CHAPTER 5

EFFICIENCY AND UNIFORMITY

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Abstract. *The objective of this chapter is to present the major factors that must be considered to best meet the demands of those competing for the use of limited water resources. It is critical for the designer to understand, define, and select the appropriate efficiency and uniformity parameters when designing irrigation systems. The concepts of irrigation efficiency and uniformity are often misunderstood and lead to confusion. Their parameters are multidimensional in both space and time. The design engineer must select the appropriate target performance parameters to meet the objectives of the system within the imposed constraints. Management and operation of the system are as important as the system design in meeting the target performance parameters.*

Keywords. *Basin efficiency, Beneficial use, Hydrologic basin, Irrigation design, Irrigation efficiency, Microirrigation, Performance parameters, Sprinkler irrigation, Surface irrigation, Uniformity, Water management.*

5.1 INTRODUCTION

Irrigation offers tremendous benefits in increased food and fiber production. In the U.S., irrigated fields account for only 15% of harvested cropland, but produce 38% of the dollar value of food and fiber (Bajwa et al., 1992). Irrigators are often criticized for growing crops that are surplus to demands for food and fiber as the public is becoming more concerned about the efficient use of water. Worldwide, irrigation is the largest consumer of water, more than municipal and industrial use.

Irrigation system type and design affect not only the efficiency but also the uniformity of water application. Uniformity refers to how uniformly water is applied; this affects many parameters that are used to assess irrigation performance. Efficiency can can be measured in a myriad of ways, and efficiency by one measure may not be efficent by another measure. Also, the highest system efficiency may not meet economic or environmental objectives. For example, under-irrigation may have the highest efficiency in the short term but can lead to salination problems in the long term. The concepts of efficiency and uniformity, as applied to irrigation, will be discussed in greater detail below.

An engineer designing an irrigation system must, then, determine the appropriate target performance parameters to meet the objectives of the system within the imposed constraints. These constraints can be economic, environmental, water quality and quantity, crops, soils, labor, service, and management skills. The target performance parameters should be selected to meet the constraints, and the highest attainable efficiency may not be appropriate. Finally, it is important to recognize that the management and operation of the system are as important as the design of the system in meeting the target performance parameters.

5.2 IRRIGATION SCHEME PHYSICAL MODELS

5.2.1 Physical and Temporal Evaluation Scale

Physical scale is important to consider when evaluating the efficiency of water use. Efficiencies may be defined for a single field, or on larger scales up to a hydrologic basin, as well as for the various pathways of the hydrologic cycle. Water use can be categorized as *beneficial* or *non-beneficial* for crop production. The water diverted to irrigation can also be divided into *consumptive* and *nonconsumptive* uses. Figure 5.1 illustrates the partitioning of water use. An understanding of these concepts is necessary in formulating definitions of irrigation efficiencies. For example, beneficial uses include more than evaporation for crop needs. The nonconsumptive use and nonbeneficial use may be undesirable from a single field viewpoint but may not be a loss from a basin viewpoint.

Efficiency is not only a function of the spatial scale but also the temporal scale. Irrigation application efficiencies are often evaluated for a single irrigation event, but the assumption that this is equal to the seasonal irrigation efficiency for growing a crop is probably incorrect. Differences in the soil conditions, stages of plant growth, climatic conditions, and other factors can result in substantially different efficiencies. Management and operation of the system can also change the efficiency.

	Consumptive Use	**Nonconsumptive Use**
Beneficial	Crop evapotranspiration Evaporation for cooling Evaporation for frost protection	Water for leaching
Nonbeneficial	Phreatophyte evapotranspiration Weed evapotranspiration Spray evaporation Evaporation from soil Reservoir and canal evaporation	Excess deep percolation Excess surface runoff Operational spill

Figure 5.1. Examples of the partitioning of some irrigation water uses.

5.2.2 Irrigation System, Farm and Field Model

The objective of this monograph is to provide state-of-the-art information for the design of irrigation systems. Economical crop production is an important consideration from the users' point of view. Conservation and environmental stewardship are recognized as another important consideration in the selection and operation of an irrigation system. Public concern for the environment and the competing demands for limited water supplies increase the need to consider the various performance parameters. Global efficiency is of more importance when the environment and limited water supplies are major factors. Drought conditions increase the problem of limited water supply. Basin efficiency and uniformity can be entirely different than that at the local level.

