ICT IN WATER SUPPLY AND IRRIGATION MANAGEMENT

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Abstract

During the 20th century, world population grew from 1.6 to 6.1 billion and the annual global water consumption increased from 1000 to 5000 km^3. The expansion rate of the arable land lagged far behind those figures. Most of the available land that can be cultivated on the globe as well as a great share of the available fresh water resources are in use. Development of additional resources is tremendously expensive. ICT is one of the most effective means in upgrading of land and water management and increasing food production. Since the middle of the 20th century, automation and ICT are increasingly employed in water supply and irrigation management. Outstanding contribution to water use efficiency was achieved mainly in countries that are exposed to strict water scarcity and benefit of high technology development. Adoption of ICT and automation enhanced water use efficiency in irrigation by 10% - 50%, increased yield per land and water unit by 20% - 100% and improved produce quality. In water supply plants and networks, ICT and automation facilitated optimization of pressure regime in delivery networks, savings of water and energy and the invoicing of consumers according to their actual water consumption. Conceptually, ICT and automation triggered the adoption of volumetric approach in water application. These achievements enabled expansion of the irrigated area, increased food production and higher profits for farmers.

Developing countries and users of surface irrigation are lagging behind the developed countries and pressurized irrigation operators in adoption of ICT and automation. Concerted international technical assistance, financial support, extension and follow-up can close the gap and disseminate wide-scale use of ICT in the lagging disciplines.

Introduction

Global water use increased fivefold during the 20th century. More than 5000 km^3 (1 km^3 = 1 billion m^3) are consumed per annum, 70% of that are used for agricultural irrigation, in addition to the rain water that is utilized by the agricultural crops.

Since 1900, world population has increased from 1.6 billion to more than 6 billion. The fast growth of the population and the rise in the standard of living aggravated the competition for the limited world's available plain water resources between agriculture and the other consumers – municipalities, landscaping, recreation and the industry. Frequent droughts in the last decades decreased yields and farmers' income in various regions of the world.

The total arable land in the world is estimated as 1.5 billion hectares – one third of the total land on the globe. Of that, about 275 million hectares, 18% of the cultivated land, are irrigated. The irrigated area yields 40% of the total agricultural produce. Hence, the output per land unit in irrigated agriculture is more than twice the output of rain-fed agriculture. In terms of farmers' income the gap is greater, since most of the cash crops and the high income products are grown on irrigated land. Expansion of the irrigated land area is a vital means to guarantee food supply to the growing world population. The expansion of the irrigated area is restricted by the scarcity of available fresh water resources.

The above mentioned developments increased the interest in efficient use of water in agriculture. Efficiency of water use is defined as the fraction of water beneficially used (crop consumption, salt leaching, frost protection, etc.) from the total amount of water applied. The present estimated average global water use efficiency in irrigation is less than 50%. Nearly 90% of the irrigated land employs surface irrigation, notoriously known as a wasteful irrigation practice with a water use efficiency bottom threshold of 30%. Ten percent of the irrigated land utilizes pressurized irrigation technologies that have higher water use efficiencies, up to 90% in sprinkler irrigation and up to 95% in drip irrigation.

Since the middle of the 20^{th} century there is a continuous improvement in the efficiency of water use. That is accomplished by conversion from surface irrigation to pressurized irrigation and scheduling of the irrigation on basis of climatic parameters, measured soil moisture and plant water potential. Introduction of automation into water supply and irrigation networks and harnessing of ICT for water management, further enhanced application accuracy and water use efficiency.

One beneficial by-product of automation and ICT in irrigation management is the adoption of volumetric approach in water application. Many of the irrigators in the world, maybe most of them, do not apply water in quantitative, or volumetric, values. The most prevalent definition of irrigation assignment is in terms of time length – hours of application. Other irrigators assign water in terms of water depth or water layer thickness above the soil surface, designated in inches or mm. Apparently these units can be converted to volume of water with multiplication by the application rate or irrigated area. The water volume that is applied in the same time length may vary up to 50%, due to fluctuations in flow in surface irrigation and differences in water head (pressure) in pressurized irrigation. Volumetric automation and scheduling commits volumetric definition of the preset water amount to be delivered, independently from time designation.

Automation and ICT

In semi-professional literature, automation and ICT in water management are considered as one entity. For the sake of accuracy it has to be clarified that this is not accurate. Automation and ICT can be implemented independently from each other. Actually, the combination of both amplifies the contribution of each technology to water use efficiency.

