Simulation Methodology to Inform Crop Yield Predictions from Remotely Sensed Soil Moisture Time Series

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Introduction

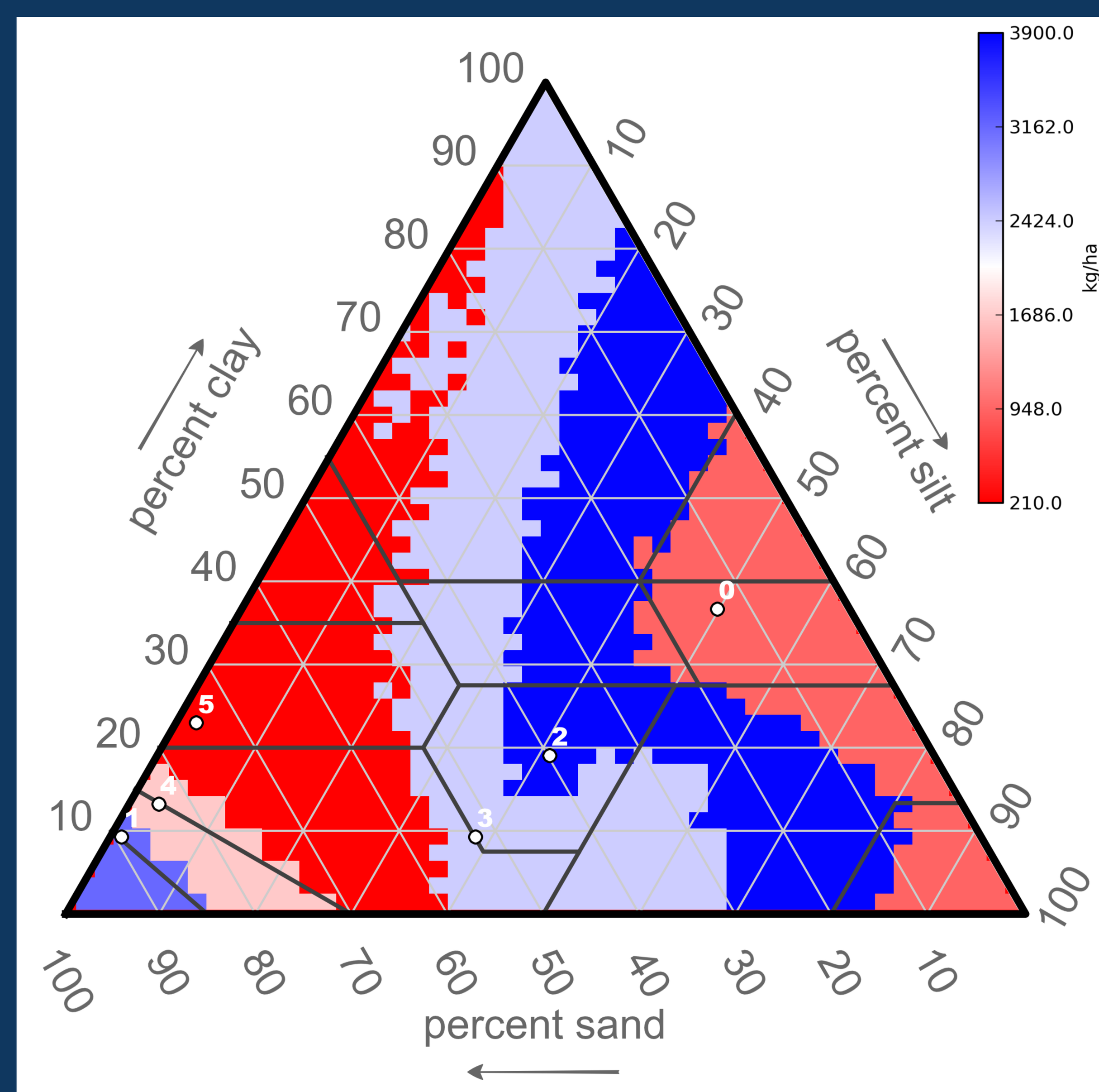
Scheduled for launch in 2014, the Soil Moisture Active Passive (SMAP) satellite will combine L-band radar and radiometry to produce a 10 km soil moisture product with an average global repeat time of about 2 to 3 days. One important application for this sensor is to evaluate and predict the impact of drought conditions on crop yield. However, simulation methodologies are needed to effectively use the observed soil moisture information for yield prediction.

