Long-term evolution of evapotranspiration components in a semi-arid forest using chambers measurement of soil evaporation

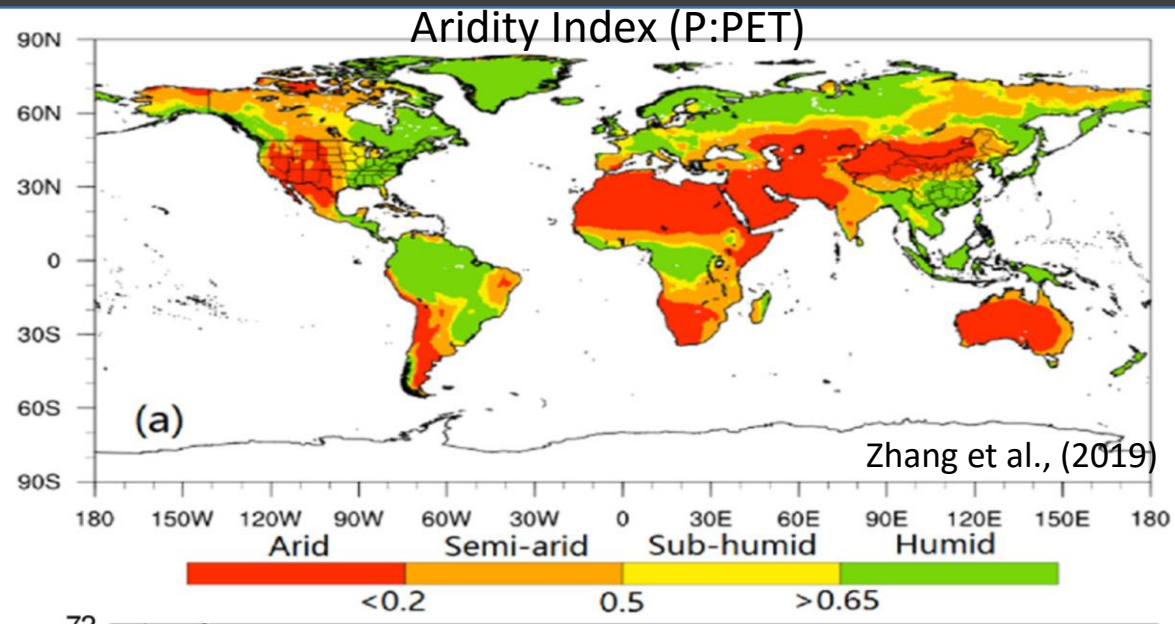
Rafat Qubaja, Dan Yakir, Madi Amer, Fyodor Tatarinov, Eyal Rotenberg, and Yakir Preisler

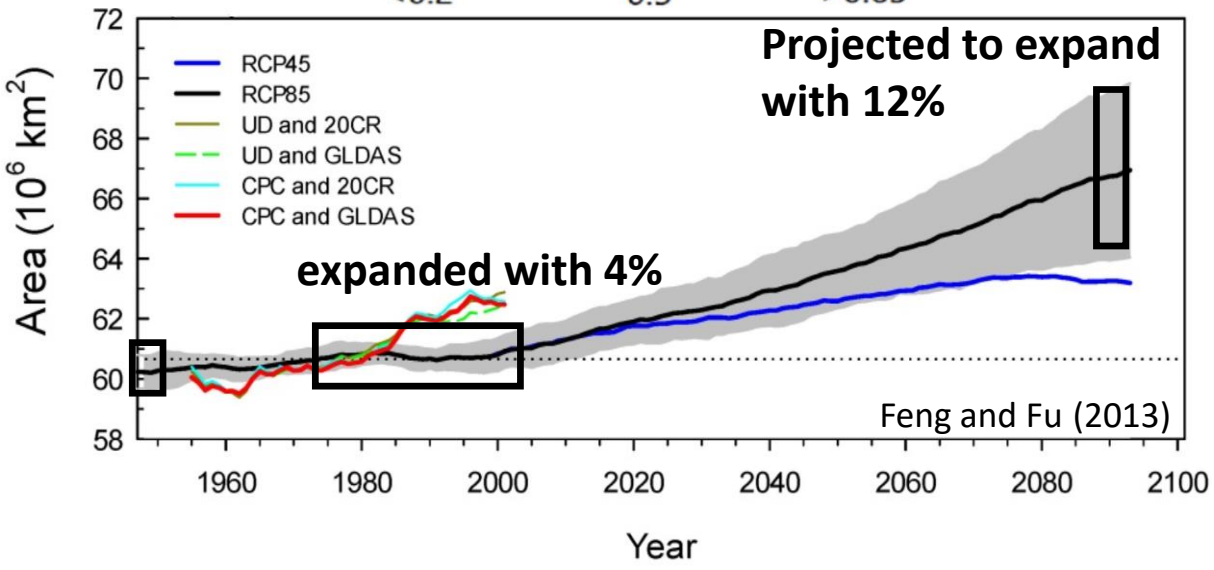
Earth & Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel

