P-ISSN: 2305-6622; E-ISSN: 2306-3599
International Journal of Agriculture and Biosciences
www.ijagbio.com; editor@ijagbio.com
Review Article https://doi.org/10.47278/journal.ijab/2022.033

Sustainable Water Use in Agriculture: A Review of Worldwide Research

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Article History: 22-294 Received: 24-Aug-2022 Revised: 29-Sep-2022 Accepted: 28-Oct-2022

ABSTRACT

Water is widely considered as the most important resource for long-term agricultural development. Irrigated land will be added to as residential and industrial demand increases and agricultural freshwater supplies will be transferred to do so. Furthermore, crops consume less than 66% of irrigation water, which is a very low efficiency. Arid-region agriculture prioritizes irrigation water conservation. Many efforts have been made over time to enact policies aimed at improving water efficiency in response to water scarcity and climate change, on the assumption that better management may achieve more with less water. Increased water allocation and greater irrigation water efficiency are typical components of improved management. In comparison to the latter, the former is mostly determined by irrigation technique, environmental conditions, and water application schedule. Sustainable water management in agriculture includes soil management, irrigation, fertilizer application, pest and disease control, and environmental preservation. Water resources for agriculture are limited due to socioeconomic demands and climate change. Rural community social behavior, economic constraints, and the institutional and legal context all have an impact on the adoption of sustainable water management in the Mediterranean. Depending on these criteria, certain solutions may be more likely to be implemented. Changes in irrigation application, soil and plant practices, water price, reusing treated wastewater, farmer participation in water management, and capacity building are all approaches to achieve sustainable water management in Southern European agriculture.

Key words: Efficient irrigation, Irrigation system, Sustainability.

INTRODUCTION

The most important component of the ecosystem is water since it has a significant impact on both human and animal health. Industry, agriculture and economic growth all depend on it (Du, Kang, Zhang, & Davies, 2015). Numerous factors, including population growth, the rise of irrigation agriculture, industrialization, and climate change, are putting pressure on the quantity and quality of the ecological ecosystems. Man is aware that given the problems, he cannot continue to use natural resources like water in a "use and throw away" fashion. As a result, having a consistent plan is essential for the effective management of water resources (Luis S Pereira, Cordery, & Iacovides, 2012). The amount of irrigated land on earth has increased by more than 2610 lac hectares since 1901, more than doubling it from 40 million hectares. 39% of the world's food supply is currently produced through irrigated agriculture. Due to the expansion of irrigated fields by more than 1.2% year, the demand for irrigation water will have increased by 14.8% by 2028. In order to meet the growing demand from residential and commercial sectors, 9–16% of the fresh water utilized for agricultural will be transferred (Du et al., 2015; Luis S Pereira et al., 2012). The crop utilizes only 57% of the water that is available, therefore irrigation is inefficient. Increasing water efficiency and using marginal rivers are crucial for reducing the water shortage in agriculture (Chartzoulakis & Bertaki, 2015).

Cite This Article as: Ahmed W, Safdar U, Ali A, Haider K, Tahir N, Sajid S, Ahmad M, Khalid MN, 2022. Sustainable water use in agriculture: a review of worldwide research. Int J Agri Biosci, 11(4): 246-250. https://doi.org/10.47278/journal.ijab/2022.033

Agriculture Productivity and Water

Agriculture currently uses 71% of all water resources, primarily for irrigation. Despite the fact that irrigation has been used for thousands of years, most irrigated land was first developed in the 20^{th} century (Gomiero, Pimentel, & Paoletti, 2011). Irrigated land may be enlarged and agricultural productivity may be increased with sufficient irrigation. The extension of irrigated land was significantly delayed in the 1980s by a number of causes, including the high cost of installing irrigation systems, soil salinization, the depletion of irrigation water sources, and environmental concerns. But as the population grows, irrigation will become more crucial for increasing the effectiveness of crop breeding and land use. Water for irrigation is expected to become more and more scarce as irrigated agriculture expands. Water must always be available in order for irrigation to be sustained (Davis, Rulli, Seveso, & D'Odorico, 2017). Water conservation is the main goal of irrigation development, especially in regions with scarce water supplies. It is critical to support and motivate farmers as they switch from antiquated irrigation and agricultural practices to those that conserve water in this period of fast change and resource scarcity. It has taken a lot of work over the years to develop regulations that promote water conservation in times of water constraint. This is predicated on the idea that with better management, more may be done with less water. The phrase "better management" refers to raising irrigation and/or water allocation efficiency. The latter is substantially impacted by irrigation technique, setting, and timing of water application (Harwood, 2020).

