MEMO

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Date: May 17, 2021
To: Gary Spackman, P.E., Director
Cc: Linda Davis, Geospatial Technology Section Manager
From: Philip Blankenau, Evapotranspiration Analyst
Subject: METRIC evapotranspiration as a means to identify possible injury, Basin 37 Administrative Proceeding, AA-WRA-2021-001

This memorandum has been prepared in response to the Request for Staff Memorandum In the Matter of Basin 37 Administrative Hearing (Request) issued by the Director of the Idaho Department of Water Resources (IDWR) on May 11, 2021. This memorandum addresses item 10 b. in the Request.

Background information

The Mapping Evapotranspiration at High Resolution with Internalized Calibration[1] (METRIC) model is a remote sensing energy balance model that produces spatial maps of estimated actual evapotranspiration (ET_a). Initial development of the model began in 2000 with a NASA grant to IDWR and the University of Idaho. After successfully completing the grant, the model was put to use for water resources administration at IDWR. METRIC accuracy is variable but was found to be within 4% of lysimetric measurements by Allen and others.[2] Other studies have shown good

[1] Allen, Richard G., Masahiro Tasumi, and Ricardo Trezza. 2007. "Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration (METRIC)—Model." Journal of Irrigation and Drainage Engineering 133 (4): 380–94. https://doi.org/10.1061/(ASCE)0733-9437(2007)133:4(380).

[2] Allen, Richard G., Masahiro Tasumi, Anthony Morse, Ricardo Trezza, James L. Wright, Wim Bastiaanssen, William Kramber, Ignacio Lorite, and Clarence W. Robison. 2007. "Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration (METRIC)—Applications." Journal of Irrigation and Drainage Engineering 133 (4): 395–406. https://doi.org/10.1061/(ASCE)0733-9437(2007)133:4(395).

agreement between METRIC ET_a estimates and independent ground-based estimates.[3,4,5] METRIC has been used extensively by IDWR as an input to groundwater models, including the Wood River Valley Aquifer System model.[6]

Since initial model development, IDWR has continued to work with Dr. Richard Allen's team at the University of Idaho to produce model data. As a result, IDWR has an archive of monthly growing season evapotranspiration data, covering south-central Idaho, including the majority of Administrative Basin 37. These data can be downloaded from the IDWR GIS data hub (https://data-idwr.opendata.arcgis.com/pages/gis-data). The data consist of georeferenced images with pixel values representing depth of ET_a in millimeters.

Analysis for 2021 Basin 37 Administrative Proceeding

This analysis aimed to explore the utility of METRIC ET data as evidence for determining the possibility of injury to senior water right holders. Water right places of use (POUs) with insufficient supply during past years may have insufficient supply again in 2021. Insufficient water supply causes diminished ET_a rates which should be observable in METRIC ET_a data.

METRIC ET from fields known to have an adequate water supply during dry years was compared to ET from fields suspected of having an inadequate water supply during dry years. There were five areas of analysis:

1. Irrigated fields within groundwater POUs located in the area of potential curtailment[7] ("Potential Curtailment Area" in Figure 1). This area is considered to have a full supply and serves as a reference to compare with areas with insufficient supply.

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[3] Morton, Charles G., Justin L. Huntington, Greg M. Pohll, Richard G. Allen, Kenneth C. McGwire, and Scott D. Bassett. 2013. "Assessing Calibration Uncertainty and Automation for Estimating Evapotranspiration from Agricultural Areas Using METRIC." JAWRA Journal of the American Water Resources Association 49 (3): 549–62. https://doi.org/10.1111/jawr.12054.

[4] Madugundu, Rangaswamy, Khalid A. Al-Gaadi, ElKamil Tola, Abdalhaleem A. Hassaballa, and Virupakshagouda C. Patil. 2017. "Performance of the METRIC Model in Estimating Evapotranspiration Fluxes over an Irrigated Field in Saudi Arabia Using Landsat-8 Images." Hydrology and Earth System Sciences 21 (12): 6135–51. https://doi.org/10.5194/hess-21-6135-2017.