Methods

Homogeneous vertical soil columns representing soils on the texture triangle on a 2% grid were created, resulting in 1326 unique soils. Simulations were performed in HYDRUS1D that was coupled to a basic crop model. Forcing data from an irrigated wheat experiment conducted at the USDA-ARS facility in Maricopa, AZ was used for the simulations. Clustering was completed using the k-means algorithm and was limited to 6 clusters.

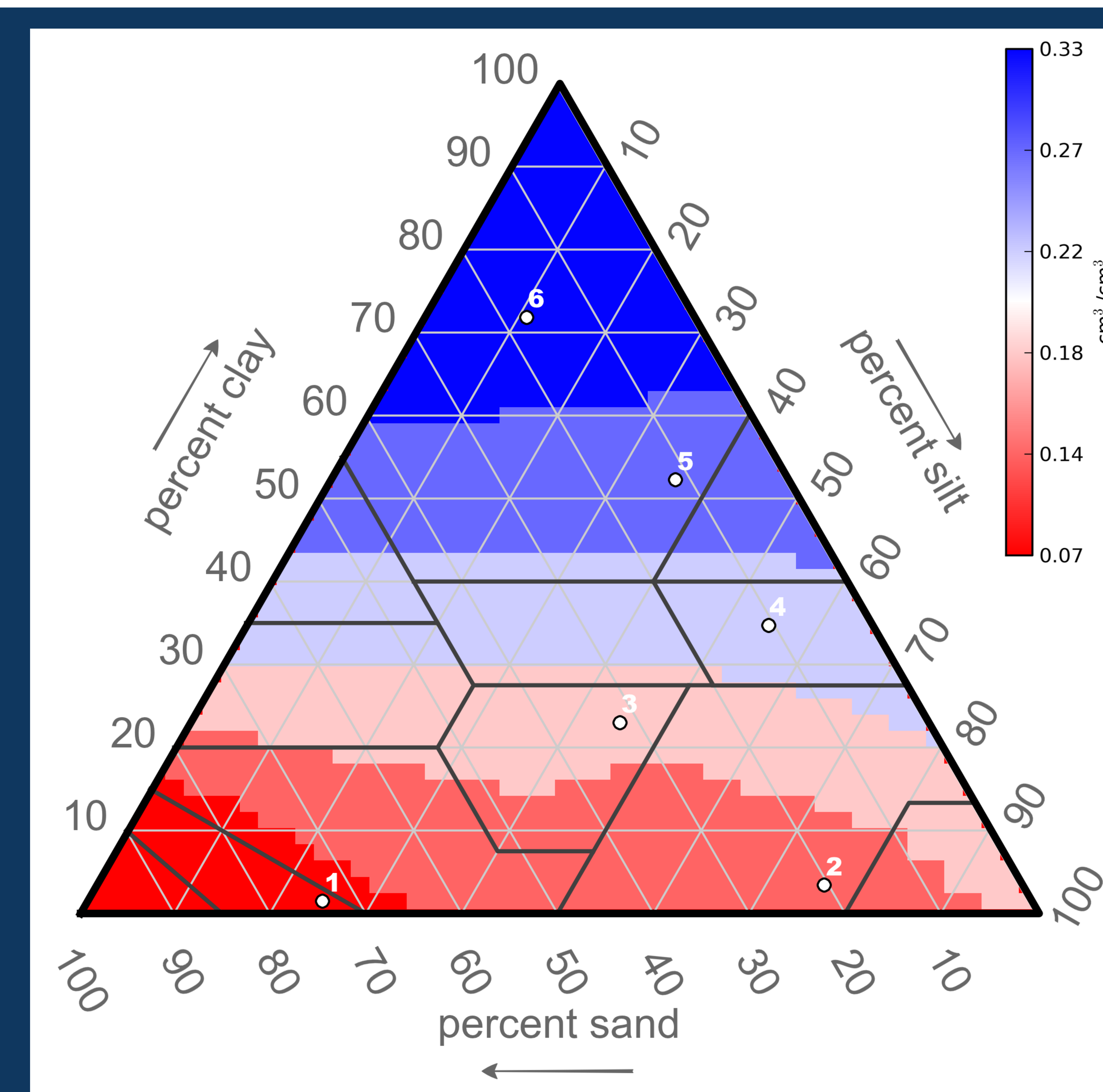
Objective - Yield

Rice (2010) and Bormann (2010) proposed that clustering is a technique that is useful for reclassifying the soil texture triangle based on time-series water balance information. We postulate that