It is well known that up until a saturation point, agricultural productivity rises with root zone water availability, but then falls. Climate, soil type, and the use of less agricultural inputs like fertilizers and pesticides have an impact on each crop's production response curve. As a result, a farmer would find it challenging to predict when a water scarcity would occur (Du et al., 2015; Gomiero et al., 2011). When associated costs are reasonable and there is no chance of a water surplus, farmers may routinely raise irrigation flow to "play it safe." Over-irrigation can result in nutrient loss through leaching or deep percolation, groundwater pollution with pesticides, temporary water shortages for other farmers, wet crops, a climate conducive to the development of disease, a drop in crop yield and quality, and an increase in production costs (Chartzoulakis & Bertaki, 2015).

Agriculture's Sustainable Water Management

Sustainable water management in agriculture is to achieve a balance between water supply and demand in terms of quantity, quality, location, cost, time and environmental impact. Social norms, economic restrictions, institutional and regulatory frameworks, and farming techniques all impact the adoption of technology in rural areas. In water demand management, irrigation scheduling has been given greater consideration than irrigation technology (how to apply the water in the field). Numerous factors, including crop development stage, susceptibility to water stress, climatic conditions, and soil water availability, influence irrigation schedule and frequency. Timing and irrigation technology are intricately related, as irrigation technique determines the frequency with which plants are watered (Falkenmark, 2013).

Localized Irrigation

Localized irrigation is typically considered one of the most effective agricultural irrigation systems. Standard targeted irrigation systems supply water to specific plants through underground plastic pipes. Less than 12 l/h of water is distributed through small emitter pores in plastic tubing during drip irrigation. Micro sprayers distribute between 13 and 300 l/h of irrigation water to a plant's soil surface (micro-sprinkler). Lower application costs, direct water delivery to the root system in conveniently accessible regions, and less water loss during or after water administration are the three primary objectives of localized irrigation (less labor). According to research conducted in India, Israel, Spain, and the United States, drip irrigation increases agricultural yields by 20 to 90 percent while decreasing water consumption by 30 to 70 percent (Baye, 2011; Venot, Kuper, & Zwarteveen, 2017). Drip irrigation is a crucial answer to the problem of boosting agricultural productivity in the face of severe water scarcity because it frequently results in a 50% increase in yield per unit of water. Despite a 50-fold increase over the past two decades, localized irrigation accounts for less than 6% of the world's irrigated land. Its expanding potential is constrained by its high investment requirements and sensitivity to obstruction (Davis et al., 2017).

Planning of the Irrigation System

Irrigation scheduling is the process of deciding when and how much water to apply to crops. It is required to promote agricultural sustainability while conserving water and improving the performance and longevity of irrigation systems. To determine when to irrigate, the peculiarities of the soil's water content, and the amount of water to apply, research is required. When to irrigate is also influenced by the efficacy of the irrigation method (Nazari, Liaghat, Akbari, & Keshavarz, 2018). At the field level, the efficiency of irrigation scheduling is typically determined by the farmer's skill. A well-planned irrigation strategy will boost agricultural yields and quality, improve soil moisture conditions for plant growth, and prevent the water table from gradually being salinized. Flooding is avoided by relocating fertilizers and agrochemicals away from the root zone and regulating deep percolation. Irrigation planning is more important in locations with limited water resources than in areas with ample water resources, because increased water demand may result in a shortage for other users or applications (Dhawan, 2017).