[5] Gonzalez-Dugo, M.P., C.M.U. Neale, L. Mateos, W.P. Kustas, J.H. Prueger, M.C. Anderson, and F. Li. 2009. "A Comparison of Operational Remote Sensing-Based Models for Estimating Crop Evapotranspiration." Agricultural and Forest Meteorology 149 (11): 1843–53. https://doi.org/10.1016/j.agrformet.2009.06.012.

[6] Wylie, A., J. Sukow, M. McVay, J. Bartolino, 2019, Groundwater flow model for the Wood River Valley aquifer system, Version 1.1. Idaho Department of Water Resources, 39 p., https://idwr.idaho.gov/files/projects/wood-river-valley/20190627-Groundwater-Flow-Model-forthe-Wood-River-Valley-Aquifer-System.pdf.

[7] https://idwr.idaho.gov/legal-actions/administrative-actions/basin-37.html

2. Irrigated fields north of Shoshone and east of the Milner-Gooding Canal ("North Shoshone Area" in Figure 1). This area receives water primarily from Magic Reservoir. Magic reservoir completely fills roughly half of the time and cannot provide an adequate supply to downstream water rights when it does not fill.[8]
3. Irrigated fields in the area northwest of Richfield and the Little Wood River ("Richfield Area" in Figure 1). This area receives water primarily from Magic Reservoir, and is known to have an insufficient supply during years the reservoir does not completely fill.
4. Irrigated fields within an area west of the Milner-Gooding Canal supplied by the American Falls Reservoir District Number 2 and not overlapping the North Side Canal Company service area or other surface or groundwater POUs ("AFRD2" in Figure 1). This area was selected because it has a full supply of water nearly every year from the Snake River. It is intended to serve as a reference.
5. Irrigated fields within surface water POUs having no overlapping groundwater POUs and supplied by the Little Wood River, Silver Creek, and tributaries of Silver Creek ("Little Wood and Silver Creek Area" in Figure 1). Refer to the IDWR staff memorandum from Tim Luke dated May 17, 2021, for a more detailed description of which rights were included in this area. This area contains rights that may become injured during the 2021 growing season and may have been injured during previous low water supply years.

Note that Figure 1 shows the 2013 final analysis areas not yet filtered for alfalfa, as explained below. Field boundaries vary between years, but Figure 1 is intended to illustrate the general areas being examined.

The years 2011, 2013, and 2016 were analyzed. 2011 had an above-median April Surface Water Supply Index (SWSI) of 1.5 for the Big Wood River above Hailey.[9] 2013 had a below-median SWSI of -1.7, and 2016 had a near-median SWSI of 0.1. The SWSI is a product of the Natural Resources Conservation Service, and normalizes the projected supply volume against historical water supply volumes. It ranges from -4.1 (extremely dry) to 4.1 (extremely wet). The SWSI for the Big Wood River above Hailey was used because, according to the IDWR staff memorandum from Sean Vincent dated May 17, 2021, it better predicts supply for surface water users diverting from Silver Creek and the Little Wood River. The selection of years was also dictated by the availability of METRIC and the crop and irrigation spatial data discussed below.

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[8] Idaho Department of Water Resources, Wood River Basin Hydrologic and Hydrogeologic Relationships Prepared for the BWRGWMA Advisory Committee; IDWR Observations March 17, 2021, 11p, https://idwr.idaho.gov/files/groundwater-mgmt/big-wood-gwma-advisory-comm/20210324-Big-Wood-GWMA-Advisory-Committee-Meeting-Materials.pdf

[9] https://www.wcc.nrcs.usda.gov/ftpref/states/id/webftp/swsi/tables/Apr/Big_Wood_above_Hailey_Apr.pdf

