Irrigation, Site-Specific

Dennis C. Kincaid
United States Department of Agriculture (USDA), Kimberly, Idaho, U.S.A.

Gerald W. Buchleiter
United States Department of Agriculture (USDA), Fort Collins, Colorado, U.S.A.

INTRODUCTION

Irrigation systems have evolved from flood systems to pressurized sprinkler and trickle systems. In flood irrigation, water is applied to a field in a controlled stream and allowed to flow over the soil surface by gravity, the final distribution being affected by variations in surface slope and water infiltration rates. Well-designed pressurized irrigation systems apply water at sufficiently low rates that it infiltrates with little or no surface movement, thus providing a greater degree of control and improved uniformity of application.

The primary objective of irrigation system design is to apply water (and dissolved chemicals) uniformly over a field planted with a uniform crop, the water requirement being determined primarily by the crop and climate. In recent years, sophisticated control systems have been developed that enable water and chemical application to be tailored to smaller areas if and when it is desirable to do so. The term site-specific irrigation (also known as precision-variable irrigation) refers to the practice of intentionally applying different amounts of water to different areas of a field to optimize crop production, minimize chemical and water use, or reduce environmental concerns. Although site-specific irrigation can be applied with any type of pressurized irrigation system, most of the potential application is with continuous-move sprinkler laterals, primarily center pivots.[1–5]

DESIGN AND MANAGEMENT OBJECTIVES

Some of the main reasons for site-specific irrigation are the following:

- Avoid watering nonproductive areas such as roads, rock outcrops, canals, ditches, and ponds. Center pivots often traverse these areas that lie within a generally circular area.
- Apply different amounts of water and nutrients to different zones according to crop production capability. Soil depth, salinity, or other soil-related factors may limit the potential yield and the total water requirement on some soil types.
- Apply reduced amounts of water to steep slopes or zones of low infiltration where runoff is difficult to control. A permanent cover crop may be planted in these areas.
- Variable soil types within a field may benefit from different amounts of water during certain time periods. Under water-short scenarios, crops on coarse-textured soils having low water holding capacity need small, frequent water applications to avoid water stress, while the crop on finer-textured soils may be able to withdraw stored soil water.

SCALE CONSIDERATIONS

One of the main considerations is determining the minimum size area that must be treated individually.[6] The cost and complexity of the system escalate rapidly as the treatment area decreases. The wetted radius of the individual sprinkler patterns, the start–stop movement of the lateral, and the accuracy with which the lateral position can be determined all affect the minimum practical differential area. Typically, a 300-m^2 area is about the smallest desirable unit.

Maps defining soil types, unproductive areas, cropping and fertility patterns are used to define management zones (Fig. 1) requiring different water amounts. These zones should be created from the intersecting areas of only the map parameters that affect the water or chemical requirements.

EQUIPMENT FOR SITE-SPECIFIC IRRIGATION

Sprinkler Laterals

Continuous-move laterals that move in a straight line are called "linears" and those that rotate about a fixed pivot at one end are called "center pivots."[7] These laterals consist of several rigid spans, typically 40–50 m in length

Encyclopedia of Water Science
DOI: 10.1081/E-EWS 120010137

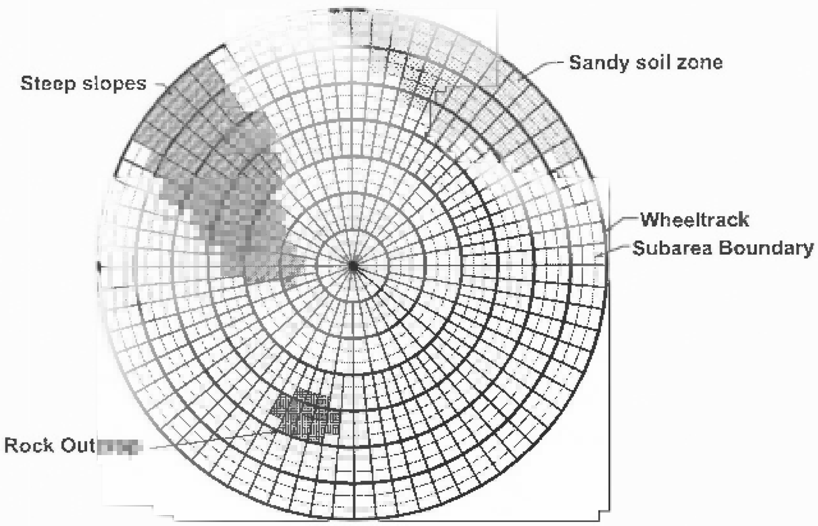

Fig. 1 Schematic of a field irrigated by a 7-span center pivot, with each span subdivided into three segments. Crosshatched areas are special water management zones (photo by Kincaid). (*View this art in color at www.dekker.com.*)

with a total length of about 400 m, although longer laterals are used. The outermost tower controls the rotation speed. The entire lateral is maintained in a nearly straight line by switches at intermediate towers that start and stop the drive motors according to the flex angle between adjacent spans. Center pivots use a transducer (pivot resolver) to determine the position of the first span with an accuracy of about 1° of rotation and a radial coordinate system to determine the position of any point on the lateral relative to the field map at any time. Recently, differential global positioning system (DGPS) units placed on the outer end of the lateral have been used to improve the positioning accuracy of center pivots.

