ENERGY EFFICIENCY IN PUMPING AND IRRIGATION SYSTEMS

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Contents

Summary

A well designed and maintained irrigation system will keep the environmental impacts, as well as the operating costs, of irrigation low. Both the water and the energy consumption required to distribute the water can be minimized with careful planning and implementation of irrigation efficiency measures. In addition, the installation of high-efficiency pumping equipment, or improvements to an existing pumping plant, will help reduce unnecessary pumping losses. This article summarizes efficiency measures for agricultural irrigation, and places particular emphasis on electric pumping plant efficiency, computerized irrigation scheduling, and irrigation load management.

1. Introduction

Irrigation accounts for a substantial portion of agricultural energy consumption. In the United States, irrigation is the fourth largest end use of energy in food production, following chemicals (fertilizers and pesticides), agricultural equipment, and transportation. Improving an irrigation system's efficiency can save both water and energy. An optimized irrigation plan will use the minimum amount of irrigation required. As the quantity of irrigated water is reduced, the energy required to distribute the water will likewise be reduced. Another essential factor of energy-efficient irrigation is the efficiency of the pumping plant. Careful selection and upkeep of the plant's components are paramount to highly efficient operation.

This article presents the primary efficiency opportunities for irrigation systems. The measures outlined relate to both water conservation and energy conservation and efficiency. Section 2 presents an overview of general efficiency opportunities, and

Sections 3 through 5 describe specific topics in greater length. In particular, Section 3 discusses the inherent inefficiencies associated with electric pumping plants, and provides recommended sources of information for improving plant efficiency. Section 4 details the merits of computerized scheduling for optimizing irrigation, and Section 5 describes how irrigation load management can benefit consumers and utility companies.

2. Energy-Efficient Irrigation

The energy required in crop irrigation is a function of the level of pumping required. Pumping energy requirements, in turn, depend on several main factors:

- the amount of vertical lift from the depth of the water source to the height of the application,
- the water pressure required for the type of irrigation (e.g., high pressure for hydraulic gun sprinklers and low pressure for micro- and surface irrigation),
- depth of irrigation,
- frequency of irrigation, and
- the water system efficiency of the pumping system (i.e., the combination of water source, pumping plant, and distribution system).

Therefore, energy may be saved in irrigation by addressing these five points. First of all, is it possible to reduce the depth of the water source? Are there any water sources at higher elevations? Second, is it feasible to choose an irrigation method with lower pressure, such as micro-irrigation? Low-pressure systems eliminate the need for additional booster pumps. Third, can the depth of irrigation be reduced? Is the crop watered extensively? Is it watered too heavily in particular areas? For example, many surface irrigation systems that rely on gravity for water distribution end up watering the high side of fields more than necessary. Fourth, is the field watered more frequently than required? Care must be taken to know the correct amount of water required, and at what interval, for a given crop. Last, and very important, is the pumping system operating with high efficiency? Pumping system efficiency is related to the proper match between the pumping plant, water source, and distribution system. It is also a function of components, including the motor or engine, the drive shaft, and the pump assembly. Good design, as well as maintenance of the pumping system (e.g., pump repair and distribution system leak repair), can go a long way towards improving efficiency. Some of the primary efficiency measures associated with irrigation use are itemized below. It is important to remember that any conservation of water also conserves pumping energy.

Choose the appropriate crop for a given soil: It is best to plant the types of crops that use water most effectively for a given soil type.

Use only the required amount of water: Table 1 lists some approximate annual amounts of water required for various crops. It is important to use only the amount of water necessary for a particular crop, soil type, and region. Over-watering and nonuniform watering—in which some areas are over-watered while others are watered correctly—result in wasted water and pumping power.

Type of crop	Approximate annual water requirement (acre-feet)*
Alfalfa	3 to 4.5
Barley	Dryland to 1
Beans	1.25 to 1.75
Beets	2 to 3
Chile peppers	1.5 to 2
Corn	1 to 2
Cotton	3 to 3.5
Grapes	2.5 to 3.5
Grain, sorghums	1.5 to 2
Lettuce	1
Onions	1.5
Orchard, fruit	2 to 3.5
Peanuts	1
Pecans	3 to 4
Permanent pasture	3 to 4.5
Potatoes	2.75 to 3.5
Tomatoes	2 to 3
Wheat	Dryland to 2

*****4047 m^2 30.48cm^{-1} (1 acre = 4047 m^2; 1 foot =30.48cm)

Table 1. Representative water requirements of selected crops. Source: data compiled from Energy Conservation and Management Division of the New Mexico Energy, Minerals and Natural Resources Department, with assistance of the Water Resources Research Institute at New Mexico State University. (1992). *Saving Energy in Irrigation,* Table 1. Santa Fe, NM, USA: New Mexico Energy, Minerals and Natural Resources Department and Water Resources Research Institute.

Apply water at proper intervals for the soil type: Sandy soils generally require more frequent irrigation than heavy soils such as clay, because sandier soils drain more quickly. Therefore, it is usually best to apply the same quantity of water during a given application to a sandy soil as would be applied to a clay soil, but the applications should be more frequent for sandy soils. Heavy frequent irrigation wastes water and energy, and heavy infrequent irrigation is not as productive for sandy soils.

Eliminate unnecessary water loss: Water can be lost through leaks in pipes, valves, fittings, connections, and so on. Make sure that leaks are repaired in a timely manner to reduce water and pumping energy loss.

Consider nighttime irrigation: Irrigate at night if feasible. Nighttime irrigation will save significant water and energy compared with daytime irrigation, since less water will evaporate. Nighttime irrigation is particularly attractive for crops that are sprinkler-irrigated.

Increase pump and engine or motor efficiency: Pump and engine or motor efficiency can be increased by good operation and maintenance practices. In addition, it may be feasible to replace inefficient equipment with high-efficiency models.