Surface runoff may be of little concern to a user if sufficient water is available at low cost and soil erosion is not a problem. This may not represent a loss in terms of the basin hydrology. Also, costs may not be impacted, as some water supplies and costs are based on water rights per unit of area irrigated without a limitation on the volume. However, where water is limited, the system should be designed to limit runoff. One option is a pumpback system, which recirculates the water back to the head end of the field. Often a pumpback system is designed for an entire farm, where the runoff from one field is collected and either pumped or diverted to another field.

A major concern from a basin perspective is degradation of the quality of the water, in both runoff and deep percolation, by the pickup of salts and other pollutants. The degradation only affects the user in the added costs of the water and chemicals that may not be used effectively. Physical definitions of performance parameters do not generally consider the environmental degradation of the water supply. This is a separate issue that is growing in importance with the concern for the environment.

Water rights for either surface sources or groundwater are often limited to "reasonable use," which has a legal meaning that may change with technology. Generally, reasonable uses include water for satisfying the crop evapotranspiration (ET), water for beneficial leaching, and evaporation from canals and water emission devices. Thus, reasonable use includes beneficial water use that can be both consumptive and nonconsumptive (Figure 5.1). Some unavoidable, nonbeneficial consumptive uses may also be accepted as reasonable. Even some nonbeneficial, nonconsumptive uses, such as excess deep percolation and surface runoff, may be considered acceptable in the design if sufficient water is available. Major concerns of excess deep percolation is water quality degradation as the water moves through the profile into the groundwater and the loss of soluble plant nutrients. Nonbeneficial nonconsumptive use is a loss with respect to a field or farm but may be used to satisfy another water right within a basin.

Uniformity of water application affects whether water use is beneficial, consumptive, or not. Sprinkler and microirrigation systems provide better control of water application compared to surface irrigation systems, which have the inherent problems of runoff and nonuniform soil infiltration that strongly affect how much water is available for each plant. Even with uniform soils, it is difficult to design and operate a surface irrigation system that provides a uniform application of water, without under-irrigation in part of the field and/or excessive deep percolation in other parts. Even sprinkler systems do not always apply water uniformly, as they are influenced by system hydraulics, uneven terrain, and surface translocation of applied water when application rates exceed soil intake rates. Similarly, with microirrigation the application may vary because of nonuniform system pressure, plugged emitters, and undetected leaks. (Detailed characteristics of the various types of irrigation systems are given in later chapters.)

5.2.3 Hydrologic Basin Model

A hydrologic basin is a collection of many fields or farms that are in the same hydrologic drainage area. The irrigation efficiency of a basin is often higher than the typical irrigation efficiency for an individual field or farm, because inefficiencies of water use on one farm may result in water that is used on another. Recall that irrigation efficiency is typically defined as the ratio of water beneficially used to that diverted from the source. The surface water runoff from one farm may be rediverted and used on another farm. Even the water that deep percolates on one farm may be pumped for use on either the same farm or another farm downstream in the basin. Thus, the sum of water diverted for each field in a basin often exceeds the total supply because a given quantity of water may be diverted several times. A disadvantage of reusing either irrigation return flow or deep percolation water is that the quality may be degraded. In some cases, water quality degradation is such that it cannot be used satisfactorily for crop production. Some groundwater moves in the aquifer, the quality may be reduced, and it may become uneconomical to pump. Only surface runoff and groundwater that move out of the basin are lost for potential use in crop production in the basin, and even this water may be available in another basin unless it runs into the ocean.

The current trend is to place a higher priority or value on leaving the water instream for ecological benefits. This is another constraint that may effectively decrease the available water supply and often has not been considered in the design of irrigation systems.

5.3 IRRIGATION PERFORMANCE PARAMETER DEFINITIONS

The following sections define commonly used parameters that are useful in the design and performance evaluation of irrigation systems. This is not an all-inclusive list; engineers are encouraged to clearly describe any efficiency terms that are needed to meet the particular objectives and constraints of the system being designed. The following sections provide definitions published by Israelson (1950), Jensen et al. (1967), ASCE (1978), Bos (1979), Hansen et al. (1980), Jensen et al. (1983), Walker and Skogerboe (1987), and Burt et al. (1997).