*With the help of the eco-physiological group

Aridity & Dry land expansion

- Aridity is measured by the aridity index (AI=P/PET), the ratio of annual mean precipitation (P, water supply) to potential evapotranspiration (PET; atmospheric demand).
- Drylands are defined as regions with AI < 0.65.
- Drylands cover 47% of the land area, and are projected to expand by ~12% by the end of the century.
- **Is there enough water for Drayland afforestation?**



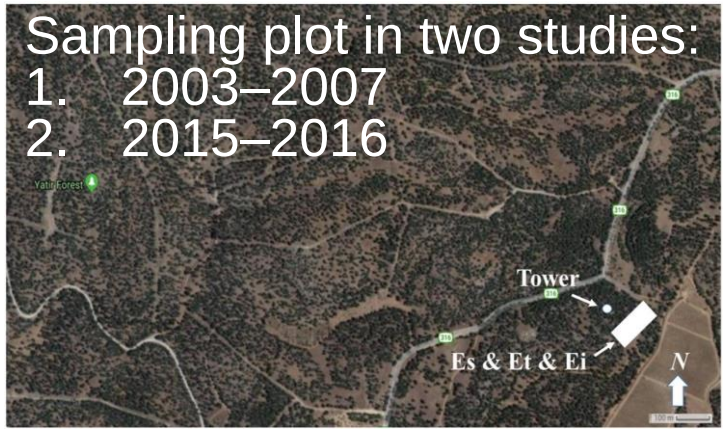


Temporal changes global dryland area

Methods

I. Study site (across 15 years; 2001-2016)

- Pine-trees (*P. Halepensis*)
- 55 years old
- 2800 ha
- Low P (286 mm)
- High T (26 °C daily mean July)
- Low AI (0.18)



Water budget components:

$$ET = Et + Es + Ei + Ea + S + D + F + Q$$

- Es: soil evaporation
- Et: transpiration
- Ea: soil adsorption
- Ei: interception
- $\boldsymbol{S; D; F; and\ Q}$: are Storage; Leakage; Flow out; and Runoff ≈ 0

II. Eddy covariance: Evapotranspiration (ET)

III. Soil chambers: Soil evaporation (Es)

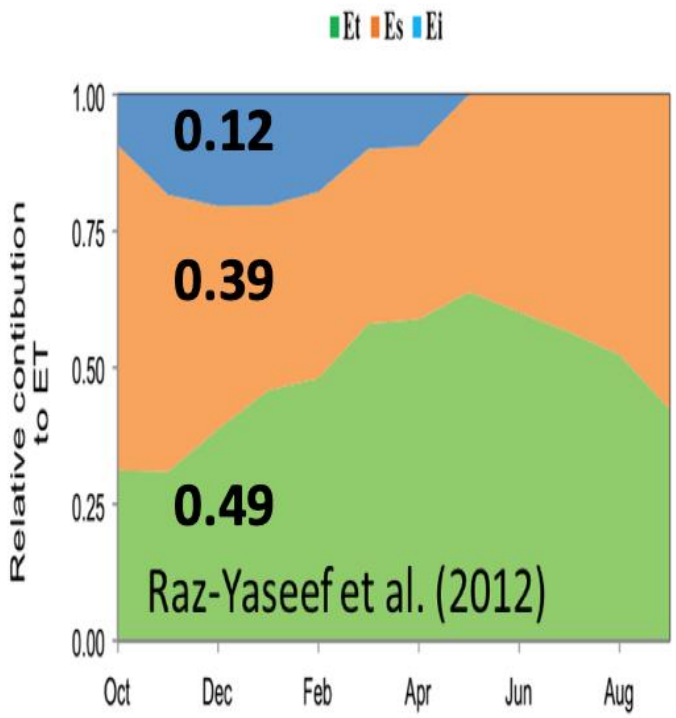
IV. Sap flow (Granier system: Transpiration (Et)

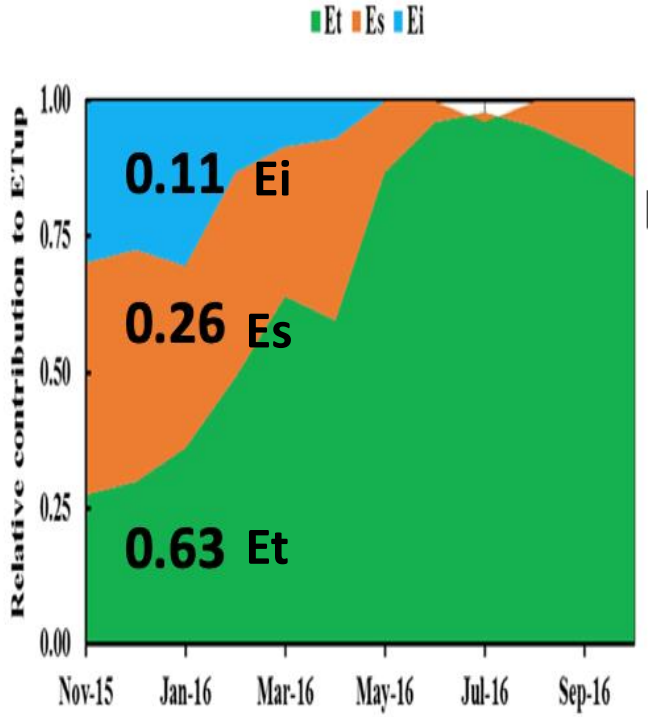
V. Interception (Ei)

$$Ei = P - (0.94 * P) - 0.76$$

Shachnovich et al. (2008)