The development of automation in irrigation commenced in the mid-fifties of the 20^{th} century and gained momentum in the sixties.

Automation in irrigation is classified in two categories:

1. Automation on time basis – using timers for opening and shutdown of valves.

2. Automation on volumetric basis – automatic shutdown of the valves after a preset volume of water had been delivered.

The integration of ICT with the automation of irrigation promoted higher levels of sophistication as well as comprehensive services beyond automation, like water supply and irrigation network design, water budgeting, scheduling of irrigation timetables, etc.

Beyond agricultural irrigation, ICT and automation are extensively used in water supply networks, landscape irrigation, municipal household water allocation and consumption monitoring.

Basics of Automation in Water Supply and Irrigation Systems

Modern automation systems are comprised of five basic components: measuring and sensing equipment, control and regulation instrumentation, input and output devices, communication between the different components and power sources. Information technology is inherently integrated in the more advanced automation systems.

Automation can be classified according to the extent of water application control.

- Point automation: an automatic device mounted directly on one valve, controlling exclusively this valve with no relevance to other valves or systems.
- Local automation: Several valves in a plot controlled and coordinated by one unit.
- Central automation: Local automation units that are connected to and controlled by a central unit.

Automation can be implemented in diverse levels of sophistication.

- Shutdown of water flow after the application of a preset amount. Valve opening is done manually.
- Time-based automatic opening and shutdown of the water.
- Opening by timer, automatic shutdown after a preset water amount had been delivered.
- As above plus feedback and recording of the delivered water amount.
- Combined irrigation and fertilization (fertigation), with or without recording of the applied water and fertilizer amounts.
- Sequential activation of valves in the plot.
- Irrigation Control adjusted in real-time by information about temperature, wind, rain, soil moisture, water pressure, etc., received from sensors.
- Control of water sources in correspondence with water demand by consumers.
- Integrated control of water sources and irrigation systems.
- Integrated scheduling and control of irrigation systems.

Incorporation of ICT in automation systems facilitates full exploitation of the potential of automation.

Controllers

The early automation devices were composed of mechanical gear interfaces that were mounted on ordinary flow meters or clocks that were converted to timers that controlled the automatic valves, hydraulically or electrically. The hydraulic valves stopped water flow by means of a piston or a flexible membrane movement, activated by signals of the inherent hydraulic pressure of the water in the irrigation system. The electric valves were opened and closed by electric signals sent to solenoids.

The incorporation of ICT increased the sophistication of automation and reduced the operative costs.

Programmed controllers of the first generation were bulky and complex. Programming was done manually by shifting mechanical switches and required qualified professional programmers. Gradually, Programmable Logic Controllers (PLC) and standard industrial microcomputers replaced the first generation of controllers, facilitating the use of “off the shelf” software for the management of irrigation. One central unit can nowadays control hundreds of local satellite field units.

The most noteworthy contributions of ICT to the automation of irrigation are real-time troubleshooting, failure identification capability and correction by remote control. Advanced automated systems allow the pre-definition of the accepted range of flow rate and pressure in the system. Deviations from the accepted range send alert signals to the operator and/or suspend the water application until the correction of the malfunction. Common identifiable system failures that cause water losses and decreases water distribution uniformity are pipe breakage; multiple emitters' clogging and pressure fluctuations.

Automation has a particular contribution to filtration of irrigation water. In water contaminated by sand, clay and organic debris; arrays of automatic centrifugal or media filters are flushed automatically. Timing of flushing is determined on time basis or by preset allowed pressure difference between the inlet and the outlet of the filter. The automatic flushing of the filtration systems prevents pressure and flow fluctuations in the irrigated plots, due to filters clogging.

Controllers operation requires energy sources. These may be the inherent hydraulic pressure of the irrigation system or electricity from AC network or DC battery. Solar energy is used yet sparsely but is expected to expand in the future, following the declining prices and increasing reliability of that technology.

Communication

The most outstanding progress in the last decade occurred in the area of communications. Initially, communication between units had only two options: hydraulic or electric. Hydraulic communication utilized small diameter tubing connection between the controller and the controlled units. Hydraulic pulses activated the on/off operation of the valve. Communication was unidirectional, from the controller to the valve. In electric communication, wires substituted the hydraulic tubes and the valves were activated by solenoids. In the first generation of the electric wiring, only unidirectional data transfer was possible – signals were sent from the controller to open or close the solenoids. Later on, bi-directional communication was established that facilitated flow of feedback from the satellites to the central unit. Contemporary high technology enables the exclusive decoding of different satellite units along the same wire, scanning the satellite units, one after another, delivering signals from the central unit to satellites and returning feedback in a bi-lateral wire.

