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This is, in hardcopy, the abstract of paper no.110 on ***IMPROVING FURROW IRRIGATION SYSTEMS MANAGEMENT BY USING FIELD DATA AND A SIMULATION MODEL*** for poster presentation, for to be published in the booklet of abstracts, and, for submitting, the full text of poster presentation to be published in the conference proceedings on CD. Excuse me for these few days of delay.

With best regards,
António Canatário Duarte

CASTELO BRANCO, 05/02/2001

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IMPROVING FURROW IRRIGATION SYSTEMS MANAGEMENT BY USING FIELD DATA AND SIMULATION MODEL

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ABSTRACT

Surface irrigation, specially with furrows, is still a very important irrigation technology, offering an enormous application potential if the systems are well designed, implemented and managed. Improved systems should be automated, in order to save labour, in a one hand, and save water and protect the soil against erosion, on the other hand. Such an optimal design and management of the irrigation systems must be based on a rigorous evaluation of experimental systems on representative conditions of soil and topography. Mathematical simulation models of the irrigation could be used with experimental field data for optimal design of the systems.

An experiment furrow irrigation field with Fluvisols was prepared in a farm in Idanha-a-Nova Irrigation Project, near of the Castelo Branco, Portugal. Land surface was levelled to a 0,002 slope by using a levelling equipment. For each experimental irrigation event the following data were determined: inflow and run-off rates and hydrographs; advance and recession times; furrow cross section geometry data, as width, area and wetted perimeter as functions of water depth in the furrows. Some of these field data were inputted to the simulation model SRFR_331, the evaluation carried out and the irrigation performance indicators (application efficiency, low quarter distribution uniformity) outputted from the model.

For the first irrigation event, the values for the application efficiency and for the low quarter distribution uniformity were 75,6% and 64,0% respectively. Distribution uniformity was not good, due to the fact that a large application time with a small inflow rate was practised, leading to considerable percolation losses at the upstream part of the furrows. For the second irrigation event, the values for the same evaluation parameters were 75,5% and 91,1% respectively, showing the effective improvement that can be obtained by managing the irrigation system according to the model's simulations when using data collected with earlier irrigation events.

Key words: surface irrigation systems; simulation models; evaluation of irrigation; irrigation management.

INTRODUCTION

One of the activities water consumers is the agriculture, in the practical of the irrigation. Of the practiced irrigation methods in Portugal, have particular importance the surface irrigation, with special prominence for the furrow irrigation. It is evident the interest of the characterization and evaluation of the irrigation methods in the perspective of one better management of the systems, that has led to a bigger water economy and an reduction of environment disadvantages caused out and in the irrigation parcels. The principal objective of evaluating surface irrigation systems is to identify management practices and systems configuration, that can be feasibly and effectively implemented to improve the irrigations efficiency (Walker, 1989). The evaluation parameters that generally are considered are the efficiencies (application and infiltration), and the uniformity with that the water is distributed in the parcel. So that the evaluation can be made rigorous, the implementation of an experimental field for retraction of field data is necessary. In this study it is considered the following objectives:

- observation of the irrigations, with retraction of field data that serve as parameters of input in a simulation model of surface irrigation;
- evaluation of the irrigations through the use of a simulation model of surface irrigation.

MATERIAL AND METHODS

An experiment furrow irrigation field with Fluvisols was prepared in a farm in Idanha-a-Nova Irrigation Project, near Castelo Branco, Portugal. Land surface was levelled to a 0,002 slope by using a levelling equipment. The culture installed was the hybrid maize spaced 0,75 meters between lines of culture. The field distribution system was a plastic gated pipe (200 mm of diameter) with regulable windows of flow for each furrow, like that show in Fig.1. During the experiment field data was registed using the experimental techniques that to relate in the following text.

Fig.1 – Plastic gated pipe with regulable windows of flow for each furrow.

Furrow irrigation flow rate and runoff

The flow rate had been evaluated with portable trapezoidal flumes (Replogle and Bos, 1982), and register of the regular intervals of time (10 minutes), having verified a situation of relative stability. These flumes can be, with easiness, carried from a place to another, and especially indicated for the measurement of flow rate in furrows (Fig.2). Some observations were confirmed by volumetric measurement with a graduated container and a chronometer, in a procedure also used for Reddell and Latortue (1986). The runoff in the other extreme of the experiment field had been evaluated through the same techniques that the flow rate, with greater difficulty for the volumetric measurement. During the irrigations the technique of cut-back was practiced (reduction of the volume when all, or almost all, the length of the experiment field is under infiltration, with the objective of runoff reduction).

