Estimating actual evapotranspiration for a coupled human environment system: sensitivity to drought

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1. Introduction

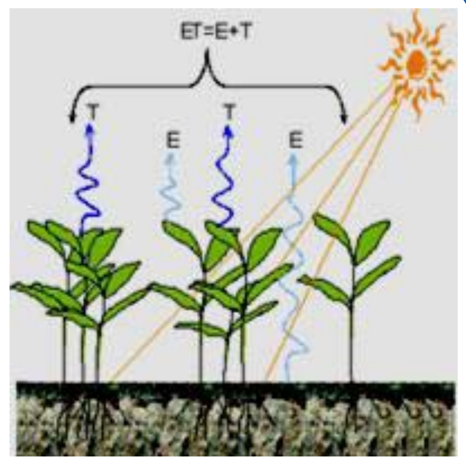

Figure 1: Evapotranspiration

Evapotranspiration (ET) is a controlling factors of water cycle and energy transport between the biosphere, atmosphere and hydrosphere. Quantifying actual ET (ET_a) and its spatio-temporal variability over areas undergoing bio-physical changes (e.g. urban expansion) is important to understand water cycle, climate dynamics and ecological processes. Understanding these can influence water resources planning, water regulations and water use efficiency; especially in arid regions where ET is the largest water consumer and irrigation sustains urban vegetation and associated ecosystem services. Therefore we can use ET as a surrogate to outdoor water use.

Using remote sensing reduces the need for ground data while providing regional coverage and information on the spatial and temporal variability of actual consumption

2. Objectives

Given recent decade's urban growth, coupled with the region's climatic conditions and water sources , the overall aim of this study is to quantify regional water consumption using remote sensing. More specifically:

(a) Estimate ET_a and determine its variation with regards to different types of land use and land cover in urban settings

(b) Compare and contrast actual ET losses (water consumption) between wet (i.e. 2008) and drought (i.e. 2000) years in order to imply land use sensitivity to drought.

3. Study area

Central Arizona Project Long Term Ecological Research (CAP-LTER)

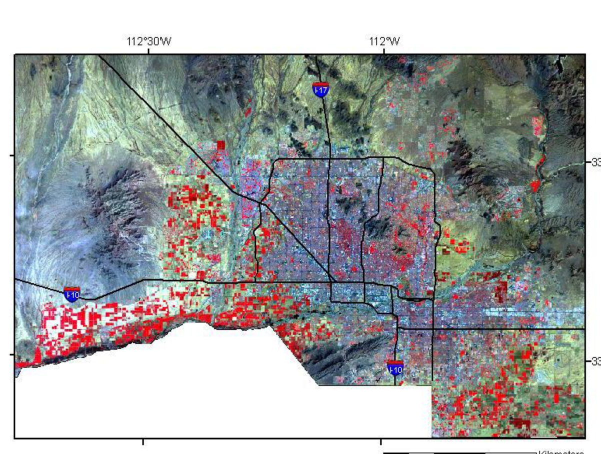
Figure 2: CAP-LTER study area as seen by Landsat

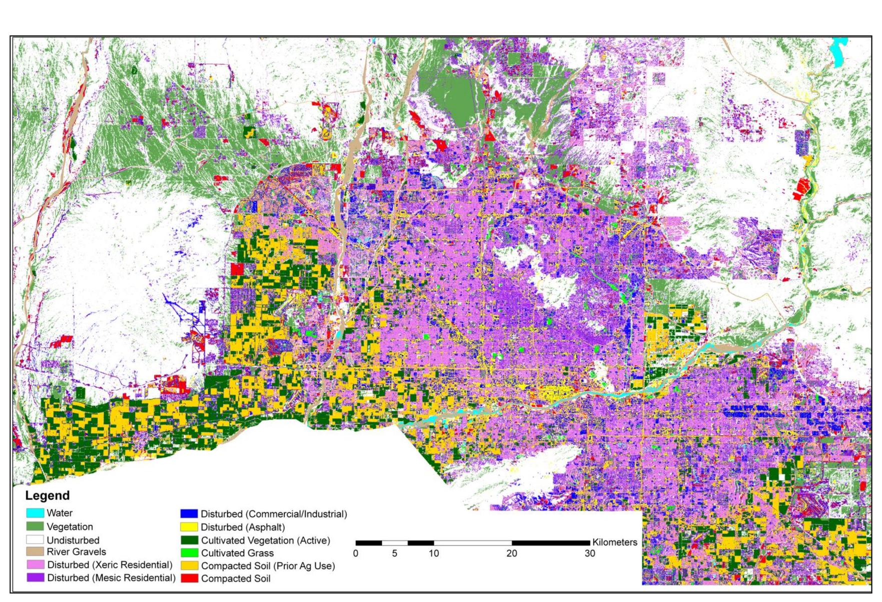
Figure 3: CAP-LTER land cover map (Buyantuyev, 2005)

