ASEL weather station - soil moisture and temperature comparison

Summary

Concerns were raised regarding the unusually low soil moisture levels recorded at the ASEL weather station in southwestern Marshall County, Indiana (Figure 1). These readings were notably lower compared to other Purdue Mesonet weather stations. On June 6, 2024, a field comparison was conducted using a portable Acclima TDR-310W sensor to cross-check the in situ CS655 sensor, both measuring at 10 cm (4 in) below the surface. The CS655 sensor recorded an average volumetric water content (VWC) of 1.6%, while the Acclima sensor—using both horizontal and vertical measurements—showed an average of approximately 4.8%. Given the CS655 sensor's accuracy of ±3% (Campbell Scientific, Inc., July 19, 2024) and the Acclima sensor's accuracy of ±2.5%, these values are within the expected accuracy range for both devices. The low soil moisture levels are consistent with the geology, sandy soils, local flora, and topography of the site. These readings represent some of the driest soil conditions recorded across the state.

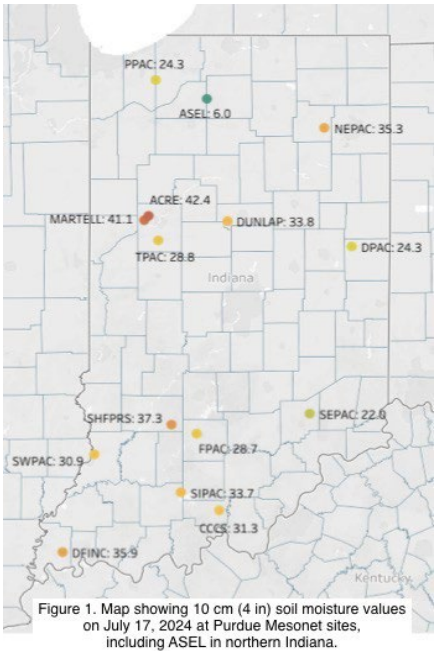

Figure 1. Map showing 10 cm (4 in) soil moisture values on July 17, 2024 at Purdue Mesonet sites, including ASEL in northern Indiana.

Method

VWC and temperature were measured with an Acclima SDI-12 reader and TDR-310W sensor at eight (8) locations surrounding the CS655s location. The CS655s were installed horizontally into the soil in a vertical stack at 5, 10, 20, and 50 cm or approximately 2, 4, 8, and 20 in below grade. Holes were dug with a post hole digger to a depth of over ten (10) cm for the Acclima sensor comparison. Four (4) holes were dug approximately 1 m from the CS655s location in the cardinal directions and remaining four (4) holes were dug approximately 3 m from the CS655s location in the cardinal directions. The Acclima reader has an internal GPS that records latitude and longitude for each location with an accuracy of approximately ±1-2 m. It turned out that the latitude and longitude were not accurate enough for this relatively small, 6 by 6 m study area. A relative site coordinate system was used to map data.

Threshold was set to a silt loam soil using Read Sensor > Analysis > Threshold, but Threshold is only used for field capacity calculations in Analysis. The sensor was inserted sensor horizontally at 10 cm below grade in each post hole for comparison to the 10 cm CS655 values. At least 2 readings were taken at each location with several minutes between readings. A second set of readings were collected adjacent to each post hole by inserting the sensor vertically with 2 readings per location.

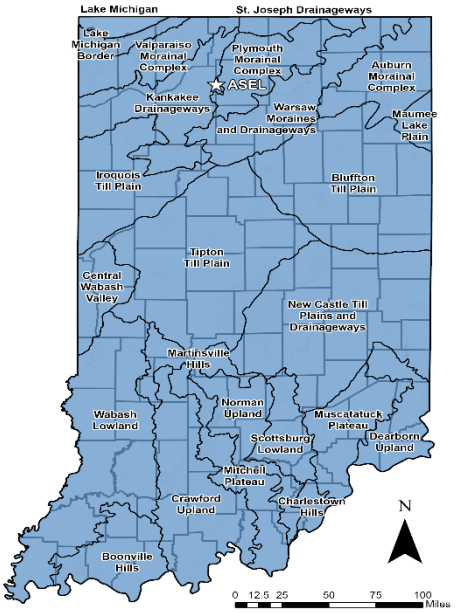

Figure 2. Map showing physiographic regions.

