008), who found that long-lived leaves can serve as sources of mobile nitrogen to new leaves. Light harvesting and light utilisation in photochemistry or excitation energy dissipation responses were considered by Posch *et al.* (2008) with N-fertilisation of pines. Their results may have implications not only for forest management, but also for the vulnerability of trees to photo-oxidative stress in regions receiving depositional N inputs.

Water availability is a predominant concern in Australia as the major cities of eastern Australia have experienced marked water shortages and anomalously low rainfall has persisted across the eastern seaboard. Wood *et al.* (2008) assessed tree water use across an age sequence of the world's tallest angiosperm, *Eucalyptus regnans*, in the Victorian highlands. While fewer, larger trees reaching 90m tall dominated older forests, water-use in these forests did not decrease with tree age as predicted, in part due to increasing transpirational water losses from the understorey. In another highland *Eucalyptus*-dominated forest at the Tumbarumba flux tower site, Pepper *et al.* (2008) investigated possible mechanisms by which productivity was reduced during drought even though total stand water-use was not affected. Their study alongside the Zeppel *et al.* (2008) study of a woodland in the Sydney basin both suggested that tree utilisation of deeper sources of soil moisture during periods of water deficits was as an important mechanism for maintaining water-use during drought. Zeppel *et al.* (2008) also showed incomplete stomatal closure at night as a source of nocturnal water losses in this forest. Collectively, these tree water-use studies demonstrate how increased understanding of plant hydraulics may hold the key to evaluating the ability of different tree species to sustain productivity during drought.

The major plant resources constraining plant production were considered in a coupled fashion through a simple model considering plant carbon–nitrogen–water economy using underlying plant physiological principles (McMurtrie *et al.* 2008). This novel approach was parameterised in a 10-year experiment on elevated CO₂ effects on forest trees (Norby *et al.* 2006) using free-air CO₂ enrichment (FACE) to generate understanding of how photosynthetic enhancement in enriched atmospheric [CO₂] depends on availabilities of major resources, N and water. The physiologically based model generates key hypotheses to be tested in future [CO₂] enrichment experiments for forests and grasslands alike.

The EcoFIZZ 2007 conference was held at the conference centre on the UWS Hawkesbury campus. In keeping with this theme, the meeting also involved a fieldtrip to the Hawkesbury

Forest Experiment facility (www.hawkesburyforest.net), a new and unique facility in Australia with a focus on global climate change (atmospheric CO₂ concentration and drought) effects on trees. As chair and co-chair of the organising committee, we acknowledge that the organising committee comprised of ourselves and Jann Conroy (UWS) and Oula Ghannoun (UWS) working with assistance from David Harland of the Centre for Plant and Food Science (UWS). We also wish to acknowledge Professor Jann Conroy's retirement from UWS in 2008 after nearly two decades of research on the impacts of rising atmospheric CO₂ concentration on plants, starting with her landmark work on Monterrey pine (*Pinus radiata* L.) (Conroy *et al.* 1986; Conroy *et al.* 1988), which helped pioneer elevated CO₂ research in Australia and highlighted the limitations of nutrients in physiological responses of trees to [elevated CO₂]. We encourage our colleagues to emulate Jann's boundless energy and enthusiasm for research that characterised such a productive career. These traits and her characteristic irreverent stripe will not soon be forgotten at EcoFIZZ meetings. We owe a personal debt of gratitude to Professor Jann Conroy for advancing elevated CO₂ research in Australia including our current work at the Hawkesbury Forest Experiment.

Sponsorship of EcoFIZZ 2007 was provided by the Centre for Plant and Food Science, the College of Health and Science, and the Office of Research Support at UWS. We gratefully acknowledge these contributors as well as the presenters, including the authors in this special issue, who collectively enhanced the success of EcoFIZZ 2007.

