Appendix S2. Details of theoretical carbon balance simulations**.**

A. Details of leaf gas exchange and energy balance model

We calculated "positive carbon balance" (C) for each member of the four simulated populations, described in the next section, from a carbon balance, given by

$$C = A - \chi_{\mathrm{w}} E - \chi_{\mathrm{t}} H, \qquad \text{(Eq. S1)}$$

where A is leaf net CO_2 assimilation rate (μmol CO_2 m^{-2} s^{-1}), E is leaf transpiration rate (mol H_2O m^{-2} s^{-1}), χ_{w} is an assumed amortized cost of acquiring and transporting water from the soil to leaves to match the transpiration demand (μmol CO_2 mol^{-1} H_2O), H is relative trichome density (unitless; H = whole-leaf trichome density divided by its population median), and χ_{t} is the amortized carbon cost of constructing trichomes per unit of relative trichome density (μmol C m^{-2} s^{-1}). Estimation of χ_{w} and χ_{t} is described in section B, Parameter estimation below.

We calculated A from the Farquhar et al. (1980) biochemical model, which predicts A as the lesser of two values: A_{v} (limited by RuBP carboxylation rate) and A_{j} (limited by RuBP regeneration rate). In practice, we used hyperbolic minimization to smooth the transition between the two limitations:

$$A = \frac{0.5}{\theta_{\mathrm{A}}}\left(A_{\mathrm{v}} + A_{\mathrm{j}} - \sqrt{\left(A_{\mathrm{v}} + A_{\mathrm{j}}\right)^2 - 4\theta_{\mathrm{A}} A_{\mathrm{v}} A_{\mathrm{j}}}\right), \qquad \text{(Eq. S2)}$$

where $\theta_{\mathrm{A}} = 0.99$ is a dimensionless curvature parameter. We calculated A_{v} and A_{j} as

$$A_{\mathrm{v}} = V_{\mathrm{m}} \frac{c_{\mathrm{i}} - \Gamma_*}{c_{\mathrm{i}} + K_{\mathrm{c}}\left(1 + \frac{O}{K_{\mathrm{o}}}\right)} - R_{\mathrm{d}} \text{ and} \qquad \text{(Eq. S3)}$$

$$A_{\mathrm{j}} = \frac{J}{4} \cdot \frac{c_{\mathrm{i}} - \Gamma_*}{c_{\mathrm{i}} + 2\Gamma_*} - R_{\mathrm{d}}, \qquad \text{(Eq. S4)}$$

where V_m is the maximum velocity of RuBP carboxylation, c_i is intercellular CO_2 mole fraction (μmol mol^{-1}), Γ_* is the photorespiratory CO_2 compensation point (μmol mol^{-1}), K_c and K_o (μmol mol^{-1}) are the Michaelis constants for RuBP carboxylation and oxygenation, respectively, O is the mole fraction of O_2 (210,000 μmol mol^{-1}), R_d is the rate of non-photorespiratory CO_2 release (μmol m^{-2} s^{-1}), and J is the potential electron transport rate (μmol m^{-2} s^{-1}). We calculated A_v and A_j using values of c_i calculated for each limitation by combining Eqs. **Error! Reference source not found.**~~S3~~ or **Error! Reference source not found.**~~S4~~, respectively, with the diffusional constraint on CO_2 assimilation (Eq. **Error! Reference source not found.**~~S5~~) and solving the quadratic expression that results for c_i. The diffusional constraint is

$$A = g_{tc}(c_a - c_i), \quad \text{(Eq. S5)}$$

where g_{tc} (mol m^{-2} s^{-1}) is total conductance to CO_2 and c_a is ambient CO_2 mole fraction (μmol mol^{-1}). g_{tc} is the sum of abaxial and adaxial values:

$$g_{tc} = g_{tc,ab} + g_{tc,ad}, \quad \text{(Eq. S6)}$$

which in turn are parallel sums of stomatal and boundary layer conductances:

$$g_{tc,x} = \left(g_{sc,x}^{-1} + g_{bc,x}^{-1}\right)^{-1}, \quad \text{(Eq. S7)}$$

where x denotes abaxial or adaxial. We calculated g_{sc} for each surface from stomatal conductance to water vapor, g_{sw}, as $g_{sc} = g_{sw}/1.6$, reflecting the smaller diffusivity for CO_2 than for H_2O, and we calculated g_{bc} from boundary layer conductance for water vapor as $g_{bc} = g_{bw}/1.37$, which reflects the partial contribution of advection (which is not affected by molecular diffusivity) to transport through the boundary layer. g_{sw} was determined from stomatal density for each surface separately as

$$g_{sw,x} = 0.001 D_{s,x}, \quad \text{(Eq. S8)}$$

where again x denotes abaxial or adaxial, g_{sw} has units of mol m^{-2} s^{-1}, and D_s has units of stomata mm^{-2}. We calculated boundary layer conductance for each surface from trichome density, D_t, as

$$g_{\mathrm{bw,x}} = \left[r_{\mathrm{bw,min}} + (r_{\mathrm{bw,max}} - r_{\mathrm{bw,min}}) \cdot \frac{H_{\mathrm{x}}}{H_{\mathrm{x}} + 1}\right]^{-1}, \quad \text{(Eq. S9)}$$

where $r_{bw,min}$ and $r_{bw,max}$ (m^2 s mol^{-1}) are values of boundary layer resistance in the absence of trichomes or in the limit of infinite trichome density, respectively, and H_x (unitless) is the relative trichome density for surface x.

Potential electron transport rate was calculated as

$$J = \frac{0.5}{\theta_{\mathrm{j}}}\left(J_{\mathrm{m}} + \phi i - \sqrt{(J_{\mathrm{m}} + \phi i)^2 - 4\theta_{\mathrm{j}} J_{\mathrm{m}} \phi i}\right), \quad \text{(Eq. S10)}$$

where J_m is maximum potential electron transport rate (μmol m^{-2} s^{-1}), ϕ is the effective maximum quantum yield of electrons from absorbed photosynthetic photon flux (PPFD), i is absorbed PPFD (μmol m^{-2} s^{-1}), and θ_j is a dimensionless curvature parameter. i was calculated as $(1 - \rho)i_o$, where i_o is the incident PPFD and ρ is leaf reflectance (unitless), estimated from trichome density as

$$\rho = \left[\rho_{\mathrm{min}} + (\rho_{\mathrm{max}} - \rho_{\mathrm{min}}) \cdot \frac{H}{H + 1}\right]^{-1}, \quad \text{(Eq. S11)}$$

where ρ_{min} and ρ_{max} are the values of reflectance with no trichomes and in the limit of infinite trichome density, respectively, and H is the relative whole-leaf trichome density. Estimation of V_m, R_d, Γ_*, K_c, K_o, J_m, ϕ, and θ_j are described in section B, Parameter estimation below.

Transpiration rate was calculated as

$$E = g_{\mathrm{tw}}(\Delta w_{\mathrm{a}} + s\delta), \quad \text{(Eq. S12)}$$

where Δw_a (mol mol^{-1}) is the vapor pressure deficit of the air expressed as a mole fraction, calculated as $\Delta w_a = w_{sa} - w_a$, where w_{sa} is the saturation water vapor mole fraction calculated at air temperature T_{ac} in °C as $w_{sa} = 0.006112 \cdot \exp[17.62T_{ac}/(243.12 + T_{ac})]$, and w_a is the ambient water vapor mole fraction; s (mol mol^{-1} K^{-1}) is the slope of saturation water vapor mole fraction vs temperature calculated as $s = w_{sa}17.62 \times 243.12/(243.12 + T_{ac})^2$; and δ(K) is the difference between leaf and air temperature; g_{tw} is total leaf conductance to water vapor, calculated as the sum of abaxial and adaxial values, which are given by

