Irrigation Scheduling Tools – Selection & Operation

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Equipment Selection

Soil Considerations

Many good soil moisture sensors are on the market. Selection of the best sensor for your purposes depends on the amount and type of information you desire. At the most basic level, the device should give a repeatable index of soil moisture content (either soil moisture as percent by volume or matric potential (as in tensiometers or granular matrix sensors).

If you work with a soil that shrinks as it dries, or with a low water holding sandy soil, devices that require good contact with the soil may not give good, repeatable readings after the soil has passed through one drying cycle. Devices with the contact area shaped as a flat plate are particularly prone to breaking contact on shrink – swelling soils, particularly if a crack forms through the installation area.

Devices that require direct soil contact and free interchange of soil water with the sensor (tensiometers and watermarks, etc.) may have problems on very sandy soils. Watermarks require the movement of soil water into the sensor to equilibrate the matric potential of the soil to that in the sensor. In very sandy soils, except near saturation, the minimal pore water present does not move readily so measurements may be in error. Because water flows out through the ceramic cup of a tensiometer to the soil as it dries, tensiometers can maintain better soil contact and function better in very sandy soils than watermarks.

Data Requirement Considerations

Do you want a basic soil moisture indication at a given depth with manual reading on a several day interval, automatic soil moisture readings at user-selected time intervals at several soil depths connected by telemetry to your home computer, or something in between? This consideration is a trade-off between equipment cost and labor/convenience/data desired. The more expensive systems provide additional data for decision making if it is of value to you in your crop management. Systems that automatically collect data at specified intervals from several soil depths can detect short-duration leaching events due to over-irrigation and can show slow wetting or drying trends in the surface or deeper soil layers that “point in time” manual data collection will miss. The ability to monitor soil moisture at several depths with time and have a record of your good irrigation management will also become more important as a tool to prove to regulatory agencies that you have indeed irrigated properly and are not contributing to high nitrate levels in shallow aquifers.

General Types of Irrigation Scheduling Devices

A wide variety of sensors have been developed and new sensors are available each year. The following descriptions are not intended to be an exhaustive list of current equipment, but are provided for general information. The methods listed here were evaluated during several plot-years of field tests. The results indicated that for sandy loam or silt loam soils, potato yield and quality were not significantly different for any method, if the method was used carefully and correctly.

Watermark Moisture Sensor: These sensors relate an electrical resistance measurement to soil moisture. Soil moisture tension in centibars (how hard the plant has to work to get water out of the soil) is the measurement provided by the meter. Reading repeatability is good to within + 3 centibars. Each unit costs about $30-$35, depending upon lead length, and the meter is about $250. The sensor is composed of an electrical resistance element surrounded by a gypsum block to minimize salinity effects. The sensor/block is then surrounded by sand of a specified diameter to provide the repeatable porous medium in which the sensor functions. Sensor range is zero (saturation) to 200 centibars (drier than irrigation should begin on any crop). The sensors are soaked in water for 48 hours to saturate the resistance element and then installed in a near-saturated soil at the desired depth. Good contact between the sensor and soil is essential for water content in the sensor to equilibrate with that in the soil. Guidelines for sensor placement and threshold values at which to begin irrigation on a variety of crops and soils have been developed.

Tensiometers: These sensors use a porous ceramic cup attached to the bottom of a clear plastic tube/water reservoir and calibrated vacuum gage to measure soil moisture tension in centibars. Tensiometers come in varying lengths, from 1 foot to 4 feet in length, with cost ranging from $45 to $60 each, depending on length. These devices are also soaked in water for at least one day before installation. Good contact between the ceramic cup and the surrounding soil is also essential for this device. As water flows out of the tensiometer into the surrounding soil until moisture equilibrates, it creates a partial vacuum in the tensiometer body which is read on the calibrated vacuum gage as matric potential or soil moisture tension. Guidelines for sensor placement and threshold values at which to begin irrigation on a variety of crops and soils have been developed. This device responds more quickly to changes in soil moisture than does the watermark sensor, but operating range is only from zero to about 70 centibars. This is sufficient for potatoes, but may be a little restrictive for grain, alfalfa, and beets on silt loam and heavier soils.