uncertainty in yield is related to soil texture and consequently soil moisture. In a similar manner we cluster using measurements of wheat yield predicted using a common atmospheric time series and differing only in soil type. The pattern describes the dependence of yield on soil type. Interestingly, the highest yield is in a narrow band that cuts across soil types and lies in a range of intermediate sand content.



K-means clustering with 6 levels based on end-of-season wheat yield.

Soil Moisture Time-Series

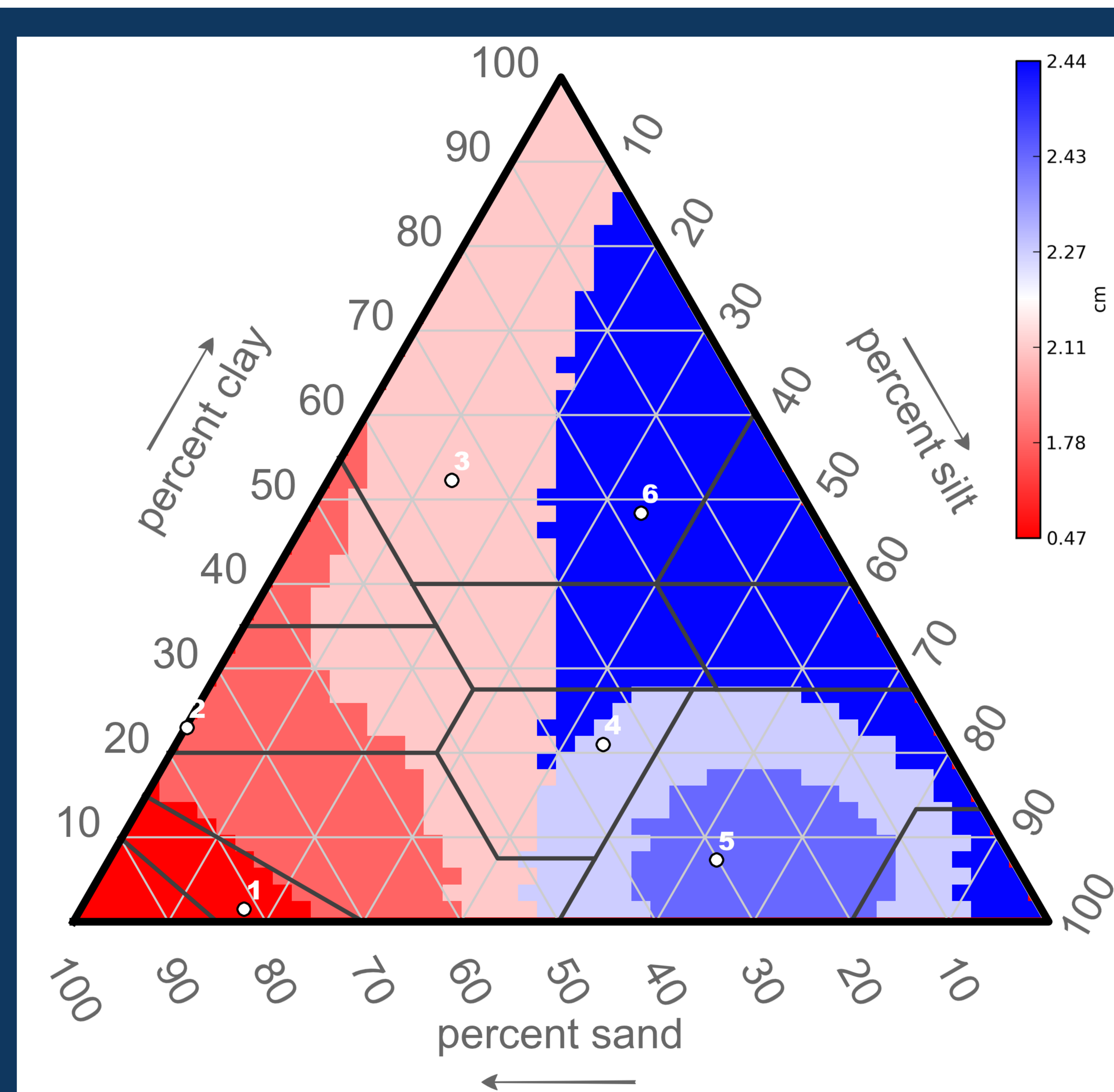


K-means clustering with 6 levels based on average soil moisture down to 30 cm over the entire simulation period with wheat growth.