The most recent advance in communication is the introduction of wireless communication. Wireless communication reduces costs and eliminates cut-offs of command lines by routine activity in the farm. At the beginning, twenty years ago, wireless communication was non-reliable due to interference in the restricted and crowded range of frequencies that was available for agriculture. In due time, wireless communication became highly reliable with the introduction of cell phones, ISM, GSM and Wi-Fi technologies, SMS bi-directional delivery, as well as the use of satellite communications and internet networks for remote control and data transfer.

Technical institutes, extension services and commercial irrigation equipment suppliers, uploaded to the internet software packages that enable irrigators to calculate online the head losses in irrigation systems and the distribution uniformity of emitters and laterals. Additional online software packages facilitate the scheduling of on-farm irrigation and fertigation.

Wireless communication has all the requested merits of dominance in the future. The miniaturization of wireless appliances, the growing broadcasting range and reliability as well as price decline ranks wireless communication as a technology of choice for a growing number of irrigators. Its potential of incorporation into computer and telephone networks simplifies and amplifies its operation convenience.

ICT in Irrigation Network Design

From the early sixties, computers were harnessed to improve the hydraulic design of irrigation systems. Initially, elementary software has been developed for the calculation of head losses by water flow in pipes. That software replaced the nomograms and slide-rulers used by water and irrigation engineers. Next step was the release of net-solvers that simulated water flow in complicated loops in water networks and facilitated the optimization of the pressure-flow regime in irrigation systems.

The final stage was the development of comprehensive network design software that facilitates the computerized design of irrigation systems based on topography, aerial photography and GIS data. Future advancement will enable the incorporation of irrigation systems design and monitoring as a component of comprehensive precision agriculture.

Water Budgeting and Irrigation Scheduling

ICT facilitates computerized water budgeting, based on soil properties and its water retention; climatic data; crop water requirements; soil moisture and plant water potential measurements. Once the water budget of the crop had been calculated, it can be used for the programming of concrete irrigation scheduling of discrete plots or a comprehensive irrigation schedule for the farm as a whole. Advanced scheduling software facilitates the optimization of the water distribution in the farm, relating to topography and validation of favorable pressure regime. Expert systems for support of decision making had been developed by research institutes and commercial bodies. In most cases these programs had not been adopted by the community of irrigators, seemingly because of the abundance of the requested data that was beyond the capacity of the average irrigator. The developed expert systems are used nowadays mainly in research. On the other hand, the practical budgeting and scheduling programs, supported by on-line delivery of weather information, are gaining momentum with expanding users community.

Fertigation Control

In advanced irrigated agriculture, fertilizers are applied with irrigation water by fertigation technology. Precise dosing of the fertilizers in a pre-defined ratio to the irrigation water is carried out by various types of fertilizer injectors that are synchronized with the applied water amount by controllers. Water flow rate is measured by flow/water meter and the fertilizer solution flow rate is measured by counting the pulses of the fertilizer pump or by dedicated small flow meters. The information is sent to the controller that regulates the ratio between the irrigation water and the fertilizer solution. In intensive agriculture in greenhouses, nurseries and detached beds, the ratio of water – nutrients and the ratio between the different nutrients are adjusted according to feedback from sensors that measure the EC and pH levels in the drainage water.

In highly sophisticated greenhouses, the fertigation control is embedded in a comprehensive control system of the environmental parameters like temperature, light, aeration, relative humidity, etc. inside the greenhouse.

Future development seems to branch in two paths:

1. Higher sophistication and comprehensiveness in the greenhouses sector.
2. Wide scale dissemination and expansion in open field agriculture, relying on soil and crop nutrient level measurements.

ICT and Automation in Mechanized Irrigation

Mechanized irrigation, using center pivots and lateral move machines had been extensively expanded since the mid-fifties. It is generally used for wide-scale irrigation of field crops, saving labor and solid-set equipment. In the last two decades, mechanized irrigation harnessed the power of computerized controllers to improve water distribution and machine performance. Sensor units installed at the lateral distal ends, guarantee repetitive passage on the same track in consecutive irrigations. The controllers match the application rate to changing velocity of the machine due to change in slope on its way. Alerts on malfunction and crashes are sent by wireless to the operators that can be located far away from the irrigated area. Automatic readings of soil moisture and canopy temperature are used for scheduling of the operation of the irrigating machines.