4. Methodology

Remote sensing can estimate ET as a residual of the energy balance:

$$ET = \lambda LE = Rn - G - H$$

where LE - the latent heat flux; λ - latent heat of vaporization; Rn - the net radiation flux at the surface ; G - the soil heat flux; and H - the sensible heat flux to the air (all in W/m²)

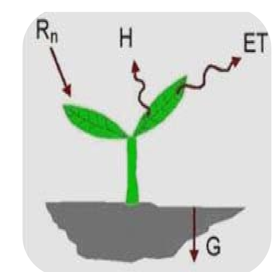

Figure 4: Energy balance fluxes

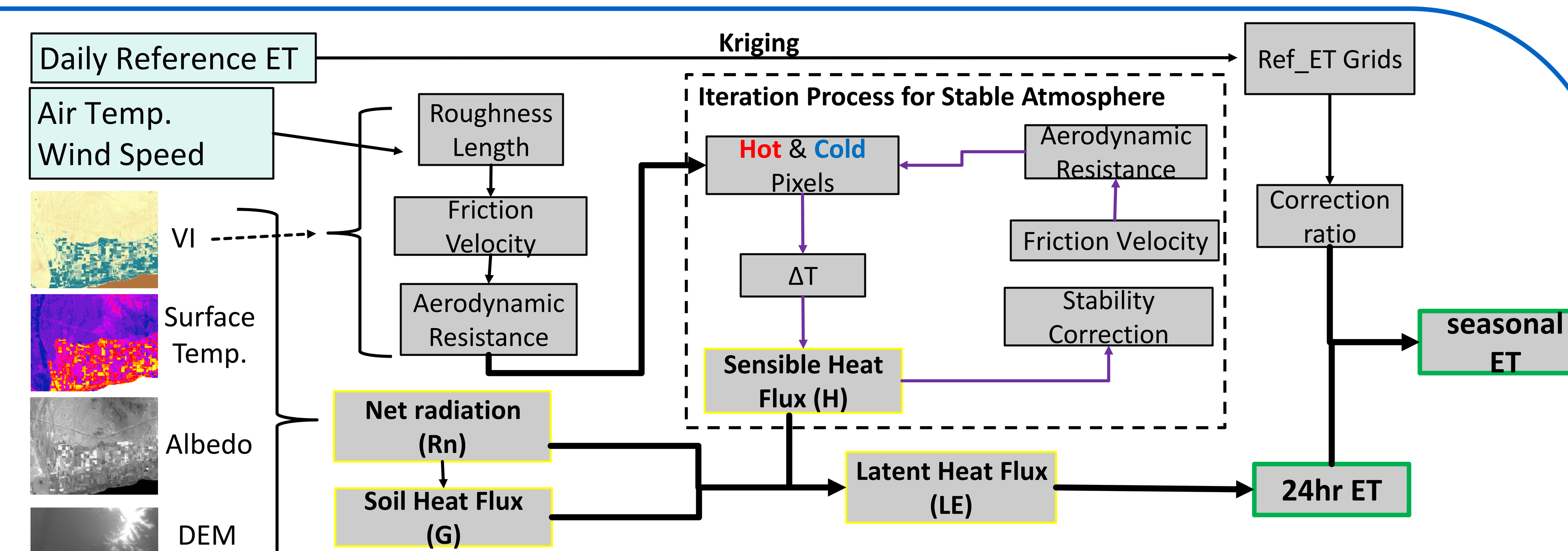

Figure 5: The S-ReSET model flow chart.

Empirical equations for daily estimates are based on the METRIC model (Allen et al. 2007). Seasonal algorithm is based on the ReSET models (Elahddad and Garcia, 2011). For validation, daily estimations were plotted against reference ET from meteorological station; Seasonal estimates over agricultural fields were compared to ground water usage from four irrigation districts and urban parks actual water usage (Fig. 6). Using the MESMA algorithm (Myint and Okin 2008) the vegetation fraction for each field were extracted for the year 2000, and a new model (Fig. 7) for daily ET estimates was fitted to characterize the vegetation fraction relationship to ET. This model was then applied to the urban environment.

