African Journal of Agriculture and Food Science
ISSN: 2689-5331
Volume 8, Issue 1, 2025 (pp. 73-82)
www.abjournals.org

IMPLEMENTING EFFICIENT IRRIGATION SYSTEMS FOR CROP PRODUCTION

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Cite this article:

Tom, C. N., Edet, J. A., Gam, E. N., Sam, E. O. (2025), Implementing Efficient Irrigation Systems for Crop Production. African Journal of Agriculture and Food Science 8(1), 73-82. DOI: 10.52589/AJAFS-OFRKH9VD

Manuscript History

Received: 16 Jan 2025

Accepted: 19 Feb 2025

Published: 25 Mar 2025

ABSTRACT: *Irrigation is the supply of water to crops by artificial means. It is designed to permit the desired plant growth in arid regions and to offset drought in semiarid regions or subhumid regions. Even in areas where average seasonal precipitation may seem ample, rains are frequently unevenly distributed, or soils have low water holding capacities so that traditional rain-fed agriculture is a high-risk enterprise. Irrigation provides a means for stable food production. In some areas, irrigation prolongs the effective growing season. With the security provided by irrigation, additional inputs like higher producing varieties, additional fertilizer, better pest control, and improved tillage, become economically feasible. Irrigation reduces the risk of these expensive inputs being wasted by drought. As the worldwide population continues to grow, irrigated agriculture will be an increasingly important contributor to meet the worldwide demands for food, fiber, animal feed and biofuels. In the United States, irrigated farmlands comprise just 17 percent of crop acres, which contributes about half the value of total crops sales. However, irrigated farmland is credited with the largest share of the national consumptive use. While striving to meet the growing demand for more crops, the competing demands on the available water supply for human well-being and protecting the environment have to be resolved. Efficient irrigation is an integral part of meeting these future challenges.*

KEYWORDS: Implementing, Efficient, Irrigation, Systems, Crop, Production.

Article DOI: 10.52589/AJAFS-OFRKH9VD
DOI URL: https://doi.org/10.52589/AJAFS-OFRKH9VD

INTRODUCTION

According to the 2006 Census of Agriculture, there are 1.3 million farms with about 613 million acres of land or about 25 percent of all land area in the Nigeria is farmland. Of that, 210 million acres are harvested cropland. The 2016 Farm and Ranch Irrigation Survey reveals that there are 103,314 farms (5 percent of all farms) using irrigation. Based on the various irrigation methods being used, more than 49 million acres are irrigated. Included in the irrigated acreage are more than 300,000 acres and 1.2 billion square feet of protected growing space for horticultural crops (FAO, 2011). The irrigation association recognizes that there are many experts who have devoted their careers to improving agricultural crop production. While adequate water applied at the correct time is necessary to produce significant yields, irrigation is just one part of all that a grower must take into account. The principles for irrigation efficiency must work in harmony with other best practices for growing plants, including soil, nutrient and pest management (Edet *et al*., 2022).

According to Jovicich (2018), the Principles of efficient Agricultural irrigation identifies the key concepts that a grower or producer should follow to attain the most efficient use of water. The following are the major principles for efficient agricultural irrigation:

- Use qualified professionals. While demand increases for food, fiber, animal feed and biofuels, there is equally as much demand that agricultural growers be good stewards for all resources — including water used to produce a crop.

The marketplace is becoming much more complicated and sophisticated, and the need for good advice is essential for success. There are many sources a grower can turn to for education, information and help in making good decisions on how to best use resources. This is especially true as growers adopt precision agriculture methods and strive to be more sustainable in their operations. According to reports from the United States Department of Agriculture, only about 10 percent of growers seek advice to help them manage water resources better.

Irrigation professionals who are engineers and designers trained in irrigation systems are a great advantage when managing water resources for irrigation. All irrigation systems should be evaluated to determine the best method for applying water to a field. Irrigation professionals are trained in understanding the details and specifics of various types of irrigation systems (Usoh *et al*., 2023).

A grower can obtain valuable information by consulting with an irrigation equipment dealer or manufacturer for design, installation, maintenance and management of the system. Seek out professional agricultural engineers or certified irrigation designers to help select an appropriate irrigation system and equipment to match the needs of farm operations (Edna, 2003).

In addition to irrigation professionals, Natural Resources Conservation Service personnel, many universities, state extension agents and independent crop advisors are trained in many aspects of agricultural production. Often, they are aware of programs that are available for implementing or improving irrigation efficiency and how that would integrate into the overall crop production. They can provide expertise in soils and nutrient management that can influence irrigation management decisions.