5.3.1 Water Conveyance Efficiency

The conveyance of water from the source to the irrigated field can be through natural drainage ways, constructed earthen or lined channels, or closed conduits. Many conveyance systems have transmission losses, thus, water delivered to the field is usually less than the direct diversion from a flowing stream, reservoir, or underground aquifer. The *conveyance efficiency* of a conveyance system is the ratio of the volume of water delivered to the field boundary to the volume of water diverted from the source and can be expressed as:

$$e_c = \frac{V_f}{V_t} \tag{5.1}$$

where e_c = conveyance efficiency

V_f = volume of water delivered to the field
V_t = volume of water diverted from the source.

The difference between the two volumes in Equation 5.1 is the amount evaporated, seeped from the canal, leaked from the closed conduit, spilled, and/or otherwise lost from the conveyance and distribution system. The numerator of Equation 5.1 becomes smaller as the losses increase, thus decreasing the conveyance efficiency. Conveyance efficiency is often expressed for various reaches along main, secondary, and tertiary canals. A logical subdivision is the reaches that are under common management. Each management unit can evaluate the need, benefits, and costs of decreasing the losses under its control. The total conveyance efficiency is the product of the efficiencies for individual sequential reaches.

Increasing conveyance efficiency for efficiency's sake may not be economically justified nor increase the available water supply. The entire demand on a given water supply must be examined to determine the necessity and value of increasing the conveyance efficiency. For example, operational spills may cost very little and only return high quality water back to the stream for rediversion downstream. However, when water demands cannot be satisfied, it may justify decreasing operational spills. Similarly, actual cost and available water supply must be considered before lining canals or installing pipelines to reduce losses, but this may be necessary to meet the demand for water and/or to reduce water quality degradation caused by seepage.

Hydraulic grade lines can be kept more constant, which in turn provides a more constant flow rate to each turn-out on the system. Variability in flow delivery is an important factor that must be considered when designing an irrigation system for individual fields on a farm. Rapid changes in the grade line can frequently lead to structural failures of canal walls and control structures, increasing the maintenance costs and inability to make timely deliveries of irrigation water.

5.3.2 Water Application Efficiency

Water application efficiency is a measure of the fraction of applied water that is stored in the soil profile and available for crop use. It is commonly expressed for an individual field as *field water application efficiency*, expressed as:

$$e_a = \frac{V_s}{V_f} \tag{5.2}$$

where e_a = water application efficiency of the field
V_s = volume of irrigation water stored for evapotranspiration by the crop
V_f = volume of water delivered to the field.

Spray drift from the field, runoff, spray evaporation, and deep percolation losses all contribute to reduce the application efficiency of irrigation systems. The volume of water loss in spray evaporation or wind drift is difficult to estimate or measure. It may satisfy some of the evaporative demand and reduce the potential ET for the crop, thus indirectly satisfying part of the crop water requirements. Such water is, therefore, part of the beneficial use and would not decrease the application efficiency. However, water intercepted on the crop canopy is evaporated at a rate higher than the transpiration rate of adequately watered plants and tends to decrease the application efficiency.

The water application efficiency can be unity when irrigation amounts are small, the soil profile is not filled (minimizing deep percolation), and surface runoff is minimized, as all of the water delivered is available to meet the crop water requirements (ET plus leaching requirement). Even so, the available water may not be sufficient to satisfy crop water requirements, causing yield reductions.

5.3.3 Soil Water Storage Efficiency

The *soil water storage efficiency* (Hansen et al., 1980; Walker and Skogerboe, 1987; and James, 1988) is the ratio of the volume of water stored in the soil root zone to the volume of water required to fill the root zone to field capacity. It is expressed as:

$$e_s = \frac{V_s}{V_{fc} - V_a} \tag{5.3}$$

where e_s = soil water storage efficiency
V_s = volume of water stored in the soil root zone from an irrigation event
V_{fc} = volume capacity at field capacity in the soil root zone
V_a = volume of water in the soil root zone prior to an irrigation event.