Fig.2 - Portable trapezoidal flume (Replogle and Bos, 1982).

Water advance and recession times

These times were determined by direct observation of each occurrence in control stations (markers or stakes), spaced 10 meters (ASAE, 1998). In the experiment field of 1999, the advance of the water was burst until 120 meters since the field inlet. In Fig.3 we can evidence relatively fast times of advance, that if they justify for the value of the declivity of the furrows and for a low roughness coefficient of the surface where it processes the flow, motivated for the vegetation absence in the furrows. For surface irrigated fields the recession phase ends when the surface water disappears at each measuring station. In the irrigation parcels with longitudinal declivity, the recession occurs of the end from the field inlet, more or less quickly depending, among others factors, of the flow rate and the declivity of the furrows. It is considered that the recession occurs, for one given control station, when the water disappears in about 50% of the area represented per this station (Ley and Clyma, 1980). Some irregularities in the topography of the surface, particularly in the field inlet, had determined that the water remained during fast time, what limited in some stations the control of the recession.

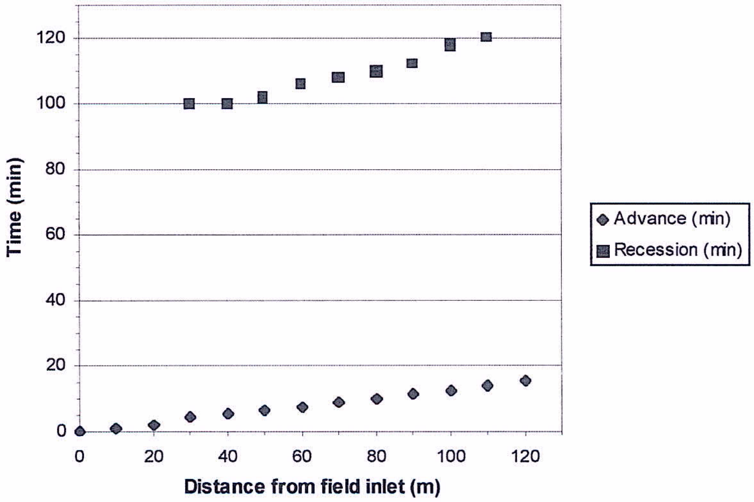

Fig.3 - Observed advance and recession in the irrigation realized in 29/07/99 (second irrigation).

Field infiltration characteristics

Infiltration is the most important process in surface irrigation, and change dramatically throughout the irrigation season. An erratic evaluation can lead to an incorrect analysis and management of the irrigation process (Duarte and Sousa, 1995). The technique employed for measuring infiltration was the blocked furrow infiltrometer (Walker, 1989). The infiltration functions used, Kostiakov and Kostiakov-Lewis, are gotten by linear regression, of the logarithmized series of the times and infiltrated volumes (Duarte, 1994), whose parameters are registed in Table 1. Both the equations of infiltration previously related, disclose a good adjustment to the field data, fact that is evidenced by the observation of the graphical representation of the curves adjustment calculated to the observed data (Fig.4). The criterion for the selection of the equation that better adjusted to the field data is the visual analysis of the graphical representation. Taking as example the test of infiltration realized in 22/07/99, it can see that the equation better adjusted to the field data is the equation of Kostiakov-Lewis.

