Optimizing Use of Green Water in Irrigated Agriculture: Development of a Soil Survey Decision Support Tool

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Introduction and objectives

- Globally, irrigated agriculture relies on 2200 million-acre feet of 'blue' water
- Agriculture in Mediterranean climates depends on 'blue' water: 80% of California's (CA) diverted stream flows and pumped groundwater is for agriculture (40-50% of annual runoff from CA watersheds)
- Green water is the soil-stored water from natural rainfall that is potentially available to plants
- Provision of 'green' water is a soil ecosystem service that can reduce reliance on 'blue' water in irrigated agriculture
- **To highlight this soil service, we are developing a place-based decision support tool for scheduling time to first irrigation of the growing season**

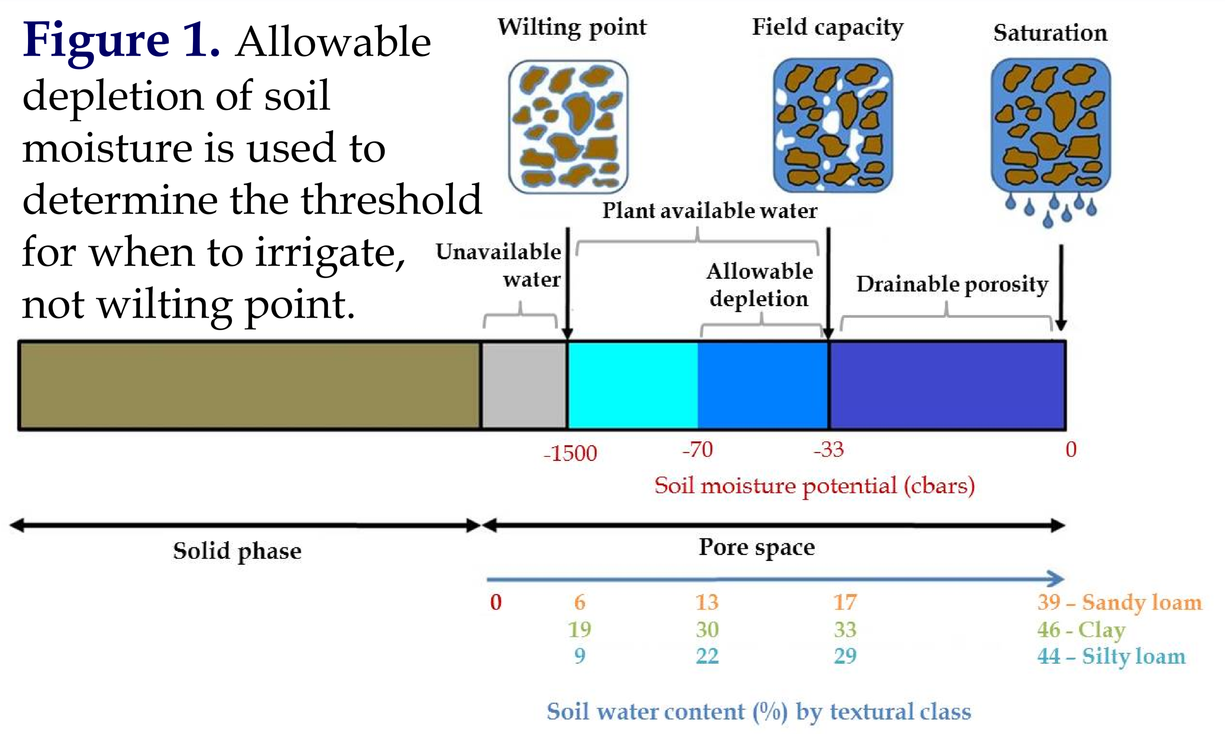

Figure 1. Allowable depletion of soil moisture is used to determine the threshold for when to irrigate, not wilting point.