- Know the water supply. Understanding the source of water is a key part of selecting an irrigation method or system that will deliver water efficiently. The availability, quantity and

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reliability of the various sources of water are extremely important in planning an irrigation system. Growers should first maximize the benefit of rainfall, but the challenges of ever-changing weather patterns complicates determining when and how much rainfall will be available. Irrigation systems provide a producer with a method to apply water when it is needed (Sam *et al*., 2022c). However, the source of the water can also change or depend upon advanced notification for delivery to the field. If surface water is the source for the grower, it is likewise influenced by changing weather patterns. Many irrigation systems rely on pumped groundwater, and as water tables change, the quantity of water available from a well can change. As important as a reliable source of water is, it is also important to understand the quality of the water so that 1) crops selected can work well with the water source, and 2) the water is safe for producing food crops. Additionally, a grower must understand and comply with local water laws and water rights (FAO, 2005).

Figure 1: The Water Supply Source

- Identify the soil type. A fundamental requirement for efficient irrigation is to know the type of soil or soils in the field. A few simple soil tests can provide valuable information that impact irrigation efficiency, such as soil type and the water-holding capacity and infiltration rate of that soil. Having access to soils maps and/or surveying the soil to identify variations within the field are useful for making adjustments to the nutrient and water application requirements during the growing season. Additionally, understanding some of the soil chemistry and how it may interact with the water source can influence the effectiveness of irrigation scheduling events. While not a specific soil property, understanding the topography of the field will influence the selection of the most appropriate irrigation method or system depending on the type of crops being grown (Lifarraga, *et al*., 2003).

Figure 2: Soil Type Determination

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- Understand crop water needs. As crops grow, it is important to account for the stages of development and response to changes in weather. Some stages of growth are very sensitive to having an adequate amount of soil water to achieve the best yield. One of the best methods to determine and plan for crop water needs is to use evapotranspiration [ET] data. Accessing reference ET data and modifying it to fit the particular crop can be used by the grower to estimate the next irrigation event and the amount of water that will need to be applied. This needs to include accounting for the current level of available water in the root zone. The irrigation water requirements determined by using ET data should be field-verified with site measurements and observations to maximize the benefit of each irrigation event. Using sensors of different types, probing the soil and observing crop conditions all work together to provide the grower with essential information that will contribute to improved irrigation efficiency.

- Select appropriate irrigation methods. Irrigation methods fall into two basic categories: pressurized irrigation and surface or gravity-fed irrigation. Pressurized irrigation involves the use of pumps, piping, valves and either sprinklers or low-volume emission devices. Surface systems rely on slope, contours and field geometry so that the water moves to cover the intended area by gravity. An efficient irrigation system or method must consider the soil type and properties, field topography and the type of crops being grown. Another consideration is how the irrigation system integrates into other farm operations such as planting, cultivating and harvesting. Additionally, water quantity, availability and reliability will influence the type of system that best meets the needs of the area to be irrigated (USDA, 2013).

The type of crop, cost of water and energy, availability of skilled labor, and long-term cost of system ownership should be part of the evaluation process when selecting the irrigation system. Usually, several methods can be used for a given field, but often the economics influence the final selection of the irrigation method. Properly designed and maintained systems will have a positive impact on the expected application efficiency of any system, but the management skill of the operator in implementing irrigation schedules will impact the overall irrigation efficiency the most.

- Implement irrigation scheduling. Irrigation scheduling is a planning and decision-making process used to determine the amount and timing of irrigation applications. Because water is such a critical component for a good yield, and depending on the cost of water and energy, the grower can have different motivations or goals that will influence irrigation scheduling and the amount of water applied.

Depending on the grower’s goals, irrigation scheduling can be achieve based on the following: (FAO, 1999)

- Highest yield.
- Optimum yield per unit of water applied.
- Maximum net return.

Usually, the goal of highest yield is pursued when water and energy costs are relatively low. However, when the available water supply is restricted or energy costs are high, the goals of optimum yield and maximum return begin to influence the decision of when and how much to irrigate. Sometimes a reduced yield is preferred when the net return improves because the cost of additional irrigation is not offset by an increase in yield. Irrigation scheduling can be either

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reactive or predictive. The reactive approach is usually based on a visual indication such as plant stress, soil water measurements or canopy temperature. The reactive approach doesn't determine how much water should be applied nor anticipate when the next irrigation event should be. The predictive method of irrigation scheduling estimates the amount of water to be applied and when it should be applied based on recent crop water use, soil water properties and depth of the rooting system. Efficient irrigation will strive to maximize the benefit of rainfall. Accounting for rainfall and even anticipating the next rainfall will greatly influence irrigation scheduling (FAO, 2011).

