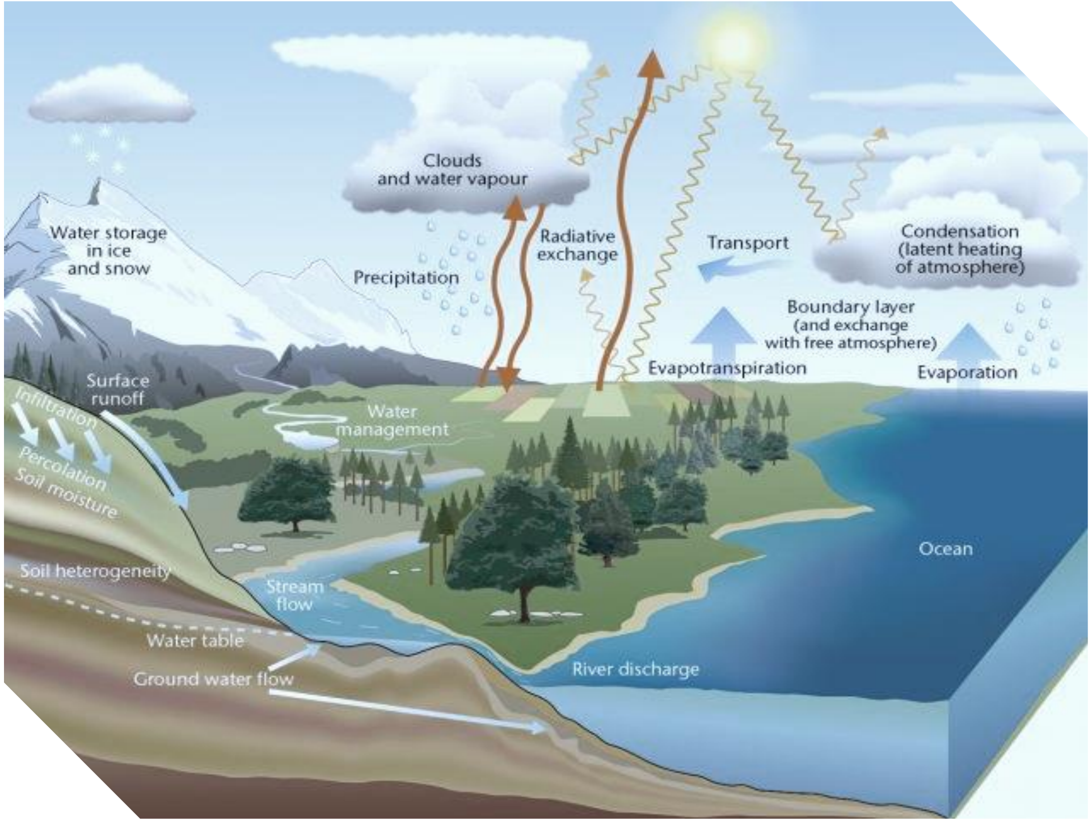
Linking Budyko Framework and the Complementary Evaporation Principle for proper consideration of surface energy balance



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BUDYKO FRAMEWORK

For quick first-order precipitation partitioning

$E \rightarrow P$ when $\frac{R_n}{P} \rightarrow \infty$ (*water limited*)

$E \rightarrow R_n$ when $\frac{R_n}{P} \rightarrow 0$ (*energy limited*)