$$g_{\mathrm{tw,x}} = \left(g_{\mathrm{sw,x}}^{-1} + g_{\mathrm{bw,x}}^{-1}\right)^{-1}, \quad \text{(Eq. S12)}$$

where x = adaxial or abaxial. δ is calculated from the energy balance using an approximation that arises from linearizing the saturation vapor pressure response to temperature near leaf temperature, and omitting terms in δ^2, δ^3 and δ^4 from the expansion of T_{LK}^4 as $(T_{aK} + \delta)^4$ (where T_{aK} and T_{LK} are air and leaf temperatures, respectively, in K), giving

$$\delta = \frac{Q + (\epsilon_{\mathrm{air}} - \epsilon_{\mathrm{leaf}})\sigma T_{\mathrm{aK}}^4 - \lambda g_{\mathrm{tw}} \Delta w_{\mathrm{a}}}{4\epsilon_{\mathrm{leaf}}\sigma T_{\mathrm{aK}}^3 + c_{\mathrm{pa}} g_{\mathrm{bh}} + \lambda g_{\mathrm{tw}} s}, \quad \text{(Eq. S13)}$$

where Q is absorbed shortwave radiation (J m^{-2} s^{-1}), σ is the Stefan-Boltzmann constant (5.67 × 10^{-8} J m^{-2} s^{-1} K^{-4}), ε_{air} is the IR emissivity of the atmosphere [$0.642(w_a 101325/T_{aK})^{1/7}$]; unitless), ε_{leaf} is the leaf IR emissivity (0.98), λ is the latent heat of vaporization (4.4 × 10^4 J mol^{-1}), c_{pa} is the heat capacity of air (29.2 J mol^{-1} K^{-1}), and g_{bh} is boundary layer conductance to heat, calculated as the sum of abaxial and adaxial values, given by

$$g_{\mathrm{bh,x}} = \frac{g_{\mathrm{bw,x}}}{1.08}, \quad \text{(Eq. S14)}$$

where 1.08 is the ratio of the diffusion coefficients for water vapor and heat. We calculated Q as $Q = 0.322i$, where 0.322 converts from photosynthetic photon flux to total shortwave energy flux

based on the energy distribution of the shortwave spectrum (incident shortwave energy = $0.5666 i_o$; de Pury and Farquhar 1997) and the ratio of absorptances for total shortwave and visible radiation (0.568) given by Ehleringer and Mooney (1978).

B. Parameter estimation

Marginal carbon cost of transpiration (χ_w). We estimated χ_w by assuming, based on the equimarginal theorem, that when carbon investments in plant structure and function are optimized, the marginal carbon cost and revenue of transpiration are equal. The latter is $(\partial A/\partial g_{sw})/(\partial E/\partial g_{sw})$, for which a typical value under conditions of plentiful water supply would be on the order of 400 μmol CO_2 mol^{-1} H_2O. We used that value for the "high moisture" environment, and values of 1000 and 700 μmol CO_2 mol^{-1} H_2O to represent "low moisture" and "intermediate moisture" environments, respectively.

Marginal carbon cost of trichomes (χ_t). This parameter represents the direct carbon cost of construction for trichomes, not any indirect costs to growth, etc. We estimated χ_t by arbitrarily assuming that the carbon content of trichomes represents 10% of the carbon content of the leaf when trichome density equals the population median in this study (165.5 mm^{-2}), then calculating leaf carbon content for a typical leaf with dry mass per area 250 g m^{-2} and 37% carbon by dry mass, and dividing by an effective amortization period of 3.1×10^6 s (which scales midday, midsummer gas exchange rates to an effective annual total assuming sinusoidal diurnal and seasonal patterns (Buckley and Roberts, 2006). These assumptions make amortized trichome C content commensurable with the instantaneous midday values of net photosynthesis calculated as described earlier. This calculation gives $\chi_t = 0.25$ μmol m^{-2} s^{-1}, which also equals the amortized carbon cost of trichomes when $H = 1$ (i.e., at median trichome density).

