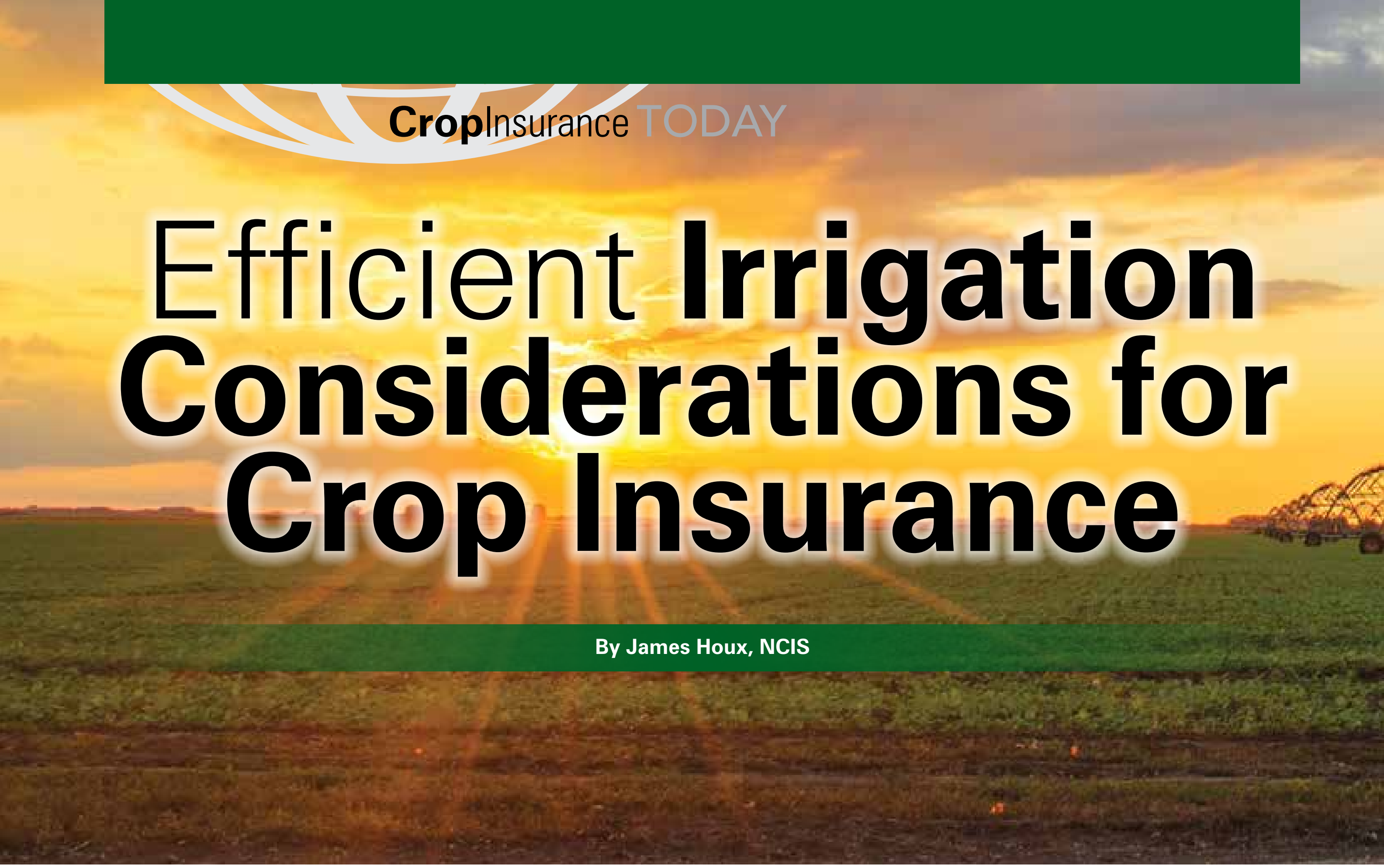

Efficient Irrigation Considerations for Crop Insurance

By James Houx, NCIS

The practice of efficient irrigation has become more prevalent in farming as growers face decreasing amounts of irrigation water to grow their crops. Farmers became concerned that they may be penalized under their crop insurance policy for using less water than they had historically applied, which could negatively affect their Actual Production History (APH). On November 15, 2015, the Risk Management Agency (RMA) released manager's bulletin MGR-15-009 that addresses these concerns indicating that adjustments to an irrigated APH yield may be coming in the future for situations where farmers intend to apply less water and not achieve the irrigated APH yield, but still yield higher than insurance guarantees for non-irrigated acreage.