Geology/Soils

The ASEL weather station is situated on a glacial outwash deposit known as the Kankakee Drainageways, within the Northern Moraine and Lake physiographic region, or alternatively, the Kankakee Outwash and Lacustrine Plain physiographic region (Fenelon, Bobay, et al., 1994) (Figure 2). This area is characterized by glacial outwash, dune sands, alluvial deposits, and lake sands. In line with the region's physiographic mapping, the ASEL farm is primarily underlain by sandy soils, including the Brems-Morocco loamy sands

(0 to 1 percent slopes) and Plainfield sand (2 to 6 percent slopes), both of which are typically found in outwash plains (USDA NRCS, 2024).

Flora

Prickly pear cacti were observed growing in the field surrounding the weather station (Figures 3 and 4). According to The Spruce (2024), "The most important requirement for any plant in the *Opuntia* genus is well-draining soil. While prickly pear thrives in sandy or gravelly soils, it can tolerate other soil types as long as drainage is good and water is not excessive." The presence of these plants aligns with the area's sandy soil conditions.

Figure 3. Photograph showing blooming prickly pear cactus.

Figure 4. Photograph showing blooming prickly pear cactus relative

Topography

The weather station is located on a low ridge or hill which will also contribute to internal soil drainage.

Discussion

Figures 5, 6, 7, and 8 (featured on the next page) are maps that show soil moisture and temperature values compared between the horizontally-installed CS655 sensor versus the horizontally and vertically-installed Acclima sensor. The CS655 sensor is centrally located relative to the Acclima sensor readings. The heat maps use red (i.e., warmer) colors for higher values and blue (i.e., cooler) colors for lower values.

The Acclima soil moisture values showed an increase toward the south and east, likely due to the presence of some silt content in the otherwise sandy soils in these areas, which may have enhanced the soil's moisture-holding capacity. Although the CS655 sensor recorded slightly lower soil moisture values (Table 1, pg. 4) compared to the Acclima sensor (Table 2, pg. 5), the differences were minimal, within a few percentage points. Considering the CS655 sensor's water content accuracy of ±3% (Campbell Scientific, Inc., July 19, 2024) and the Acclima sensor's accuracy of ±2.5%, these values fall within the expected accuracy range of both sensors.

Soil temperature readings from the CS655 and Acclima sensors are generally in good agreement, differing by no more than 1°F. However, the vertically installed Acclima sensors recorded warmer temperatures compared to the horizontally installed sensors. This discrepancy may be attributed to the sensor design, where the temperature sensor is located in the body of the device, while the prongs extend out from it. The horizontal measurements were taken at a depth of 10 cm, whereas the vertical sensors captured temperatures closer to the surface. As expected, soils are cooler at depth compared to the sun-exposed surface, explaining the warmer readings from the vertical sensors.

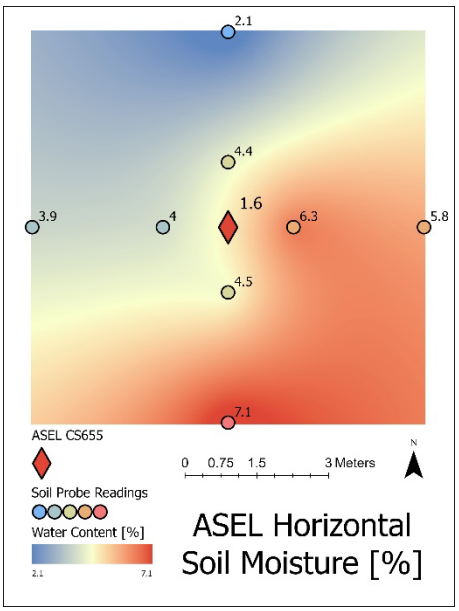

Figure 5. Heat map showing soil moisture values for horizontally installed sensors.

