Elevated CO2 and Plant Water Use

An increase in the atmospheric CO_2 concentration (C_a) leads to a decrease in stomatal conductance (g_s) in most species (Morison 1985; Eamus 1991; Medlyn et al. 2001), which typically leads to a decrease in the transpiration rate per unit leaf area (E_L). The magnitude of the response of g_s to elevated C_a is highly variable, and appears to differ by plant functional type (Saxe et al. 1998; Ainsworth and Rogers 2007), making it difficult to predict vegetation water use in a future high C_a world. Furthermore, it is widely assumed that the response of stand water use to C_a follows that of the leaves (Leakey et al. 2009), but this is largely untested.

The reduction in water use due to elevated C_a is highly variable, and depends whether water use is measured as g_s (or E_L), sap flow velocity or total stand water use. For g_s, the C_a response ranges from a 5% increase to a 50% decrease (Medlyn et al. 2001; Ainsworth and Rogers 2007; Keel et al. 2007). Even co-occurring species can have a dramatically different response of g_s to C_a. For example, Lauber and Körner (1997) found reductions in g_s between 0-50% for four co-occurring grassland species. Wullschleger et al. (2002b) suggested that conditions that limit g_s, such as soil moisture availability or shading limit the effect of elevated C_a on g_s. Elevated C_a has frequently been reported to lead to a modest to large reduction in sap flow velocity (Cech et al. 2003; Leuzinger and Körner 2007; Li et al. 2002; Senock et al. 2006; Tognetti et al. 1999; Tognetti et al. 2002). Total stand water use either increases or decreases depending on whether elevated C_a led to an increase in leaf area index (Eamus 1991; Tricker et al. 2009; Warren et al. 2011). When whole-plant water use is expressed on a per unit leaf area basis (i.e., canopy-average E_L), there typically is a reduction in whole-plant water use at elevated C_a (Dugas et al 1997, Dugas et al 2001, Winter et al 2001, Wullschleger and Norby 2001, Wullschleger et al 2002) with few exceptions (e.g. Dugas et al 1994).

The magnitude of the response of water use to elevated C_a may also be expected to vary with different scales of measurement, such as leaf, branch, whole-plant, and stand scale. How plants respond at various scales to elevated C_a has not been widely studied.

Few studies have compared the C_a effect on water use between different scales of measurement, typically reporting a reduction in water use at the leaf and whole plant scales (Tognetti et al. 1998, 1999; Wullschleger & Norby 2001; Wullschleger et al. 2002). However, the magnitude of the response may differ. For example, a study on 12-year old Liquidambar styraciflua grown at ambient and elevated C_a found a 23% reduction in leaf-level g_s, 13% reduction in sap flow and a 14% reduction in stand-averaged water use (Wullschleger and Norby 2001; Wullschleger et al. 2002a). As a consistent response across scales is desirable for ease of modelling and prediction (e.g. Rayment et al. 2002), a greater understanding of the effect of elevated C_a on plant water use at different scales is needed.