Geophysical Research Abstracts
Vol. 17, EGU2015-5398, 2015
EGU General Assembly 2015

Optimal allocation in annual plants and its implications for drought response

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The concept of plant optimality refers to the plastic behaviour of plants that results in lifetime and offspring fitness. Optimality concepts have been used in vegetation models for a variety of processes, including stomatal conductance, leaf phenology and biomass allocation. Including optimality in vegetation models has the advantages of creating process based models with a relatively low complexity in terms of parameter numbers but which are capable of reproducing complex plant behaviour. We present a general model of plant growth for annual plants based on the hypothesis that plants allocate biomass to aboveground and belowground vegetative organs in order to maintain an optimal C:N ratio. The model also represents reproductive growth through a second optimality criteria, which states that plants flower when they reach peak nitrogen uptake. We apply this model to wheat and maize crops at 15 locations corresponding to FLUXNET cropland sites. The model parameters are data constrained using a Bayesian fitting algorithm to eddy covariance data, satellite derived vegetation indices, specifically the MODIS fAPAR product and field level crop yield data. We use the model to simulate the plant drought response under the assumption of plant optimality and show that the plants maintain unstressed total biomass levels under drought for a reduction in precipitation of up to 40%. Beyond that level plant response stops being plastic and growth decreases sharply. This behaviour results simply from the optimal allocation criteria as the model includes no explicit drought sensitivity component. Models that use plant optimality concepts are a useful tool for simulation plant response to stress without the addition of artificial thresholds and parameters.