EVALUATION OF MICRO IRRIGATION SYSTEMS

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Recommendation-oriented irrigation system evaluation procedures have been developed at Cal Poly State University, San Luis Obispo, for six irrigation methods. These procedures have been adopted for use by private consultants and the Calif. Dept. of Water Resources (DWR) Mobile Lab irrigation evaluation teams. The development was funded by the Calif. Water Resources Control Board, and directed by the Office of Water Conservation, Calif. DWR. The techniques for drip and micro-sprinkler (grouped under the term "micro irrigation") are presented here.

Two questionnaires are used for each evaluation:
  a. A General Survey form which requires estimations of last year's gross application, scheduling, water quality, net rainfall, ET, and special irrigation requirements.
  b. A Single Event evaluation form for field measurements of pressure distribution, flow rates, observations, excessive pressure losses, runoff, and maintenance practices.

Programs written in Basic for personal computers are used to provide blank data sheets, enter and edit the data, perform the necessary calculations, and print summaries and recommendation paragraphs. Users need no knowledge of computer programming. Program disks, documentation, sample runs, and blank sheets are included in a handbook (Burt et al. 1985).

Standard terminology of "Irrigation Efficiency", "Emission Uniformity", and "Distribution Uniformity" have been used. Calculation procedures have been modified where necessary to incorporate new types of measurements.

Micro Irrigation Evaluation History

There have been several approaches to micro irrigation evaluation, each depending upon the background of the developers and the objectives. Pacific Gas & Electric Company irrigation specialists use a rapid survey incorporating a rapid on-site evaluation with annual data to pinpoint the potential for energy savings. The techniques proposed by Merriam and Keller (1978) and Merriam, et al (1981) look at events of a single day to examine flow rate variability and management problems. Other methods, as described by Bucks et al (1982) emphasize the necessity of statistical accuracy with emission uniformity measurements taken during a single day in a field with uniform spacings and a single mode of operation.

Objectives of Developing Revised Evaluation Procedures

The Cal Poly evaluations built upon the experiences of the authors and others with

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procedures mentioned above. Using existing evaluation methods for reference, the following objectives for the revised procedures were defined:

a. Irrigation efficiency (defined as the ratio of water beneficially used to the water applied) should be estimated based upon annual water records rather than upon the evaluation of a single day event.
b. The various factors contributing to inefficiency must be clearly spelled out so that a grower can see what actions should be taken for maximum impact.
c. The potential savings in water and power due to various actions must be defined.
d. The evaluations should concentrate upon the big picture rather than complete statistical accuracy on just a few points. A reasonable estimate, including as many factors as possible, is more accurate than a precise analysis of a few details which overlooks many points.
e. The evaluations should result in specific written recommendations in addition to a numerical summary. Some of those evaluations may not deal specifically with water savings but would indirectly contribute through improved overall management.
f. The evaluation of a field should take no more than 1.5 man-days.
g. The evaluators should not have to be irrigation experts or mathematicians; however, they must be able to take measurements properly.
h. The recommendations from the evaluation of a system should be the same regardless of who performs the evaluation.
i. Training requirements for evaluators should be minimized.
j. Any computer programs must be usable in field offices and be user-friendly.
k. The results should be available to the grower as rapidly as possible (within one day) in a neat, complete format.

Fig. 1. Sample First Output Page From Single Day Micro Irrigation Evaluation.
Single Event Evaluation Results

A sample output summary for the field evaluation of a single day is shown in Figure I. The recommendation paragraphs (printed on subsequent pages) are not shown.

The first value to be listed is Emission Uniformity. Four factors contribute to the calculation of this value:

1. Variable tree and emitter spacing
2. Unequal drainage of hoses and submains
3. Pressure differences
4. Other (clogging, temperature differences, leaks, manufacturing variability).

Pressure differences are not listed by cause (elevation vs. friction vs. misadjustment), because a manager cannot change hose or submain friction or elevation differences. However, the differences between hose inlet pressures can be minimized with proper pressure regulation. Therefore the summary sheet distinguishes between the two possible locations of pressure differences which affect uniformity. Results from flow rate calculations and visual observations determine which statements are printed under "OTHER CAUSES OF FLOW VARIATION--".

The two other key output values are "% Runoff" and "Excess Pressure". The "% Runoff" is greater than zero (and therefore considered as a loss in the General Survey program) only if it is not collected and reused by the land owner. In California there have been serious permeability problems under drip, but most systems have no design provision to capture and reuse runoff. The last value, "Excess Pressure", results from duplicate pressure regulation, high losses across filters, and throttled valves along the critical hydraulic path.