Dedicated software is used for calculation of the diverse flow rate to be assigned to each emitter along the distributing pipes in center pivots. Since the center pivot is irrigating by radial movement, emitter's flow rate has to be gradually increased from the center to margins, keeping the same application rate in the whole irrigated circle.

The growing diversification of the emitters in mechanized irrigation, the introduction of low flow (LEPA) application technology and the expanded demand for precise pressure and flow control, increase the essentiality of ICT and Automation in mechanized irrigation. Since the price of addition of automation is negligible, compared with the cost of mechanized systems and the high cost-benefit ratio, it seems rational that most of the mechanized systems will be equipped with automation in the near future.

ICT and Automation in Surface Irrigation

Surface irrigation is lagging behind the pressurized irrigation in utilization of automation and ICT. Nevertheless, the latest advancements in surface irrigation technologies triggered the adoption of ICT and automation, although in a relatively small extent.

Big border flooding plots are leveled with zero level Laser technology. The Laser sensors are electronically coordinated with the leveling blade and automatically control the sloping degree. Modeling and computation software is used for calculation of the amount of soil to be removed or added to achieve a pre-defined slope degree.

Automation is used to control valves and gates in furrow surge irrigation. Surge irrigation significantly improves water distribution uniformity in furrow irrigation. In that technology water is applied intermittently in several cycles. In the first cycles a large amount of water wets the whole length of the furrow for a short time. In the later phases slow water flows fills the furrow for a longer time length. The automation eliminates the need for manual intervention in these operations. The estimated contribution of automation in furrow surge irrigation to water savings is 15% - 30%.

In canal automation, a gate or pump changes its position in response to changes in water level, flow rate or pressure, by activation of hydraulic, electrical or electronic devices without human intervention. Early canal automation, pre-fifties, utilized hydraulic gates for automatic upstream and downstream control. In the 1960’s and 1970’s, Electro-mechanical controllers were developed in Western U.S.A. Large water conveyance canals like the California Aqueduct were equipped with remote monitoring and control facilities.

In the early nineties, the use of PLC based automation systems was introduced in canal management. SCADA (Supervisory Control and Data Acquisition) and communications were upgraded and became more reliable. Integration of the different components had also been improved. Lately, internet cameras are installed next to central control gates in canal delivery systems sending photos in real-time, by wireless or the internet, to remote control centers that supervise their operation.

Nevertheless, automation of canal water supply remains a complex assignment. It needs reliable algorithms, sound simulation capabilities and high-skilled integrators for the programming of the operative plan.

Wide-scale integration of ICT and automation control in surface irrigation in the future has a substantial potential to increase water use efficiency also in that old-fashioned technology. Since surface irrigation encompasses most of the irrigated land on the globe and is the most water wasting technology, wide-scale incorporation of ICT and automation may have a tremendous impact on water savings in the world.

Automation and ICT in Water Supply Facilities

Automation and ICT were adopted in water supply facilities and networks since the early fifties. Most of modern water supply plants in the developed countries are nowadays fully automated, utilizing ICT for synchronization of water supply with demand, regulation of pumps operation for energy savings, coordination of withdrawal from different sources and reservoirs and control of purification processes in sewage reclamation facilities. The introduction of variable speed pumps, incorporating frequency adjustment drives, facilitates high-level regulation of discharge and pressure regime for savings of energy and water. The use of this advanced technology was boosted by the increase in oil price during the last decade.

The anticipated oil price hike in the future increases the incentive for more extensive adoption of ICT in water supply facilities. Energy savings by installed appliances, amount to 20% - 30% by increasing the efficiency of pumping units, balancing withdrawals and eliminating pressure surges and fluctuations.

Automation and ICT in the Municipal Sector

The municipal sector, particularly household water supply is lagging behind the agricultural and industrial sectors in controlling the water supply and consumption.

Most household consumers in the world do not pay for water according to consumption. Many of them do not pay at all for the water consumed. Only in limited number of countries, like Israel, each consumer's water outlet is equipped with a water meter. But, due to increasing worldwide water shortages, interest is growing in measuring household water consumption and invoicing the users according to the actual amount of water consumed.

In those countries that invoice households according to water consumption, labor saving devices have been developed like hand-held water-meter readers and wireless data broadcasting from consumers' water meters to central data loggers.

It had been proved that just the invoice of consumers according to the actual water consumption, brought about significant decrease in the municipal water demand, up to one third of the prior non-invoiced consumption. The ICT supported ample household invoice according to actual water use is essential for drastically decreasing the waste of water in the urban sector.