According to Stetson (2011), irrigation scheduling requires knowing two things: 1) the appropriate amount of water to apply, and 2) when to apply that water. For most irrigation events, a fixed amount of water is applied allowing only a certain fraction of the available water o be used by the plant. The variable becomes the interval between irrigation events. If the irrigation event timing or interval is fixed, then the quantity of water to apply becomes the variable, which becomes more challenging to manage, especially for most surface irrigation methods.

The main methods of irrigation scheduling include climate-based, soil-based or plant-based. Soil-based and plant-based indicate when irrigation is needed. Climate-based scheduling, on the other hand, determines the amount of water to apply and can then be used to predict the next irrigation event.

- Apply technology. There are and have been many new innovations and advances in technology, which can be utilized by the grower/producer and will help in using water resources more efficiently to achieve desired yield goals. The concept of "precision agriculture" relies extensively on technology to maximize the benefit of resources being used to grow a crop. The challenge of being able to grow enough food, fiber, feed and fuel for a growing world population will rely on the innovations in technology that can be applied to agriculture and adopted by the grower (Tom *et al*., 2022).

Advances in wireless technology have greatly facilitated getting information from the field. Wireless technology such as Wi-Fi or cloud-based is being incorporated into other technologies such as soil moisture sensors and plant canopy sensors, making it easier for the grower to access the data and get real-time feedback on field conditions. Irrigation controllers on center pivot or linear move machines can utilize GPS and customize water application to areas of the field. Other technologies such as thermal imaging in different spectrums from instruments on unmanned aerial vehicles can affordably survey an entire crop so that a grower or a consultant/advisor can make better and quicker management decisions (Udom et al., 2023).

The key to success for using any of the technologies is making it practical for the grower to use. The evolution of smart technology allows a grower to use mobile devices such as smart phones and tablets to access information readily. Getting data from field instruments or accessing weather data or irrigation scheduling programs enables a grower Principles of Efficient Agricultural Irrigation to respond quickly to changing conditions. Timely decisions can have a profound impact on improving irrigation efficiency and crop yields (Hakari, *et al*., 2017).

In addition to technology that can directly affect the amount of water used for irrigation, many pressurized irrigation systems can be combined with other technologies to deliver fertilizers

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and other chemicals to the crop. Fertigation and chemigation can save time, energy and products, but success is very dependent on the proper equipment and the skill and knowledge of the irrigator (Edet et al., 2022).

- Maintain accurate records. Keeping records is not the favorite activity of most growers, but careful record keeping is essential to comply with numerous regulations or to meet the requirements of crop buyers. However, good records that are organized and easily accessed are a great management tool. Good records provide the information that influence the decision-making process and guide future planning. For efficient irrigation, the following types of records and data are useful:

- Weather data — Access to a nearby weather station to obtain recent weather such as ET data is needed for irrigation scheduling. ET data along with stages of crop development help estimate the root zone soil moisture balance. Tracking area rainfall is also important, but a way to track rainfall at the field is best, since weather stations can be located a number of miles from where the crop is located (Sam *et al*., 2022c).

- Water measurement — keeping water use records is essential to truly identify how efficient the irrigation events are. Estimating how much water to apply and then comparing it to the water actually applied will give the grower valuable information for making any necessary adjustments in the irrigation schedule. It can also provide good information about the reliability of the source of water. Having a reliable meter or flow sensor can make this job easier. Having it accessible from a remote location such as the grower's office makes collecting and recording the quantity of water use easier. Maintaining thorough water use records also provides growers an invaluable tool to defend and justify the amount of water being used, especially when combined with energy costs and yield records. In some jurisdictions, accurate water use records are currently required (Edet *et al*., 2022).

- Water quality — having water samples tested is necessary to ascertain what is in the water. Poor water quality can have a negative effect on the crop. Water quality can impact what type of crops could be successfully planted and grown. It is important to know information about the water chemistry and document how it might react with the soil chemistry. If leaching is necessary, the data can help determine how much additional water is needed to minimize damage to the crops and the soils.

- System performance — Documenting how a system is performing can help reveal how well water is being distributed across the field. It can provide an indication of the performance by the emission devices and how well the systems are being maintained. Performing system audits can give guidance on system maintenance procedures and longevity of emission devices. As system performance degrades over time, it will impact the amount of water being used or how effective the water is being applied. Systems performing well facilitate management strategies such as deficit irrigation and its impact for lower water use.

