STEP 5

Steps in the Irrigation Series

B-1264 | E3A-IE.5

E3A: Irrigation Application Uniformity

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The overall performance of an irrigation system also relies on water application uniformity. Irrigation application uniformity is a statistical property describing the distribution of water applied from an irrigation system. Irrigation systems are designed and managed to apply water as uniformly as possible to enhance crop production by providing equal access of water to crops. Poor water distribution can result in over- and under-irrigated areas. Under-irrigated areas can experience water stress and reduce crop growth and grain development; over-irrigated areas can experience surface runoff, deep percolation of water along with nutrients, and waterlogging, which can cause plant oxygen stress and ultimately reduce crop growth and grain development. Irrigation systems with low uniformity are often managed to prevent the under-irrigated areas from experiencing water stress, which results in over-irrigation for most of the field and increases energy use and operational costs.

Caleb Carter. CC-BY-NC-4.0. http://uwyoextension.smugmug.com/Irrigation-Efficiency/i-brkd2Xm/0/O/P1010406.jpg

Barley under sprinkler irrigation in the Big Horn Basin, WY.

Idaho. http://photogallery.nrcs.usda.gov/netpub/server.np?find&catalog=catalog&template=detail.np&field=itemid&op=matches&value=4059&site=PhotoGallery

A side roll, or wheel line, irrigation system in alfalfa.

Factors Impacting Uniformity

Factors that can impact application uniformity depend on the irrigation method and system characteristics (e.g., pressure and flow rate) as well as topography and soil properties, among others. Table 8 lists several factors that affect uniformity for sprinkler, surface, and micro-irrigation methods. Poor management practices can affect application uniformity for all system types.

E3A: Irrigation Efficiency is a peer-reviewed publication series.

Original available at: www.wyoextension.org/publications/

Suggested acknowledgment: Daran R. Rudnick, Suat Irmak. Milt Geiger, ed., 2015. "Irrigation Application Uniformity." *E3A: Irrigation Efficiency.* University of Nebraska-Lincoln, University of Wyoming Extension. B-1264|E3A-IE.5

Table 8. Factors impacting irrigation application uniformity for sprinkler, surface, and micro-irrigation methods. Adapted from Irmak et al. (2011).

Irrigation Method	*Factors Influencing Uniformity*
Sprinkler irrigation	☐ Improper selection of delivery pipe diameters ☐ Incorrect operating pressure ☐ Improper selection of sprinkler heads and nozzles ☐ Inadequate sprinkler overlap ☐ Wind drift ☐ Wear and tear on system components over time ☐ Nozzle clogging
Surface irrigation	☐ Differences in opportunity time caused by advance and recession ☐ Spatial variability of soil-infiltration properties ☐ Non-uniform grades
Micro-irrigation	☐ Variations in pressure caused by pipe friction and topography ☐ Variations in hydraulic properties of emitters or emission points ☐ Variations in soil wetting from emission points ☐ Variations in application timings

Irrigation Uniformity Measures

Several procedures and equations evaluate application uniformity for various irrigation systems. Application uniformity is typically evaluated based on the depth of water applied; however, emitter discharge is used for micro-irrigation since the area is not entirely wetted (Howell, 2003). Sprinkler irrigation often uses catch cans to determine the distribution of applied water; surface irrigation uses intake opportunity time and infiltration rate to estimate applied depth due to challenges in measuring applied depth along the furrow. The conventional uniformity measures are Christiansen's uniformity coefficient for sprinkler irrigation, adjusted Christiansen's uniformity coefficient for center pivot sprinkler irrigation, low-quarter distribution uniformity for surface irrigation, and emission uniformity and coefficient of design uniformity for micro-irrigation. Further details of the uniformity measures are in the references and further readings section.

Improving Application Uniformity

Improving application uniformity requires (i) estimating current uniformity, (ii) identifying major influencing factors, and (iii) determining if improving application uniformity is economically justifiable. The previous section listed commonly used uniformity measures to estimate current application uniformity for various irrigation methods. With several sources of error when collecting data to determine uniformity, Heermann and Solomon (2007) recommend the following American Society of Agricultural and Biological Engineers (ASABE – formerly ASAE) standards and engineering practices be reviewed prior to evaluating and/or designing an irrigation system.

☐ ASAE S436.1. Test Procedure for Determining the Uniformity of Water Distribution of Center Pivot and Lateral Move Irrigation Machines Equipped with Spray or Sprinkler Devices.

☐ ASAE EP405.1. Design and Installation of Microirrigation Systems

☐ ASAE EP419.1. Evaluation of Irrigation Furrows

The ASABE standards also provide how to improve uniformity. For sprinkler irrigation, the catch can test can help identify areas along the system that are applying below-or-above average depths, which provides a starting point to identify the sources of non-uniformity. Faulty sprinkler nozzles as well as pressure differences along the lateral are a primary source of non-uniformity. Supplying equal pressure to individual nozzles can account for pressure differences. Kranz et al. (2007) reported pressure regulators to control sprinkler flow rate are desirable when:

1. Elevation differences exist between sprinklers
2. Pipeline friction loss causes large differences in pipeline pressure
3. Excessive pressure is supplied to small sprinklers on the first few spans of the center pivot
4. A constant pressure is required for installations where more than one set of sprinklers are supplied by the same pump

Figure 5. Aerial image of a center pivot irrigation system that has low application uniformity. (Courtesy UNL: Gary Zoubek)

Visual observations and aerial imagery can also identify areas experiencing poor uniformity. For example, as shown in Figure 5, aerial imagery can show distinct patterns in crop growth due to water stress caused by missing, clogged, or worn nozzles; stuck impact sprinklers; out-of-sequence nozzle packages; inadequate pressure to operate end gun; and other causes. Improving irrigation uniformity will require investment in system improvements and maintenance and/or labor cost for improved management. The source and magnitude of non-uniformity dictates whether promoting uniformity is economically justified. Duke et al. (1992) presents a method to determine the potential savings from improving center pivot irrigation uniformity.

Variable Rate Irrigation

Advancements in irrigation systems and controllers can now intentionally apply water non-uniformly to meet spatial differences in crop water needs. Variable rate irrigation (VRI) has the potential to conserve energy use by limiting areas that would normally get over-irrigated under uniform irrigation management; however, the success of VRI to conserve energy and water use depends on how accurate a producer can characterize a field (irrigation prescription) to account for spatial and temporal differences in crop water demand as well as the system's ability to accommodate the prescription. The notion that VRI can enhance irrigation efficiency is not a straightforward process. VRI may or may not reduce irrigation water requirements or enhance irrigation efficiency as compared to fixed irrigation application, depending on the variability of the field, how soil water status is monitored across the field, and most importantly, how VRI prescriptions are prepared and decisions are made. Kranz et al. (2014) explains different VRI methodologies along with benefits and shortcomings of VRI to conserve energy and water.

References and Further Readings

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Notes