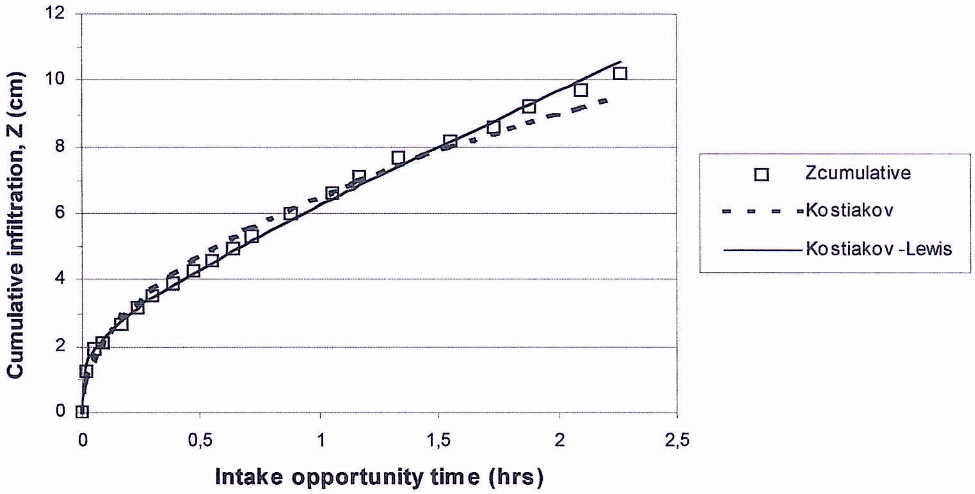

Fig.4 - Adjustment infiltration functions to the data observed in test of infiltration in 22/07/99 (same day of the first irrigation).

Table 1- Parameters of the infiltration functions, Kostiakov and Kostiakov-Lewis, adjusted from the data observed in test of infiltration in 22/07/99.

INFILTRATION FUNCTIONS	PARAMETERS		
	K (mm/h^a)	a	I_f (mm/h)
Kostiakov	64.88	0.465	-----
Kostiakov- -Lewis	33.30	0.210	29.14

Depth of the flow

This observation was realized with rulers placed in the furrows (Fig.5), and registed depths at regular intervals of time, normally when the values of the flow rate were registed. In alternative, the depth of the flow could be measured with rulers in T supported in furrow sides and placed normally near of the field inlet, middle and end of the furrows (Serralheiro, 1988). In the parcels with longitudinal declivity, the objective of this observation is the determination of the flow cross-section (area and perimeter wetted), for calculation of the roughness coefficient of the Manning-Strickler formula.

Fig.5 - Graduated rulers placed in the furrows for observation of the depth of the flow.

Furrow cross-section characterization

The geometry of flow under furrow irrigation is difficult to describe. The furrow shape is continually changing because of erosion and deposition of soil as the water moves it along, but its typical shape ranges from triangular to nearly trapezoidal (Walker, 1989). The referring data to the geometry of the furrow cross-section are necessary for the determination of the area and perimeter wetted of the flow cross-section, for one given depth. Jointly with the flow rate and the longitudinal declivity of the furrows, make possible the calculation of the roughness coefficient, of the Manning-Strickler formula. The data of this observation can also serve for the determination of power equations, that relate the depth of the flow, with top-width of the flow, as form of its cross-section characterization (Duarte, 1999). This information can be gotten in the sections where the depth of the flow it was observed, by using an furrow perfilometer described per Walker & Skogerboe (1987). Individual scales on the rods of the profilometer provide data to plot furrow depth as a function of the lateral distance. After supported in the sides of the furrow, the rods become free and they are supported in furrow surface, multiplying in the rectangular board the furrow cross-section (Fig.6).

Fig.6 - Profilometer for register of the furrow cross-section.

RESULTS AND DISCUSSION

In the evaluation of the irrigations they are used the mathematical model SRFR_331 (Strelkoff, 1998); it is one-dimensional mathematical model for simulating surface irrigation (borders, basins and furrows). This model assumes that all flow characteristics vary only with distance from the inlet and time. The simulations consist of numerical solutions of equations which represent, mathematically, universal physical principles like conservation of mass and momentum. The results of a simulation depend on the hydraulic properties of the soil and crop (if the vegetation is immersed in the flow), the physical design of the system (length, slopes, etc.), and the irrigation management: flow rates, duration, etc., as well as the target depth of infiltration for the irrigation. The results (the advance and recession curves, the runoff, and the distribution of infiltration depth along the length of the run when recession is complete), can be presented both graphically and numerically through a series of performance indicators. During the course of each simulation, an animated graphic of the soil and water surfaces, and the growing infiltration profile in the soil are displayed (Strelkoff, 1998). Among the factors used to judge the performance of an irrigation system or its management, the most common are efficiency and uniformity (Walker, 1989). The definition of application efficiency, has been fairly well standardized as volume of water added to the root zone, divided by volume of water applied to the field (Hoffman et al., 1992; Serralheiro, 1996). Merriam and Keller (1978) propose distribution uniformity defined as average infiltrated depth in the low quarter of the field, divided by the average infiltrated depth over the whole field. The information supplied to the model is presented in the Table 2 based in the field data, and in the Table 3 simulated results of the irrigations.