Methods

- Soil survey geographic database (SSURGO) has estimates of plant available water (PAW) by horizon for most US soils
- PAW's lower limit, the wilting point, is drier than the soil moisture threshold for profitable irrigation management
- Estimate 'green' water availability based on rooting depth and recommended allowable depletions of PAW for several major perennial crops in CA, using CropScape (Figures 3a-d)
- Use SSURGO texture and water retention data and a pedotransfer function (ROSETTA) to generate soil water retention parameters for 34,000 horizons and compare different definitions of field capacity: -0.1 bar, -0.33 bar, and a HYDRUS estimate, the latter defined as the soil water content when the flux out of a horizon reaches 0.01 cm day^{-1}
- Modify the SSURGO database by populating data for map unit 'inclusions' (Figure 2) and removing pedogenic restrictive horizons (e.g. duripans shattered by deep tillage). Combine this database modification with different definitions of field capacity to explore uncertainty in the SSURGO database relative to estimating allowable depletion of PAW (Figure 4a-f)

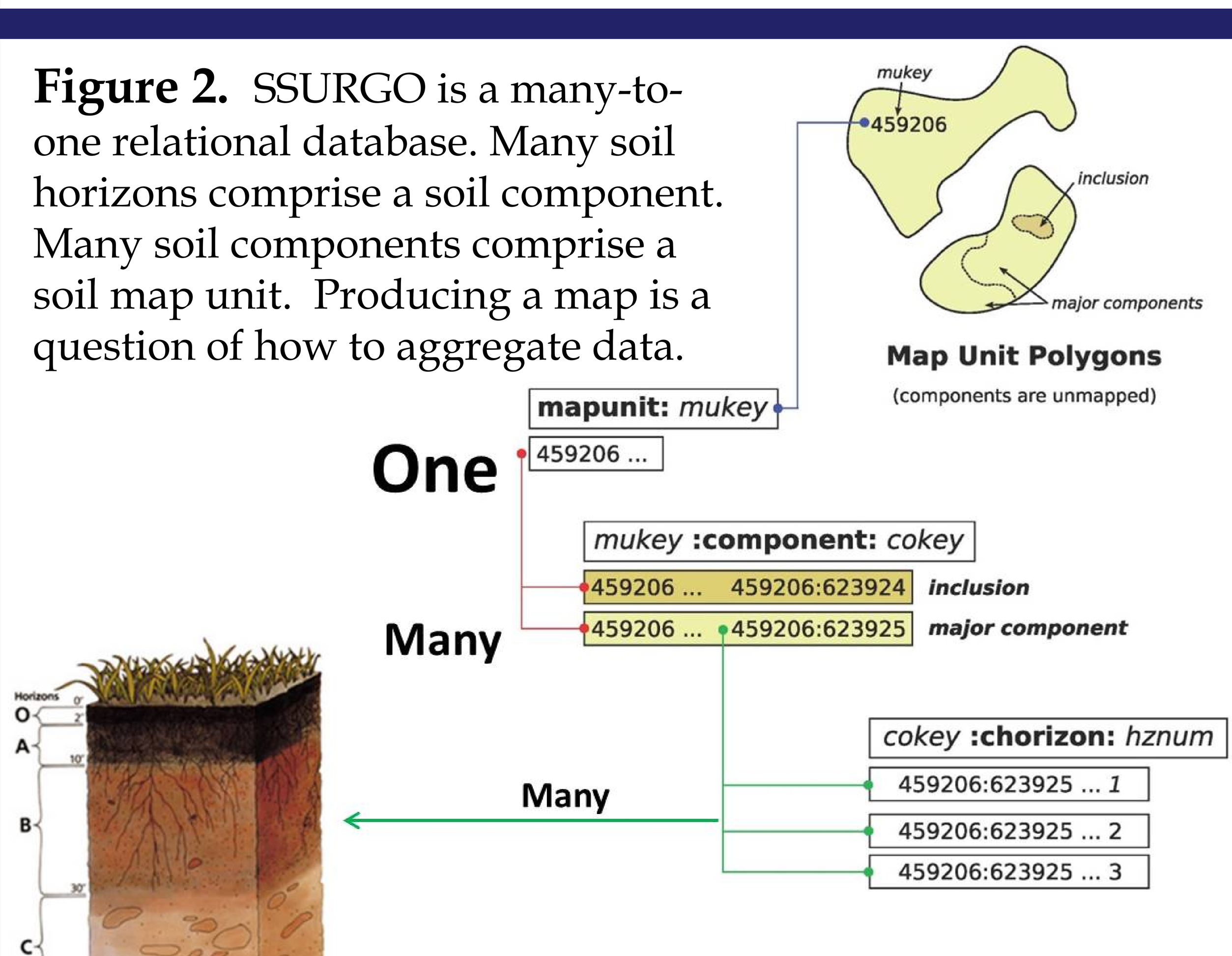

Figure 2. SSURGO is a many-to-one relational database. Many soil horizons comprise a soil component. Many soil components comprise a soil map unit. Producing a map is a question of how to aggregate data.

Figure 3. Allowable depletion (AD) estimates from SSURGO and CropScape. (Crops) Land cropped to alfalfa, almonds, grapes, and walnuts in or near the Central Valley, CA. **(Wtd avg)** Weighted component average of each map unit *x* crop combination. **(Max)** Maximum AD estimate of all the SSURGO components in a given map unit *x* crop combination **(Min)** Minimum AD estimate of all the SSURGO components in a given map unit *x* crop combination. AD estimated by crop-specific rooting depths and % AD of SSURGO PAW values, using the method in Figure 4c below, except no removal of restrictive layers from alfalfa cropland.