In other words, a high e_s means that irrigation brings the soil to, but not beyond, field capacity in the root zone. To minimize deep percolation, the maximum net amount of water that should be applied in a given irrigation event is the difference between the field capacity and the average water content in the root zone at the time of irrigation. We discourage the use of the soil water storage efficiency because of difficulty in determining the root zone, which changes during the season and is different for every crop, soil, and management practice. The main use of the soil water storage efficiency is to manage surface and sprinkler irrigation systems where the objective is to minimize labor and the number of irrigation events, and prevent overirrigation.

One problem with using storage efficiency with sprinkler and microirrigation systems is that even if it is low, frequent irrigations may still provide sufficient water for crop production, and this management practice leaves some soil water storage room for rainfall. Sprinkler and microirrigation systems are typically operated on a frequent basis and can supply just the water needed without filling the profile.

5.3.4 Irrigation Efficiency

Water to satisfy crop ET requirements is not the only beneficial water that can be supplied with an irrigation system. The ASCE On-Farm Irrigation Committee (ASCE, 1978) defines the *irrigation efficiency* as the ratio of the volume of water which is beneficially used to the volume of irrigation water applied, expressed as:

$$e_i = \frac{V_b}{V_f} \tag{5.4}$$

where e_i = irrigation efficiency
V_b = volume of water beneficially used
V_f = volume of water delivered to the field.

Beneficial uses may include crop water use, salt leaching, frost protection, crop cooling, and pesticide or fertilizer applications. Excessive deep percolation, surface runoff, weed ET, wind drift (in part), and spray evaporation are not beneficial uses and thus would tend to decrease the irrigation efficiency. Other factors that impact beneficial use and thus water use efficiency include theft, misallocation, water rights, social rules, night irrigation, and management.

5.3.5 Deep Percolation Ratio

High water tables and subsurface return flow to streams can result from deep percolation. The deep percolation ratio is an important evaluation parameter when these conditions exist and is more effectively used with another efficiency term, such as the water application or irrigation efficiency. It is particularly significant when high water tables need to be avoided and when the groundwater returned to the streams is of low quality. Degradation of many streams and rivers in the arid western United States has resulted from the return of low-quality groundwater. The deep percolation ratio is defined (Walker and Skogerboe, 1987) as:

$$DP_r = \frac{V_{dp}}{V_f} \tag{5.5}$$

where DP_r = deep percolation ratio
V_{dp} = volume of water percolated below the root zone
V_f = volume of water delivered to the field.

5.3.6 Tailwater Ratio

Tailwater (surface runoff) is lost from the lower ends of fields and does not contribute to crop production on that field unless it is recirculated by pumping the tailwater to the head end of the field. Tailwater may also be captured and pumped or diverted to another field. Tailwater is often allowed to return to a nearby stream. The tailwater ratio is an important performance parameter if the water flows directly into the ocean or if runoff is prohibited by law. The tailwater ratio may be quite different from the deep percolation ratio. Disposition of tailwater relative to other components of the total water budget is important in evaluating an irrigation system. The degree of water quality degradation and the potential reuse in the basin affect the negative impact of tailwater. The ratio is defined (Walker and Skogerboe, 1987) as:

$$TW_r = \frac{V_{ro}}{V_f} \tag{5.6}$$

where TW_r = tailwater ratio
V_{ro} = volume of surface runoff
V_f = volume of water delivered to the field.

5.3.7 Irrigation Uniformity

Irrigation efficiencies are expressed as functions of the volumes of water diverted and the use or disposition of the water as it is applied with the irrigation system. The nonuniformity of application within a given field is not accounted for in the efficiency definitions. However, when or where the soil profile is not filled (perhaps in only some areas because irrigations were not applied uniformly), the crop may exhibit stress. An irrigation system that does not apply water uniformly must apply excess water in some areas in order that there is enough water in other areas, such that minimal plant stress occurs over the entire field. The excess water may cause surface runoff and/or deep percolation beneath the root zone. Also, when water is applied in excess (whether by irrigation or rainfall) and the soil is saturated for several days or more, plant oxygen stress may occur. Resulting deep percolation may even cause a perched water table, depending on the subsoil conditions. Percolation beneath the root zone is required to leach salts that accumulate in the root zone.

Many of the volumes used in the efficiency definitions—for irrigation, for deep percolation, etc.—are difficult to measure in practice, because they are affected by uniformity. Generally irrigation uniformity is based on indirect measurements. For example, the uniformity of water that enters the soil is assumed to be related to that caught in catch cans for sprinkler systems, to emitter discharge for microirrigation systems, and to intake opportunity time and infiltration rates for surface systems.