David S. Ellsworth and David T. Tissue
Conference Chairs
University of Western Sydney

References

- Conroy JP, Smillie RM, Kupperts M, Bevege DI, Barlow EW (1986) Chlorophyll *a* fluorescence and photosynthetic and growth responses of *Pinus radiata* to phosphorus deficiency, drought stress, and high CO₂. *Plant Physiology* **81**, 423–429.
- Conroy JP, Kupperts M, Kupperts B, Virgona J, Barlow EW (1988) The influence of CO₂ enrichment, phosphorus deficiency and water stress on the growth, conductance and water use of *Pinus radiata* D. Don. *Plant, Cell & Environment* **11**, 91–98.
- Falkowski P, Scholes RJ, Boyle E, Canadell J, Canfield D, *et al.* (2000) The global carbon cycle: a test of our knowledge of earth as a system. *Science* **290**, 291–296. doi:10.1126/science.290.5490.291
- Field C (2001) Plant physiology of the “missing” carbon sink. *Plant Physiology* **125**, 25–28. doi:10.1104/pp.125.1.25
- Field C, Chapin FS, Matson PA, Mooney HA (1992) Responses of terrestrial ecosystems to a changing atmosphere: a resource-based approach. *Annual Review of Ecology and Systematics* **23**, 201–235. doi:10.1146/annurev.es.23.110192.001221
- Gruber N, Galloway JN (2008) An Earth-system perspective of the global nitrogen cycle. *Nature* **451**, 293–296. doi:10.1038/nature06592
- McMurtrie RE, Norby RJ, Medlyn BE, Dewar RC, Pepper DA, Reich PB, Barton CVM (2008) Why is plant-growth response to elevated CO₂ amplified when water is limiting, but reduced when nitrogen is limiting? A growth-optimisation hypothesis. *Functional Plant Biology* **35**, 521–534.
- Norby RJ, Wullschlegel SD, Hanson PJ, Gunderson CA, Tschaplinski TJ, Jastrow JD (2006) CO₂ enrichment of a deciduous forest: the Oak Ridge FACE experiment. In ‘Managed ecosystems and CO₂: case studies, processes and perspectives’. (Eds J Nöberger, SP Long, RJ Norby, M Stitt, GR Hendrey, H Blum) pp. 231–251. (Springer: Berlin)
- O’Grady AP, Worledge D, Wilkinson A, Battaglia M (2008) Photosynthesis and respiration decline with light intensity in dominant and suppressed *Eucalyptus globulus* canopies. *Functional Plant Biology* **35**, 439–447.
- Ow LF, Whitehead D, Walcroft AS, Turnbull MH (2008) Thermal acclimation of respiration but not photosynthesis in *Pinus radiata*. *Functional Plant Biology* **35**, 448–461.
- Pepper DA, McMurtrie RE, Medlyn BE, Keith H, Eamus D (2008) Mechanisms linking plant productivity and water status for a temperate *Eucalyptus* forest flux site: analysis over wet and dry years with a simple model. *Functional Plant Biology* **35**, 493–508.
- Posch S, Warren CR, Adams MA, Guttenger H (2008) Photoprotective carotenoids and antioxidants are more affected by canopy position than by nitrogen supply in 21-year-old *Pinus radiata*. *Functional Plant Biology* **35**, 470–482.
- Raupach MR, Marland G, Ciais P, Le Quéré C, Canadell JG, Klepper G, Field C (2007) Global and regional drivers of accelerating CO₂ emissions. *Proceedings of the National Academy of Sciences of the United States of America* **104**, 10288–10293. doi:10.1073/pnas.0700609104
- Reich PB, Hungate B, Luo Y (2006) Carbon-Nitrogen interactions in terrestrial ecosystems in response to rising atmospheric carbon dioxide. *Annual Review of Ecology and Systematics* **37**, 611–636. doi:10.1146/annurev.ecolsys.37.091305.110039
- Thomas MM, Millard P, Watt MS, Turnbull MH, Peltzer D, Whitehead D (2008) The impact of defoliation on nitrogen translocation patterns in the woody invasive plant, *Buddleia davidii*. *Functional Plant Biology* **35**, 462–469.
- Wood SA, Beringer J, Hutley LB, McGuire AD, van Dijk A, Kilinc M (2008) Impacts of fire on forest age and runoff in mountain ash forests. *Functional Plant Biology* **35**, 483–492.
- Zeppel M, Macinnis-Ng C, Palmer A, Taylor D, Whitley R, Fuentes S, Yunusa I, Williams M, Eamus D (2008) An analysis of the sensitivity of sap flux to soil and plant variables assessed for an Australian woodland using a soil-plant-atmosphere model. *Functional Plant Biology* **35**, 509–520.