$$R_n = \lambda_v E + H$$

$$\frac{\lambda_v E_p}{P} = \frac{\lambda_v E}{P} + \frac{B \lambda_v E}{P}$$

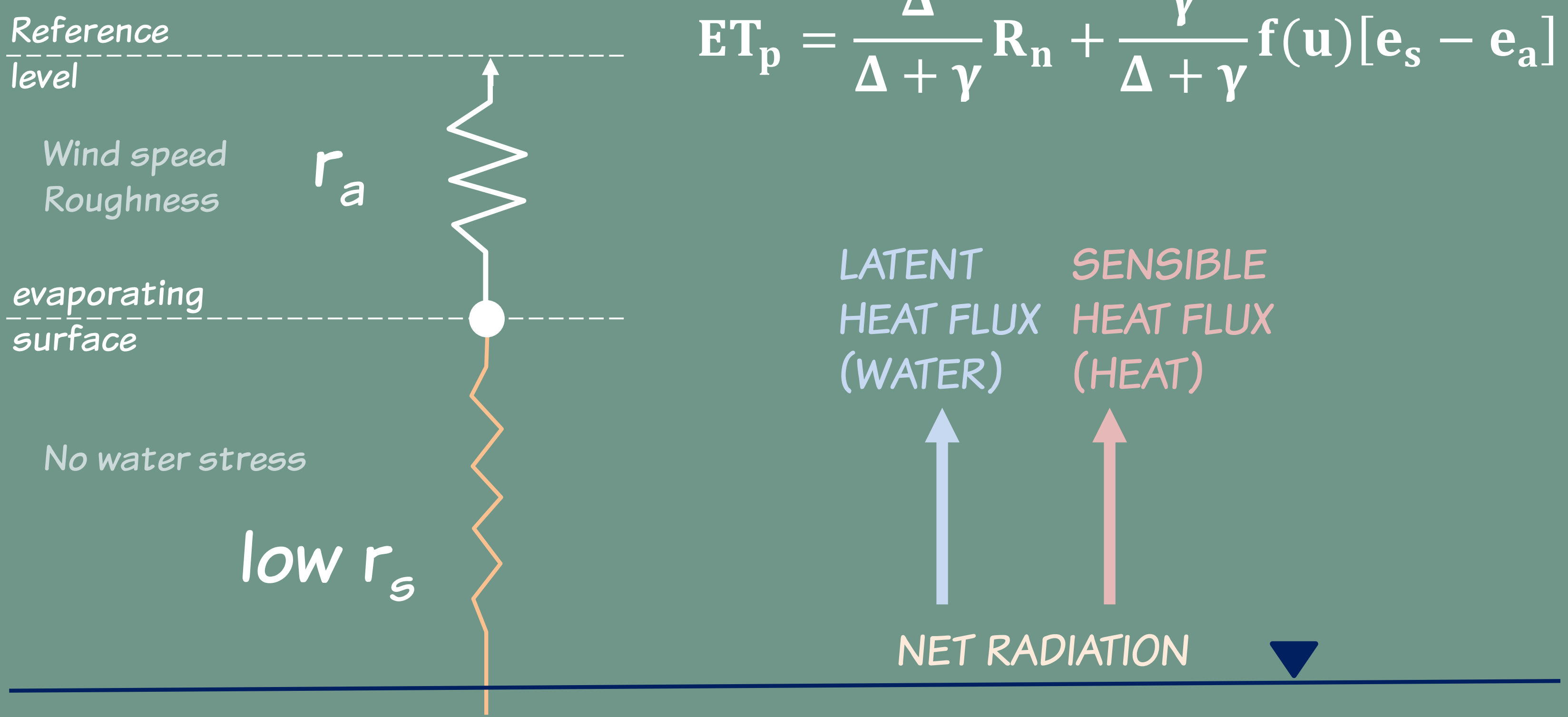
$$\frac{E_p}{P} = \frac{E}{P}(1 + B)$$

$$\frac{E}{P} = F\left(\frac{E_p}{P}\right)$$

ATMOSPHERIC EVAPORATIVE POTENTIAL (AEP)

AEP = E_p = E under no water stress:

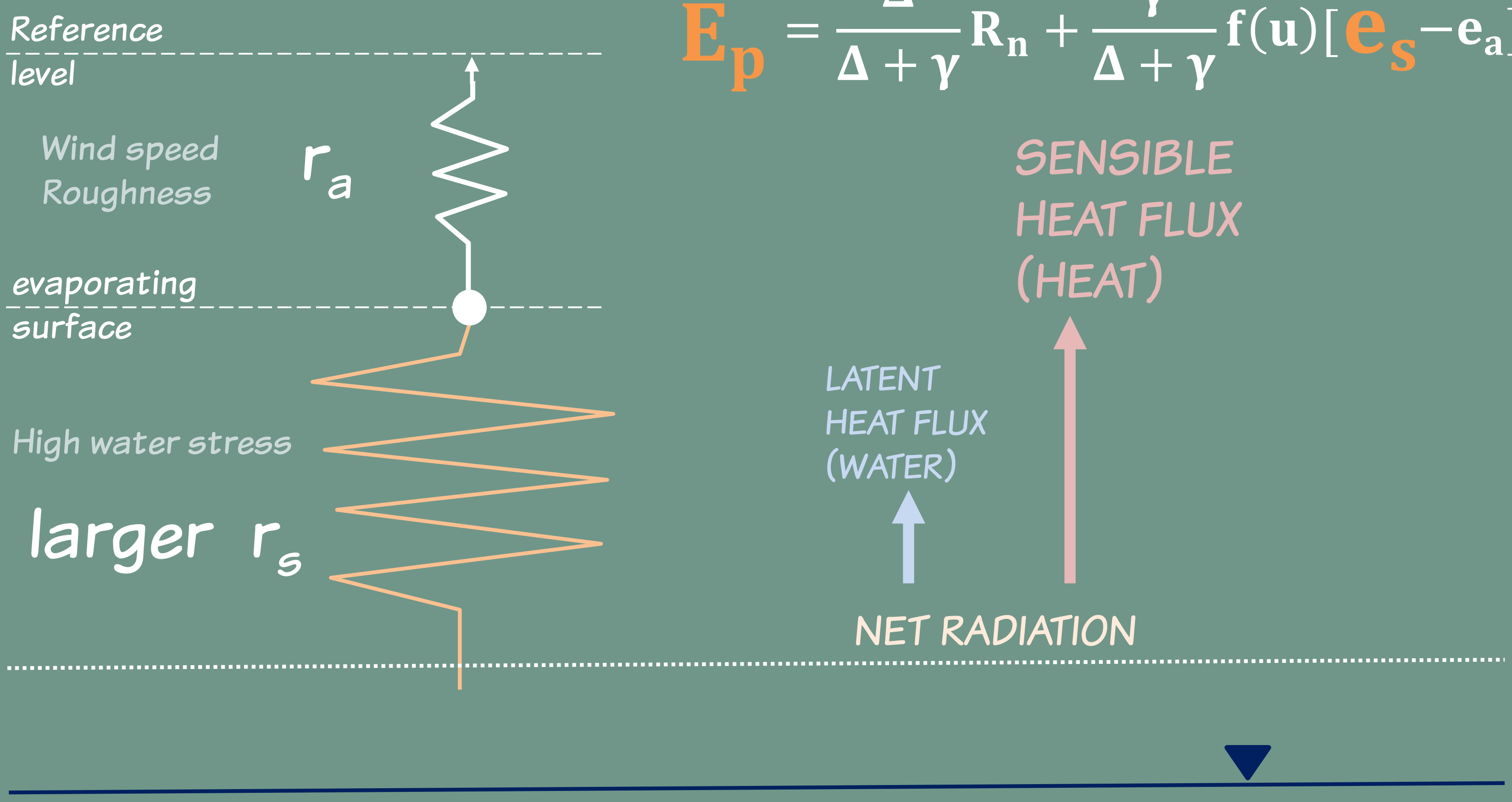
$$\mathbf{ET_p} = \frac{\Delta}{\Delta+\gamma}\mathbf{R_n} + \frac{\gamma}{\Delta+\gamma}\mathbf{f(u)}\underbrace{[\mathbf{e_s}-\mathbf{e_a}]}_{\text{VPD}}$$



ATMOSPHERIC EVAPORATIVE POTENTIAL (AEP)

AEP › E_p › E under water stress:

$$E_p = \frac{\Delta}{\Delta + \gamma} R_n + \frac{\gamma}{\Delta + \gamma} f(u)\underbrace{[e_s - e_a]}_{VPD}$$



TO CORRECT AEP to E_p

Linking the Budyko framework with the CR:

$$\frac{E}{P} = \frac{AEP}{P}\left[\frac{1}{1+\left(\frac{AEP}{P}\right)^{n}}\right]^{1/n}$$

$$\frac{E}{P} = \frac{E_p}{P}\left[\frac{1}{1+\left(\frac{E_p}{P}\right)^{n}}\right]^{1/n}$$