Single Event Calculations

In many orchards, blocks of trees have different tree spacings but equal emitter spacings down a hose without compensation in set duration. The non-uniformly caused by this unequal irrigation of blocks can be significant. For system designers this is a major consideration; it has been ignored in most evaluations.

\[
EU_{\text{spacings}} = \left( \frac{AR_n}{AR_e} \right) \times 100
\]  

(1)

Where \( AR_n \) is the lowest average block application rate, and \( AR_e \) is the mean block application rate. If there is only one block spacing, this component equals 100. In this calculation, it is impossible to use the "average of the low 1/4" as the definition of the "minimum".

Unequal drainage can be a persistent management problem on sloping ground, as some emitters never "shut off" due to line drainage at low points. Special design considerations can eliminate this problem.

\[
EU_{\text{drainage}} = 100 \left[ 1 - \frac{1}{(UE)(T_d)/(100T_c)} \right]
\]  

(2)

Where \( UE \) is the percentage of emitters which drain after the system is shut off, \( T_d \) is the average minutes of drain time, and \( T_c \) is the average set time.
Pressure variations between emitters throughout the complete micro-irrigation system contribute to the element of emission uniformity which is most discussed in professional papers.

\[ EU_{\text{pressure}} = 100 \left( \frac{P_n}{P_a} \right)^x \]  

(3)

Where \( P_n \) is the average of the low one quarter of the emitter pressures, \( P_a \) is the average emitter pressure, and \( x \) is the emitter discharge exponent. The emitter exponent is determined by taking emitter measurements at one location under two different pressures. Pressures are measured throughout the system at hose entrances and ends.

The coefficient of flow variation due to "Other" sources is found at two specified locations, using 15 individual emitter flow measurements per site. The formula developed by Keller and Karmell (1975) was then used as follows to determine the EU component of "Other" sources:

\[ EU_{\text{other}} = \left[ 1 - 1.27(C_v)\bar{P}^{1/2} \right] 100 \]  

(4)

Where \( C_v \) is the average coefficient of flow variation from the two sites, and \( n \) is the number of emitters per plant.

The EU of the drip system is calculated using the above components.

\[ EU_{\text{system}} = \frac{(EU_{\text{spacing}})(EU_{\text{drainage}})(EU_{\text{pressure}})(EU_{\text{other}})}{1000000}. \]  

(5)

General Survey Evaluation Results

Figure 2 is a sample of the summary for the General (Annual) Survey evaluation, minus the pages with recommendations. Included is an estimated irrigation Efficiency, a water balance, and cost estimates. Three points deserve special attention:

a. Beneficial uses may include water other than ET and water for salinity control. For example, water applied for frost control in excess of what can be stored in soil is considered a beneficial use, because it is as important as the ET requirement in terms of growing a crop. Many micro-sprinkler systems and some drip systems are used for full or partial frost protection.

b. It is possible to have both underirrigation and deep percolation in the same field. This may be due to non-uniformity and/or improper scheduling of irrigations.

c. Runoff which leaves the field, and is not returned to the same field but is used elsewhere on the owner's property is not considered "lost" and would not appear as "Runoff".

General (Annual) Survey Calculations

Since most evaluations are conducted in the middle of an irrigation season, annual water delivery and ET estimates are not yet available. Therefore, the General Survey uses data from the last year, under the assumption that this year's practices will be similar. Annual water supply and use are essential because results from a single day's evaluation may lead to conclusions of tremendous water and energy saving potentials when in reality a farmer may have a seasonal deficit.
Fig. 2. Sample First Output Page From The General (Annual) Evaluation.

A water balance is calculated at 3 points (points receiving average, minimum, and maximum depths of infiltrated water, based upon uniformity values from the Single Event Evaluations (up to three soil types in a field). Although the concept is simple, in reality it can be difficult to obtain good records of water deliveries and to make proper estimates of seasonal and peak ET requirements. Unless this data can be obtained or estimated accurately, the irrigation efficiency is impossible to calculate. This is the weakest link in many evaluations.

Conclusions

An evaluation procedure has been developed and implemented which fulfills the objectives originally set forth. The widespread availability of personal computers has made it possible to train personnel to conduct comprehensive and practical irrigation evaluations without requiring them to have expert knowledge of the logic and computations. Irrigation experts can use the evaluation procedures with confidence once they understand the computation procedures used. They can then concentrate on selecting and implementing the solutions required for maximizing efficiency and profit.

REFERENCES


