



Program 4: Groundwater–Vegetation–Atmosphere Interactions (GVI).

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The groundwater balance is determined by rates of recharge and discharge and estimates of these are required at a range of spatial and temporal scales. Although there have been advances in methods for estimating recharge, many issues relating to the underlying processes as well as its spatial and temporal extrapolation require resolution. Vegetation plays a critical role either directly through discharge, where it abstracts water from the watertable or capillary fringe, or indirectly by mediating recharge. Apart from the obvious implications for groundwater management, this control on recharge has important ramifications for proposed plantation-based strategies for climate change mitigation: we don't yet have a clear understanding of the trade-off between carbon sequestration and the associated reduction in groundwater recharge and dependent stream and river flow. In fact, how climate change will modify the functional attributes of vegetation related to its water use is also poorly understood. While groundwater use by vegetation has been observed at a number of sites, scaling measurements from individual trees to regional scale catchments in order to estimate the water balance and the impact of watertable drawdown on groundwater-dependent vegetation are largely unexplored. Modelling GVI also remains a challenge, particularly its representation in groundwater hydrological models used in water resource management. Research in this program will address these and other critical gaps in knowledge. Field work will be undertaken at a number of sites across Australia. *Key investigators: CI Lockington, CI Eamus, CI Guan, CI Daly and CI Webb, with assistance from PI Cook.*

Sub-program 4A: Regional groundwater discharge through evapotranspiration. A key source of uncertainty in efforts to monitor the movement of water through the hydrological cycle is characterizing the moisture flux between the groundwater and surface-atmosphere interface. Groundwater loss to evapotranspiration (through direct soil evaporation plus plant transpiration) accounts for the major component of the moisture flux into the atmosphere, particularly under water-limited conditions. While soil moisture storage might be depleted due to lack of incident precipitation, dynamic root systems may have access to groundwater sources, assisting in vegetation survival during prolonged dry periods. Deep lysimeter measurements under crops, indicate that groundwater evapotranspiration can account for more than 16% of total evapotranspiration. For forested stands this would be expected to be even greater. This Sub-program will examine controls on groundwater discharge via evapotranspiration by developing quantitative relationships between discharge rate, vegetation and soil type, water table depth and other key variables using a multi-scale monitoring and modelling program that includes: 1) sapflow devices to determine volumes of individual tree water use; 2) isotopic techniques to discriminate between plant transpiration and direct soil evaporation (Farquhar et al., 2007); 3) eddy-covariance techniques for larger scale evapotranspiration measurement (Su et al, 2005); and 4) remote sensing-based approaches to extrapolate field-based measurements to catchment and regional scales (McCabe and Wood, 2006). These estimates will be compared with independent measurements of diurnal fluctuations in groundwater and soil moisture levels and modelled fluxes to form a fundamental basis for upscaling (McCabe et al., 2008).

Sub-program 4B: Impact of watertable decline on groundwater dependent vegetation (GDV). GDV uses groundwater when it is within reach, via roots accessing groundwater at depth or through groundwater discharge to the surface followed by plant uptake (Eamus and Froend 2006). Understanding how vegetation responds to a decline in the watertable remains a significant research challenge. This Sub-program will compare and contrast key vegetation attributes (root depth, basal area, leaf area index, rates of water use, pre-dawn and midday water potential, turgor loss point and vulnerability of xylem to cavitation) at sites of contrasting climate, soil type, vegetation structure, and depth to groundwater. Stable isotope analyses of groundwater, soil water and xylem water and root distribution data will be used to quantify the contribution of groundwater to annual water budgets of each GDV. Long-term meteorological data will be used to examine inter-annual variability in the potential for vegetation groundwater use. These data will be used, in conjunction with Soil-Vegetation-Atmosphere (SVAT) models, to develop rules governing the impact of declining watertable on Australian GDV.

Sub-program 4C: Effect of climate change on GVI and groundwater recharge and discharge. The relationship between recharge and discharge and climate forcing requires rigorous and more detailed scientific investigation. It is clear that climate change will not only alter rainfall and temperature, but also the functional attributes of vegetation (leaf area index, stomatal conductance, standing basal area, hydraulic architecture of the vegetation) that govern rates of water use (Eamus and Palmer 2007). Rainfall through much of Australia is episodic, and recharge is likely to be more sensitive to changes in the frequency and intensity of rainfall events than to changes in mean annual rainfall. While some site specific assessments have been conducted, a generalised understanding of fundamental processes has not been developed. An unstated assumption is that recharge will reduce under future climates but we do not know that this is the case and it has not formally been demonstrated in the scientific literature. This is, however, critical, and the state of current knowledge is extremely poor. This Sub-program will employ and develop SVAT models to determine the sensitivity of recharge to changes in important climate variables. To be accurate, these models must combine highly mechanistic descriptions of plant growth, carbon fixation and water use, with climatic models that predict changes in rainfall frequency and intensity, and potential evaporation. An important part of model calibration is examining the extent to which models are able to predict modern day spatial and temporal variations in recharge and discharge.