The physical uniformity (size, color, wilt differences, etc.) of the growing plants is another possible performance parameter for the design and evaluation of an irrigation system. The purpose of an irrigation system is to enhance the growth of plants for crop production and/or their aesthetic value. Having water application events that result in uniform biological responses (measured yield or visual appearance) over the entire irrigated area of production is generally desirable. This may require that the entire land surface area receive a uniform application of water (i.e., for closely spaced seeded or drilled crops). However, tree crops do not require uniform water applications over the entire land surface area. Rather, application of uniform amounts of water *per tree* is more important and influences the spacing requirement of microirrigation and under-tree sprinkler irrigation systems.

Precision farming emphasizes the need to apply the production inputs in the proper amounts and locations to maximize their effectiveness. Site-specific farming may require that irrigation systems apply water in a nonuniform pattern, but with precise control of the application to satisfy the spatial requirements. The biological and economic models of plant growth and production are quite complex and are generally evaluated with a physical measure of the uniformity of the inputs. The complexity of the biological and economic models result from interactions between the crop, fertility requirements, soil differences, and system management. They cannot be expressed as a single function of the irrigation uniformity. Thus, the selected design uniformity is more subjective than objective.

Several mathematical definitions have been proposed and used to describe the uniformity of a system. Christiansen's uniformity coefficient (1942) was defined to evaluate sprinkler irrigation systems and has the strongest historical precedent in the sprinkler irrigation industry. It is defined as:

$$CU = 100\left[1.0 - \frac{\sum |x_i - x_m|}{\sum x_i}\right] \tag{5.7}$$

where CU = Christiansen's uniformity coefficient, %

x_i = measured depth (volume or mass) of water in equally spaced catch cans on a grid

x_m = mean depth (volume or mass) of water of the catch in all cans.

This requires that each catch can represents the depth applied to equal areas. This is not true for data collected under center pivots where the catch cans are equally spaced along a radial line from the pivot to the outer end. For center pivot systems it is necessary to adjust and weight each measurement based on the area it represents (Heerman and Hein, 1968).

Specific definitions will be given in the chapters discussing the various irrigation systems. There are many different formulations and expressions for quantifying uniformity. However, most uniformities can be calculated from one another with assumed statistical distributions of the applied depths. The standard deviation and coefficient of variation are examples of other ways to quantify uniformity. The different formulations are quite like expressing a length in either millimeters or inches. One can be led to believe that one uniformity calculation method is more sensitive than another because of a different scale, but the various formulations will maintain the same relative order when different irrigation systems are compared.

Since the measurement of applied depths is difficult for surface and many microirrigation systems, the uniformity coefficient is not generally determined directly. The intake opportunity times or measured soil water differences from before to after an irrigation are used to estimate application depths for surface irrigation systems.

For microirrigation systems, the emitter discharge rates are used in place of measured application depths. Thus, microirrigation uniformity is affected by the emitter discharge rates, which are in turn affected by emitter manufacturing and irrigation system hydraulic characteristics. The variability of emitter discharge caused by variations in orifice size (or shape) and hydraulic characteristics can result from inadequate manufacturing quality control. Keller and Karmeli (1975) defined an empirical design emission uniformity relationship for microirrigation systems as:

$$EU = 100\left(1.0 - 1.27\,\frac{C_v}{\sqrt{n_p}}\right)\frac{q_{min}}{q_a} \tag{5.8}$$

where EU = emission uniformity, %

C_v = manufacturer's coefficient of variation

n_p = number of emitters per plant, at least one per plant

q_{min} = minimum emitter discharge rate computed from the minimum pressure

q_a = average emitter discharge rate.

The above definition is based on the ratio of the discharge rate for the lowest 25% of the emitters to the average discharge rate.

Nakayama et al. (1979) developed a coefficient of design uniformity, CU_d, which is based on the discharge rate deviations from the average rate. It is expressed as:

$$CU_d = \left[1 - \frac{0.798(C_{vm})}{\sqrt{n}}\right]100 \tag{5.9}$$

where the terms are defined as above and the constant 0.798 results from assuming a normal distribution of discharge rates and using the Christiansen uniformity definition (Equation 5.7). Hart (1961) developed a similar relationship for the Christiansen distribution uniformity where the coefficient of variation of sprinkler application is described by the ratio of the standard deviation divided by the mean.