Many studies implicitly assume a simple dependence of yield on soil moisture. Recent work [Nearing, 2012] has called this into question. Plotting the average soil moisture in the root zone using the same visualization approach shows a starkly different pattern than yield. This is a clear indication that values of soil moisture have a functionally different dependence on soil type than yield.

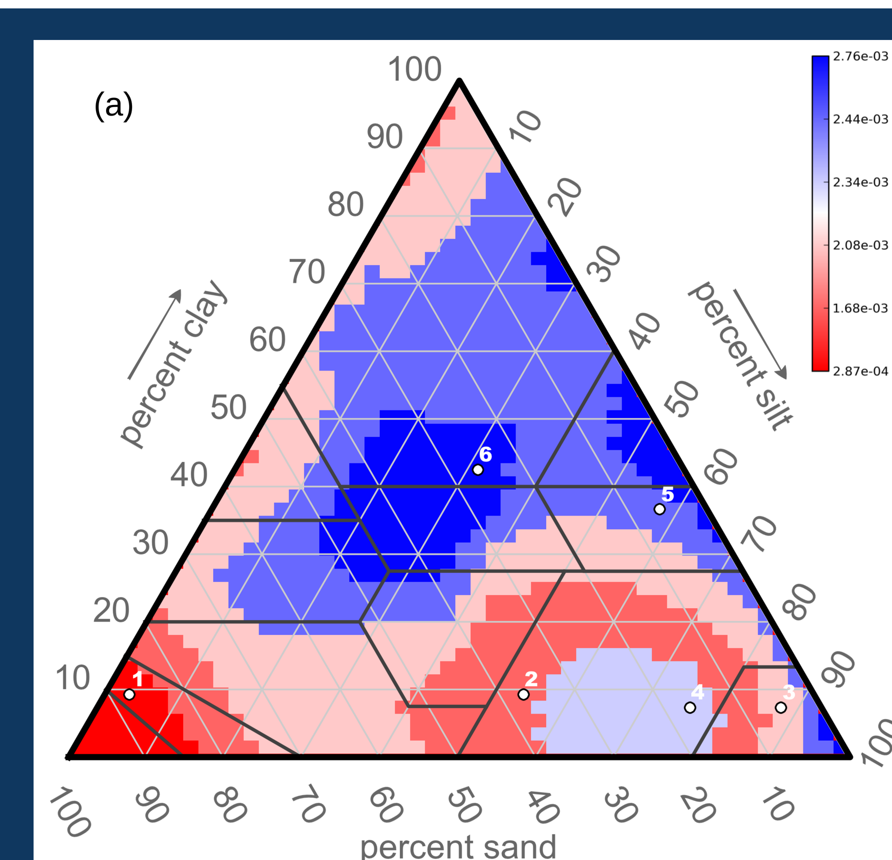
Plant Available Water

It is well known in agronomic science that yield is affected by plant available water (PAW). PAW is defined as $\theta(t)-\theta_{wp}$ multiplied by soil layer thickness. The average of PAW over the simulation period was calculated to a depth of 30 cm. Plotting the average length of PAW for each soil results in a response pattern dependent on soil type. This result is similar to the response pattern obtained based on yield.