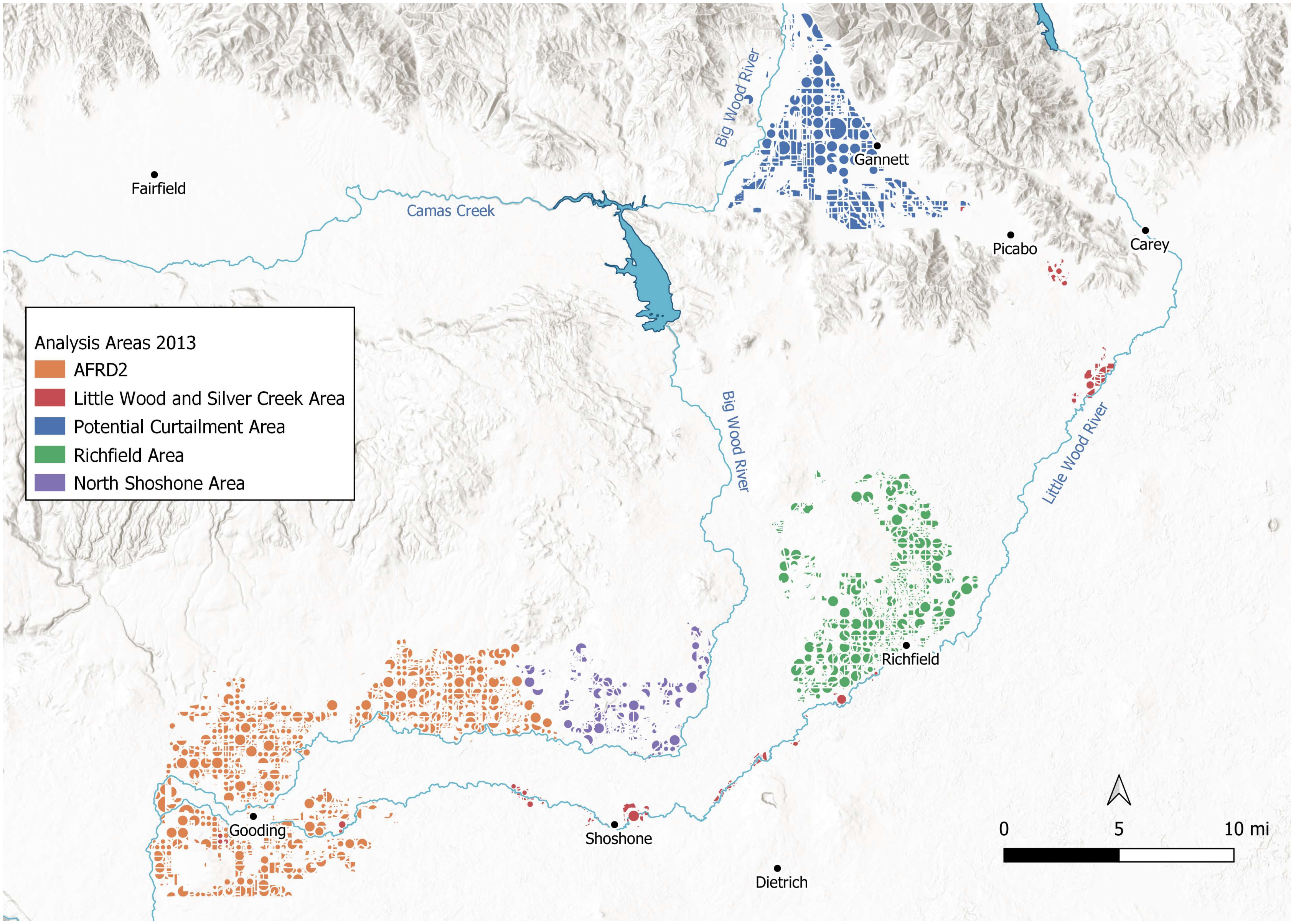

Figure 1. 2013 Analysis Areas before isolating alfalfa

Observed differences in METRIC ET_a between fields can result from variation in many variables, including crop type, cutting schedules (in the case of hay), soil, pests, disease, fertilization, planting date, harvest date, local weather, model error, and irrigation. Irrigation is the variable related to injury, so measures were taken to mitigate the effects of other variables on the analysis.

