Evaluating Spatial and Temporal Variations in Sub-field Crop Water Demands

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ABSTRACT

The Southern and Central Regions of the High Plains Aquifer have been heavily depleted in the last 70 years (Figure 1). Extrapolation of previous depletion rates of the aquifer suggests that 35% of its Southern region will be unable to support irrigation within the next 30 years. Regardless of the path to sustainability in the High Plains Aquifer, irrigators will need to maintain high yields in a water-limited future. More efficient irrigation practices, like variable rate irrigation (VRI), have the potential to extend the useful life of the High Plains Aquifer in Western Kansas. However, these more efficient irrigation practices require accurate knowledge of crop water demands at the sub-field level. Existing VRI practices use electrical conductivity, historical yields, and topographic maps to delineate variable rate zones. However, these data sets do not quantify within season variability in crop water demands. Crop coefficients are widely used to help estimate evapotranspiration (ET) at different stages of a crop's growth cycle, and past research has shown how remotely sensed data can identify differences in crop coefficients at regional and field levels. However, the amount of spatial and temporal variation in crop coefficients at the sub-field level has not been widely researched. This study aims to compare subfield ET estimates from two remote sensing platforms and quantify spatial and temporal variations in aggregated sub-field level ET. This work provides new ways for researchers to evaluate crop water demands, and may help irrigators make more informed VRI management decisions.

