

Editorial

Celebrating the ecosystem's three-quarter century: Introduction to a *Virtual Special Issue* on Sir Arthur Tansley's ecosystem concept

Ecosystem ecology has played a central role in our understanding of the natural world, and the importance of plants as the organisms that define the amount and flow of energy entering the ecosystem demonstrates the essential role of plant science in our understanding of how ecosystems function. *New Phytologist* has a tradition of publishing original research papers and reviews focused on the interface between plant and ecosystem science. But there is an additional reason for the collection in this *Virtual Special Issue* (www.newphytologist.com/virtualissues), which is the commemoration of the publication of a seminal paper by Sir Arthur Tansley (1935) (the founding Editor of *New Phytologist* and after whom the Tansley Reviews are named), which was fundamental in establishing the ecosystem concept in biological studies. And so, three quarters of a century on we celebrate the ecosystem concept, with a series of *New Phytologist* publications that span the range from the gene to the globe, from the tropics to the tundra, with an eye on the visionary influence of Sir Arthur Tansley on modern ecosystem science.

Kicking off the *Virtual Special Issue* is a recently published Tansley Review by William Currie of the University of Michigan, which sheds light on the history and current use of the ecosystem concept, tracing the origin in Sir Arthur Tansley's paper (1935) to the present, with a special emphasis on how the ecosystem has served as a central organizational concept for ecology and plant science in the last 75 yr (Currie, 2011). In addition, we have collected a number of examples of the ecosystem concept at work, demonstrating the explosion of research that has not only become relevant for large-scale ecological studies, but in a realm of other disciplines, including genetics, plant–organism interactions, and evolutionary biology. It is clear

that the usefulness of the ecosystem concept continues, becoming even more relevant as we try to understand human impact in the twenty-first century.

Global change and ecosystem ecology

It is possible that Sir Arthur Tansley might not have imagined the importance of ecosystem science for the important challenge facing humankind – the impact of human activities on the biosphere. Global climate change is now an accepted phenomenon by the vast majority of the scientific community (IPCC 2007), and the wide-ranging consequences of climate and land-use change are being documented in biomes around the world using the tools of ecosystem ecology. As Currie (2011) correctly highlights, 'Ecosystem science has become an important applied science for studying global change and human environmental impacts'. Studies with small-scale manipulations of multiple global change factors have been especially relevant for identifying interactions among global change factors. The effects of elevated CO₂ are important in determining the strength of biotic interactions for a plant–endophyte symbiosis in a temperate grassland ecosystem (Brosi *et al.*, 2011), whereas counteractive effects of elevated CO₂ decreasing nitrogen (N) availability with warming increasing N turnover (Dijkstra *et al.*, 2010) highlights the complexities of multiple global change interactions. Observational studies in areas where climate change has already been observed are providing important insights into the importance of extreme climatic events such as heat waves, which overwhelm the effects of nutrient addition (Gerdol *et al.*, 2008), and shrub expansion in the Arctic due to changes in snow cover (Hallinger *et al.*, 2011). The latter study sparked a productive debate on the interpretation of trends observed in an already changing planet (Büntgen & Schweingruber, 2010; Hallinger & Wilmking, 2011), and underscores the need for more research to try and identify the relative importance of multiple simultaneous global changes. An innovative study by Högberg *et al.* (2011) examined what happens to heavily impacted forest ecosystems after the cessation of N deposition. They demonstrated that while this ecosystem appears to be very sensitive to changes in N availability due to human impact, it also shows high potential resilience, mediated through the recovery of the functioning of the ectomycorrhizas. Finally, plant invasions of nonnative species have demonstrated multiple effects on community composition, but a recent meta-analysis has demonstrated that ecosystem-scale alterations in carbon (C) and N cycling can also occur (Liao *et al.*, 2008). These invasive plant

Papers included in this *Virtual Special Issue* are indicated by their citations set in bold type (www.newphytologist.com/virtualissues)

species often come with their symbionts in tow, an aspect of invasion ecology whose impacts are not well understood, but appear to be wide-ranging for ectomycorrhizal introductions (Vellinga *et al.*, 2009).