Yearly crop type raster maps from the USDA Cropland Data Layer[10] (CDL) were used to identify the crops being grown in each field, and only alfalfa fields were selected for this analysis. Alfalfa fields were analyzed in isolation because alfalfa is widespread in the analysis areas; it is drought tolerant and grown even in areas expecting periodic water shortages. Additionally, isolation of a single crop removes differences in ET_a caused by differences in water requirements between crop types.

Rather than analyzing monthly ET_a directly, it was first divided by the monthly sum of the ASCE standardized Penman-Monteith alfalfa reference ET (ET_r). Alfalfa reference ET is the amount of ET occurring over a hypothetical, extensive, and well-watered surface of alfalfa with specific stipulated characteristics. Therefore, the monthly fraction of reference ET (ETrF) represents the amount of ET occurring from the actual surface relative to the reference crop under the same meteorological conditions. By analyzing ETrF, we partially removed the variation in ET_a due to local weather conditions. The variations due to precipitation and growing season duration remained.

POUs from the AFRD2, Little Wood and Silver Creek, and Potential Curtailment analysis areas were intersected with annual irrigated land classification vector data developed at IDWR, (https://data-idwr.opendata.arcgis.com/pages/gis-data) to better define the field boundaries and isolate irrigated agriculture. Intersecting the POUs with the irrigated land classification and isolating alfalfa fields creates variation in the area of analysis between years. The Richfield and North Shoshone areas were created by selecting irrigated land polygons within certain boundaries. The resulting field polygons were buffered in to remove pixels straddling the borders of field edges. Pixels along field edges tend to have lower ET because they include natural vegetation. Polygons smaller than 1,800 square meters (two METRIC pixels) and with circularity index smaller than 0.15 tended to not resemble actual fields and were removed. CDL classes were assigned to each field polygon by finding the majority pixel value for pixels within field boundaries. Fields with only one 30 meter CDL pixel center within their boundary were left out of the analysis. The mean ETrF was assigned to each polygon by taking the mean of pixels within

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[10] USDA National Agricultural Statistics Service Cropland Data Layer. 2011, 2013, 2016. Published crop-specific data layer [Online]. Available at http://nassgeodata.gmu.edu/CropScape/. USDA-NASS, Washington, DC.

the field boundaries. ETrF was resampled from a 30 meter to a 15 meter resolution using nearest neighbors to improve estimates of the mean for small fields.

Results

Figures 2 through 4 show monthly ETrF for each field, within each area of analysis, for the three selected years. Mean field ETrFs are plotted as points randomly spread along the abscissa to avoid overlap and are translucent so that when overlap occurs, the density of overlap is visible.

Considerable variation in mean field ETrF within each analysis area is visible in Figures 2 through 4. One downside to analyzing a hay crop is that cuttings may create more variation than would be seen in other crops (see Attachment A). James Wright found that after a cutting, alfalfa ET dropped to less than a quarter of its pre-cutting magnitude for up to a week.[11] Additional causes of variation have already been mentioned. Despite the large variations within areas, 2013 shows a markedly different monthly pattern than 2011 and 2016 in the Richfield and North Shoshone areas. The pattern can safely be identified as fields being dried down. Corroborating evidence comes from the USGS streamflow gauge 13142500, located on the Big Wood River below Magic Reservoir. The gauge data indicates that the approximate last date of release from the reservoir in 2013 was June 29. The subsequent drop in ETrF seen in July makes sense in light of the last release date.

[11] Wright, James L. 1988. "Daily and Seasonal Evapotranspiration and Yield of Irrigated Alfalfa in Southern Idaho." Agronomy Journal 80 (4): 662–69. https://doi.org/10.2134/agronj1988.00021962008000040022x.

