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Stomatal control of gas-exchange is related to assimilate transport from leaves

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In land plants, the carbon fluxes are closely associated with those of water. The loss of water from leaves pulls water from soil in plants. High transpiration relative to compensating water flux from soil increases the tension of water column that may lead to its rupture and catastrophic dysfunction of the xylem if the transpiration rate is not regulated.

Modification of the size of stomatal openings in leaves regulates the interconnected fluxes of water and carbon. Stomatal regulation of transpiration has direct influence also on the carbon transport from source leaves to sinks. Under given conditions, the water tension of xylem in leaves is linearly related to stomatal conductance while the assimilation rate, which is linked to the loading capacity, has saturating relationship with stomatal conductance. High sugar loading at source could compensate for the high water tension in xylem resulting from eg. high transpiration. However, excessive loading rate of the most commonly transported sugar, sucrose, causes rapid viscosity build up that effectively blocks the phloem transport.

Assimilate transport from the shoot is a clear requirement for continuous photosynthetic production in leaves. Without transport the storage capacity of the leaves would be rapidly exhausted and accumulation of excess sugars in leaves lead to downregulation of photosynthesis. In this presentation we study the stomatal response to environment and its linkage to xylem and phloem tranport with dynamic model. We hypothesize that stomatal reaction to environment would maintain maximal assimilate transport in phloem under those conditions.

We added to the xylem phloem transport model stomatal control of leaf gas-exchange, light and CO2 concentration dependent photosynthesis rate and carbon storage in leaf. For each time step we varied the stomatal conductance and selected the sollution that maximised the transport of assimilates in phloem.

Our hypothesis reproduced realistically stomatal response to main environmental drivers and it reproduced the measured variation in leaf gas exchange both during daily variation of light, temperature and vapor pressure deficit and also during gradually developing drought. During the normal soil water availability the modeled results were identical to those that the optimal stomatal control of gas exchange would give. However, this new approach could also predict directly how soil drying is influencing the gas-exchange and also feed-forward response of stomatal conductance that has not been possible previously. Although maximising sugar transport from leaves to sink tissues as such is not mechansitic explanation to the actual control of stomata, the approach gives new possibilities to evaluate the impact of number of plant processes and environmental variables on tree production.