Plants and biogeochemistry

The connection between plant traits and ecosystem processes, particularly biogeochemical cycles, has been a particular focus of recent research in ecosystem ecology. Reflecting on the fundamental importance of the evolution of lignin biosynthesis in terrestrial plants (Weng & Chapple, 2010), it seems clear that the diversity of plant traits in terrestrial ecosystems, and their interaction with environmental controls can have important impacts on C and nutrient cycling. For example, it has been shown that leaf surfaces emit methane in living plants due to the absorption of ultraviolet radiation by plant pectins (Keppler *et al.*, 2006; McLeod *et al.*, 2008), although it was recently determined that these emissions, while locally important, may not be significant at the global scale (Bloom *et al.*, 2010). The effects of plant traits on biogeochemical cycles go far beyond the living plant, however, with consequences for litter decomposition and C turnover after plant senescence. Inhibitory effects of plant litter can have repercussions on C turnover as Bonanomi *et al.* (2011) demonstrated with an elegant experiment in which phytotoxicity, rather than microbial immobilization of nutrients, explains reductions in plant litter turnover. In tropical ecosystems, these relationships are particularly significant, as the importance of plant assemblies and their chemical characteristics are notoriously diverse. Asner & Martin (2011), using sophisticated remote sensing techniques, demonstrated a wide range of variation in chemical and spectral assemblies in tropical forests, and the importance of soil fertility in determining these plant responses. In addition, a recent review by Hättenschwiler *et al.* (2011) reminds us that the impact of plant species on litter decomposition in tropical ecosystems due to variation in lignin and other C components is a critical determinant for C turnover, but not a simple legacy of living plant traits. These connections between plant traits and C cycling extends to even larger scales, as plant diversity itself, rather than the individual traits of plant species, demonstrated in a study where diverse plant communities, but not single-species plantations could be used as a predictor of C stocks in tropical forest ecosystems (Ruiz-Jaen & Potvin, 2011).

Genetic convergence: new tools for understanding ecosystems processes

The connection between the smallest biological unit, the gene, and the ecosystem, has not always been clear since the ecosystem concept was first established, but modern eco-

system science has incorporated new thinking in the value of linking scales and a recent review highlights the utility of incorporating population community genetics for addressing effects of climate change and invasive species (Wymore *et al.*, 2011). The emergence of new tools, and particularly large-scale Sanger sequencing and high-throughput pyrosequencing has been an ecological quantum leap forward for the possibility of classification of those organisms that evade taxonomic identification but are critical to our understanding of ecosystem functioning – the microbes. Several papers have begun to elucidate the identity and host specificity of ecto- and arbuscular mycorrhizal fungi (Öpik *et al.*, 2009; Tedersoo *et al.*, 2010), and additionally how seasonal trends in the mycorrhizal communities may be related to fluctuations in C supply (Dumbrell *et al.*, 2011). Surprisingly, these tools have served to identify hyperdiverse fungal communities in the phyllosphere (Jumpponen & Jones, 2009) and in forest soils (Buée *et al.*, 2009). Clearly, the next step is to link this enormous amount of genetic information with specific ecosystem function in order to provide mechanistic connections between microbial genetic diversity and ecosystem processes.

In 1935, it may have been difficult to imagine the lasting and profound impacts that the term ecosystem would have as an organizational concept for plant science. Nevertheless, it is a testimony to the strength of the ideas that started with Sir Arthur Tansley and that are collected here in this *Virtual Special Issue* that this conceptual framework will certainly continue to be highly relevant as we open new frontiers for research in ecosystem science.

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Key words: Arthur Tansley, biogeochemistry, biotic interactions, climate and land-use change, ecology, ecosystem concept, plant and microbial genetics, plant science.

Commentary

Conserved chromatin structural proteins – a source of variation enabling plant-specific adaptations?

In his 2002 paper ‘Plants compared to animals: the broadest comparative study of development’ (Meyerowitz, 2002; pp. 1482–1485), Elliot Meyerowitz concluded that as regards the molecular basis of pattern formation and cell–cell signaling, the two fundamental systems underlying

development, there is little homology between plants and animals. Similar processes in the two lineages are usually controlled by nonhomologous genes. For example, the master regulatory genes responsible for establishing segmental identity during embryonic development of animals, the *Hox* homeobox genes, have no evolutionary relationship to master regulators acting in plant development/patterning, the *MADS* box genes. Similarly, the receptor tyrosine kinases, like Sevenless or Gurken, or the Ras proteins, that are critical components of cell signaling in animals, have no homologous counterparts in plant signaling pathways. This strongly suggests independent evolution of the molecular systems responsible for the assembly of phenotypic forms in plants and animals. However, it appears that beneath this