Figure 2. Monthly mean field ETrF for alfalfa fields in 2011 (above-median SWSI)

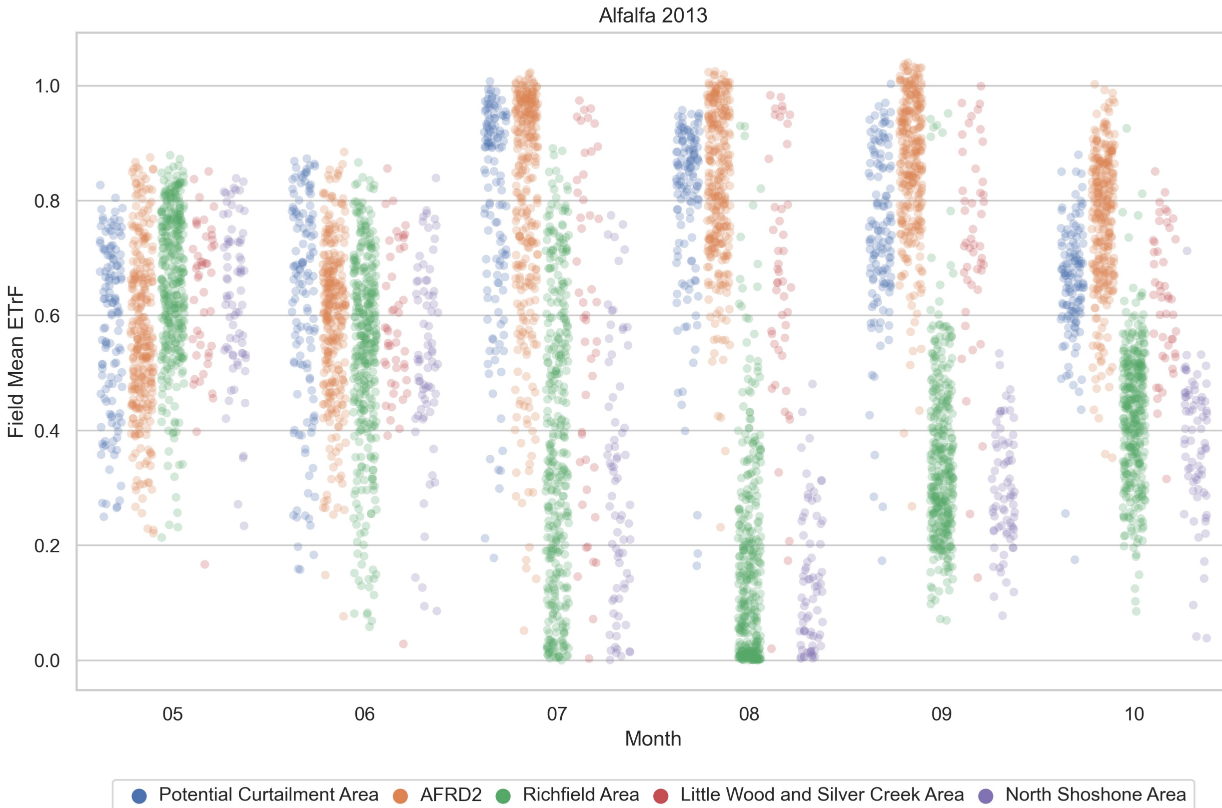


Figure 3. Monthly mean field ETrF for alfalfa fields in 2013 (below-median SWSI)