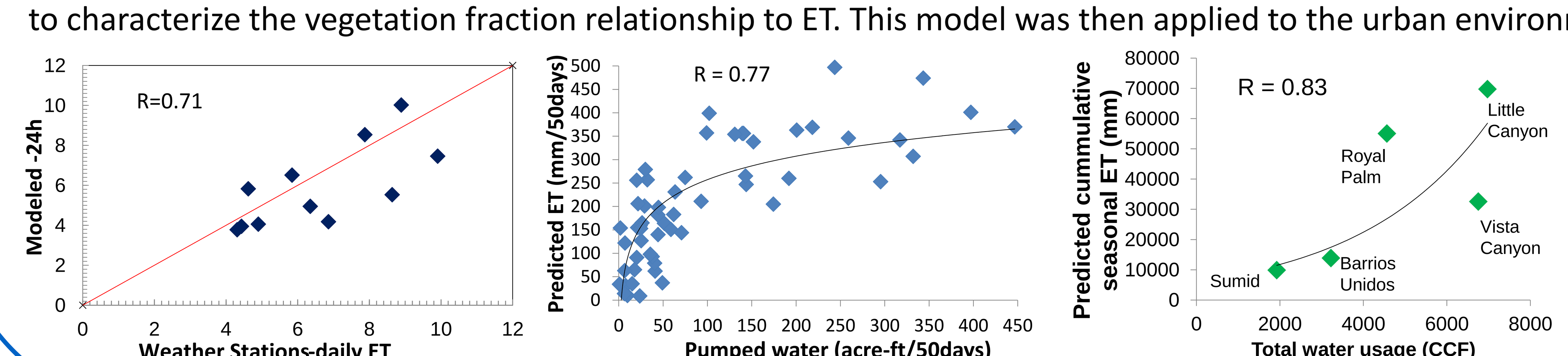

Figure 6: Model daily (left) and seasonal validation for agricultural fields from four irrigation districts (middle) and urban parks (right).

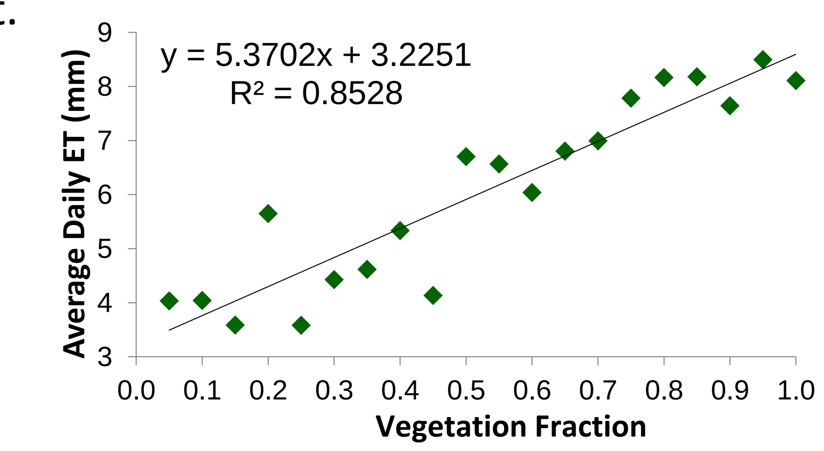

Figure 7: The new Model depicting the average daily ET-Vegetation fraction relationship.

5. Preliminary Results

- Bare soil Evaporation = 3.22 mm/day.
- Vegetation fraction explains 85% of the ET variance under irrigation.
- S-ReSET seasonal estimates (Fig. 9) reveal the effect of drought: cultivated vegetation, Mesic residential and cultivated grasses show seasonal ET > 250 mm for both years; The desert and xeric land cover experienced high variation between drought and wet years with lower cumulative ET (<200 mm) during drought.
- Controlled (Irrigated) landscapes show smaller changes in coefficient of variance between drought and wet years.
- Mesic residential outdoor water consumption is significantly higher during drought. Grass and xeric residential outdoor water consumption is not significantly different between wet and dry years.