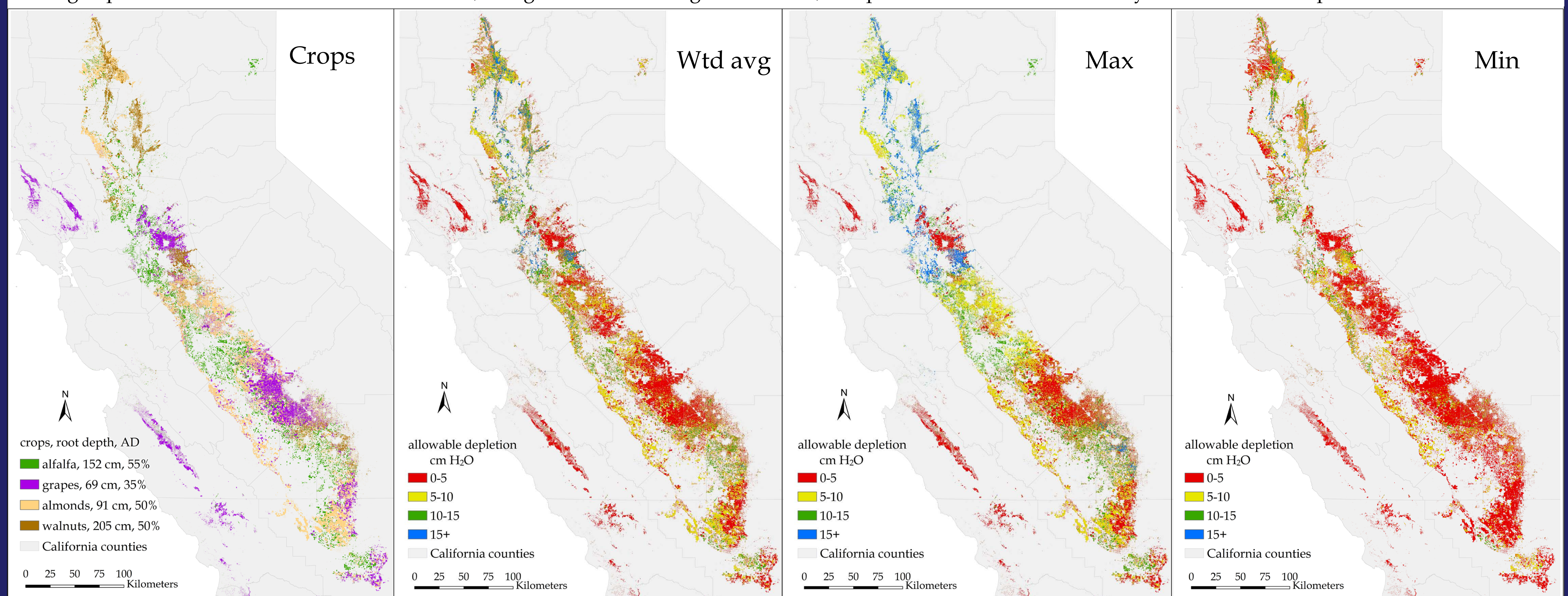

Figure 4a-f. Uncertainty in SSURGO and field capacity (FC). Effect of modifying SSURGO database and different definitions of FC less wilting point (WP) on aggregated estimates of plant available water (PAW) at the map unit level. Muggatt 0-150 cm PAW (y-axis) is the SSURGO version of a map unit estimate for a 0-150 cm soil profile. It is the *major* component weighted average of PAW horizon sums (Figure 2). Red dashed lines are 1:1 lines.