Boundary layer resistance with and without trichomes ($r_{bw,max}$ and $r_{bw,min}$). We calculated $r_{bw,min}$ (the value in the absence of hairs) using expressions given by Nobel (1999), assuming a leaf characteristic dimension of 5 cm and wind speed of 2 m s^{-1}. These assumptions give $r_{bw,min}$ = 0.613 m^2 s mol^{-1} at 28°C. We then assumed that trichomes of very high density would double the boundary layer resistance, based on Parkhurst (1976), giving $r_{bw,max} = 1.226$ m^2 s mol^{-1}.

Leaf albedo with and without trichomes (ρ_{max}, ρ_{min}). We estimated ρ_{min} and ρ_{max} from observations of Ehleringer and Mooney (1978) in *Encelia farinosa*, as $\rho_{min} = 0.19$ and $\rho_{max} = 0.71$.

Environmental conditions. We assumed ambient CO_2 mole fraction, c_a, was 400 μmol mol^{-1}; ambient water vapor mole fraction was $w_a = 0.02$ mol mol^{-1} (wet/mild environment), 0.015 (semi-arid environment) or 0.01 (dry/hot environment); incident PPFD was $i_o = 1700$ μmol m^{-2} s^{-1}; and air temperature was $T_{ac} = 25$°C (wet/mild), 35°C (semi-arid) or 40°C (hot/dry).

Photosynthetic parameters. We arbitrarily set the value of V_m at 25°C as 50 μmol m^{-2} s^{-1} and assumed the values of J_m and R_d at 25°C were 2.1 and 0.01 times that of V_m, respectively (Wullschleger, 1993; de Pury and Farqhar, 1997). We calculated V_m, J_m and R_d at the actual leaf temperature, and values of Γ_*, K_c, K_o, ϕ and θ_J from temperature response functions given by Bernacchi et al. (2002, 2003).

C. Procedures used to generate four species sets

We applied the model to each leaf in three "species sets", simulated using the marginal density distributions for each variable (abaxial and abaxial D_s and D_t) but modified and/or filtered to represent four extreme scenarios: whole-leaf D_s and D_t are completely uncorrelated ("independent" species set), perfectly negatively correlated due to a developmental trade-off ("trade-off"), or perfectly positively correlated due to a positive developmental constraint ("positive coordination"). We generated these three species sets as follows. First, we fitted density distribution functions to each variable in (abaxial and abaxial D_s and D_t) in the California species data set. Then we sampled 1000 times from these marginal distributions to create a species set in which the four variables varied independently from one another. We repeated this procedure 1000 times using different randomization seeds, in each case eliminating species for which D_s or D_t for either surface was negative or whole-leaf D_s or D_t exceeded the maxima observed in the original species set, and selected the resulting species set that gave the weakest correlation between whole-leaf D_s and D_t ($r = 0.000075$). This procedure left a species set of 842 species in which D_s and D_t were, for practical purposes, perfectly uncorrelated, which we refer to as the "independent" species set. We then generated three species sets by modifying the

independent species set. For the "positive coordination" species set, we replaced sampled values of whole-leaf D_t in the independent species set with values calculated from sampled whole-leaf D_s using the positive correlation in the original data set ($D_t = 0.321D_s + 5.36$); This positive correlation represents the extreme scenario in which D_t and D_s are fully mutually determined by a positive developmental constraint. For the "trade-off" species set, we recalculated D_t as for the positive coordination case, but with the direction of the correlation reversed to simulate what would occur if D_t and D_s were fully mutually constrained by a developmental tradeoff, which gives $D_t = 0.321[\max(D_s) - D_s] + 5.36$, where the quantity $\max(D_s) - D_s$ can be understood as a reflection ("flipping" horizontally) of the D_s axis.

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