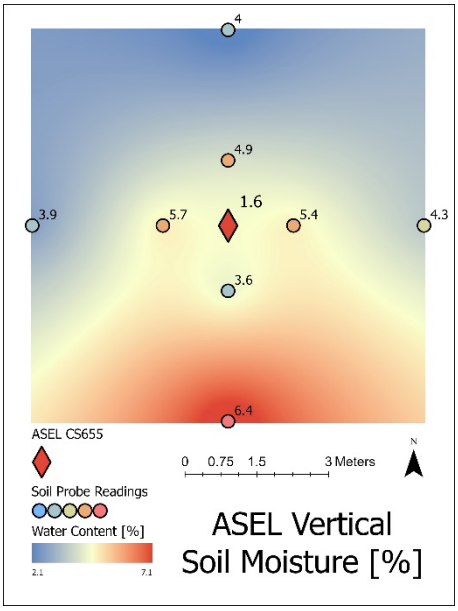

Figure 6. Heat map showing soil moisture values for vertically installed sensors.

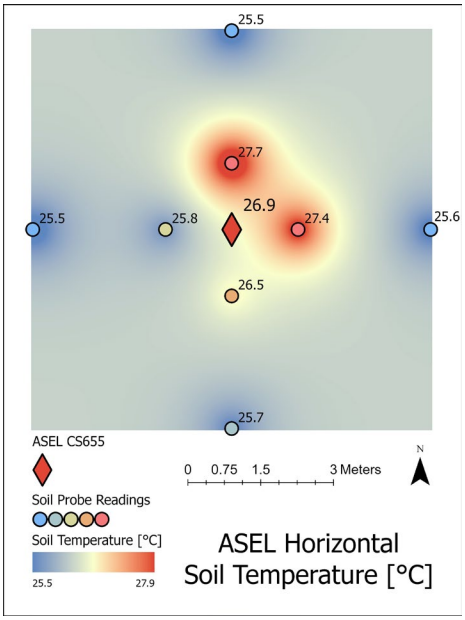

Figure 7. Heat map showing soil temperature values for horizontally installed sensors.

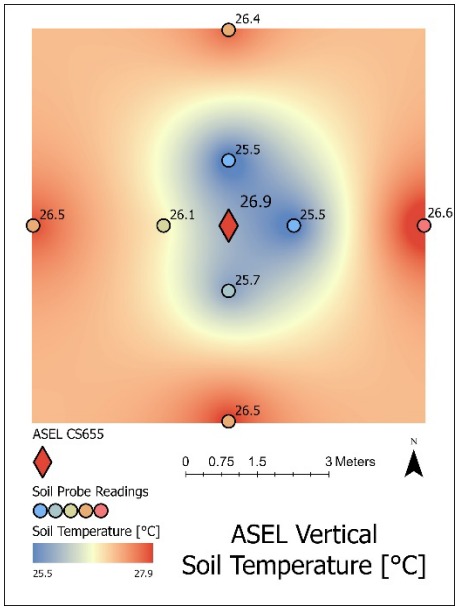

Figure 8. Heat map showing soil temperature values for vertically installed sensors.

References

Acclima, Inc., July 19, 2024, https://acclima.com/tdr-310w-soil-moisture-sensor-sdi-12-data- sheet/
Campbell Scientific, Inc., July 19, 2024, https://www.campbellsci.com/cs655

Fenelon, J.M., Bobay, K.E., Greeman, T.K., Hoover, M.E., Cohen, D.A., Fowler, K.K., Woodfield, M.C., and Durbin, J.M., 1994, Hydrogeologic atlas of aquifers in Indiana: U.S. Geological Survey Water-Resources Investigations Report 1992–4142, 197 p., https://pubs.er.usgs.gov/publication/wri924142.

IndianaMap. July 17, 2024. Physiography Regions. https://arcg.is/1SuC0K the spruce. June 14, 2024. https://www.thespruce.com/grow-prickly-pear-cactus- inside-1902533#:~:text=The most important requirement for,and not too much water.