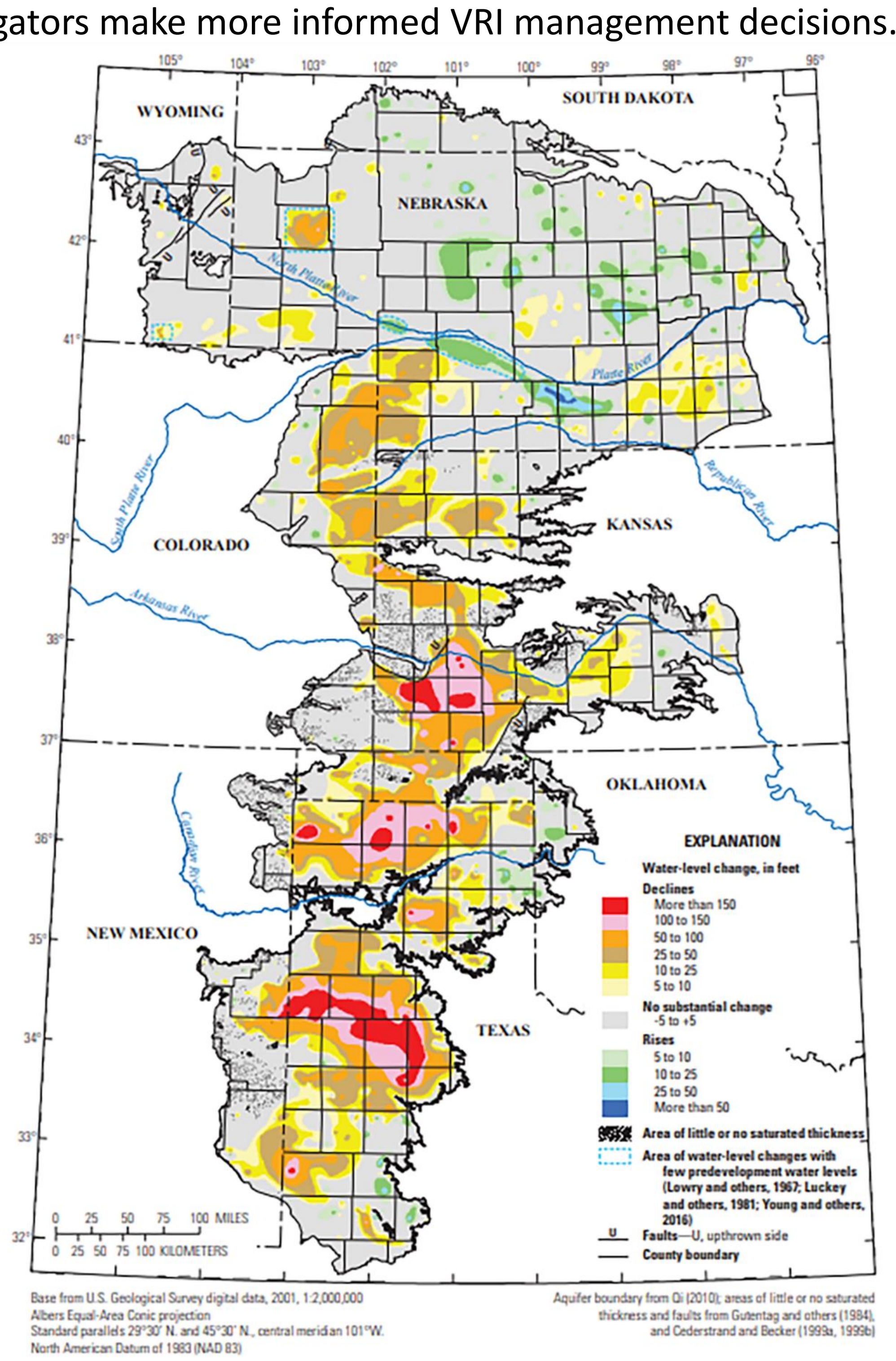

Figure 1. Water level declines in the High Plains Aquifer, 1950-2015 (McGuire, 2017)

OBJECTIVES

1. Compare predicted crop water demands at the subfield level from two new remote sensing data sources.
2. Evaluate the spatial and temporal variability in subfield crop water demands to identify useful insights for irrigation management decision making.

DATA COLLECTION

LOCATION:

- 2 Water Technology Farms in Western Kansas
- 1 Experimental plot operated by K-State's Southwest Research Extension Center

REMOTE SENSING IMAGERY:

- 30-meter resolution satellite images of fractional ET were downloaded from the EarthExplorer Database every 16 days
- 1-meter resolution aerial images of multispectral indices were collected by an agricultural technology company every week

IN-FIELD WEATHER DATA:

- Kansas Mesonet stations (Figure 2) collected windspeeds, solar radiation, and temperature measurements
- These measurements are used to calculate reference ET at each location

Figure 2. Kansas Mesonet station at a Water Technology Farm used to collect weather data for reference ET calculation

ANALYSIS METHODS

CALCULATING ACTUAL ET:

- Linear models connecting vegetation indices (NDVI and SAVI) to crop coefficients are combined with reference ET to create 1-meter maps of actual ET.
- Fractional ET from the Landsat Provisional ET dataset is multiplied by reference ET to get 30-meter maps of actual ET.

COMPARING REMOTE SENSING DATA SOURCES:

- 1-meter ET maps are aggregated to a 30-meter resolution.
- Aggregated ET maps are interpolated to match collection dates between data sources.

DELINEATING ET ZONES TO COMPARE SPATIAL AND TEMPORAL VARIABILITY:

- Maps of weekly ET were aggregated using two techniques to mimic VRI management zones.