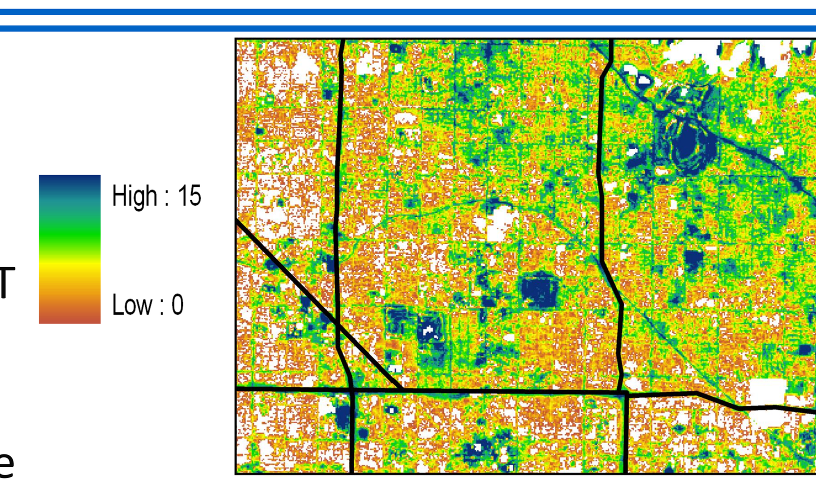

Figure 8: Daily ET estimations over urban area.

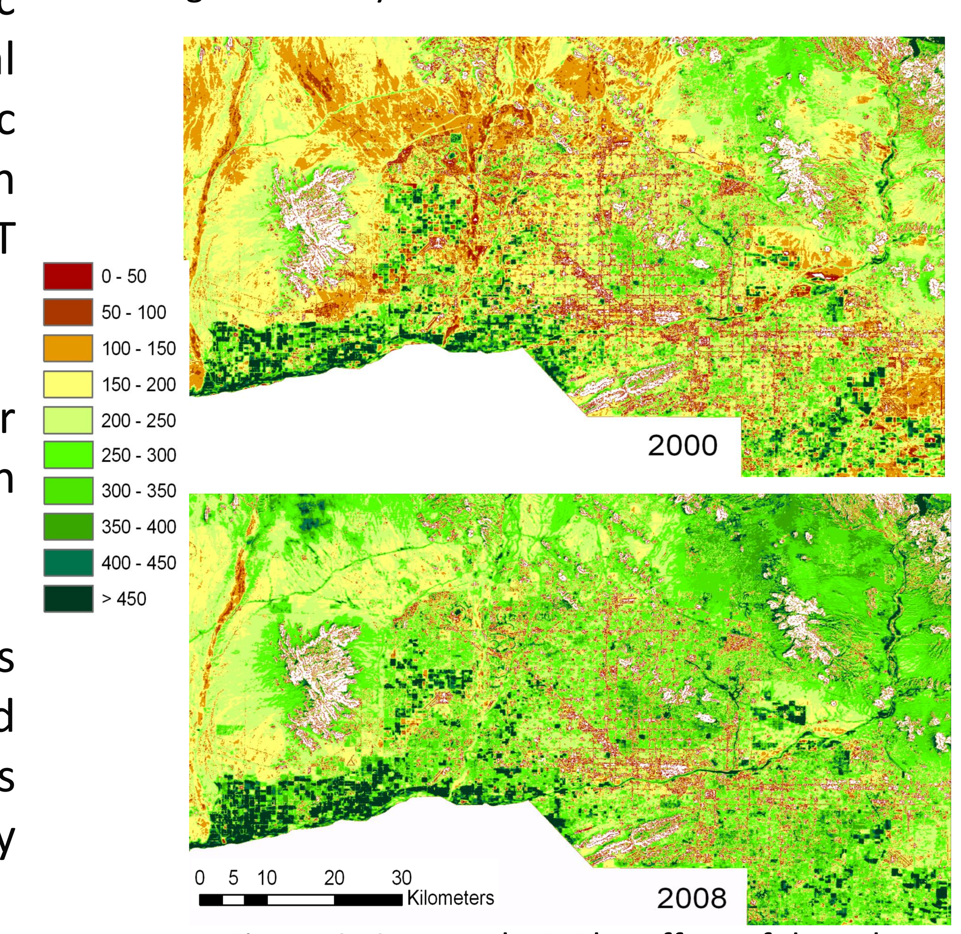

Figure 9: Seasonal ET; The effect of drought.