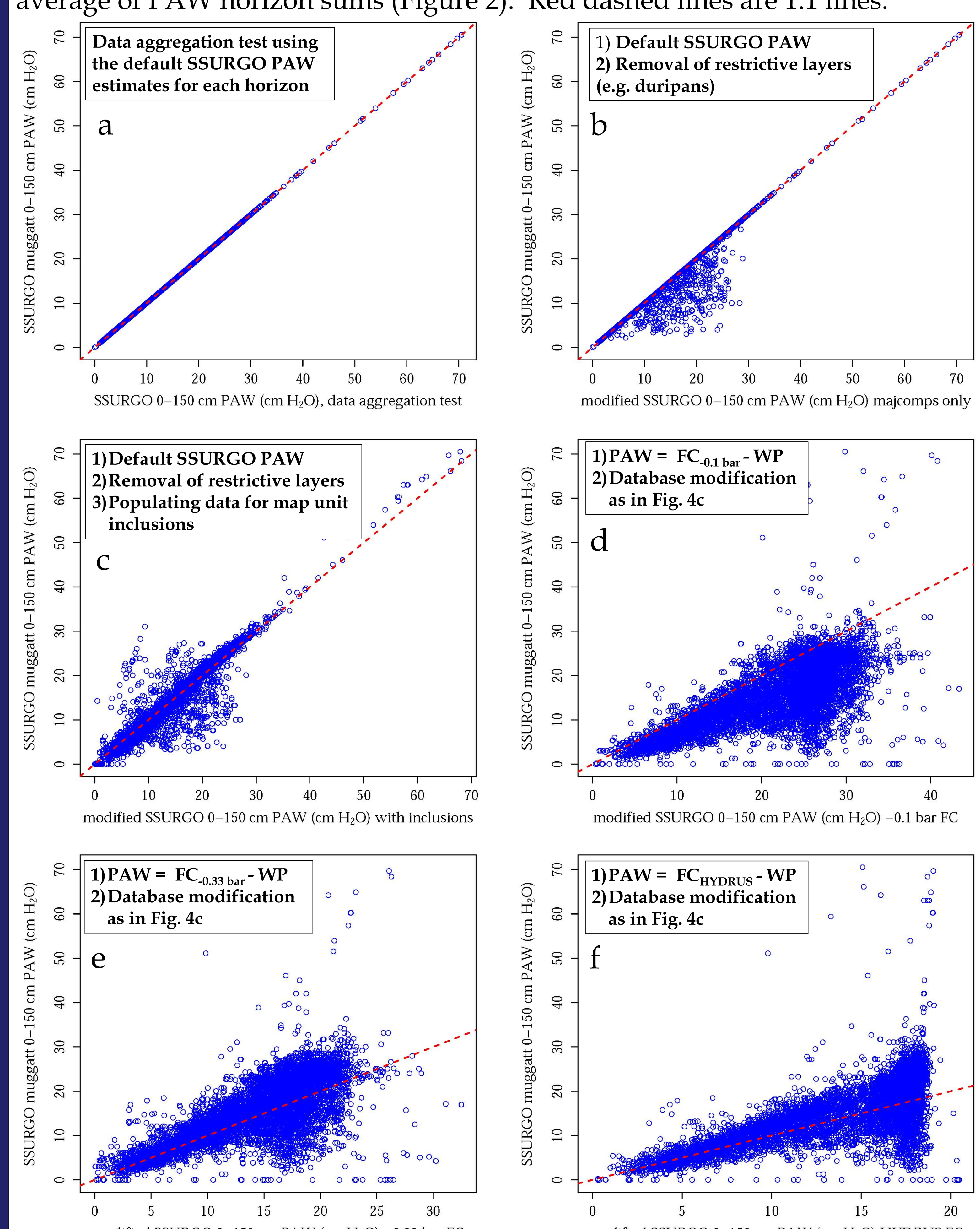

Figure 5. Draft model for calculating time-to-first irrigation

For each crop, let:

θ_{fc} = root zone water content when flux out of the root zone is equal to 0.01 cm day^{-1}, to be determined in HYDRUS soil profile drainage simulations before model runs

θ_t = root zone water content at time, t

θ_{AD} = root zone water content when allowable depletion has been exhausted; defined by summation of θ_h for each horizon in the rooting zone using soil water retention curves

θ_h = soil horizon water content in each root zone horizon at the minimum recommended soil water tension, *h*, by crop; defined before model runs

θ_s = saturated root zone water content

D_t, $K_{c,t}$, $ET_{ref,t}$, and P_t are the drainage, crop coefficient, reference evapotranspiration, and precipitation, respectively at time, t in days

Then:

1. $If\ (\theta_t \le \theta_{fc})\ \{D_t = 0\}$ Else $\{D_t(component) = f(\theta_t, component)\}$, where f is an unknown function relating D_t to θ_t, determined in HYDRUS soil profile drainage simulations for each unique component in SSURGO
2. $If\ ((D_t > 0)\ \&\ (\theta_t - D_t) < \theta_{fc})\ \{D_t = \theta_t - \theta_{fc}\}$
3. $\theta_{t+1} = \theta_t - D_t - K_{c,t} * ET_{ref,t} + P_t$
4. $If\ ((\theta_{t+1}) > \theta_s)\ \{(\theta_{t+1}) = \theta_s\}$
5. $If\ ((\theta_{t+1}) < \theta_{AD})\ \{time\ to\ irrigate, print(t)\}$
6. $Else\ \{next\ time\ step\}$

Conclusions

- Allowable depletion estimates show substantial 'green' water utilization opportunities may exist early in the growing season (Figure 3): 15 cm green water x 100,000 ha walnuts in California = 120,000 acre-feet blue water. *Next step:* **model daily time step climactic variables to develop 'green' water availability estimates and time-to-first irrigation**
- Problem of defining field-capacity to determine plant available water or allowable depletion is clear (Figure 4). *Next step:* **use HYDRUS to develop soil profile drainage estimates that vary as a function of profile water content for each soil component. This should permit a tension based definition of allowable depletion specific to each crop** (Figure 5)
- Examine spatial and temporal variability of time-to-first irrigation as a function of climatic variability, crop type, and soil properties
- Highlight opportunities to improve crop utilization of 'green' water through delayed irrigation and management practices that increase 'green' water accessible to crop roots