IRRIGATION INFORMATION

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Predicting the Last Irrigation of the Season using Watermark™ Soil Moisture Sensors

This is the last of a series of three factsheets on Watermark™ Soil Moisture Sensors. The first factsheets details "How to Make a Watermark™ Sensor." The second factsheet discusses "How to use Watermark Soil Moisture Sensors", and this factsheet provides additional detail about deciding how to schedule the last irrigation of the season using Watermark™ soil moisture sensors.

The last irrigation of the season is one of the most challenging decisions irrigators face. The last irrigation either provides the last remaining water necessary to maximize yield or reduces profitability by adding water that will not result in any additional revenue in crop yield. Leaving the soil dry at the end of the season is beneficial because harvest efficiency is improved and compaction is minimized. Terminating needs to be done on a field by field basis, using soil moisture sensor and visual observations. Verify the soil sensor reading with observations of the soil profile using a slide hammer and probe or shovel. The amount of water in the soil profile can be determined using Watermark™ sensors. Other sensor types can also be used, check with the manufacturer for directions. Use the full profile, in most soil types this will be 30-36 inches and an allowable depletion of 50%.

The premise for terminating the last irrigation of the season is,

$$
\begin{aligned}
Plant\ Water\ Need\ (inches) &= Water\ needed\ to\ finish\ the\ crop, inches\ (Table\ 1\ or\ 2)\\
&- Water\ Available\ in\ the\ root\ zone\ (sensor\ readings), inches\\
&- effective\ rainfall\ (inches)
\end{aligned}
$$

$$
Irrigation\ Application\ Depth\ (inches) = Plant\ Water\ Need\ (inches) \div Irrigation\ Efficiency (\%)
$$

If this is positive there is additional irrigation needed, if it is negative, there is no need for a final irrigation. At times rainfall provides the last remaining water to carry the crop to maturity.

Step 1. Determine the amount of water needed to finish the crop.

Table 1 and 2 provide the amount of crop water required to finish out corn and soybeans respectfully by growth stage. For example, for corn at R5 and the starch line ¾ of the way down, there are 7 days to maturity and 1.0" of water needed in the soil profile to reach black layer. If there is more than 1.0" in the profile then additional irrigation or rainfall is not needed. For soybeans that are past R6.5, depending upon maturity group there is 20-30 days left to reach maturity and 2.9 inches of water are required.

Table 1. Crop Water Demand for Corn

Stage	Stage	Days to maturity	Water needed to mature (in)
R4	Dough	34	7.5
R4.7	Beginning dent	24	5
R5	¼ milk line	19	3.7
R5	½ milk line /full dent	13	2.2
R5	¾ milk line	7	1.0
R6	maturity	0	0

Source: Yonts, C.D., S.R. Melvin and D.E. Eisenhauer. Predicting the last irrigation of the season. Nebguide G1871. Lincoln, Nebraska. This table reports inches of water for simplicity but is acre-inches/acre.

Table 2. Crop Water Demand for Soybeans

Stage	Stage	Days to maturity	Water needed to mature (in)
R4	End of Pod Elongation	50-60	No data
R5	Beginning of seed enlargement	40-50	10.0
R6 – R6.5	End of seed enlargement to leaves beginning to yellow	30-40	4.71
R6.5 – R7	Leaves begin to yellow	20-30	2.9
R7	Beginning Maturity	10-15	0.75
R8	Maturity	0	0.27

Source: Results from sap flow experiments conducted at Lon Mann Research and Extension Center, 2017. This table reports inches of water for simplicity but is acre-inches/acre.

Step 2. Determine the amount of water available in the effective root zone.

The effective root zone can be determined from the sensor responses. It is recommended to deploy sensors at 6", 12", 18" and 30" depths. These equate to the top foot, second foot and third foot of the rooting profile, with the 6" and 12" representing the top foot and the most active profile. If watermark readings have moved from wet to dry during the reproductive stage of plant development, then this is an indication of the effective rooting zone. For example, if the 18" sensor has moved from 22 cb to 90 cb, then use a rooting depth of 24 inches. If the 30 inch sensor has shown subsoil extraction, then assume an effective rooting depth of 30 or 36 inches.

During the growing season it is suggested, to use an allowable depletion of 30-35% for center pivots, and 35-50% for furrow irrigation systems. Select an allowable depletion that matches risk and ability to deliver timely irrigations. For example, use 35% for a furrow irrigation system that has limited water supply and 45% or 50% for normal furrow system that can apply irrigation on a timely basis. In center pivot systems about an inch of water is applied, so a lower allowable depletion is used. In furrow irrigation systems 2-3 inches of water is applied, so a higher allowable depletion should be used since more the profile must be depleted to store the larger irrigation application. However, for the last irrigation of the season, for both center pivots and furrow systems use a 50% allowable depletion to use all remaining soil water and save on pumping cost. Any additional water applied beyond what is needed by the crop will not be used. Using an allowable depletion of up to 60% is considered acceptable for the last irrigation, so using 50% has a factor of safety included.

Use Table 3 and the following equation to convert Watermark™ readings to water holding capacity. It is strongly recommended to use the mobile app available on the iTunes store for these calculations rather by hand.

$$Plant\ Available\ Water\ (in) = \ WHC(\frac{in}{ft})\ \times MAD\ (\%) \times Effective\ Rooting\ Depth\ (ft)$$

For example if the four Watermark readings are 60, 45, 50, and 10, the average is 41 cb.

For a silt loam soil with a pan, the total WHC at 40 cb is 1.52 in/ft (not shown in Table 3), therefore at a 50% MAD the plant available water would half this or 0.76"/ft as read from Table 3 for 40 cb. When at field capacity (33 cb) the most water this soil can hold is 1.58"/ft.