Aquateer: This device measures capacitance changes in soil and relates these changes to soil moisture content. It is portable and allows the user to take any number of measurements at any location and depth. Cost is about $400. The probe length is about 3 feet, but many times the measurement depth is limited by the ability to push the probe into the soil. Its output is in percent saturation, or the percent of soil pore space filled with water. Percent saturation can be experimentally related to soil moisture tension and to percent soil moisture by volume. The threshold reading that indicates that irrigation should begin has been somewhat developed for a variety of crops and soils. With individual irrigator experience, the threshold value for particular crops and soils can be well developed. Reading repeatability is good.

AGRIMET Checkbook/Feel and Appearance: This method, also known as the "checkbook" method, uses soil and crop properties to determine how much water can be extracted by the crop between irrigations without moisture stress. Daily ET (crop water use and evaporation from soil) is calculated based on local climate data. A number of weather stations in southern Idaho are linked to the US Bureau of Reclamation AGRIMET system in Boise by satellite. Calculations are made for each station for each crop grown in the area at 15-minute intervals. This information is available at any time on the Internet at http://www.usbr.gov/pn/agrimet. It is also published in a number of southern Idaho newspapers. In operation, the water that can be extracted between irrigations is determined, and then daily ET subtracted from that "balance". When the "balance" nears zero, irrigation should begin. Sufficient water is added back to refill the soil in the crop root zone and the process begins again. The timing of irrigation is usually checked with the "feel and appearance method" of determining available soil moisture to make sure that calculations match reality. The cost for this method is minimal and it can perform very well. It does take some time to update for each field each day, but new computerized delivery methods are being developed.

Portable TDR: This device uses a 2 or 3-prong sensor about 12 inches long that is inserted into the soil to full length. It sends a high-frequency pulse and measures the time required to sense the reflected signal. This method determines the dielectric constant of the moist soil. From this the moisture content of the soil can be accurately and repeatably determined. To use this method, readings should be taken daily and the threshold number for irrigation determined from the pattern of the readings, the irrigator's experience, and perhaps another method. Once the threshold is determined, then readings at several day intervals are sufficient to determine when the soil is nearing the threshold and needs irrigation. Cost is about $800.

Aquaflex: This instrument, developed in New Zealand, uses technology similar to the TDR instrument to determine volumetric soil moisture content. The sensors are about 10 feet long and are buried horizontally at the desired depth. This length takes some of the variability out of the readings. It can be programmed to collect data from up to four sensors at one of a variety of time intervals. It provides a nearly constant record of soil moisture variation. Irrigator experience, along with the instrument readings must be used to establish an irrigation threshold. Once established, it can be used for irrigation scheduling and forecasting quite effectively. Data can be downloaded at any desired interval onto a palmtop or laptop computer for plotting and analysis. Cost is about $1,800-$2,500 depending on cables and sensors required.

Enviroscan: This instrument, developed in Australia, uses technology similar to the TDR instrument discussed above to determine volumetric soil moisture content. The data logger can accommodate up to 32 sensors distributed among up to 8 sites (e.g., 4 depths at each of 8 sites, and can be solar-powered. Data are downloaded to another computer for analysis. The sensors are installed in a PVC access tube placed in the soil with cables connected to the data logger unit. This site has sensors at 10, 20, 30, 50 and 60 cm depths (15 cm = 6 inches). This unit provides a nearly continuous record of soil moisture variation which can be used to determine depth of rooting and if leaching from any soil layer occurred on a daily basis. Irrigator experience, along with instrument readings, must be used to establish an irrigation threshold condition. Once established, it can be used for irrigation scheduling and forecasting quite effectively. Costs range from about $4,000 for a 2-probe, 8-sensor unit to serve one center-pivot to about $6,000 for a 4-probe, 16-sensor unit that can serve two adjacent pivots or other irrigation systems.