The uniformity for surface irrigation systems is more commonly characterized by distribution uniformity, defined as the average depth infiltrated in the low one-quarter of the field divided by the average depth infiltrated over the entire field, expressed as:

$$DU = \frac{D_{lq}}{D_{av}} \tag{5.10}$$

where DU = distribution uniformity

D_{lq} = average depth infiltrated on the one-quarter of the field with the least infiltration

D_{av} = average depth infiltrated over the entire field.

The distribution uniformity is also often applied to microirrigation and sprinkler irrigation systems including center pivots.

The literature has many definitions for evaluating the uniformity of an irrigation. Many of them use the moments of the measured or estimated distribution of depths. However, it has been reported (Hart and Heermann, 1976) that many measured distributions can be expressed as mathematical functions of each other. Another parameter often used assumes a normal distribution and all that are needed is the mean depth and standard deviation. Warrick (1983) summarized the interrelationships of irrigation uniformity terms with a number of population distributions. The Christiansen uniformity and low-quarter distribution uniformity are related mathematically for normal, log normal, uniform, specialized power, beta, and gamma distributions of water applications.

The coefficient of uniformity is typically evaluated for an individual irrigation, but it may be more important to evaluate the uniformity of several irrigation events or even over an entire irrigation season. The uniformity coefficient generally increases if the depths are accumulated for multiple irrigations because of the random nature of application and wind effects.

Redistribution in the soil can affect the variability of the water actually available to the crop. Initial soil water content, application rates, surface distribution of applied water, length scale of distribution on the soil surface, soil hydraulic conductivity, soil depth, and total applied water are factors that affect the potential redistribution within the profile. Hart (1972) estimated that CU could increase from 54% to 61% with lateral redistribution for one simulation with a surface scale length of 1 m. Root distribution is another factor that can influence uniformity. It should be emphasized that crop production or landscape response is the important consideration when evaluating an irrigation system. If the root distribution is such that it can remove water from the areas receiving more water, the effective uniformity for crop growth may be higher than the calculated physical parameter.

The measurement of the depths applied is important for calculating the sprinkler CU. A number of sources of error could reduce the resulting uniformity coefficient. Selection of the catch collector is a major consideration. The collector should have a sharp edge so that the area of the catch is defined by the surface dimensions of the collector and the water does not run either in or out of a broad, flat lip. The depth of the collector must be sufficient to prevent water from splashing out of the container. The projection of the opening of the collector must be horizontal so that the water caught is the depth applied to the surface area and not larger or smaller. The effect of evaporation must also be considered to prevent losses from the can before the collected amounts are measured. It is recommended that a small depth of oil be added to the catch can to limit the evaporation from the time of application until the depth is measured. Another alternative is to measure the evaporation from an outside can. The use of non-evaporating collectors (Clark et al., 2002) can eliminate the effects of evaporation. Wind has also been shown to divert the water from catch cans resulting in the measured depth being less than that actually reaching the surface of the soil for infiltration. Another source of error for moving irrigation systems is leaks in the pipeline or drips off of the system trusses, support structure, or sprinkler drops that can run directly into the catch can causing extremely large depths. Also, cans can tip over and cause a missing or smaller reading. Caution should be taken when calculating CU with data that may have measurement errors. It is recommended that the data obviously in error be adjusted before use in calculation. The error would generally contribute to a decrease in the uniformity coefficient.

Current ASABE (formerly ASAE) standards and engineering practices should be reviewed for evaluation procedures of irrigation systems. The following are examples; they are routinely updated.

- 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.

5.4 SUMMARY

An irrigation system is designed to enhance plant growth for crop production or aesthetic value of turf and ornamentals. This can be accomplished with a nonuniform and inefficient irrigation system, but that is unacceptable to the public for water quantity and environmental concerns. Current designs must be uniform and efficient. This chapter presented the various factors that need to be considered as well as performance parameters and indices for evaluating new designs and existing irrigation systems. The evaluation indices will provide the measure for more efficient systems to conserve water and enhance the environment.

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