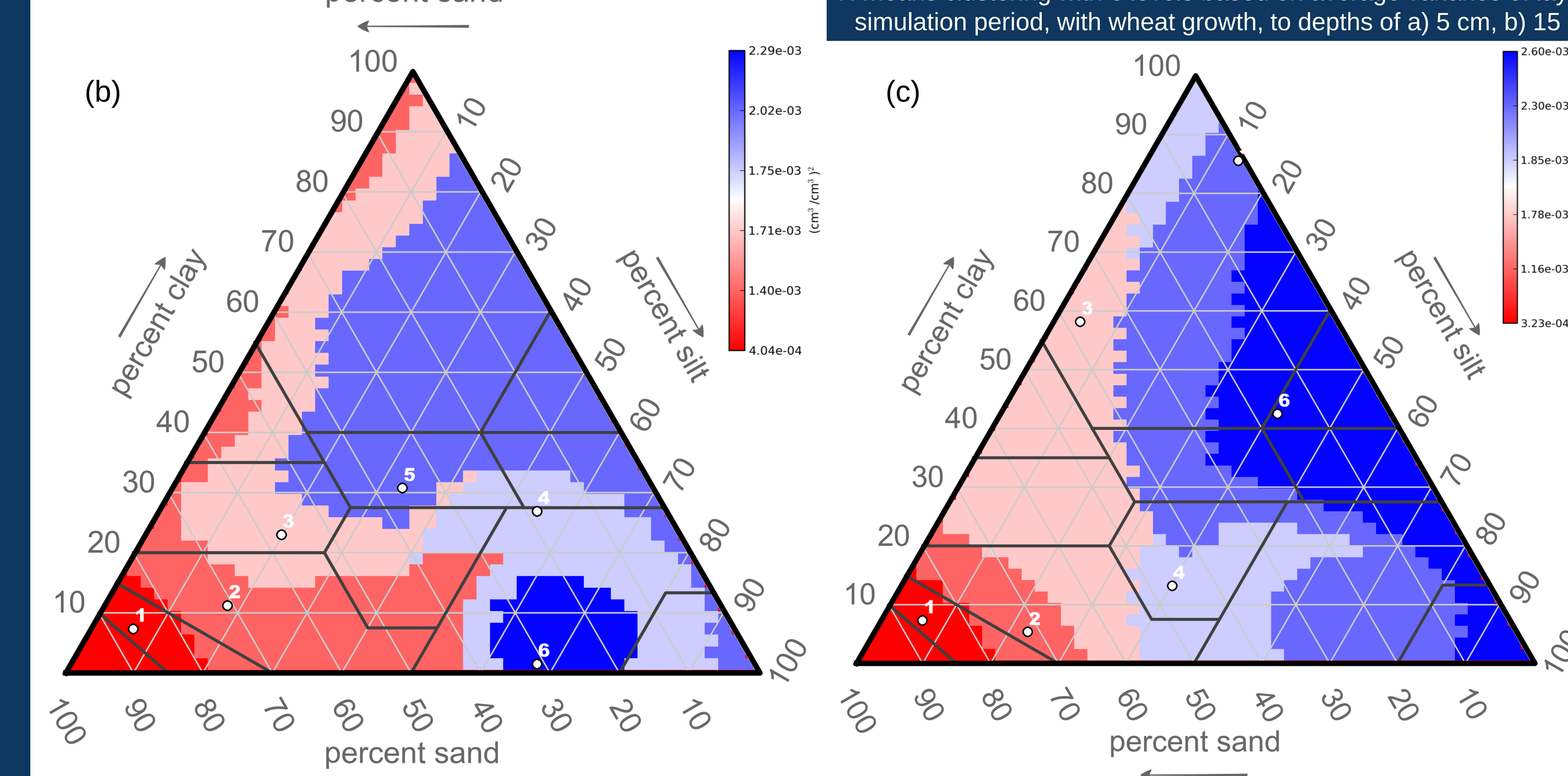
K-means clustering with 6 levels based on average plant available water down to 30 cm over the entire simulation period with wheat growth.

Soil Moisture Variance



We contend that a simple screening approach to find informative measurements is to look for those that have similar patterns of dependence as yield. Soil moisture values themselves resulted in patterns that weren't consistent with patterns of yield. However, it was discovered that the characteristics of the soil moisture observations were useful. Moving deeper into the subsurface a similar response pattern to yield is obtained when using soil moisture variance. The near surface is likely showing weaker pattern similarity due to stronger evaporative effects. Future studies will continue to investigate this hypothesis.

K-means clustering with 6 levels based on average variance of layer soil moisture over the entire simulation period, with wheat growth, to depths of a) 5 cm, b) 15 cm, and c) 30 cm.



References

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