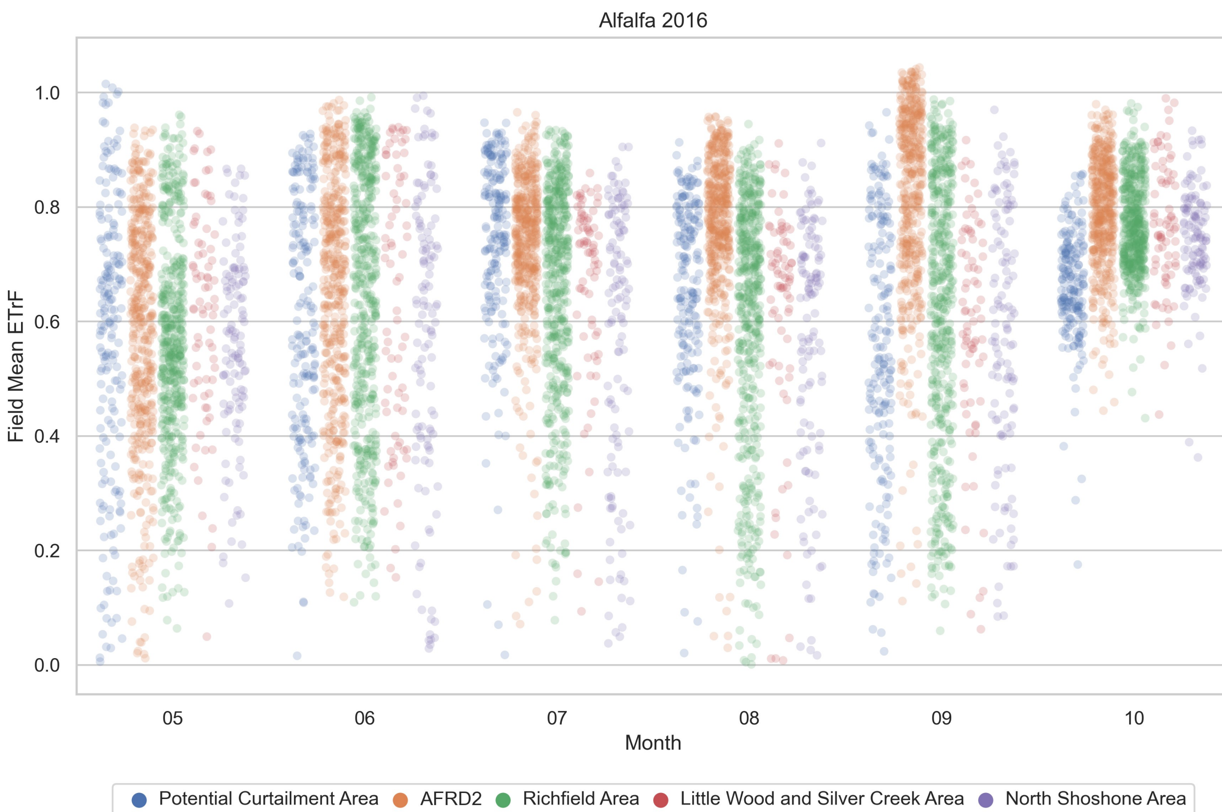


Figure 4. Monthly mean field ETrF for alfalfa fields in 2016 (near-median SWSI)

METRIC ET works well for identifying water shortage for the fields in the Richfield and North Shoshone areas because numerous fields were affected, and the effects were large. The widespread effects seen in METRIC show that many fields were concurrently seeing less ET, so one could surmise that the cause must be widespread and common to all the fields. A depleted supply from a common surface water source is a likely cause. A large effect means that ET has been reduced by more than one might expect due to natural between-field differences (for example, hay cuttings).

The Little Wood and Silver Creek area does not appear to be water short in 2013. The majority of fields maintain an ETrF above 0.5 during the months of peak demand, July and August. Only a small proportion of fields show ETrF as low as the Richfield and North Shoshone areas. In contrast to the widespread drop in ETrF seen in the Richfield and North Shoshone areas, the small number of low ETrFs in the Little Wood and Silver Creek area can be plausibly explained by causes other than a water shortage. Some scenarios, provided below, show how the analysis presented here might err regarding water supply at individual fields.