Automation in Landscaping and Sports Grounds

Since the early fifties of the 20th century, automated irrigation has been introduced to landscaping and sports grounds. In those disciplines, most of the irrigation control is time-based, using time as the parameter of irrigation programming. Only a minority of landscaping and sports irrigation systems are controlled on volumetric basis. In intensively cultivated areas, fertilizers are applied quantitatively or relatively with irrigation water by fertigation. In automated golf courses and soccer playgrounds, the turf can be kept vital and green, using half of the water amount used in manually operated systems.

Converting automation to volumetric basis and more extensive incorporation of ICT in landscaping and sports grounds irrigation networks may enable the charging for water according to consumption in these categories.

Modeling

Water supply to plants encompasses diverse factors relating to physiology, hydraulics, soil science, chemistry, climate and the environment. The optimization of water utilization by the crop requires the synchronization of the relevant factors in one comprehensive program.

Utilization of ICT in modeling facilitates the simulation and testing of the partial contribution of each single factor to optimization of water utilization. Research institutes have developed models that enriched our understanding of the plant-soil-water-environment relationships and facilitated improved irrigation scheduling.

Dedicated software has been developed for simulation of water distribution uniformity in different spacing between sprinklers based on the measured distribution pattern of a single sprinkler. Other software packages facilitate the calculation of the distribution uniformity (DU) of emitters in microirrigation. Software developed by ITRC (Irrigation Training and Research Center, California Polytechnic State University. San Luis Obispo, CA 93407) presents visually the distribution pattern of various emitters.

Modeling is widely used for the prediction of water distribution patterns in diverse soil types in different spacing of emitters in microirrigation. The simulation supports taking decisions in choosing equipment and its installation in the farm.

Modeling is also used extensively to predict the distribution pattern of nutrients and salts in the soil. That modeling supports the determination of plant nutrition and salt leaching policies.

Simplification of the models for support of taking decisions may expand their utilization by the community of irrigators. That will further improve land conservation; decrease the pollution of the environment and decrease fertilizer costs.

Phytomonitoring

In the last decade, comprehensive phytomonitoring systems have been developed for real-time monitoring of the plant response to changing environmental conditions. The monitoring appliances are comprised of sensors positioned on, or installed in proximity to a plant, a data collecting device and an information processing unit that receives and processes the data for determining the state of the plant. Communication channels transmit the data from the sensors to the decision maker.

Present available sensors are comprised of air humidity, air temperature, boundary diffusion layer resistance, solar radiation, soil moisture and soil temperature detectors.

Vegetal sensors include leaf temperature, flower temperature, fruit surface temperature, stem flux relative rate, stem diameter fluctuations, fruit growth rate and leaf CO_2 exchange detectors.

Each sensor has a built-in transmitter for broadcasting data signals to a data logger (a data storage device) and a receiver for the command signals sent from the controller. The communication between the data logger and the controller may be by wire or wireless (infrared or radio frequencies).

Phytomonitoring is yet implemented in limited scale, mainly in greenhouses. A vast amount of information and experience have been collected from these systems but beneficial wide-scale use of phytomonitoring in agriculture is yet doubtful.

Phytomonitoring needs intensive refinement and being more user friendly before it would be adopted by the average farmer for routine use.

Conclusions

ICT and automation in water supply and irrigation systems increased the efficiency of water use, facilitated higher production levels per land and water units and decreased manpower requirement. The water saved was used for expansion of the irrigated area and the increase of food production to feed the fast growing population on the globe.

Cost reduction, higher capabilities, improved reliability and higher wireless communication competence, turned automation and ICT into “must haves” in irrigation and water management. Investment capital can be recovered in 1 – 3 years by saving water and energy, expansion of the irrigated area and yield increase.

The price decline and increased efficiency are triggered by intensive competition between the veteran manufacturers and new players in the IT arena. Research institutes and advanced farmers, continuously expand and variegate the use of IT and automation in water management, saving manpower, rationalizing the utilization of inputs, resources and human capital as well as increasing production and farmers' net income.

Integration of scheduling capacity in water application controllers; real-time adjustment of timing and water amount by soil moisture and plant water potential sensors, fine-tuning of fertilizer – water ratio in fertigation and refinement of communication facilities tag irrigation in the high-tech category regarding precision and efficiency of input utilization. The expanding greenhouse sector implements comprehensive control systems that facilitate four to ten times yield increase in cash crops like tomatoes, peppers and cucumbers, comparing with uncontrolled open field cultivation.