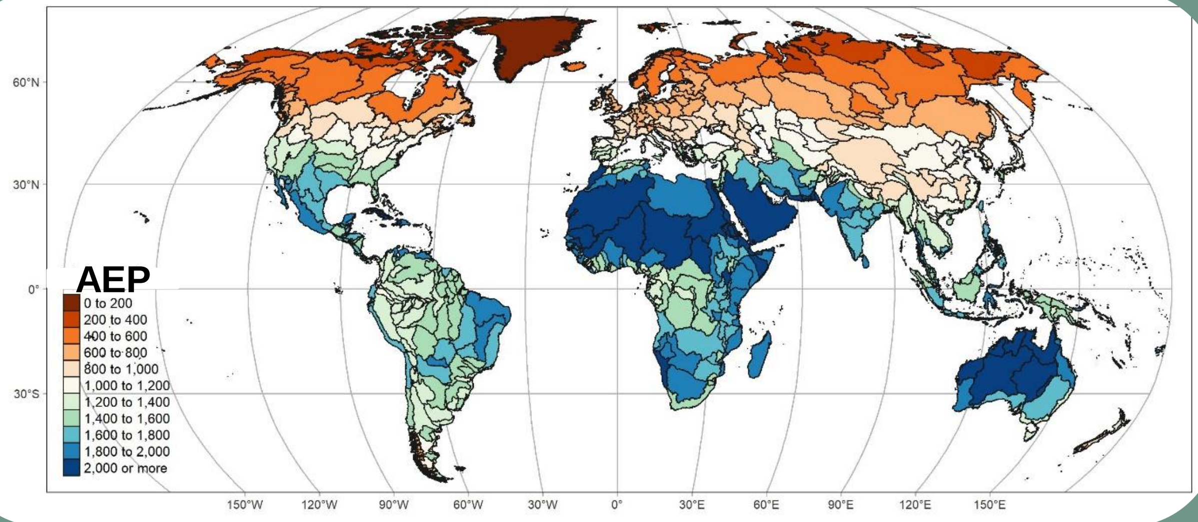
CR by Szilagyi et al. (2017)

$$y = 2X^2 - X^3$$

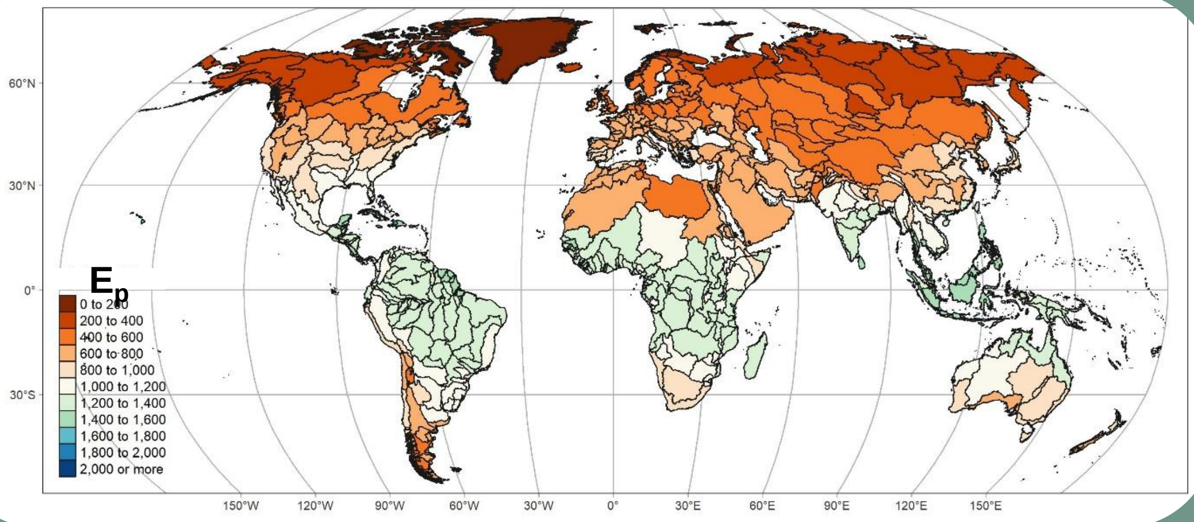
$$y = \frac{E}{AEP} \quad X = f\left(\frac{E_p}{AEP}\right)$$