- System maintenance — Part of system maintenance is doing inspections and keeping track of identified problems and when they are corrected. System maintenance is done so that the system is operating or functioning optimally. Broken pipes, fittings, sprinklers and emission devices, as well as banks and furrows, allow water to be wasted or used ineffectively. A proactive approach to system maintenance anticipates problems and takes corrective action ahead of time. This will have a positive impact on irrigation efficiency, where as a reactive

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approach to problems when they are obvious usually means water has already been wasted. Tracking the maintenance procedures and the associated costs can influence when a system needs to be modified, upgraded or replaced.

- Energy costs — the embedded energy in water to make it useful has to be considered not only in the initial design and installation but also over the long term to properly operate the system. Timing irrigation events carefully and potentially skipping an event or reducing the run time can save a significant amount of money and water.

- Efficiency analysis — There are many types of efficiency associated with water and irrigation that can be analyzed. Each type has a useful purpose. The key efficiency measurements that should be considered, depending on the irrigation method include: (Usoh *et al*., 2023).

❖ Water conveyance efficiency, which is an important consideration for surface irrigation methods. Conveyance efficiency is the amount of water delivered to the field boundary compared to the amount of water diverted at its source. There can be many losses if there is a long ditch and if the type of ditch is lined or an earthen or unlined ditch.

❖ Application efficiency, which is the amount of water stored in the crop root zone compared to the volume of water delivered to the field. This can be evaluated after every irrigation event. Wind drift, canopy interception, runoff and deep percolation are examples of losses that will impact application efficiency.

❖ Irrigation efficiency, which is defined as the amount of water beneficially used compared to the amount of water delivered to the field. Water used for leaching salts out of the root zone, frost protection, crop cooling, and pesticide or fertilizer applications are all examples of beneficial uses of water that are not directly linked to crop growth. Losses similar to those listed under application efficiency also negatively affect irrigation efficiency (FAO, 2021).

Other analysis that could be done includes comparing the goals identified in irrigation scheduling to the end result. For example, water productivity compares yield to water input, which can be a useful data point for future decisions. Good records and proper analysis will be useful as a grower moves toward a more sustainable operation.

- Respond to water shortages. Water shortages are often a reality in areas where irrigation is most often required to have a successful crop. Changing weather patterns including changes in precipitation or temperature can impact the grower. Irrigation is one way to ensure a viable crop if an area is hit by drought or other water shortages. Sometimes water shortages can be created by policy, regulation or pricing, and the effect on the grower and crop production is nearly the same. When it is necessary to reduce the amount of water being used, the principles of efficient irrigation offer the grower several strategies that may promote success. Improving the performance and efficiency of the irrigation system needs to be a high priority (USDA, 2016).

- Delivering water to the field very uniformly can actually reduce the total amount of water needed. Changing crops could be an option if it is an annual or seasonal crop and if the grower’s existing equipment can still be used. Reducing the acreage planted can be an option, but if it is a permanent crop such as a vineyard or orchard, that is not easily done or would be extremely costly considering the time invested in growing and establishing the plants. Another

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option is to practice deficit irrigation-purposely not irrigating adequately at opportune times during crop development. Some crops will respond well to that strategy while others are very sensitive to being water-stressed, making this a nonviable option. Some water shortages can be planned for, while others are beyond the control of the grower, and severe drought will have a huge impact, especially if it becomes multiyear in duration (Georgios, *et al*., 2019).

CONCLUSION

On a global scale, irrigation has a profound impact on fresh water supplies, world food production, and the aesthetics and value of landscapes. One-third of the world's food comes from the 21% of the world's cultivated area that is irrigated. In the U.S., irrigated agriculture accounted for about half of the total value of crop sales on 28% of harvested crop land in 2012 (USDA, 2019).

Irrigation has turned many of the earth's driest and most fertile lands into important crop producing regions. For example, Egypt could grow virtually no food without water drawn from the Nile or from underground aquifers.

A report from the United Nations Food and Agriculture Organization states, Irrigated land is more than twice as productive as rain-fed cropland. Today, only 16 percent of the world's croplands are irrigated, but those lands yield some 36 percent of the global harvest. In the developing countries, irrigation increases yields for most crops by 100 to 400 percent. Irrigation also allows farmers to reap the economic benefits of growing higher-value cash crops. Half or even two-thirds of future gains in crop production are expected to come from irrigated land.

According to the Economic Research Service of the United States Department of Agriculture in a report updated in October 2016, irrigated agriculture accounts for the largest share of the nation's consumptive water use and makes a significant contribution to the value of U.S. agricultural production. In 2012, irrigated farms accounted for roughly half of the total value of crop sales on just 17 percent of U.S. cropland. The ERS/USDA report also states that, "The future of irrigated agriculture will depend in part on producers' ability to improve on-farm water management for crop production. Upgrades in irrigation system technologies and improved water-management practices can enhance on-farm water-use efficiency."

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