Future development and expansion of ICT and automation in irrigation and water management is closely linked to the developments in five related topics:

1. Stricter demand for water use rationalization.

2. Empowerment and miniaturization of controlling and processing appliances.

3. Advancement in communication power.

4. Cost decline.

5. The capacity of financial and advisory bodies to introduce ICT and automation to new user circles of low-tech farmers and in developing countries including financial aid and follow-up.

The anticipated fast growth of world population in the near future and the scarcity of land and water resources, commit increasing the efficiency of natural resources utilization. Only extensive use of ICT in water and irrigation management, as well as the wide-scale implementation of comprehensive control systems in protected crops, will guarantee sufficient food supply to world population for the long run.

References

Boman B., S. Smith, and B. Tullos. (2002). ***Control and Automation in Citrus Microirrigation Systems***. University of Florida, IFAS Extension, Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville, FL 32611.

Burt C.M, P. Xianshu (2002). ***Advances in PLC-based canal automation***. ITRC paper no. P-002-001. USCID conference on Benchmarking Irrigation Systems Performance Using Water Measurement and Water Balances, July 9-12 2002, San Luis Obispo, CA.

Energy Savings with Adjustable Frequency Drives. (2001). Allen-Bradley, Rockwell Automation, 777 East Wisconsin Avenue, Suite 1400, Milwaukee, WI, 53202-5302 USA

Giacomelli G. A. (1998). ***Monitoring Plant Water Requirements within Integrated Crop Production Systems.*** In ISHS Acta Horticulture 458 publication – Proceedings of the International Symposium on Water Quality & Quantity in Greenhouses.

Hansen R., A. Hilton1, B. Berger, W. Pullan, Z. Gao and C. M. Lee (2004). ***Low-Cost Automation and Scada: A Pacific Rim Perspective***. Bureau of Reclamation, 302 East 1860 South, Provo, Utah, 84606, USA.

Harms T. (2004). ***Soil Moisture Based Web to Wireless Centre Pivot Operation***. Irrigation Branch, Alberta Agriculture, Food and Rural Development.

IriSense - a revolutionary, sophisticated, automatic sensor for irrigation control. AgriSupportOnline a.sh, Melbourne, Australia 2004.

Lamm F., T. Trooien, G. Clark, D. Rogers and M. Alam. (1997). ***SDI and Electrotechnologies.*** Kansas State University, KSU Northwest Research-Extension Center, Colby, Kansas 67701-1697.

Leib B.G., G. Matthews and M. Kroeger. (1999). ***Monitoring Irrigation System "On-Time" with Micro-Loggers.*** Paper No. PNW 99101. ASAE, 2950 Niles Rd., St. Joseph, MI 49085-9659 USA.

Panoras A.G.and I.G. Mavroudi. *(1996)*. ***Charging for irrigation water by volume-electricity would conserve water resources in Greece***. in: Water Reports 8 Irrigation Scheduling: From Theory to Practice – Proceedings of the ICID/FAO Workshop on Irrigation Scheduling FAO - Food and agriculture Organization of the United Nations ICID – CIID Rome, Italy, 12-13 September 1995.

PC-Based Automation Six Times More Efficient Than Before. Managing Automation, Thomas Publishing Co. 2005.

Playán E. and L. Mateos. (2004) ***Modernization and optimization of irrigation systems to increase water productivity.*** In Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 Sep – 1 Oct 2004.

Sapir E. and M. Sne. (2001) ***Sprinkler Irrigation.*** Center for International Agricultural Development Cooperation, Ministry of Agriculture and Rural Development, Bet Dagan 50250, ISRAEL

Shock C. C., E. B.G. Feibert, and L. D. Saunders. (1996). ***Automation of Subsurface Drip Irrigation for Onion Production.*** Malheur Experiment Station, Oregon State University Ontario, Oregon, 1996.

Sne M. (2005) ***Drip Irrigation***. Center for International Agricultural Development Cooperation, Ministry of Agriculture and Rural Development, Bet Dagan 50250, ISRAEL

Zazueta F. S., A. G. Smajstrla and G. A. Clark. (2002). ***Irrigation System Controllers.*** IFAS Extension, Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville, FL 32611.

Zoldoske, D. F., (1990). ***Computer Software for Irrigation Scheduling***. Center for Irrigation Technology (CIT) California Agricultural Technology Institute (Cati).

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