USDA NRCS, June 14,2024, Custom Soil Resource Report for Marshall County.

Table 1. CS655 data

ASEL Table (5-min) 10 cm CS655 Soil T & VWC Data		
Time (LST)	**Soil Temp (°F)**	**VWC (%)**
06/06/2024 06:25 PM	81.7	1.6
06/06/2024 06:30 PM	81.7	1.6
06/06/2024 06:35 PM	81.5	1.6
06/06/2024 06:40 PM	81.3	1.6
06/06/2024 06:45 PM	81.3	1.6
06/06/2024 06:50 PM	81.1	1.6
06/06/2024 06:55 PM	81	1.6
06/06/2024 07:00 PM	81	1.6
06/06/2024 07:05 PM	80.8	1.6
06/06/2024 07:10 PM	80.6	1.6
06/06/2024 07:15 PM	80.6	1.6
06/06/2024 07:20 PM	80.4	1.6
06/06/2024 07:25 PM	80.2	1.6
06/06/2024 07:30 PM	80.2	1.6
06/06/2024 07:35 PM	80.1	1.6
06/06/2024 07:40 PM	79.9	1.6
06/06/2024 07:45 PM	79.7	1.6
06/06/2024 07:50 PM	79.5	1.6
06/06/2024 07:55 PM	79.5	1.6
06/06/2024 08:00 PM	79.3	1.6
06/06/2024 08:05 PM	79.2	1.6
Average	**80.5**	**1.6**

Table 2. Acclima data

10 cm Horizontal TDR-310 Measurement Data			Relative Site Coordinates (m)	
Date	**VWC (%)**	**Temp (F)**	**X**	**Y**
06/06/2024 18:26:24	4.37	82.1	3	4
06/06/2024 18:28:44	4.44	81.6	3	4
06/06/2024 18:29:06	6.27	81.6	4	3
06/06/2024 18:35:18	6.32	81.0	4	3
06/06/2024 18:35:45	4.5	80.9	3	2
06/06/2024 18:49:28	4.55	78.5	3	2
06/06/2024 18:49:53	4.01	78.5	2	3
06/06/2024 18:58:52	4.08	78.3	2	3
06/06/2024 19:03:30	2.06	78.0	3	6
06/06/2024 19:05:08	2.13	77.7	3	6
06/06/2024 19:05:40	5.76	77.8	6	3
06/06/2024 19:07:10	5.78	78.2	6	3
06/06/2024 19:07:37	7.11	78.4	3	0
06/06/2024 19:09:12	7.14	78.0	3	0
06/06/2024 19:09:43	3.87	77.9	0	3
06/06/2024 19:16:17	3.92	77.8	0	3
Average	**4.77**	**79.1**		

10 cm Vertical TDR-310 Measurement Data			Relative Site Coordinates (m)	
Date	**VWC (%)**	**Temp (F)**	**X**	**Y**
06/06/2024 19:20:42	4.92	77.9	3	4
06/06/2024 19:20:58	4.92	77.8	3	4
06/06/2024 19:21:21	5.42	77.8	4	3
06/06/2024 19:21:29	5.47	77.9	4	3
06/06/2024 19:21:51	5.42	78.0	4	3
06/06/2024 19:22:11	3.63	78.0	3	2
06/06/2024 19:22:35	3.63	78.4	3	2
06/06/2024 19:22:52	5.68	78.7	2	3
06/06/2024 19:23:07	5.73	79.1	2	3
06/06/2024 19:23:22	3.94	79.4	3	6
06/06/2024 19:23:49	3.95	79.7	3	6
06/06/2024 19:24:12	4.22	79.9	6	3
06/06/2024 19:24:29	4.34	80.0	6	3
06/06/2024 19:24:57	6.37	79.8	3	0
06/06/2024 19:25:21	6.34	79.6	3	0
06/06/2024 19:25:41	3.87	79.6	0	3
06/06/2024 19:26:14	3.91	79.6	0	3
Average	**4.81**	**78.9**		