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Project Summary

Evaluating Furrow Irrigation Systems for Regional Water Quality Planning

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Field evaluations of furrow irrigation practices at three Colorado locations were conducted during the 1979 irrigation season. The data were utilized to assess four alternative field evaluation procedures and develop cost effectiveness relationships for each method. A simulation formulated from volume balance concepts was also developed and calibrated using the field data. The model was used to evaluate the relationships among furrow hydraulic and performance parameters so that proper alternatives for improving irrigation efficiency could be determined.

Analysis of spatial and temporal variabilities in the field indicates that large errors are likely in field assessments unless the study is comprehensive. Testing should include the first seasonal irrigation and at least three later irrigation events. At least six individual furrows should be studied on each field.

Relationships among soil properties, furrow hydraulics, and irrigation efficiency were not predictable unless specific intake (infiltration) relations were utilized as input data. However, with this information it was possible to identify the effects of changing various irrigation practices upon irrigation efficiencies.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Improved irrigation practices have become increasingly important to pollution control, water and energy conservation, and increased food and fiber production. Sixty-eight percent of the total irrigated acreage in the United States is surface irrigated. Furrow irrigation, comprising a major portion of this acreage, is characterized by running water down small channels called furrows located between crop rows. Properly designed and managed furrow irrigation systems can result in high crop production levels while conserving water and energy resources. However, inherent system limitations coupled with poor management practices can and often do result in large deep percolation and tailwater run-off volumes, which frequently impact downstream water quality.

Studies of the irrigation return flow system have been concerned with the severe problem of collecting data on a scale large enough to ensure adequate system characterization. Existing manpower within planning agencies and the funding committed to water quality planning are likely to be insufficient to facilitate studies of the same detail as most research field studies. Consequently, the investigative tools applicable at the planning level must be much simpler in order to accommodate the kinds of data that can be realistically collected. The objective of this project was to provide such a simplified, usable computational aid and to concisely describe the procedures and limitations of the suggested approaches.

Furrow evaluation data were collected at six locations in Colorado on fields with lengths ranging from 175 m to 625 m, slopes of 0.23% to 1.0%, and soils ranging from loamy sand to clay loam. These data provided the basis for comparing four evaluation procedures and calibrating a furrow irrigation performance simulation model called FURSIM.

Field Data Collection Procedure

Farmers cooperating in the research efforts were notified several months prior to the irrigation season of the nature and objectives of the field work. An interview with each farmer established the history of irrigation and tillage practices for each field. Following these initial interviews, groups of three or four furrows were selected at each site to be representative of general field conditions.

Furrow lengths were measured and staked at 25 meter intervals. The field was surveyed to establish average field slopes. Soil moisture sampling, furrow cross-section sampling (with a profilometer), blocked furrow infiltrometer testing, and the setting of inflow and outflow measuring flumes were all accomplished on the day just prior to the first and subsequent irrigations. During the irrigation event, data collected included advance times to each 25 m station, inflow and outflow discharge readings, and flow depth and top width measurements for selected stations along each furrow. In addition, recession times were recorded at each station following the termination of inflow (time of cutoff). Two to three days following the irrigations, soil moisture and furrow cross-section sampling was repeated.

Simulation Model Development

The traditional volume approach for predicting the distribution of water under surface irrigation systems was programmed. The model simulated furrow irrigation performance as a function of furrow discharge, time of cutoff, soil moisture deficit, and number of previous irrigations. The relations between hydraulic variables were described by a series of functions determined by a regression analysis. These "state variable" functions include relations for the advance coefficient and the basic intake rates. The primary mathematical elements of the model included (a) the furrow cross-sectional flow area and the furrow wetted perimeter; (b) Manning's roughness factor; (c) a power function used to characterize the rate of advance; (d) the modified Kostiakov equation describing infiltration with extension to incorporate wetted perimeter and seasonal variation effects; and (e) the subsurface water distribution profile.

In nearly every case where a reasonable estimate of the infiltration characteristics of the furrow was used as input to the model, the predictive results were satisfactory. Following the verifications and calibration tests, the model was used to indicate alternatives for improving irrigation performance at the local site. For example, the effects of changing furrow discharge, time of application, and irrigation frequency were calculated.