The bulletin defines efficient irrigation as "…conducting a good irrigation practice using less water than has been historically applied, while still achieving the irrigated APH yield by implementing improved or enhanced management to increase efficiency of irrigation water use." The efficient irrigation definition and what constitutes enhanced management has been integrated into the 2017 Crop Insurance Handbook (CIH) and the 2017 Document and Supplemental Standards Handbook (DSSH), however, the adjustment to irrigated APH yield has not yet been addressed.

So, what is "improved" or "enhanced management" that increases irrigation efficiency? The definitions in the 2017 CIH and DSSH indicates that these enhanced management practices include, but are not limited to, the following:

- Employing an irrigation water distribution technique or technology that has demonstrated greater efficiency.
- Converting high pressure sprinklers to low pressure sprinklers on center pivot systems.
- Using soil moisture monitoring equipment to schedule when and how much water needs to be applied.

What Makes Irrigation Efficient?

Simply put, the most efficient irrigation would provide the least amount of water required to maintain good crop growth and achieve economic yield that is not limited by lack of water. Seems simple enough, but the required amount of water changes from year to year, and within the year, and is highly weather dependent. The amount of solar radiation, precipitation, temperature, relative humidity, and wind speed are a few weather variables affecting plant water use. So are plant species, population, planting date, growth stage, and genetics. Thus, the amount of water applied to achieve irrigation efficiency can be different each year and each day within a year.

Water that is taken up by plants and later is lost to evaporation is called evapotranspiration—often simply referred to as ET. It is a metric by which many of the weather and crop variables can be encompassed and it provides an estimate of the daily amount of water required to maintain good crop production. Transpiration is necessary for plant growth and yields increase as more water flows through the plant and transpiration increases. The idea of efficient irrigation is to increase the T to ET ratio (T/ET) by reducing E and/or increasing T.

A Systems Approach

There are three predominant types of irrigation systems: gravity/surface systems,

sprinkler systems, and micro or drip systems. According to National Agricultural Statistics Service (NASS) Farm and Ranch Irrigation Survey (FRIS) these systems were used on roughly 29 percent, 37 percent, and 14 percent, respectively, of the irrigated harvested acres in 2013. The other 20 percent of the irrigated acres are mostly wheel move and permanent systems.

Traditional gravity-flow surface irrigation systems (flood or furrow irrigation) are only 50-60 percent efficient in getting water that reaches the field to the plants in the field. Part of this is because water is exposed to evaporation losses while runs across the soil surface to every part of the field. Gravity irrigation often results in water loss to deep percolation during transit to the field and while flowing down the furrow. Also, water may "overrun" the furrow and be lost as runoff. With water scarcity and increased water costs, the use of flood irrigation has steadily declined in the last 50 years.

Enhanced management practices that improve the efficiency of gravity irrigation are numerous and new equipment and applications are continually developed. The most obvious improvement that a farmer can make is to create or maintain level fields. Level fields improve application uniformity and reduce runoff. Precise leveling ensures that irrigation water will travel the entire length of the field and not pond in depressions. Another efficient management technique, surge irrigation, is widely recognized and has been used for many years. This type of irrigation sends intermittent "quick shots" of water down a furrow to obtain an optimum furrow water velocity. Often farmers must shorten their furrow lengths or reduce the size of fields to achieve this. It is based on the principle of getting water to the end of a furrow as quickly as possible, which improves distribution uniformity. This reduces the amount of water that is lost to deep percolation and to evaporation while flowing to the last plants in a furrow. In Texas' Lower Rio Grande Valley, on-farm demonstrations have shown that this technique can reduce water use in sugarcane by 52 percent, cotton 22-31 percent, and seed corn 28 percent. Although overrun and deep percolation can be minimized with proper field leveling and surge irrigation, simply capturing water that runs off the field and re-using it is an effective way for farmers to reduce irrigation water use. Further, lining conveyance ditches with plastic will reduce percolation losses before water actually gets to the field.

