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Evolution of plant economics in a water limited environment

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Plants rely on water for their photosynthesis. Water deficit initially leads to lower plant growth rate, later to hydraulic failure or carbon starvation, and ultimately to death. Plants have evolved many strategies to withstand long periods of drought, such as thick leaves, high wood density, early reproduction time, and deep roots. Our understanding of plant response to future climate depends critically on plant responses to drought. The expected increase in variation both in precipitation and temperature suggests that future models should capture flexibility in plant traits and therefore responses to drought. However, how to model adaptation and acclimation to varying conditions is still an open question. In this contribution we tackle this issue with an evolutionary eco-hydrological model that allows traits to evolve in response to hydrologic conditions and competition for limited space and water resources. With this theoretical tool, we aim to understand how traits are expected to vary along gradients of aridity.

Plants can be positioned in the plant economics spectrum depending on if their growth is fast or slow, where fast growth is associated with high mortality, and high water uptake. Functional trait changes associated with fast growth are for example a lower wood density and a lower leaf mass per area. Notably, because of coordination among traits along the economy spectrum, it is possible to start considering a single trait as a proxy for others that co-vary with it. Hence, we develop a minimal model based on a single trait related to growth rate, where plants are competing for space and water. We explore the importance of the trait and the soil water content on three functions describing birth rate, mortality and water uptake. We do this by comparing the evolutionarily stable strategy (ESS), resulting from a competitive game between strategies defined by their trait value, with the two optimal strategies maximizing plant density or soil water content.

We report the following findings: (1) When soil water only depends on plant density the trait minimizing soil water content is evolved. Increasingly fast growing plants evolve at an increasing background mortality. (2) With dynamic soil water a higher precipitation, or a lower evaporation, promotes the evolution of faster plants as well as higher plant densities and higher soil water content. (3) By comparing different model types we can conclude that a trait dependence on birth rate, mortality and water uptake is crucial to get an internal ESS between the strategy maximizing plant density and the strategy minimizing soil water content.