Evaluation of Field Procedures

All field data were reduced, coded in a computer library, and organized for each individual field. Then four levels of field evaluation were devised in which Procedure 1 is the simplest and Procedure 4 uses all of the "measured" field data. The data required for each procedure were extracted from the files and used along with appropriate assumptions to predict the actual field performance of the irrigation, as compared with the complete data set (Procedure 4). In addition, data from a single furrow and a single group of furrows were used to predict the average field performance. From these analyses, relationships were developed which indicated the accuracy of the various procedures

The projected costs associated with the use of each procedure were estimated in terms of hours of labor and equipment needs required for each field evaluation procedure. Rather than apportion hourly costs between those of supervisor and one or two assistants, the hourly wage was estimated as seven dollars per hour. Equipment costs were obtained from catalogs for equipment available in the spring of 1980. Costs for major items were apportioned over an estimated useful life on an annual basis without using a capital recovery factor. The costs were then related to the accuracy to yield a cost-effectiveness function for each procedure. Examples of the results are shown in Figures 1 and 2 for tailwater (surface) runoff and deep percolation, respectively. Similar plots were made for cost-effectiveness related to irrigation application efficiencies. An aggregate comparison of the results indicated that the most detailed approach was less cost-effective than one in which a larger number of furrows were tested.

Conclusions

The accuracy of a field evaluation procedure is directly proportional to the cost of conducting the evaluation. However, a procedure involving a moderate level of field tests will yield accurate results if the number of furrow evaluations is increased. Consequently, it was concluded that a moderate level of detail in the field testing procedure, but a large number of furrows tested, was the most cost-effective program (Procedure 3).

A volume balance computer simulation of furrow irrigation performance was shown to predict the effects of various irrigation practices so long as the infiltration rates of the soil are accurately known Efforts to correlate furrow and soil parameters with hydraulic and management parameters were only partially successful. Nevertheless, it is concluded that the simulation model can be used effectively on a site-by-site basis following local caliation

Recommendations

Measurements for evaluating an existing furrow irrigation system should include inflow and runoff (tailwater) discharge, the rate of field coverage (time of advance), soil moisture prior to the irrigation, and a typical furrow cross-sectional shape. At least three furrows spaced across the field should be tested during four irrigation events, including the first irrigation event of the season.

The basic volume balance analysis should be used to evaluate the field data and predict the effects of alternative irrigation practices. Relating the cost of improved practices to the level of improved hydraulic performance will allow an assessment of Best Management Practices to be incorporated into a water quality implementation program.