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In arid areas, such as Texas, farmers began to shift from gravity irrigation to center pivot and moving lateral sprinkler systems decades ago. Although sprinkler systems are more efficient than gravity systems, traditional high pressure sprinkler systems are still only 65-75 percent efficient. Traditional high pressure systems have impact-type sprinklers mounted on the pivot or lateral that shoot water over the top of irrigated crops. Much of the water is affected by wind and much is intercepted on the crop canopy, which results in low application uniformity and increased evaporation.

Researchers realized that significant efficiencies could result if lower water pressures were used, and if the sprinkler heads were changed to constant emission low-drift types and lowered into the crop canopy. Examples of this are medium elevation spray application (MESA) systems where the sprinkler heads are attached to drop tubes hanging from the pivot or lateral. The heads can be as high as six feet above the soil surface. MESA systems are approximately 78 percent efficient. Low elevation spray application (LESA) systems are similar to MESA, but the sprinkler heads are closer to the ground (less than two feet). LESA systems are approximately 88 percent efficient, but efficiencies can be greater than 90 percent. The most efficient sprinkler system is low energy precision application (LEPA). The LEPA system uses drop tubes like MESA and LESA systems, but instead of a standard sprinkler type head, uses drag hoses or socks to release the water directly onto the soil surface without spraying water onto the crop itself. When LEPA systems are designed with furrow dikes (dams placed intermittently across furrows to hold water), irrigation efficiencies of 95 percent can be achieved.

The most efficient irrigation systems are micro-irrigation systems. These systems operate at very low pressure and most often use drip-type emitters to release water as trickles of droplets. The emitters are attached to hoses that can be located above or below the soil surface. When buried beneath the soil surface, these subsurface drip systems can be nearly 100 percent efficient. Due to their expense and installation costs, drip systems are predominantly used in high-value perennials, such as fruit and nut crops.

Deficit Irrigation

Deficit irrigation (DI) is a practice whereby irrigation water is supplied to a crop in quantities that are less than the evapotranspiration during the season. Some quantifiable reduction in yield results, but the reduction in irrigation water use is significant. On the other hand, Regulated Deficit Irrigation (RDI) is similar to DI except that irrigation reductions are confined to certain crop growth stages and the result is no reduction in yield. The idea behind RDI is to irrigate at levels that are less than the ET demands of the crop during growth stages where replacing the full ET of the crop may not be necessary. Such could be the case for annual crops in vegetative stages where not replacing full ET of the crop may not reduce yields. This has proven successful for numerous perennial fruit and nut crops, but implementation of RDI to annual crops has not been consistent.

The Plant Itself

Researchers have worked to develop drought tolerant crops that produce yield or out-yield contemporary cultivars during water shortages. Often, however, the drought tolerant varieties would still yield better under full irrigation. Whether or not selecting drought tolerant cultivars can be shown to be an efficient irrigation management practice is yet to be seen. Irrespective, some varieties of plants have shown the ability to adapt to early season drought stresses. In some cases, rooting patterns are altered and plants develop deeper roots in response to dry soil near the surface. This type of "plasticity" may result in yields that are the same as if the plants were fully irrigated throughout the growing season. Crops with indeterminate growth habits can respond to stresses better than the same crop with determinate growth if the stress occurs at certain times, such as flowering or grain fill. However, being able to quantify the irrigation efficiency gained through genetics, and supporting that efficiency with evidence, would likely prove to be difficult for any farmer right now.

Activities like tillage and residue management can affect how the soil intercepts and stores water from precipitation and irrigation. Tillage operations can influence how much rainfall and snowpack is captured during the off-season and stored for crop use in the spring. Surface residue can also affect off-season precipitation capture and reduce evaporation at all times of the year. Further, activities that improve soil tilth can improve water infiltration and storage capacity. In the case of cover crops, they can both improve soil tilth and surface moisture capture, but they also can reduce soil moisture if not properly killed prior to planting. Irrespective, documenting the effects of these management practices on irrigation water use could also prove difficult for farmers.

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Knowing How Much to Apply

No matter what type of equipment a farmer uses to apply irrigation water, efficient irrigation cannot be conducted unless he knows how much to apply. How do you know? The answer is complex, but it can be simplified by understanding PET (Potential EvapoTranspiration), often referred to as ETo. PET can be calculated many different ways, but is often calculated as an estimate of the water required by a reference crop. Often, the reference crop is a four-inch tall grass sod growing in deep soil under well watered conditions. However, comparing grass sod water use to that of agriculture crops is like comparing apples and oranges, right? That's when crop coefficients are used. Crop coefficients encompass a specific crop's water use during the various stages of growth and are used to modify the PET of the reference grass sod.

