Geophysical Research Abstracts,
Vol. 11, EGU2009-8879, 2009
EGU General Assembly 2009

Assessing water-use-efficiency from stable isotopes and eddy covariance data

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The water and carbon cycles in terrestrial ecosystems play an essential role in the earth system by modifying the atmospheric carbon dioxide and water vapor composition and by partitioning energy at the land surface. Carbon uptake during photosynthesis and water release during transpiration are closely linked through stomatal conductance. The efficiency of carbon uptake versus water loss is called water-use-efficiency and is a key factor for agricultural irrigation practices and species competition in water limited ecosystems.

Here we review various concepts to assess water-use-efficiency at plant and ecosystem scale and present results from different biomes. We will show that inherent water-use-efficiency (estimated from eddy covariance measurements as the ratio of gross primary productivity over evapotranspiration times vapor pressure deficit) is a fairly conservative ecosystem property and only changes under sever drought conditions. Another approach to assess water-use-efficiency is the stable carbon isotope composition (δ^{13}C) of plant material. Typically, in a first approximation a simply linear relationship between leaf δ^{13}C and intrinsic water-use-efficiency (the ratio of assimilation to stomata conductance) is assumed. More recent studies, however, show that various factors influence leaf δ^{13}C independently of the exchange through the stomata leading to incorrect water-use-efficiency estimates. Based on laboratory and field experiments using stable carbon isotopes in various plant components as well as recently developed laser spectroscopy for continuous stable isotope measurements we discuss possibilities and limitations of using stable carbon isotopes to approximate plant water-use-efficiency.