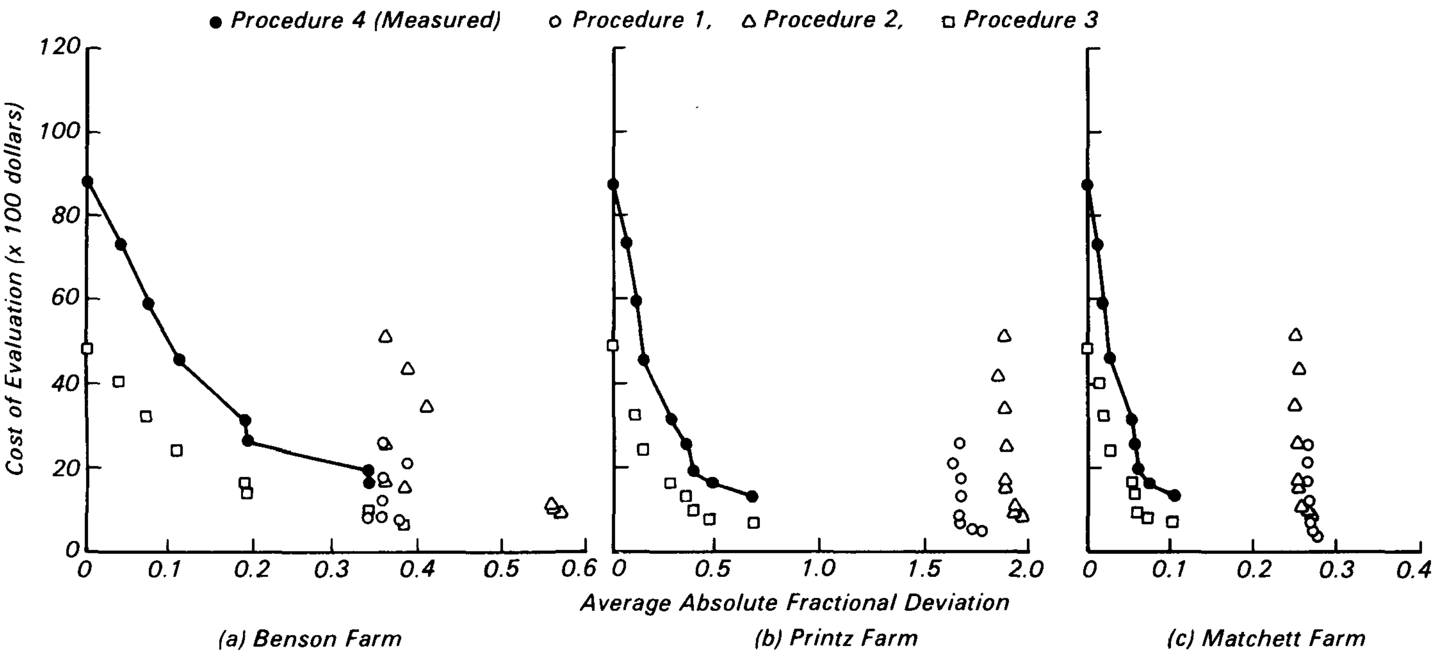

Figure 1. *Cost comparison for tailwater ratios at three farms.*

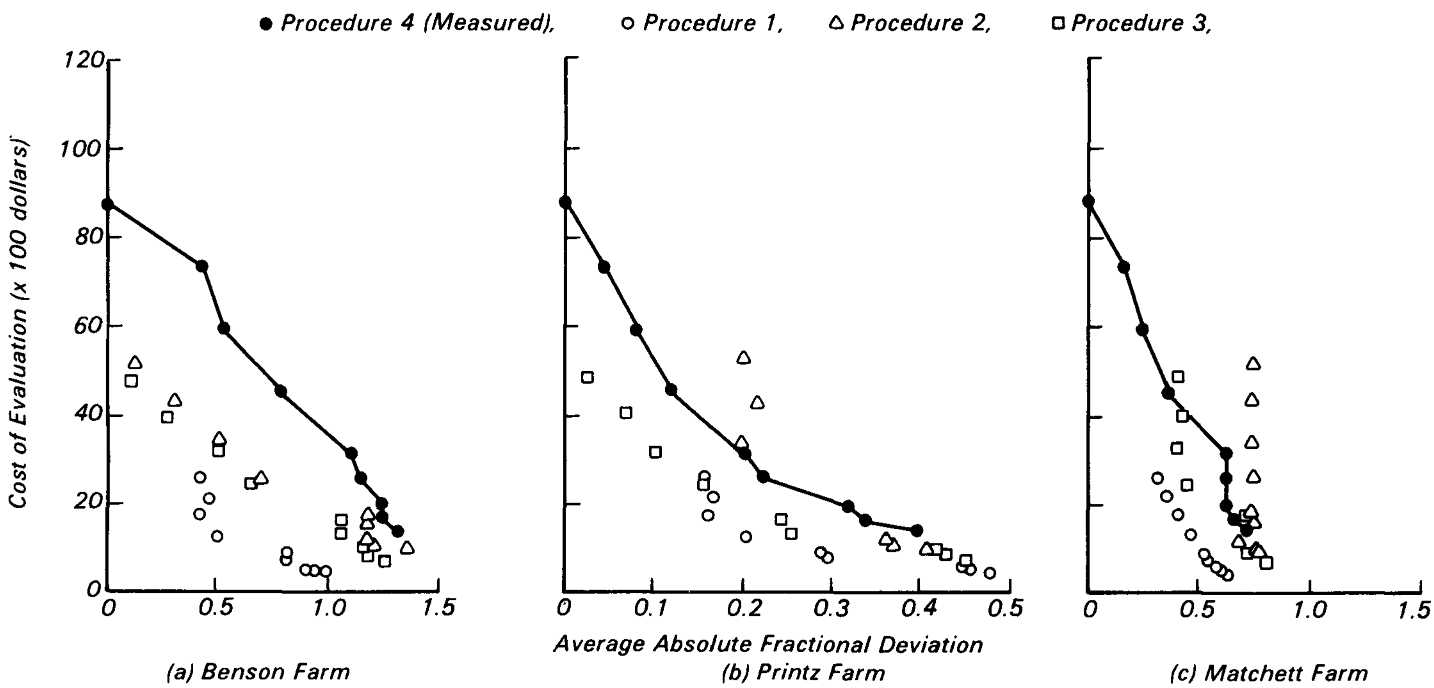

Figure 2. *Cost comparisons for deep percolation ratios at three farms.*

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The complete report, entitled "Evaluating Furrow Irrigation Systems for Regional Water Quality Planning," (Order No. PB 82-255 324; Cost: $13.50, subject to change) will be available only from:
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