Table 2 - Information supplied to the model based in the field data.

INFORMATION SUPPLIED TO THE MODEL			
FIRST IRRIGATION (22/07/99)		SECOND IRRIGATION (29/07/99)	
Parameter	**Value**	**Parameter**	**Value**
Furrow length	120.0 m	Furrow length	120.0 m
Slope	0.0024 m/m	Slope	0.0024 m/m
Furrow spacing	0.75 m	Furrow spacing	0.75 m
Breadth at 100 mm depth	0.18 m	Breadth at 100 mm depth	0.21 m
Power law exponent	1.151	Power law exponent	1.170
Total furrow depth	156.0 mm	Total furrow depth	168.0 mm
Modified Kostiakov k	33.30 mm/hr^a	Modified Kostiakov k	14.79 mm/hr^a
Modified Kostiakov a	0.21	Modified Kostiakov a	0.12
Modified Kostiakov b	29.14 mm/hr	Modified Kostiakov b	13.29 mm/hr
Modified Kostiakov c	0.00 mm	Modified Kostiakov c	0.00 mm
Limiting depth of infiltration	0.00 mm	Limiting depth of infiltration	0.00 mm
Manning coefficient n	0.054	Manning coefficient n	0.054
Inflow Rate, Q	1.00 lps	Inflow Rate, Q	1.00 lps
Cutoff Time	152.0 min	Cutoff Time	79.0 min
Cutback Time	0.810	Cutback Time	0.600
Cutback inflow rate	0.30	Cutback inflow rate	0.50
Target Infiltration Depth	70.00 mm	Target Infiltration Depth	34.00 mm

Table 3 - Simulated results of the irrigations.

SIMULATED RESULTS OF THE IRRIGATIONS			
FIRST IRRIGATION (22/07/99)		SECOND IRRIGATION (29/07/99)	
Parameter	**Value**	**Parameter**	**Value**
AE	75.6%	AE	75.5%
Dulq	0.64	Dulq	0.91
Davg	87.2 mm	Davg	31.8 mm
Dmin	29.7 mm	Dmin	27.9 mm
Dlq	55.8 mm	Dlq	29.1 mm
RO%	0.56%	RO%	24.10%
ROd	0.4 mm	ROd	10.1 mm
DP	20.7 mm	DP	0.0 Mm
Dapp	87.8 mm	Dapp	42.1 mm

AE – application efficiency;

DUlq – distribution uniformity of the low quarter;

Davg – average depth of infiltration;

Dmin – minimum depth of infiltration;

Dlq – average depth of infiltration of the low quarter;

RO% - runoff expressed in percentage;

ROd – runoff expressed in depth over the field;

DP – deep percolation;

Dapp – applied depth.

For the first irrigation event, the values for the application efficiency and for the low quarter distribution uniformity were 75.6% and 64% respectively. Distribution uniformity was not good, due to the fact that a large application time with a small inflow rate was practised, leading to considerable percolation losses at the upstream part of the furrows (Eisenhauer et al., 1991). The soil was very dry when this irrigation was realized, and flow rates practised relatively low (still that the application time has been long), they had taken that great part of the water was infiltrated in the initial parts of the field, determining that the runoff were of course small. It is important to relate that infiltration characteristics determined in the blocked furrow infiltrometer, not describe, always, of the convenient form the process of infiltration during the irrigation, what it can take the simulations more less accurate of the process (Duarte, 1994; Duarte and Sousa, 1995). For the second irrigation event, the values for the same evaluation parameters were 75.5% and 91.1% respectively, showing the effective improvement gotten in the sequence of corrections in the system that included increase of the maintenance flow rate (with influence direct in the increase of the distribution uniformity), and minor irrigation time and target infiltration depth, related with a bigger frequency of irrigations, and the maintenance of higher soil humidity.

CONCLUSIONS

Decurrent of the defined objectives, and made possible for the used experimental procedures and for the use of computers and simulation model, we present the following conclusions:

- the perfectioning of the experimental techniques is essential for the reliability of the field data, so that they can be used as parameters of input in simulation models;

- an inadequate conjugation of the irrigation parameters, takes the low qualities of the practised irrigations;

- the evaluation of the first irrigation, through the use of a simulation model, more gave indication for an adjusted combination of the irrigation parameters, that took the best results of the next irrigations.

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