The best crop coefficients are regional or locally specific, as in the case of Texas' North Plains Crop Coefficients for sorghum, cotton, corn, or winter wheat. For corn, the crop coefficient starts at 0.40 for seed and seedling emergence and increases to 1.30 for the most water-demanding stages of corn growth—silk, blister, and milk. In other words, in the seedling stage corn will need about 40 percent of the water that the reference crop will use, but when in the blister stage, corn will need about 130 percent of the amount of water. Mathematically, the calculation is quite simple.

PET (of the reference crop) x 1.30 = the PET of corn in the blister stage.

There are numerous PET Networks throughout the United States that consist of automated weather stations so PET data is often readily available for farmers. Nonetheless, PET does not tell producers how much water needs to be applied. Simply, it is a measure of how much water a crop will use. If it rains, the precipitation may replace all of the PET for the day or week. However, if it

rains, not all of the water is stored in the soil and available for the crop—some will runoff and some may percolate below the root zone and be unavailable. Nonetheless, PET does provide an estimate of daily or weekly water use by crops and is widely used in irrigation scheduling.

The installation of soil moisture sensors is perhaps the best way for producers to understand the water status in their fields and when to irrigate. Moisture sensors are used to determine the amount of water in the soil and farmers will schedule irrigation when soil moisture is depleted to a pre-defined level. Sensors need to be placed in the field with the crop and it is best if multiple sensors are installed at several depths. Farmers that are tuned-in to their practices often rely on visual inspection of their crops or the "feel of the soil" to determine when to irrigate. One with experience can be pretty good at this art, but their irrigation efficiency would likely be enhanced by utilizing PET or soil moisture sensors.

Flow meters installed at the pump or in the irrigation line are also an invaluable tool for irrigators. It is an accurate way of knowing how much water was applied and whether the amount applied actually met the PET. They are the final pieces of the irrigation efficiency puzzle and can be used to test or verify a system's efficiency.

Putting it All Together

The irrigator's equation is a way to estimate how much is applied to a field and is a good method for comparing and documenting improved efficiency. The equation is:

$$Q \times t = d \times A$$

Where: "Q" is the flow rate in cubic feet per second; "t" is the total time of irrigation; "d" is the depth of water applied in inches; "A" is the area irrigated in acres.

To put the equation to use, let's use an example for a farmer with a 40-acre field of corn and a pump output of eight cubic feet per second. Soil moisture sensors or PET measurements indicate that two inches of water need to be applied for the week to meet the demands of the corn crop. So, using these numbers, we can determine the amount of time required to apply the two inches of irrigation water:

$$(8 \text{ cfs}) \times t = (2 \text{ inches}) \times (40 \text{ acres})$$
$$t = (2 \text{ inches} \times 40 \text{ acres}) \div (8 \text{ cfs})$$
$$t = 10 \text{ hours}$$

Therefore, the farmer would have to irrigate for 10 hours to apply the two inches of water right? Actually, this 10 hours of irrigation would apply two inches to all of the field only if the irrigation efficiency of the system was 100 percent. As we know, no irrigation system is 100 percent efficient. Thus, as an example, let's first look at a traditional gravity furrow system with 65 percent efficiency.

If we divide the 10 hours by the 65 percent efficiency, the farmer would actually have to irrigate for 15 hours (10hrs ÷ 0.65). And, during the 15 hours, actually apply three inches of water to ensure that the entire field received at least two inches of water. Suppose, the farmer recently converted the 40 acres to a low pressure center pivot system with drop nozzles and improved efficiency to 82 percent. Using the same equation, he would now have to irrigate for 12.2 hours (10 hrs ÷ 0.82) and apply 2.44 inches of water. Installing the center pivot reduced irrigation water use by 18.7 percent.

Major Irrigated Areas

The vast majority of irrigation withdrawals (83 percent) and irrigated acreage (74 percent) are in the 17 states located west of Minnesota, Iowa, Missouri, Arkansas, and Louisiana. In the 2013 Farm and Ranch Irrigation Survey (FRIS), NASS reported that 34.9 million of these western acres were irrigated with sprinkler systems, 21.5 million acres with gravity systems, and another 4.9 million acres with micro-irrigation (drip, trickle, and other low flow systems).