Results 1 - Long-term evolution of ET components in a semi-arid forest





- **Long-term Evapotranspiration (ET) vs. Precipitation (P):**
  - ET = 262±15 mm y^{-1}
  - P = 286±19 mm y^{-1}
  - ET/P>90%, P fully used

Across the long-term observation period (over 10 years)

- **Canopy:**
  - Et/ET (TR) increase 0.49 to 0.63 (+29%).
  - LAI increase 1.43 to 2.06 (+44%).
  - TR/LAI remained constant at ~0.31.

- **Soil:**
  - Es/ET decreased 0.39 to 0.26 (-34%).
  - Soil adsorption (Ea) ~5% of P.
  - Ea re-evaporation ~74% of the low Es in dry season; critical protection from soil drying.

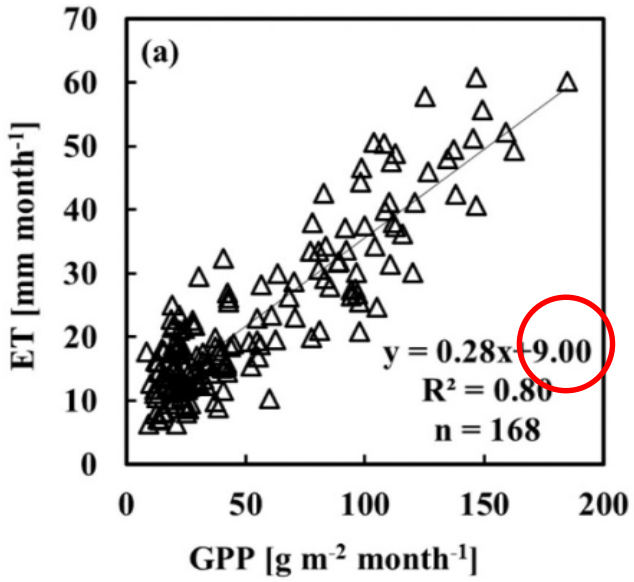
Results 2 - Long-term ET partitioning in a semi-arid forest

Validating the use of long-term flux records of ET partitioning

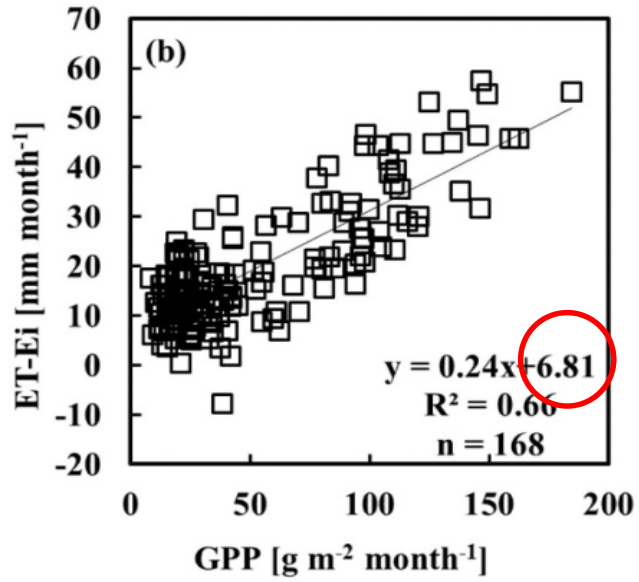
$$ET = mGPP + E$$

where E is the non-stomatal evaporation = Es+Ei (Scott and Biederman, 2017)

Entire dataset of ET vs. GPP values



Subtracting Ei from the ET vs. GPP values



- ❑ E estimate of 6.8-9.0 mm month^{-1} (82-108 mm y^{-1}), is similar to our direct Es estimate of 104 mm
- ❑ Using the long-term mean P value (287 mm) indicate mean E/P ratios of 0.28-0.38

Conclusions and take-home message

- **In water-limited environments, ET/P=0.94-1.07 of P, indicating full use of P.**
- **Mean Et/ET values are similar to global mean values (0.64 ± 0.13), attained at much higher aridity index (PET/P; 5.5).**
- **Es/P comprises a significant part of the water budget ~26%, Ea/P of ~5% can provide critical protection from soil drying.**
- **These results emphasize the competition between stomatal and non-stomatal water loss, and the importance of soil evaporation in low-density semi-arid forests, and reflect adjustments that indicate the potential for forestation in current and future dry regions.**

Thank you!