AEP > E_p IS TYPICAL ON LAND SURFACES

AEP

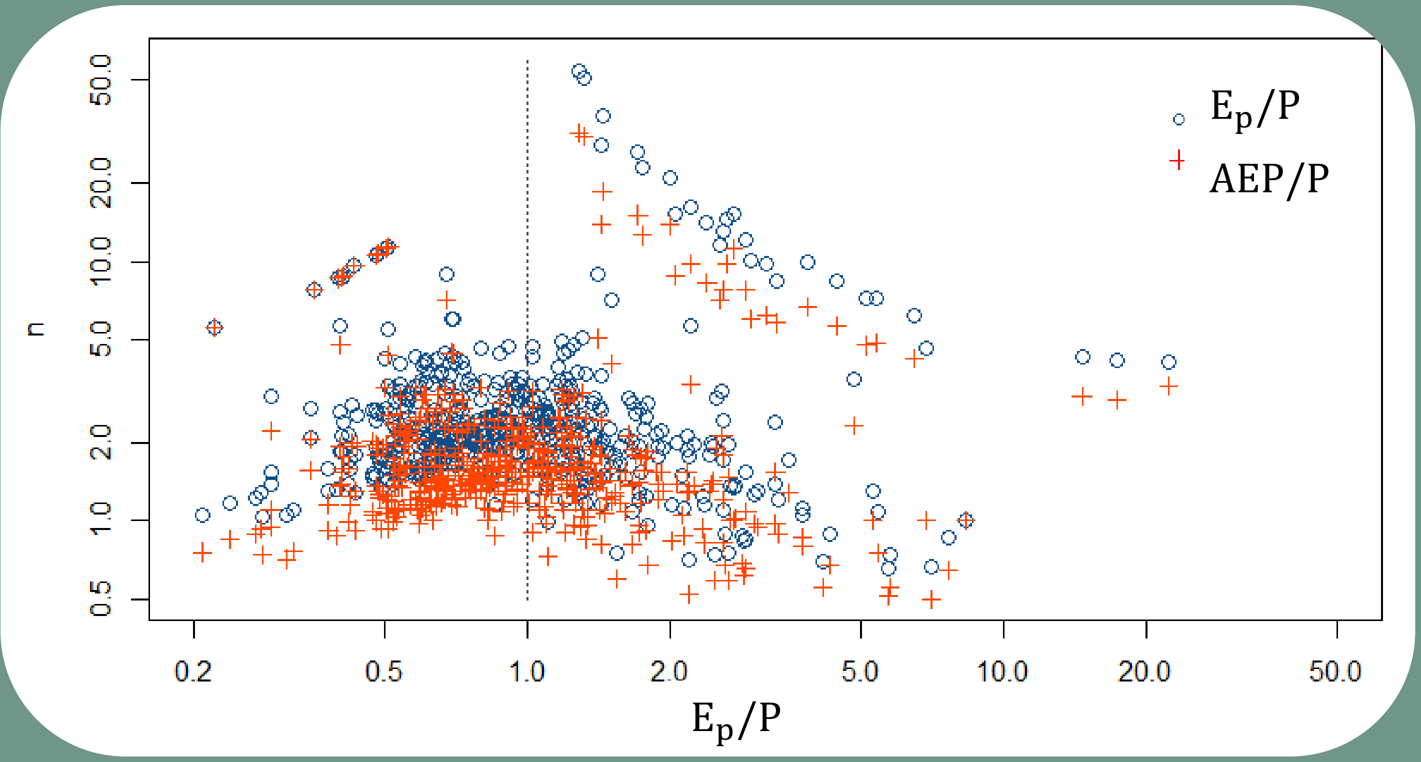


E_p



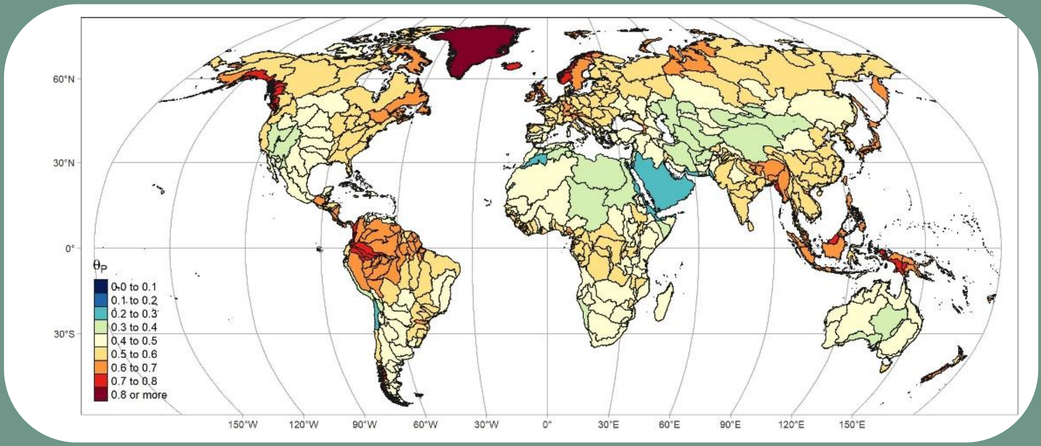
THE SHAPE PARAMTER COULD BE DISTURBED

$$\frac{E}{P} = \left[\frac{1}{1 + \left(\frac{P}{E_p}\right)^n}\right]^{\frac{1}{n}}$$