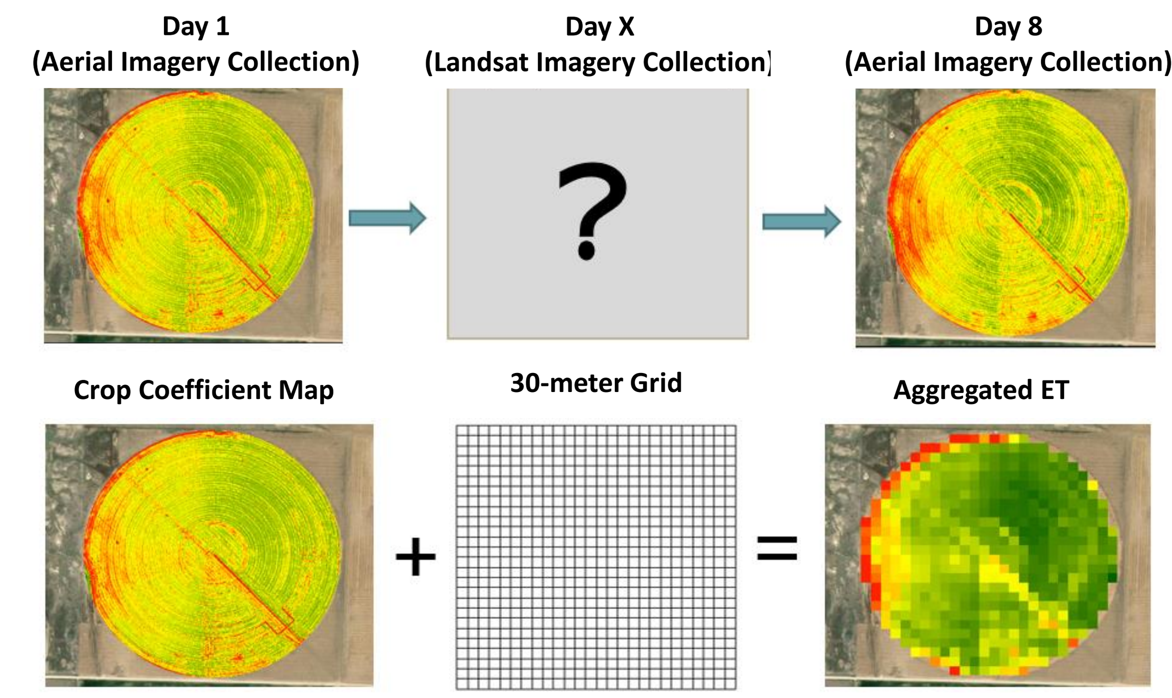

Figure 3. Diagram of image processing required to compare data from different remote sensing platforms. Top: linear interpolation is used to predict crop coefficients in between measurement dates. Bottom: 1-meter crop coefficient images are aggregated to the same spatial resolution as the satellite images

RESULTS

COMPARISON OF DATA SOURCES:

- Both data sources demonstrated spatial and temporal variability in subfield ET.
- Both data sources produced a temporal trend in crop coefficients similar to a traditional crop coefficient curve (Figure 4).
- Aerial imagery consistently predicted higher ET rates than the Landsat Provisional ET dataset.