Minimize water pressure if possible: Pressurize the water only to the point required by the given irrigation system.

Choose the most appropriate irrigation method: Evaluate the crop, soil, and region carefully when determining the most efficient and cost-effective irrigation method to use. The three primary methods are surface irrigation, micro-irrigation, and sprinkler irrigation.

Improve surface irrigation efficiency: Surface irrigation requires the least amount of pumping energy because the water flows by gravity along the field. However, a surface irrigation system can be inefficient in terms of water loss if not carefully designed. There are several types of surface irrigation, including furrow, flood, and surge. For furrow and flood systems, care must be taken to prevent soil from being over-saturated at the high point of the field due to percolation, and to reduce tail-water at the low point of the field. Surge systems apply water intermittently to a furrow with the use of surge valves. This improves irrigation efficiency over conventional furrow and flood systems. The use of gated pipes (i.e., pipes with openings called “gates” on their sides) will improve efficiency over the use of header ditches in surface irrigation systems. Automated gated pipe systems are also available. In addition, the capture and reuse of tail-water will reduce water loss, though not without the small expense of pumping the water back to the top of the field. Since the pumping power required for surface pumping is considerably smaller than required for pumping groundwater, tail-water reuse in usually justified. It is also important to reduce seepage and general water loss by lining ditches with concrete or plastic, preventing rodent burrowing, and controlling weeds.

Consider using micro-irrigation: Micro-irrigation systems, such as bubblers and drip emitters, apply water near the bases of individual plants. This reduces seepage and evaporation losses compared with systems that water the entire soil surface or row. If used correctly, micro-irrigation systems are very water-efficient, and require low pumping power. However, they are most cost-effective for applications in which the bubblers and emitters can remain in place, for example in orchards or vineyards. In some cases, they are feasible for vegetable crops, if the crops are of high value.

Choose an efficient sprinkler system: If a sprinkler system is the most viable approach for a given crop and conditions, consider selecting a low-energy sprinkler. The Low Energy Precision Application (LEPA) center pivot system is an improvement over conventional sprinkler systems. It uses lower pressure water, and applies the water between 20 and 38 centimeters (8 and 15 inches) above the soil. This reduces pumping energy, as well as evaporation losses. The system also incorporates circular farming and furrow dikes (see next item) to prevent water runoff loss.

Use furrow dikes: Furrow dikes are installed with specialized diking equipment. The equipment creates mounds in furrows to contain water and eliminate runoff. Though very effective at reducing water consumption, some farmers object to the additional labor involved to create, and later remove, the dikes.

Measure soil water content: Devices such as evaporation pans, gypsum blocks, and tensiometers can be used to measure soil moisture and to aid in irrigation scheduling. In addition, soil moisture can be judged by the “feel” method. Another valuable method for scheduling, using computers, is based on the water budget approach (see Section 4).

Use a laser for leveling fields: A laser is an excellent tool for leveling fields. Laser-leveling systems often consist of a rotating laser beam that is attached to a command post. As the laser rotates, the command post transmits a signal to a receiver located on the scraper of the tractor in the field. The signal from the laser controls the work of the scraper to produce a very level field. Level fields enable a more uniform distribution of water.

Design wells, pumps, and distribution systems carefully: An irrigation well should be designed and constructed with care by experts to ensure the well’s success as a water resource. In addition, the pump and well should be designed in concert to match the irrigation requirements. It is also important to size the piping and distribution system to handle the flow efficiently.

Choose efficient pumps: Irrigation pumps are electric or fossil-fuel fired. (Section 3 discusses electric pumping plant efficiency in more detail.) To minimize energy use, select the most efficient pump available that also meets acceptable economic criteria. In an increasing number of applications, photovoltaic water pumps are viable. Photovoltaic systems are highly efficient, but may not be economically practical for large irrigation needs. However, as energy costs rise, and as photovoltaic technology matures, these systems are becoming more feasible.

Employ load management practices: Although load management will not necessarily save pumping energy for the irrigator, it will reduce the burden on utilities during peak demand hours. Many utilities offer the incentive of reduced rates for consumers who shift loads to off-peak hours. This could also translate to energy savings for irrigators in some cases; for example, if they convert to nighttime watering, irrigators will also benefit from reduced water loss to evaporation. (Section 5 describes irrigation load management more thoroughly.)

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Biographical Sketch

Clark W. Gellings' 30-year career in energy spans from hands-on wiring in factories and homes to the design of lighting and energy systems to his invention of "demand-side management" (DSM). He coined the term DSM and developed the accompanying DSM framework, guidebooks, and models now in use throughout the world. He provides leadership in the Electric Power Research Institute (EPRI), an organization that is second in the world only to the US Department of Energy (in dollars) in the development of energy efficiency technologies. Mr. Gellings has demonstrated a unique ability to understand what energy customers want and need, and then implement systems to develop and deliver a set of R&D programs to meet the challenge. Among his most significant accomplishments is his success in leading a team with an outstanding track record in forging tailored collaborations—alliances among utilities, industry associations, government agencies, and academia—to leverage R&D dollars for the maximum benefit. Mr. Gellings has published 10 books, more than 400 articles, and has presented papers at numerous conferences. Some of his many honors include seven awards in lighting design and the Bernard Price Memorial Lecture Award of the South African Institute of Electrical Engineers. He has been elected a fellow of the Institute of Electrical and Electronics Engineers and the Illuminating Engineering Society of North America. He won the 1992 DSM Achiever of the Year Award of the Association of Energy Engineers for having invented DSM. He has served as an advisor to the US Congress Office of Technical Assessment panel on energy efficiency, and currently serves as a member of the Board of Directors for the California Institute for Energy Efficiency.