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PROCEEDINGS OF THE WORKSHOP
ON REAL TIME SENSING AND CONTROL
OF AUTOMATED IRRIGATION SYSTEMS

ACTES DU SÉMINAIRE
SUR LES CAPTEURS EN TEMPS RÉEL ET LA COMMANDE
DES SYSTÈMES D'IRRIGATION AUTOMATIQUES



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CONSTRAINTS TO REAL-TIME CONTROL OF SURFACE IRRIGATION (*)

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SUMMARY

Practical, automatic real-time control of surface irrigation faces several difficult constraints. Most surface irrigation water supplies must be scheduled in advance and use must be coordinated with other demands. Either the supply system must be able to adapt to the occasional demand of automatic systems, or the application systems must communicate their needs to the supply system with the required lead time.

Surface irrigation performance depends strongly on soil surface and infiltration characteristics. These parameters normally vary widely spatially and from irrigation-to-irrigation, and are difficult to predict. Performance monitoring and system adjustment is usually required to insure good performance, especially during early-season irrigations. Automatic real-time control systems thus must include some type of performance feed-back control. This paper discusses the severity of these constraints and possible solutions for the several types of surface irrigation systems and water supply conditions.

(*) CONTRAINTES DES COMMANDES EN TEMPS RÉEL DES SYSTÈMES D'IRRIGATION DE SURFACE

RÉSUMÉ ET CONCLUSIONS

En conditions pratiques le pilotage automatique en temps réel des systèmes d'irrigation de surface affronte des contraintes sérieuses. La plupart des réseaux de distribution d'eau aux systèmes gravitaires doivent être programmés en avance et l'utilisation de l'eau coordonnée avec d'autres demandes. Le réseau de distribution doit être capable de répondre aux demandes occasionnelles des systèmes automatiques, ou bien l'utilisateur du système sera obligé de communiquer leur besoin avec l'avance nécessaire.

Les performances de l'irrigation gravitaire dépendent des caractéristiques d'infiltration et de la surface du sol. Ces paramètres varient largement dans l'espace et d'irrigation en irrigation, étant difficiles à prédire. Une bonne information de champ et le convenient ajustement du système est normalement requis pour garantir une bonne performance, en particulier durant les premières irrigations de la saison. Les systèmes automatiques de pilotage en temps réel doivent inclure des capteurs pour un retour d'information (feed-back), étant important la définition des sites où cette information doit être recueillie. Cette communication discute la sévérité de ces contraintes et les possibles solutions en vue des systèmes d'irrigation de surface.

Des études de recherche et des développements issus sont exigés, due les limitations pratiques vérifiées dans les applications de l'automatisation à l'irrigation de surface. Dans des périmètres sans distribution à la demande, la construction de réservoirs locaux peut assouplir l'utilisation exigée dans les systèmes automatiques. Des valves à débit constant et des mesureurs de débit adaptés aux besoins de l'irrigation gravitaire sont à développer. Le problème due à la variabilité de l'infiltration et des conditions du sol doit être dépassé par des futurs développements des techniques de retour d'information, après leur validation et simplification pour utilisation par techniciens et agriculteurs. Le progrès vérifié les dernières années dans la maîtrise et la gestion des

systèmes d'irrigation gravitaire, donnent l'indication que futurs développements rendront possible l'automatisation des systèmes gravitaires, en particulier dans les bassins à fond plat et dans l'irrigation à la raie avec retour de débit.

1. INTRODUCTION

During the last two decades important improvements in surface irrigation have been achieved. The theory of overland flow was deeply studied, and simulation models appeared helping researchers, engineers, designers, technicians and farmers.

The performance of the irrigation systems have been improved, and new techniques of on-farm water application have been developed. Mechanization and different forms of automation have emerged as interesting applications to surface irrigation. Semi-automation is used to help the farmer, but still requires a periodic vigilance, because of the uncertainty of a number of management parameters, dependant mainly on the variability of soil conditions.

The full automation of surface systems place some questions not yet solved, which are discussed in this communication.

2. DIFFICULTIES OF PREDICTING IRRIGATION PERFORMANCE

Infiltration and surface variability

Surface irrigation system performance depends strongly on infiltration and surface characteristics. Unpredictable temporal variability requires surface irrigators to monitor the irrigations and adjust inflows and set times to maintain acceptable performance (Trout et al., 1990).

During an irrigation season, the average infiltration rate may register a variation of more than 50 % (Trout et al., 1990). This has an important impact on efficiency, since the water advance over the soil surface depends on the flow

infiltrated throughout the run length. Under level basin conditions, Sousa(1990) quantified these effects on irrigation quality, by using the simulation model BRDRFLW (Strelkoff, 1986). A variation of $\pm 50\%$ in infiltration parameters $a = 0.443$ and $k = 2.925 \text{ cm/h}^2$ was assumed for the fixed factors corresponding to the experimental basin 5B, second irrigation: length $L = 70 \text{ m}$, surface roughness Manning $n = 0.04$, unit inflow rate $q = 0.533 \text{ (l/s)/m}$, application time $t_{ap} = 120 \text{ min}$ and required water application $Z_{req} = 50 \text{ mm}$. The resulting curves of recession, advance and infiltration are plotted against the observed values for conditions of an irrigation with the above factors in figure 1. The impact on performance is more evident when an error in evaluation of k is committed or when k simply varies in time or space. For a variation of k from 1.463 to 4.388 cm/h^2 the Distribution Uniformity (DU) decreases 37.7% (from 99.1% to 61.4%). A drop of 16.4% in DU is observed when a changes from 0.222 to 0.665 .