Take the water holding capacity at 50% MAD times the effective root zone. The effective root zone is the depth at which the plants are extracting water or the known rooting depth of the crop. Generally, if watermark readings are changing it can be assumed that this water is available to the plants and this can be assumed to be the rooting depth.

AW = 0.8"/ ft x 3 ft = 2.4 inches of plant available water

Table 3. Plant Available Water (inches per foot) for a given Soil Matric Potential or Tension (centibars) at 50% MAD.

Soil Tension (cb)	Sand (1.0"/ft)	Sandy Loam (1.4"/ft)	Silt Loam with Pan (1.58"/ft)	Silt Loam (2.37"/ft)	Clay (1.6"/ft)
0	1.77	1.51	1.01	1.83	1.38
5	1.72	1.51	1.01	1.83	1.36
10	0.74	1.00	1.01	1.65	1.09
15	0.35	0.74	1.01	1.53	0.91
20	0.14	0.58	1.01	1.41	0.78
25	0.02	0.46	0.88	1.29	0.68
30		0.37	0.79	1.19	0.60
35		0.29	0.81	1.14	0.53
40		0.23	0.72	1.00	0.47
45		0.18	0.64	0.89	0.42
50		0.14	0.57	0.80	0.37
55		0.10	0.49	0.71	0.33
60		0.06	0.45	0.63	0.30
70		0.01	0.35	0.50	0.23
80			0.25	0.39	0.18
90			0.21	0.29	0.13
100			0.13	0.22	0.09
120			0.03	0.09	0.02
130				0.03	
140					

Source: Lab and model data of irrigated soils sampled and grouped from Arkansas farms.

Step 3. Account for any potential rainfall that may occur before the crop matures.

If rainfall occurs, this depth can be added to the water balance. For example, if a half of an inch of water is needed to finish the crop and that much or more falls on the field without runoff, then no additional irrigation need be applied.

Step 4. Determine the Irrigation Need

The irrigation need is the difference between what is available in the soil and what is needed. Irrigation is not 100% efficient, losses due to tail water, deep percolation and down furrow uniformity do not allow all of the water applied to a crop to reach all of the plants equally.

If rainfall does not provide enough to finish the crop, then the last irrigation is necessary. However, irrigation is not 100% efficient (Table 4), so if the crop needs an inch of water to finish, and the irrigation system is only 70% efficient, then 1.4 inches (1/0.7) is needed to provide that inch of water. Furrow irrigation systems are about 60-70% efficient and center pivots are between 65-85% efficient depending upon condition and sprinkler package. If only an inch of water is needed to finish out a furrow irrigation crop, then do a flush not a full irrigation, enough to provide an inch of water to the lower reach of the field. Adjust the percent run time based on the pivots chart to match the application depth needed accounting for irrigation efficiency. Irrigation application efficiency is defined as *Ea = (volume of delivered to the crop / volume of water applied) x 100*. A simplified net irrigation equation is below.

$$Applied\ Irrigation\ Depth\ (in) = \frac{Plant\ Water\ Need\ (in)}{Irrigation\ System\ Efficiency\ (\%)}$$

Thus, to apply an inch of irrigation, using an irrigation system that is 70% efficient, it is necessary to apply 1.4 inches.

Table 4. Typical Irrigation Efficiencies for Arkansas Systems

	Irrigation Efficiency Range	Irrigation Efficiency Most Common in Arkansas
Furrow Irrigation	60-80%	70%
Center Pivot	65-85%	80%
Micro-Irrigation	85-95%	90%

Table 5. Applied Irrigation Depth (in) needed for Plant Water Needs for different Irrigation Efficiencies.

	Irrigation Efficiency (%)		
Plant Water Need (in)	70%	80%	90%
0.5	0.7	0.6	0.6
1	1.4	1.3	1.1
1.5	2.1	1.9	1.7
2	2.9	2.5	2.2
2.5	3.6	3.1	2.8
3	4.3	3.8	3.3

Full Example

Use the mobile app, search for the "Arkansas Soil Sensor Calculator" on the Apple App Store (Android version is not currently available). Use this to determine the water available in the profile. If the amount available is more than is needed, no additional irrigation is necessary. The difference is the net irrigation required.

Corn at R5 with the starch line at 50% and Watermark™ centibar readings are, 40, 63, 60, and 85 cb for 6, 12, 18 and 30 inch depths. A rain of 0.15 inches occurred within 12 hours of making the readings and the field is a clay soil type that is furrow irrigated. Since this is the last irrigation, use a rooting depth of 3 feet and a Managed Allowable Depletion (MAD) of 50%.

Step 1. Amount of water needed to finish the corn from Table 1 is 2.2 inches.

Step 2. The average watermark readings are (40+63+60+85) / 4 = 62 cb. For a 50% MAD, the plant available water is 0.55 inches per foot, we assume the rooting depth to be three foot because all the sensor readings have moved during the season. From Table 3, for a clay soil at 60 cb the plant available water per foot is 0.30 inches per foot. 0.30 x 3 ft = 0.90 inches, this is the plant available water in the effective rooting zone.

Step 3. There was 0.15 inches of rainfall that fell after the readings were taken, so the total plant available water is 0.90" + 0.15 inches is 1.05 inches of plant available water.

Step 4. The irrigation need is 2.2 inches – 1.05 inches = 1.15 inches. We think our furrow irrigation system is at least 70% efficient, so we need to apply 1.65 inches of water to get 1.15 inches (1.15" x 70% = 1.65 inches). If a normal irrigation is 2 inches, we can shut off about 20% earlier than a normal irrigation to finish the corn crop. In this example another irrigation is necessary to meet crop water demand.