Installation, Placement and Data Interpretation

Sensor Installation

Installation of all sensors causes the soil immediately around the sensor to be disturbed. The challenge is to excavate and install the sensor in a manner to assure good soil contact without changing compaction level or other soil properties relative to the field you wish to describe with the sensor. The most common problem with sensors is improper installation, usually resulting in poor soil-sensor contact. If a circular sensor is installed by insertion into a hole slightly larger than the sensor, soil must be added and worked around the sensor to assure good contact. An alternative is to add thick soil slurry to fill the hole several inches deep before inserting the sensor. Adding a soil slurry works well on all but soils that shrink as they dry. For these soils, a better alternative is either to make the hole with a probe just slightly smaller than the sensor diameter, or to use a bucker auger to make a hole 2-3 times the sensor diameter and plant the sensor like a fence post (being careful not to over-compact the soil).

Sensor Placement

Sensors should be installed between plants in the row. Typically water applied by sprinkler irrigation is diverted by crop leaves so that more falls between rows than in the row area. As a result, the row or hill area will usually be drier than the soil between rows. Particularly with potatoes, the majority of the water used by the plant comes from the hill area, so it is the area to monitor. Ideally, sensors should be placed at a minimum of three depths in the hill area. In potatoes, one should be at about seed piece depth (the depth of most water uptake), another at about 16 inches (to monitor adequacy of additional water that can be extracted when needed) and a third at the bottom of the active root zone (18-24 inches, depending on soil depth, to detect movement of water below the active root zone). If only one sensor depth is used, it should be at seed piece depth.

Sensor Data Interpretation (when to irrigate or when to change manner of pivot or linear irrigation)

Irrigation management based on sensor data involves applying water to keep sensor output above a critical lower limit and below field capacity. The top soil layer will reach saturation during and after irrigation but it should drain to field capacity within 1-2 days. Each sensor manufacturer should provide information about what sensor output corresponds to saturation and to various levels of crop stress. For example, with watermarks or tensiometers, a reading of 0 indicates saturation and readings of 30 -75 correspond to the level of crop stress which should not be exceeded, depending on crop and soil. The attached tables show watermark or tensiometer readings corresponding to various levels of available soil water, and the desirable range of readings for various crop and soil conditions.

Irrigation Depth Required to Re-fill Soil to Field Capacity

The attached tables also show the depth of water to add to re-fill one foot of soil at a specified "percent available water" or watermark reading. Depth required depends on soil texture and on the application efficiency of the sprinkler system**.** It should be re-emphasized that for pivots and linear – move systems, infiltration and surface runoff considerations will limit application per revolution to generally 1 inch or less. Therefore, irrigation must occur after about 1 inch of water has been removed from the soil. This generally means that these systems will be running nearly continuously for the peak use part of the growing season.

Table 1. Relationship between watermark or tensiometer readings and percent available soil water for a sandy loam soil.

Sandy Loam (1.67 in/ft):

Percent Available Soil Water	Water-mark Reading cbars	Inches to refill 1 ft of soil **pivot or linear**	Inches to refill 1 ft of soil **hand or wheel line**
100	10	0	0
85	12	0.32	0.36
80	14	0.42	0.48
75	16	0.52	0.6
70	18	0.63	0.72
65	20	0.73	0.84
60	24	0.84	0.95
55	27	0.94	1.07
50	30	1.04	1.19
40	43	1.25	1.43
30	71	1.46	1.67

Sandy Loam (1.67 in/ft):
(Potatoes, Mint, Onions, Dry Beans)

0 Saturated soil
0-10 Leaching Possible
10-24 Best Crop Growth
>24 Crop Water Stress

Sandy Loam (1.67 in/ft):
(Alfalfa, Beets, Grain, Corn, Pasture)

0 saturated soil
0-10 Leaching Possible
10-30 Best Crop Growth
>30 Crop Water Stress

Table 2. Relationship between watermark or tensiometer readings and percent available soil water for a Light-Textured Silt Loam soil.