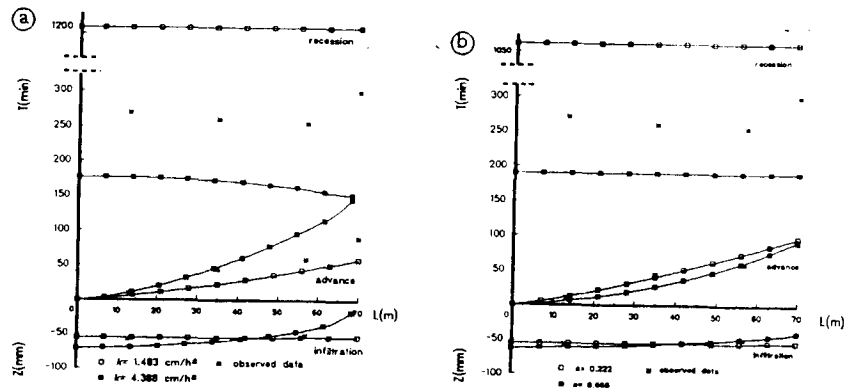


Figure 1 - Observed and simulated recession, advance and infiltration for a level basin irrigation, considering: a) $k = 2.925 \pm 50\%$ and b) $a = 0.443 \pm 50\%$.

Spatial variability also influences the irrigation. Soil texture, wheel traffic, tillage and irrigation practices can cause infiltration variability, which affects mainly distribution uniformity of the water in the field.

The preset operating conditions of an automatic system under these conditions need periodic corrections based on real-time information. Infiltration is a factor not easily obtainable without intensive field observations, which are normally beyond the farmer's capabilities.

The variability of the field microtopography can have an important influence on irrigation performance, particularly in level basin irrigation. Low areas receive and infiltrate an excessive amount of water while high areas are adequately irrigated. Differences of 2 cm in elevation may result in recession times about 50% longer in the lower areas (figure 2). For the overall experimental basin, with a microtopography expressed by an elevation standard deviation of 0.923 cm the performance parameter DU varied from 81.9% to 90.9% . Even with precise laser leveled basins, slight differences in the average elevation, expressed commonly by the standard deviation (Sd) of the surface elevations (Dedrick et al, 1982), which typically

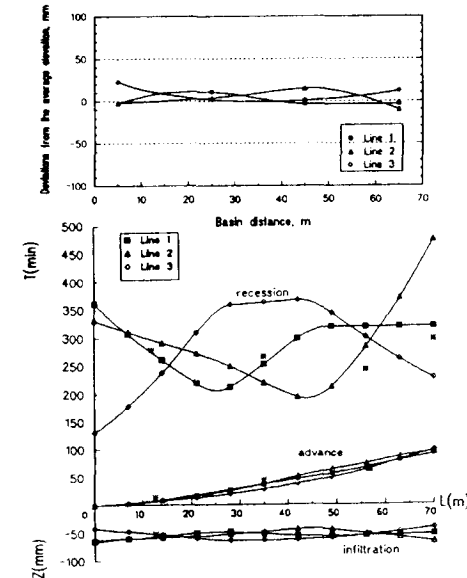


Figure 2 - Observed and simulated recession, advance and infiltration for a level basin irrigation, considering the microtopography of the field.

range from 0 to 3 cm, can have a dramatic impact on DU. Sousa et al (1992) showed that, in level-basins, when S_d increases from 0 to 3 cm, DU drops respectively by 35% to 50% and yields decrease by 20% to 25%.

Variability in inflow rates

Inflow rate and application time determines the gross application. For different infiltration conditions, the net application depends on the achieved efficiency. An incorrect inflow rate may cause a very poor efficiency in furrow irrigation. The effect of inflow rate on level basin irrigation should not be so great, affecting mostly the distribution uniformity, although a variation of $\pm 20\%$ in inflow rate can influence DU about 14.5% (DU of 96.2% and 81.7% respectively for $q+20\%$ and $q-20\%$), as shown in figure 3.