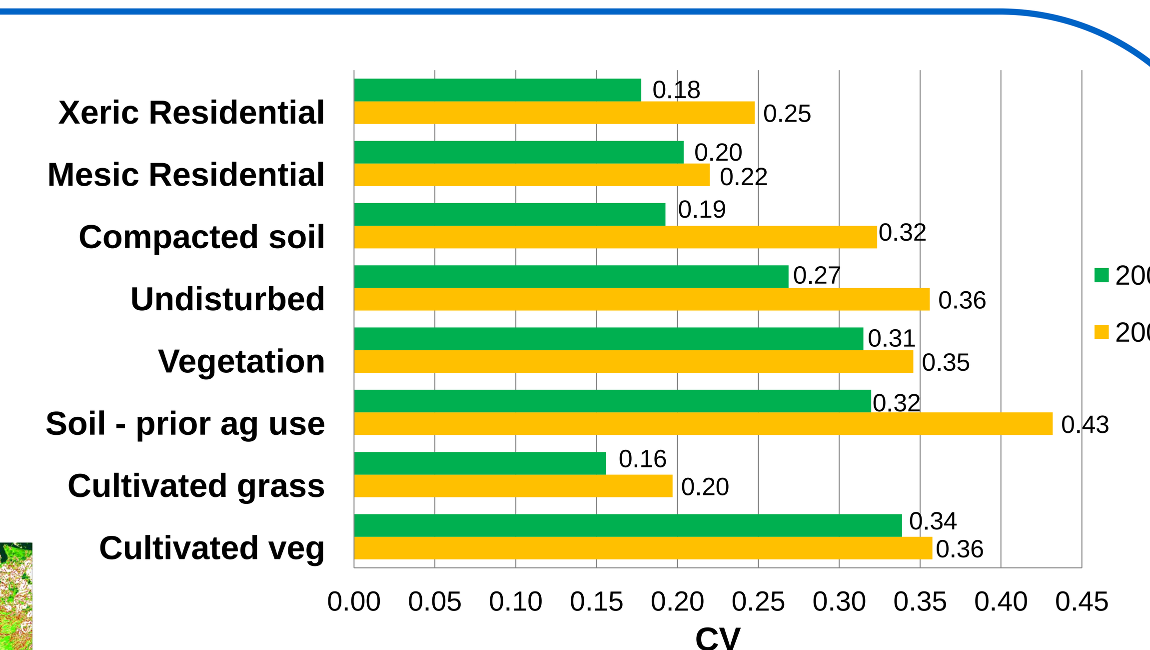

Figure 10: ET Coefficient of variance for wet (2008) and dry (2000) years.

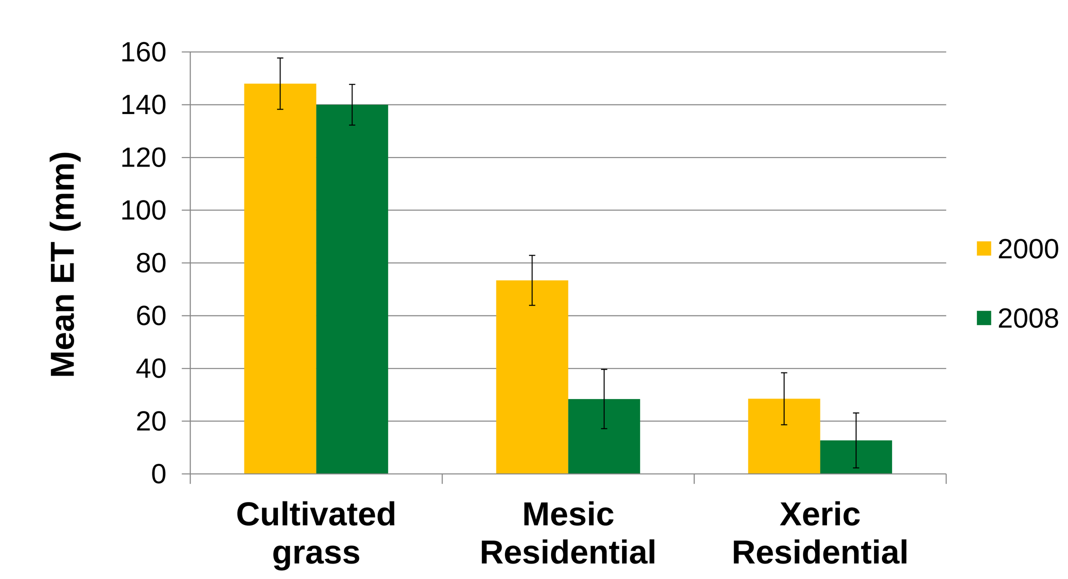

Figure 11: Mean water consumption of main urban land covers.

6. Conclusions

- **The S-ReSET and MESMA approach can be used to estimate ET over a coupled human environment system.**
- **Undisturbed desert and xeric residential areas have lower daily and seasonal ET values, with high variability between drought and wet years.**
- **Drought leads to higher variability within all land covers, especially in "unmanaged" landscapes.**
- **Cultivated grasses consumes similar amount of water regardless of climatic conditions.**
- **Mesic residential areas are sensitive to drought, and may not be sustainable. As urbanization continues to intensify, this may have significant implications for future development plans and the region's water security.**

Acknowledgments and References

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