These arid and semi-arid areas have been improving irrigation efficiency for the last 50-60 years as evidenced by the increased use of sprinkler systems compared to the less efficient gravity systems. Further, what is known today about irrigation efficiency was developed in the heavily farmed areas of Texas, Arizona, California, Washington, and Nebraska. These regions have been faced with water scarcity and future shortages necessitating action by farmers and the government. Irrespective, USDA-ERS data indicate that more than half of the irrigated acres in the West are still irrigated with traditional, less-efficient systems suggesting that there is still room for adoption of efficient irrigation management.

Nonetheless, irrigation in humid areas of the United States is increasing, in fact Arkansas follows only Nebraska and California in total share of U.S. irrigated acres at 8.6 percent in 2012. It lies in the Mississippi River Delta Region where approximately 65 percent of the acreage is now irrigated. Most of the irrigation water is drawn from the Mississippi River Valley Alluvial Aquifer and the level of the aquifer has been steadily declining with current overdraft estimates of about 370 million cubic meters of water per year.

Approximately 74, 82, and 86 percent of the irrigated acres in Mississippi, Arkansas, and Louisiana, respectively, are furrow/flood irrigated with the remaining acres under sprinkler systems. Because of this, the irrigation in the region is considered inefficient—but there is considerable effort to improve the efficiency. A software program developed by NRCS engineers called PHAUCET (Pipe Hole and Universal Crown Evaluation Tool) was created to guide irrigators in calculating pipe pressure and flow rates, and determining the sizes of the holes in their polypipe that best distributes water in furrow and flood systems. The program has been shown to reduce water usage by 20 percent in regular shaped fields and up to 50 percent in irregular shaped fields. Further, surge irrigation is becoming more prevalent.

More than 60 percent of the farmers in these states still schedule irrigation by visually inspecting the crop or by "feeling" soil moisture with their hands. This suggests that more appropriate scheduling methods such as PET, soil moisture sensors, the water balance method which tracks water inputs and outputs, and irrigation scheduling tools developed by land-grant universities in the region could greatly improve irrigation efficiency.

Documentation Will Be Necessary

If a farmer does not make their irrigated APH and they applied less water than historically applied on their acreage, MGR-15-009 states that the insured must be able to document management practices to carry out efficient irrigation that include, but is not limited to:

- The historical average irrigation water applied.
- The current amount of water intended to apply to carry out a good irrigation practice.
- A quantifiable efficiency that is gained from management changes that can be supported by evidence from agriculture experts.

If the farmer installed a low-pressure center pivot sprinkler system where the acreage had previously been furrow irrigated, it should be straight-forward and easy to document quantifiable efficiency gained that justified the reduction in water applied. Or, if a furrow irrigator starts to schedule irrigations based on PET and/or soil moisture sensors instead of when the water reaches the end of the last furrow, he should be able to document how their previous scheduling method was inefficient. And, by using sensors or PET, they are still carrying out a good irrigation practice although they may have reduced water applications by 20 percent. However, given the popularity of subjective diagnostic methods such as visual crop condition or a "feel" for the soil, it is likely that there will be some conflict regarding whether or not irrigation was properly scheduled, and the appropriate amount of water was applied. Although this method may truly be adequate, it is an art and not a science and therefore does not constitute proper documentation.

Conclusion

As time passes, the major water sources for irrigated agriculture will likely decline thus necessitating increased irrigation efficiency to get "more crop per drop." This will mean that farmers will be using less water per acre. In most instances farmers that irrigate are very tuned in to their crop water needs, adopt the latest technology, and are acutely aware of how much water they apply. These farmers will have few problems documenting their irrigation requirements and they will likely not be a problem for adjusters and claims managers. On the other hand, there are insureds that are resistant to change the way they operate irrigation systems and do not keep adequate records and documentation. These are the farmers that adjusters and claims managers need to aware of. Crop insurance personnel need to ensure that all of their insureds receive the Irrigated Practice Guidelines that outline efficient irrigation and the documentation that will be required to prove it. And, perhaps more importantly, field adjusters and claims managers will also need to understand the concepts, equipment, and available resources that farmers need to irrigate efficiently. This is necessary so that they know the difference between a conscientious farmer that is irrigating efficiently and one that thinks they are applying an adequate amount of water but, really does not know.