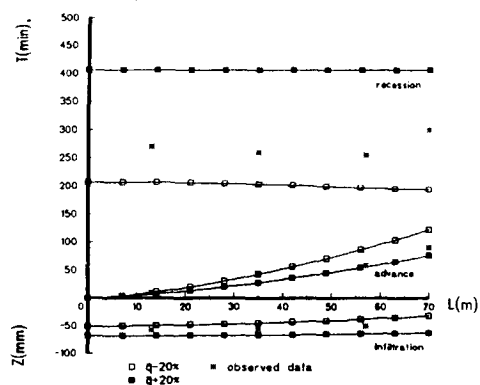


Figure 3 - Observed and simulated recession, advance and infiltration for a level basin irrigation, considering a variation of $\pm 20\%$ in inflow rate.

Application time

Once the soil water deficit is known, the infiltration of the water in the soil is characterized, and the slope or the microtopography is known, the required application time can be fixed in accordance with the inflow rate available. These two

last factors will determine the gross application, and if the control of time is dependable, gross application will depend exclusively on the constancy of the flow and on its measurement. However, even if the gross volume applied is correct, the required net application will depend strongly on accurate determination of infiltration and surface conditions. This is more evident in sloping furrow than in level basin irrigation, due to the runoff from sloping furrow, which can be very high if the inflow and the application time are not adjusted for the existing conditions. Also the deep percolation can be excessive on coarse soils irrigated with small flows and during long periods.

3. WATER DELIVERY SYSTEMS CONSTRAINTS

The majority of the surface irrigation projects in the world are supplied by an open-canal network, with three levels of operation: i) primary canals, ii) secondary canals and iii) tertiary canals and pipelines. The flexibility of each level is generally restricted by the next higher level (Burt and Plusquellec, 1990); Thus the on-farm irrigation systems strongly depends on the design and management of the two first levels.

Inflexible water delivery systems restrict the automation of on-farm systems. Old networks managed on strict schedules and delivering unsteady flows can preclude mechanization and automation of the existing irrigation systems.

The water distributed on a rotation schedule implies that all the flow on a lateral, during a fixed time, is conveyed to a particular field. An arranged schedule requires the farmer to request the water in advance 24 or 48 hours. In these two situations the automation is seriously constrained. Semiautomation is still possible, with appropriate control devices, to irrigate at predetermined times a parcel or a set of fields.

Only a demand schedule allows a total flexibility of frequency, rate and duration of delivery. This situation allows the adoption of fully automated systems, including sensors furnishing either soil, crop or climatic information to programmed controllers.

4. AUTOMATION EQUIPMENT RESTRICTIONS

The various components for automation of surface systems have not achieved significant commercial development. The main reason is the lack of reliable controllers of sufficient accuracy (Duke et al., 1990).

Electronic and computerized controllers presents important advantages, particularly the wide flexibility in the sequence of irrigation sets. Although the electronic circuits are delicate components, being vulnerable to electric disturbances, specially lightning.

The flow used with modern surface irrigation systems, normally under low head, require large-size automated valves. These valves, in general not available in low pressure, are expensive and difficult to automate in field conditions in absence of a power supply.

When irrigation controllers are used for real-time control of surface irrigation, the main concern to determine the location and density of the sensors. The variability presented by the different factors, as discussed earlier, requires the use of several sites to get the needed information. Communication means must exist, and in surface irrigation typically with long fields, that requires sophisticated non-wired self-powered systems, especially if the locations are scattered across the field. The system must be able to combine the information from the sensors and select the reliable information from the others that should be rejected. The resulting complex systems are more expensive than farmers are use willing to pay.

5. FUTURE PROSPECTS

The practical limitations to real-time control of surface irrigation systems are, at this moment, still too great. Serious research studies and further development is required.

For full automation of the irrigation system, the water delivery network has to be organized on a demand scheme. Areas supplied by wells or local reservoirs can meet this need. Large irrigation districts with different distribution schedules, generally cannot automate, although solutions can be adopted, like the construction of intermediate reservoirs.

The variation of inflow rates, mostly due to the operation of the distribution system itself, can be decreased in pipe laterals, by the use of self-regulating valves. With certain of these valves for large ranges of hydraulic head, the flow is maintained fairly constant. A good, robust, simple, economic and precise automatic valve is needed.

Other equipment for automation has to be studied, tested and made available for irrigators. It has to be compact, resistant to the adverse environment, economic and easy to install, use and store. Accurate measuring devices must be available to use together with this equipment, to conveniently control the volume of water applied.

The critical problem for which solutions are relatively uncertain is the variability of the soil conditions. Feedback techniques, allowing the automatic adjustment of inflow and/or irrigation time to improve performance, based on simple measurement of advance, runoff or water penetration are being studied and improved. Other techniques use models to optimize performance by measuring advance and predicting infiltration. Both methods require the installation of multiple sensors, scattered across the field, and communication means and a good controller to analyse and decide about the information received. These techniques are still at the research level, and

must be simplified and made reliable before being proposed for use by farmers and technicians.

The progress being made in the management of irrigation systems and on the techniques of soil preparation and water application, give us some confidence for the future developments. A well designed level basin irrigation system can be successfully automated if the management parameters are guaranteed and the supply network allows the needed flexibility. A furrow irrigation with tailwater reuse can also be fully automated, in this case with some additional equipment in place.

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