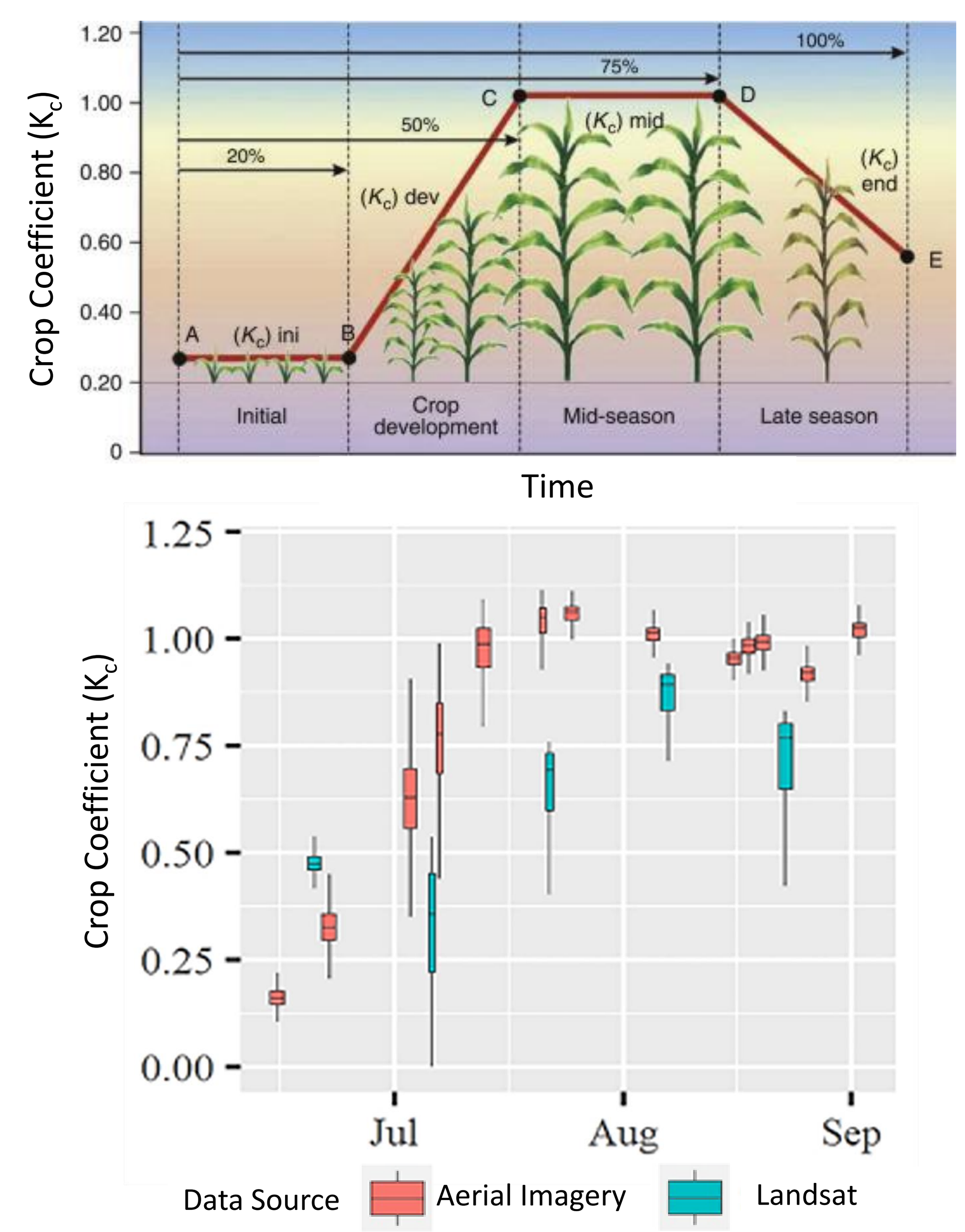

Figure 4. Top: Typical crop coefficient curve for corn. Bottom: Boxplots of crop coefficient maps from aerial imagery and satellite imagery

SPATIAL AND TEMPORAL VARIABILITY:

- Aerial imagery showed the highest variability in the first 1-7 weeks after emergence.
- The Landsat Provisional ET dataset showed higher variability than the aerial imagery beginning 7 weeks after emergence.
- Both aggregation techniques reduced subfield variability in crop water demands (Figure 5).