Light-Textured Silt Loam (1.97 in/ft):

Percent Available Soil Water	Water-mark Reading cbars	Inches to refill 1 ft of soil **pivot or linear**	Inches to refill 1 ft of soil **hand or wheel line**
100	10	0	0
85	15	0.37	0.42
80	17	0.49	0.56
75	20	0.62	0.70
70	22	0.74	0.84
65	25	0.86	0.98
60	30	0.98	1.13
55	35	1.11	1.27
50	40	1.23	1.41
40	62	1.48	1.69
30	119	1.72	1.97

Light-Textured Silt Loam (1.97 in/ft):
(Potatoes, Mint, Onions, Dry Beans)

0 Saturated soil
0-10 Leaching Possible
10-25 Best Crop Growth
>25 Crop Water Stress

Light-Textured Silt Loam (1.97 in/ft):
(Alfalfa, Beets, Grain, Corn, Pasture)

0 Saturated soil
0-10 Leaching Possible
10-40 Best Crop Growth
>40 Crop Water Stress

Table 3. Relationship between watermark or tensiometer readings and percent available soil water for a
Heavier-Textured Silt Loam soil.

Heavier-Textured Silt Loam (2.25 in/ft):

Percent Available Soil Water	Water-mark Reading cbars	Inches to refill 1 ft of soil **pivot or linear**	Inches to refill 1 ft of soil **hand or wheel line**
100	30	0	0
85	38	0.42	0.48
80	42	0.56	0.64
75	45	0.70	0.80
70	50	0.84	0.96
65	55	0.98	1.12
60	62	1.12	1.29
55	68	1.26	1.45
50	75	1.41	1.61
40	100	1.69	1.93
30	200	1.97	2.25

Heavier-Textured Silt Loam (2.25 in/ft):
(Potatoes, Mint, Onions, Dry Beans)

0	Saturated soil
0-30	Leaching Possible
30-62	Best Crop Growth
>62	Crop Water Stress

Heavier-Textured Silt Loam (2.25 in/ft):
(Alfalfa, Beets, Grain, Corn, Pasture)

0	Saturated soil
0-30	Leaching Possible
30-75	Best Crop Growth
>75	Crop Water Stress

Table 4. Relationship between watermark or tensiometer readings and percent available soil water for a Loam soil.

Loam (1.41 in/ft):

Percent Available Soil Water	Water-mark Reading cbars	Inches to refill 1 ft of soil **pivot or linear**	Inches to refill 1 ft of soil **hand or wheel line**
100	20	0	0
85	25	0.26	0.30
80	29	0.35	0.40
75	34	0.44	0.50
70	38	0.53	0.60
65	41	0.62	0.70
60	45	0.70	0.80
55	50	0.79	0.91
50	58	0.88	1.01
40	81	1.06	1.21
30	133	1.23	1.41

Loam (1.41 in/ft):
(Potatoes, Mint, Onions, Dry Beans)

0	Saturated soil
0-20	Leaching Possible
20-45	Best Crop Growth
>45	Crop Water Stress

Loam (1.41 in/ft):
(Alfalfa, Beets, Grain, Corn, Pasture)

0	Saturated soil
0-20	Leaching Possible
20-58	Best Crop Growth
>58	Crop Water Stress

Table 5. Relationship between watermark or tensiometer readings and percent available soil water for a Fine Sand.

Fine Sand (0.6 in/ft):

Percent Available Soil Water	Water-mark Reading cbars	Inches to refill 1 ft of soil **pivot or linear**	Inches to refill 1 ft of soil **hand or wheel line**
100	10	0	0
85	12	0.11	0.13
80	14	0.15	0.17
75	15	0.19	0.21
70	16	0.22	0.26
65	18	0.26	0.30
60	20	0.30	0.34
55	22	0.34	0.38
50	25	0.38	0.43
40	35	0.45	0.51
30	50	0.52	0.60

Fine Sand (0.6 in/ft):
(Potatoes, Mint, Onions, Dry Beans)

0	Saturated soil
0-10	Leaching Possible
10-18	Best Crop Growth
>18	Crop Water Stress

Find Sand (0.6 in/ft):
(Alfalfa, Beets, Grain, Corn, Pasture)

0	Saturated soil
0-10	Leaching Possible
10-25	Best Crop Growth
>25	Crop Water Stress