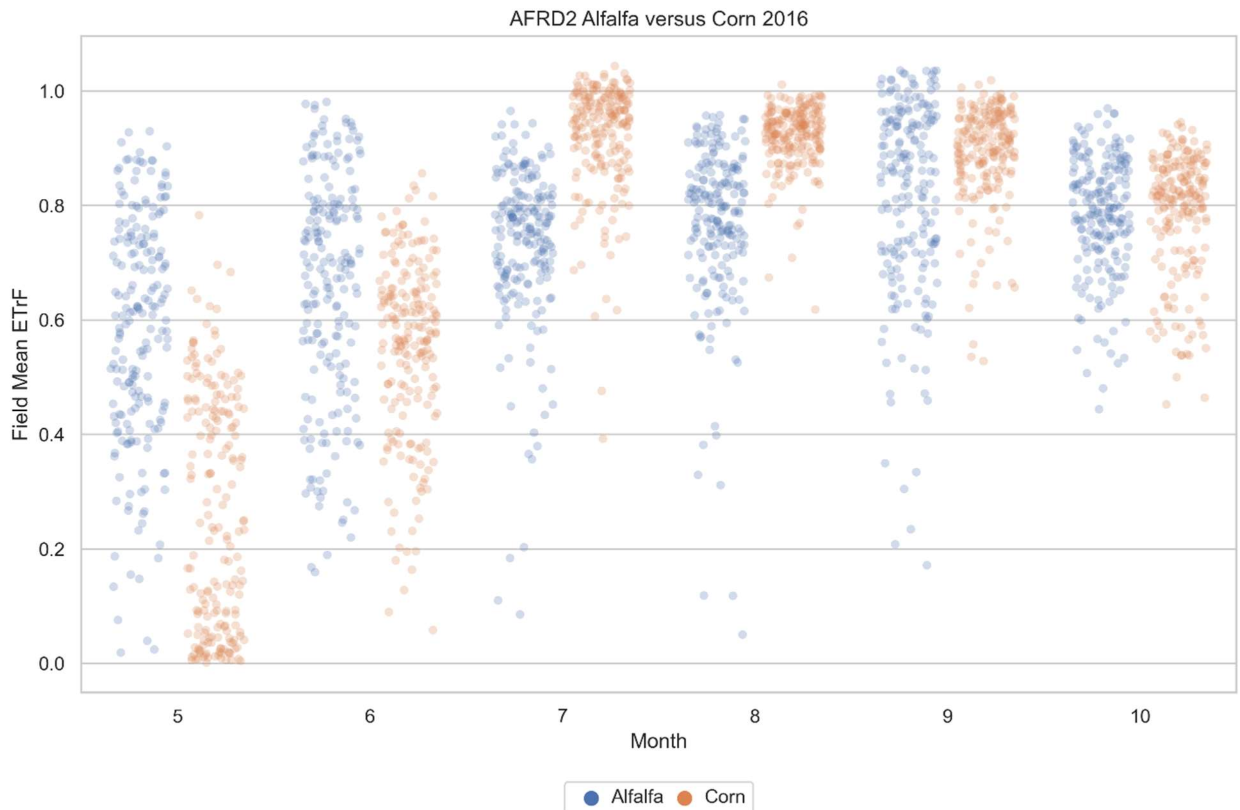
1. If a water right is only short a small amount of water, it would be difficult to confidently determine shortage with METRIC because other factors could have caused the reduction in ET.
2. If a water right is not used despite adequate supply, its POU may be erroneously identified as water short.
3. If a water right is water short but the right holder purchases water from another source, the fields may not appear to be water short.
4. If a water right has a large POU and elects to irrigate a smaller portion of it due to water shortage, this analysis would only identify the irrigated field and conclude that the field is not water short.
5. Errors in the CDL, irrigated land classification, and METRIC could make the POU of a well-supplied right look water short.

Conclusions

Water shortages during the 2013 drought in the Richfield area and North Shoshone area were evident from the low ETrF values of fields in those areas. The contrast between alfalfa fields in the AFRD2 area and the fields in the Richfield and North Shoshone areas is stark and reveals what the difference between well-watered and poorly-watered fields looks like. The visible water shortage in 2013 supports the idea that METRIC data can be used to find injury to water rights.

This analysis did not clearly identify water shortage in the Little Wood and Silver Creek area during the 2013 drought. It is possible that some fields in this area were water short, but additional information would be required to make conclusions about the water supply of individual fields.

ATTACHMENT A. PLOT OF CORN VERSUS ALFALFA ETRF



The plot above shows the 2016 monthly mean ETrF for 200 fields of alfalfa and 200 fields of corn randomly selected in the AFRD2 area of analysis. The variation in the ETrF of corn is smaller than alfalfa in July and August. Cuttings may cause more variation in hay crop ETrF during the peak of the growing season.