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Nuclear and non-nuclear techniques for area-wide assessment of water use efficiency and ecohydrology outcomes among mixed land uses

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Managing water use efficiency and ecohydrology is important for providing food, water and essential ecosystem services. Many agricultural, ecological, atmospheric and hydrological processes cannot be meaningfully managed without an area-wide or catchment-level perspective. However a vast number of factors, including mixed land uses are incorporated at such scales. There is a need for integrative, mobile and adaptable techniques to make water related measurements over large areas and mixed land uses. Nuclear techniques and analogous non-nuclear techniques may be deployed in a number of spheres within the soil-plant-atmosphere continuum (e.g. rhizosphere and above-canopy microclimate) with nuclear techniques having a distinct contribution owing to their unique ability to trace biogeochemical processes including the movement and transformation of water, nutrients and agrochemicals.
1) Soils. Isotopes can be used to trace water sources to understand groundwater dependence, rooting depth, etc. but not at all sites: early success in central USA studies has not always been repeatable in climates which produce more uniform isotopic signatures in various water sources. Soil water resources available to crops can also be studied using neutron moisture meters, but training, transport and safety issues argue for stringent management and inclusion of electrical capacitance probes for routine or automated applications. Results from capacitance probes can benefit from benchmarking against neutron probe measurements, which remain more powerful for sampling larger volumes in cases of heterogenous soils or where salinity levels are problematic. Because interpretation of soil water content in terms of plant available water also requires knowledge of soil organic matter characteristics, 13C and compound specific stable isotopes can help to identify changes in soil organic matter composition and hence water and plant nutrient availability.
2) Plants. Analysis of carbon isotope discrimination can be used to monitor water use efficiency and seasonal water stress. This includes analysis of carbon in structural leaf material and soluble sugars for different temporal scales. Some progress is also being made using 18O signatures to estimate transpiration. Furthermore xylem sap can be measured for isotopic composition can be used and absolute flow rates in the plant can be measured with thermometric tracers. Information on transpiration can help differentiate between wasteful evaporative processes versus efficient plant gas exchange.
3) Atmosphere (above & within canopy). Whilst traditional vapour related techniques such as Bowen ratio and eddy flux can measure total ET, modern cavity ring-down laser spectrometers can sample isotopes in water vapour. These devices hold much promise to identify water sources and evaporative processes using dual isotope mixing models and Keeling plots analysis: the result is improved partitioning of transpiration and evaporation.
This above suite of measurements can provide knowledge to choose correct plant species, manage irrigation and microclimate, compare land uses and predict impacts on the environment, including nutrient and agrochemical movement in the landscape. We discuss current progress in IAEA and related projects which are aimed at bringing an integrated, multi-disciplinary framework for area-wide water management that can promote food security, water resources and essential ecosystem services.