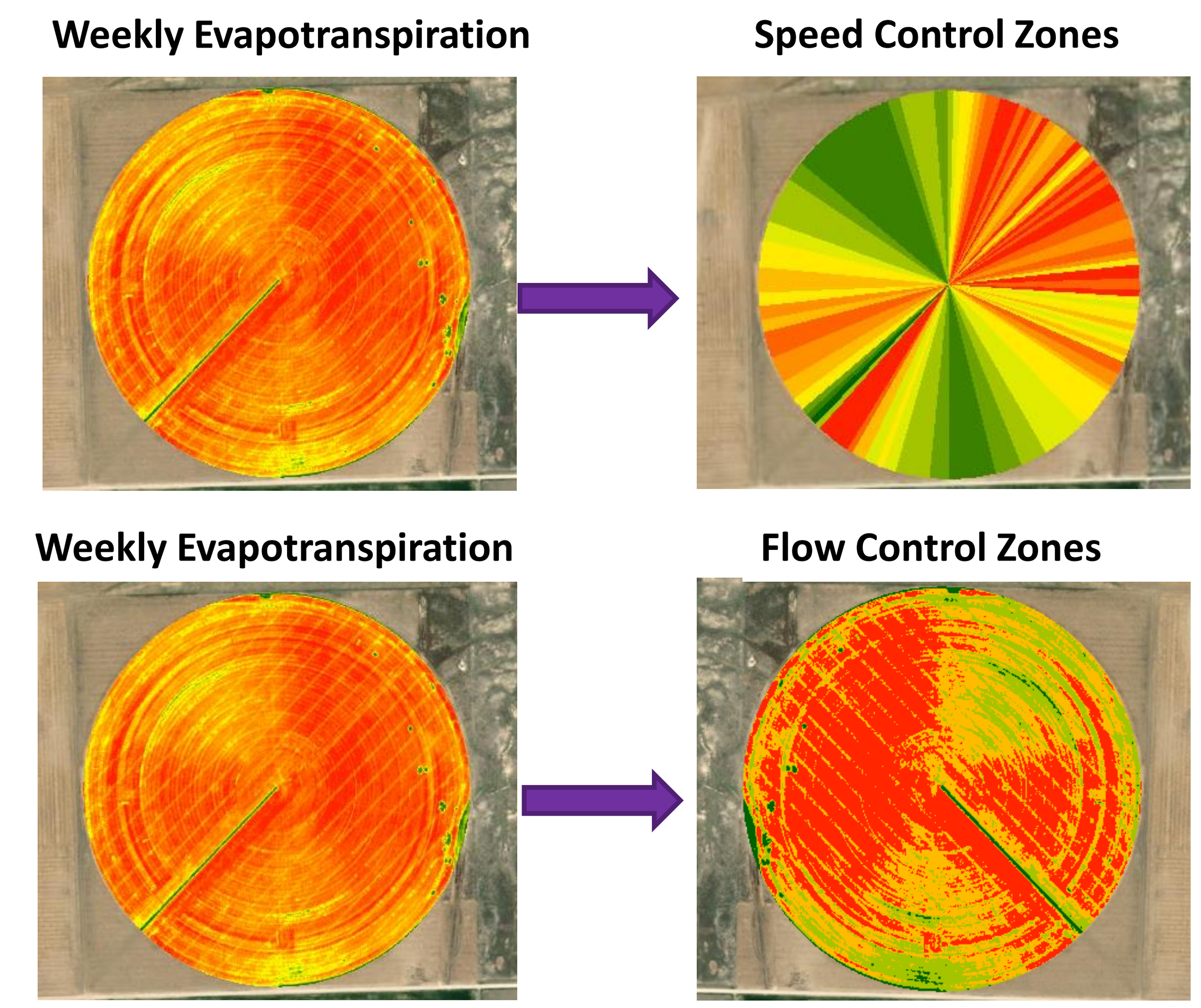

Figure 5. Maps of weekly ET (left) are aggregated using variable speed zones (top right) and variable flow rate zones (bottom right)

CONCLUSIONS

Both satellite and aerial imagery demonstrate spatial and temporal variability in subfield evapotranspiration. Aerial imagery can be collected at higher spatial and temporal resolutions and has the advantage of flexible data collection times compared to satellite images. However, new combinations of satellite platforms may produce high spatial resolution images on a daily basis. Additional work is needed to validate subfield ET estimates from both data sources to ensure they are accurately predicting crop water demands. Future research should focus on validating these data sets, integrating them into decisions support systems for irrigation management, and quantifying their ability to improve water use efficiency. These data sources have the potential to help inform irrigation management decisions without the need for intrusive sensor networks. With further validation, these data sources may help irrigators maintain high yields in a water limited future.

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