Linear laterals use a guidance system to travel on a predetermined (normally straight) path. A calibrated ground wheel, fixed ground stakes with a trip switch on the lateral, or with a DGPS unit, can determine the lateral position along the travel path. Both end towers control the travel speed and guidance. Additional error is introduced by the guidance system that "steers" the lateral by adjusting the relative speed of the end towers, thus changing the angle of the lateral relative to the travel path. Therefore the positioning accuracy of linears is usually less than that of pivots.

Sprinkler Equipment and Controls

Traveling laterals use sprinkler equipment designed to discharge a desired amount of water per unit length of

Fig. 2 An on–off spray manifold on a span of a traveling lateral. Note black automatic valve above manifold (photo by Kincaid). (*View this art in color at www.dekker.com.*)

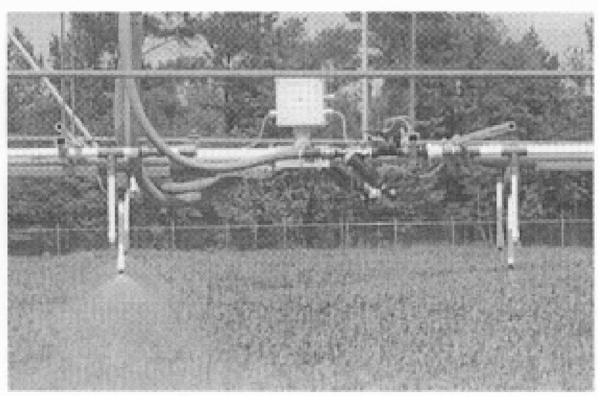

Fig. 3 Close-up of multiple-manifold spray system (photo by Sadler). (*View this art in color at www.dekker.com.*)

lateral. For pivots, the discharge rate increases with distance from the pivot. Sprinklers or spray heads are placed at fixed or variable spacing such that their water application patterns overlap, resulting in nearly uniform water distribution along the lateral. The pattern radii of the most popular spray heads are about 5–8 m. The travel speed of the lateral can be varied to change the water application depth in pie-shaped differential areas under a pivot or in rectangular differential areas under a linear. However, for all other differential areas, sprinkler flows must be varied along the lateral. There are three main methods of accomplishing this.

1. A variable flow rate sprinkler head uses a fixed nozzle with an insertable pin to produce either a high or low flow rate.[8] The pin can be cycled in or out to produce an effective flow rate anywhere between the high and low flow.
2. Automatic valves can be placed on individual sprinklers or groups of sprinklers on manifolds (Fig. 2). Manifold length is usually a fourth to half the span length. One-directional check valves are used on the individual heads to prevent the manifold from draining when the manifold valve is off. The manifold valve can be cycled on and off at different time intervals to produce effective application rates between 0% and 100% of the maximum rate. The cycle interval must be much less than the time it takes the full sprinkler pattern to traverse a point on the ground.
3. Two or three complete sets of sprinklers designed with different unit flow rates are mounted on the lateral (Figs. 3 and 4). Any combination of the sprinkler sets can be turned on one at a time, resulting in several distinct rates. Two sets provide four possible rates (e.g., 0, 1/3, 2/3, and 1), and three sets provide eight possible rates.

The variable flow sprinkler (method 1) has not yet been commercially developed. At the present time, the on–off manifold (Fig. 2) is likely the most cost-effective configuration, as this involves the least additional equipment.

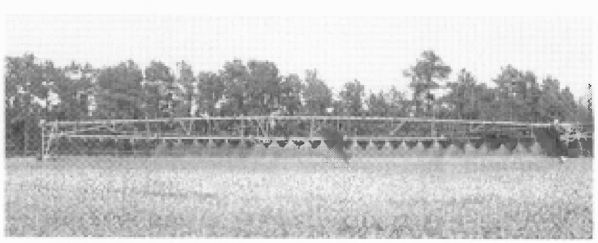

Fig. 4 A site-specific center-pivot system with selected spray manifolds off (photo by Sadler). (*View this art in color at www.dekker.com.*)

The computerized control system is normally located at the pivot or inlet end of the lateral.[9] The computer determines the location of the lateral, adjusts the travel speed, and turns sprinkler control valves on or off according to a predetermined program as the lateral passes over each subarea of the field. Valves are usually electric-solenoid-operated and each requires a separate control wire. Optionally, a code-based control system can send signals to individual valves through a single wire.[10]

CONCLUSION

New technologies have made precision variable water application technically feasible. Many different scenarios of variable soils, different crops, limited water supplies, and environmental concerns may make site-specific irrigation desirable. Because of the cost and complexity of these systems, economic feasibility will be highly case-dependent.

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