Doctoral Thesis Title: Functional trait variations and habitat affinities of karst tree species in Guangxi Province, South China

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Abstract

Karsts, i.e., jagged topography created by dissolution of carbonate rocks, are distributed extensively in tropical forest regions. They are characterized by a mosaic of water and nutrient availability, from exposed hilltops with poor soil development to valleys with occasional flooding, to which trees show species-specific distributions. The main objective of this thesis was to examine functional traits that underpin tree distribution patterns in tropical karst forests. Plant materials from tree species with known habitat affinities to hilltops, mid-slopes, foothills, and valleys were sampled in a tropical seasonal karst rainforest in South China. The results indicate that high values of leaf mass per area (LMA) of hilltop species reflect an adaptive strategy to the nutrient and water limited hilltop environment (Chapter 4). These high values of LMA of hilltop species were associated with high values of lamina thickness, leaf dry matter content, and leaf soluble sugar concentrations (Chapter 4-5). Although static leaf traits (morpho-anatomical traits such as stomatal pore index and vein length per area) should be correlated with leaf hydraulic conductance and photosynthetic capacity, they were not correlated with dynamic ecophysiological traits measured during the dry season (Chapter 6). The results suggest that evergreen trees exhibited downregulation of ecophysiological traits through stomatal closure during the drought, rather than shedding leaves in resource-limited environments. Overall, karst tree species exhibit leaf trait syndromes that apparently evolved in relation to their specialization to edaphic habitats.

Chapter 02 Title: Plant ecology of tropical and subtropical karst ecosystems

Abstract

Karst landscapes are formed on soluble carbonate rocks such as limestone, dolomite, and gypsum, and are characterized by sinkholes, caves, underground streams, and exposed hills. They occupy 10 - 15% of ice-free continental surface, overlapping with nine tropical biodiversity hotspots, where anthropogenic disturbances are acute. Hydrological, edaphic and topographic factors are extremely heterogeneous within the karst landscapes, and they influence ecology and distribution patterns of plants. The epikarst (the upper layer of karst rocks) may support little soil, but rock dissolution creates holes of various sizes resulting in substantial water storage within the epikarst. While tolerance of drought and nutrient limitation may play an important role in edaphic specialization, endemism, and biodiversity of karst plants, our literature review suggests that karst trees at large are not necessarily more resistant to drought-induced xylem cavitation compared to non-karst trees. Based on studies that examined isotopic signatures of xylem sap to locate potential belowground water sources, we here identify four types of water use strategies among karst plants: (i) soil water dependents, (ii) epikarst dependents (using both soil water and water stored in epikarst rock, but primarily epikarst water in the dry season), (iii) groundwater dependents, and (iv) fog dependants. Although karst ecosystems are generally considered infertile, particularly in terms of phosphorus availability, this review of published literature reveals that foliar nitrogen-to-phosphorus ratios vary widely across karst regions without clearly differentiating from non-karst ecosystems. In summary, the water use strategies and habitat affinities of karst tree species appear to contribute to species coexistence and community assembly. Thus, the diverse resource acquisition and utilization strategies of karst plants that allow them to grow in their habitats should be considered in developing effective restoration strategies for this unique landscape.

Chapter 04 Title: Leaf trait variations associated with habitat affinity of tropical karst tree species

Abstract

Karst hills, i.e., jagged topography created by dissolution of limestone and other soluble rocks, are distributed extensively in tropical forest regions, including southern parts of China. They are characterized by a sharp mosaic of water and nutrient availability, from exposed hilltops with poor soil development to valleys with occasional flooding, to which trees show species-specific distributions. Here we report the relationship of leaf functional traits to habitat preference of tropical karst trees. We described leaf traits of 19 tropical tree species in a seasonal karst rainforest in Guangxi, China, 12 species *in-situ* and 13 *ex-situ* in a non-karst arboretum, which served as a common garden, with six species sampled in both. We examined how the measured leaf traits differed in relation to species' habitat affinity and evaluated trait consistency between natural habitats *vs.* the arboretum. Leaf mass per area (LMA) and optical traits (light absorption and reflectance characteristics between 400 and 1050 nm) showed significant associations with each other and habitats, with hilltop species showing high values of LMA and low values of photochemical reflectance index (PRI). For the six species sampled in both the karst forest and the arboretum, LMA, leaf dry matter content, stomatal density, and vein length per area showed inconsistent within-species variations, whereas some traits (stomatal pore index and lamina thickness) were similar between the two sites. In conclusion, trees specialized in exposed karst hilltops with little soils are characterized by thick leaves with high tissue density indicative of conservative resources use, and this trait syndrome could potentially be sensed remotely with PRI.

Chapter Title 05: Nonstructural carbohydrate concentrations in leaves, stems and roots of tropical karst tree species from four contrasting edaphic habitats

Abstract

Association of plant functional traits to fine-scale environmental gradients are imperative for elucidating niche assembly process and species coexistence of tropical forest trees. Using a natural topographical gradient in a tropical karst forest in South China, we examined how nonstructural carbohydrate concentrations in leaves, distal branches, and roots vary across 13 common tree species in relation to their habitat affiliations. The study was conducted in the dry season, and soil volumetric water content decreased with increasing altitude. Species in hilltops had leaves with higher concentration of simple sugars and higher leaf mass per area than those in lower slopes. No clear differences in starch concentration in roots and branches were observed among habitats. A positive association between leaf simple sugar concentration and leaf mass per area in our dataset indicates that they covary in relation to habitat preference of the karst tree species. These results suggest a possible role of leaf oligosaccharides for osmoregulation in drought-prone habitats under natural conditions, but carbohydrate storage in roots and stems did not appear to be selected differently among contrasting topographic positions.

Chapter 06 Title: Regulation of leaf hydraulic and photosynthetic traits of six tree species in a seasonally dry tropical forest during dry season

Abstract

Soil and atmospheric water deficits affect growth and leaf ecological strategy of evergreen trees in seasonally dry tropical forests. Adaptations of leaf traits to such seasonal climates may involve dynamic regulation of ecophysiological traits and static adjustments to morpho-anatomical traits that remain relatively constant in fully-developed evergreen leaves. Here, we quantified 13 ecophysiological traits related to leaf hydraulics and photosynthesis in six tropical karst tree species. We tested how stomatal pore index (SPI) and vein length per area (VLA) differed with leaf hydraulic conductance (K_{leaf}) and photosynthetic capacity during the dry season. We used relationships reported in published studies conducted under optimal conditions as reference. The results suggest that photosynthetic and hydraulic traits measured during the dry season are downregulated compared to the reference relationships. This strategy appears to be favored over irreversible adjustments to static leaf traits that constrain photosynthetic gains during growing season.