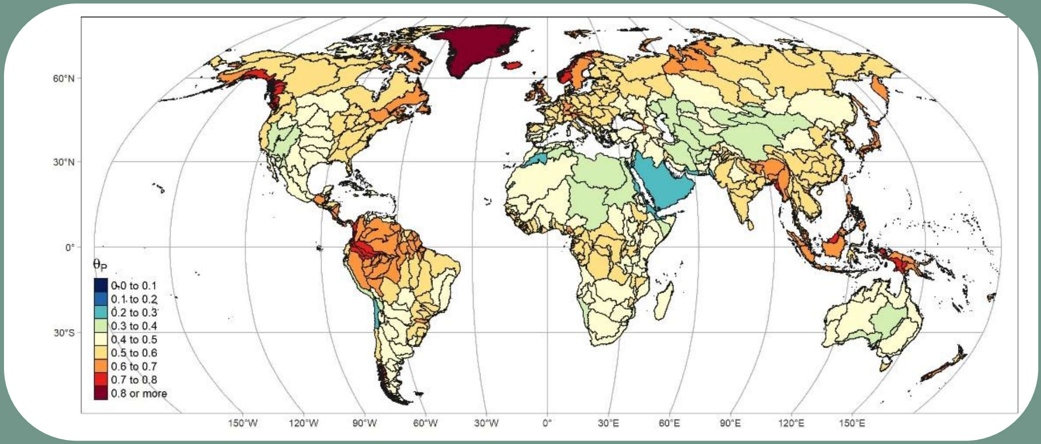


THE SHAPE PARAMTER COULD BE DISTURBED

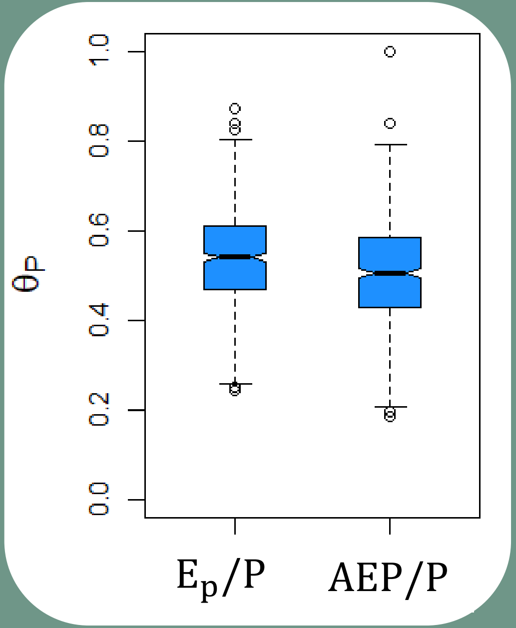
E_p



With AEP



$$\frac{\partial E}{\partial P} = \frac{E}{P}\left(\frac{E_p^n}{P^n + E_p^n}\right)$$



MORE DETAILS ARE IN HERE

Water Resources Research

RESEARCH ARTICLE
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Key Points:

- A two-parameter Budyko function was combined explicitly with the complementary evaporation principle
- The complementary evaporation principle enabled to nullify the dependence of evaporative potential on water availability
- Climatic changes play a more important role in runoff changes after nullifying the dependence of potential evaporation

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Revisiting a Two-Parameter Budyko Equation With the Complementary Evaporation Principle for Proper Consideration of Surface Energy Balance

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Abstract The Budyko framework, widely regarded as a simple and convenient tool to synthesize catchment water balance, is often employed with the atmospheric evaporative potential (E_p) that responds to water availability over a land surface. In this study, we demonstrated how the responsiveness of E_p to soil moisture deficiency affects outcomes from a conventional Budyko equation. We combined a two-parameter Budyko equation with the state-of-the-art complementary relationship (CR) of evaporation (E), and analytically showed that the two-parameter Budyko equation corrects E_p to the wet environment E (E_w) of the CR. Using the Budyko equation combined with the CR, we assessed runoff sensitivity to climatic and land surface changes. Results showed that the CR could become a constraint for calibrating the implicit parameter of the Budyko equation. When compared to the Turc-Mezentsev equation with E_p, the shape parameters of the two-parameter Budyko equation increased to regenerate an ensemble of global E data sets. Correcting E_p to E_w via the Budyko equation with CR reduced runoff elasticities to land property changes, suggesting that climatic changes are more important to changes in runoff than a prior sensitivity assessment would suggest. This study also suggests that the two-parameter Budyko equation isolates the effect of the E_p adjustment from the shape parameter, allowing it to more properly account for surface energy availability.

Plain Language Summary In this study, we showed the interactions between atmospheric evaporative demand and surface water availability using a simple tool that synthesizes evaporation over

Questions?

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