There are various successful irrigation scheduling techniques and methodologies. Based on soil water measurements, projected soil water balances, and signals of plant stress, irrigation timing and depth parameters can be established in a variety of ways, using either basic rules or more complicated algorithms. Before they can be implemented in practice, many of them need to be improved or investigated further (Lalehzari, Boroomand Nasab, Moazed, & Haghighi, 2016). They typically require the assistance of extension specialists, extension programs, and farmers who are technologically literate. However, the majority of countries lack these programs due to their high cost, a lack of qualified extension personnel, farmers' inadequate grasp of water conservation in irrigation, and the institutional frameworks created for irrigation management's low priority for farm systems. As a result, its application in agricultural operations is fairly limited. The following overview emphasizes the significance and use of irrigation scheduling systems (Dai & Li, 2013).

Soil Water Monitoring

Soil moisture directly influences plant growth by managing the plant's water status. The two techniques to determining if there is enough water in the soil for plant growth are to measure the amount of water in the soil and to analyses its capacity to hold that water (soil water potential). Because of the geographic and depth heterogeneity of soil water, the accuracy of the data is dependent on the sampling procedures and point observation sites used (Sullivan & Delp, 2012).

Crop's Response to Various Stresses

It is possible to acquire a signal from the plant itself that indicates the irrigation period but not the irrigation depth in lieu of monitoring or measuring soil water parameters. This communication can originate from the entire canopy or a single plant tissue, hence a representative sample is required. As long as irrigation depths are set and maintained during the irrigation season, crop stress variables are effective. Indicators of agricultural water stress include sap flow evaluation, canopy temperature, changes in stem or fruit diameter, and remote sensing of crop water stress (Dresselhaus & Hückelhoven, 2018).

Parameters of Climatic Conditions

Numerous municipal and regional irrigation projects consider climate. The reference evapotranspiration (ETo) for a particular location is estimated using weather data and empirical approaches that, after local calibration, produce exact estimates. The ETo of the crop is then calculated using crop-specific information. There are choices for both real-time and stored data processing and utilization (Raza et al., 2019). Among these methods are the monitoring of evaporation, the calculation of crop evapotranspiration from environmental data (such as air temperature, relative humidity, wind speed, and daylight hours), and remote sensing of ET.

Water Balance in Soil

The objective of the soil water balancing method is to forecast the soil water content using the water conservation equation shown below. AWC stands for available water content, and (AWC Root depth) equals incoming plus evaporative water fluxes. Using crop, climate, and soil water storage capacity data, sophisticated algorithms develop standard irrigation schedules. Both individual farms and regional irrigation networks can benefit from this method. You will, however, require knowledge, cooperation from respected extension agencies and access to information systems. It is effective, but advancements in agricultural technology and/or support services are required (L. S. Pereira, Paredes, & Jovanovic, 2020).

Timely and Efficient Planning of Irrigation

Effective irrigation scheduling is widely recognized to improve irrigation management efficacy, particularly on farms. The farmer must have perfect control over the amount, depth, and timing of irrigation. In actuality, however, the ideas and strategies have fallen far short of expectations. Reliance on community groups has social, cultural, and legal consequences. Lack of farmer education and training, institutional issues and lack of interactive communication (Gany, Sharma, & Singh, 2019).

The success of any irrigation scheduling technique, as well as the execution of the associated supply schedule, is heavily dependent on the system's physical ability to distribute water in accordance with this plan, as well as management's ability to run the system successfully. The inability of the majority of water supply and conveyance systems to consistently and adaptably distribute water to farm gates is one of the most fundamental hurdles to the widespread implementation of crop-based and water-saving irrigation scheduling (Baye, 2011; Chartzoulakis & Bertaki, 2015; Dai & Li, 2013; Davis et al., 2017; Dhawan, 2017; Dresselhaus & Hückelhoven, 2018; Du et al., 2015; Falkenmark, 2013; Gany et al., 2019; Gomiero et al., 2011). Water is easily accessible on demand in modern pressurized irrigation networks, albeit outputs may be limited for technical or budgetary reasons. Farmers are permitted to design and implement irrigation programs that are best suited to their crops and farming operations. During times of drought or limited water supplies, the government may collect fines for excessive water consumption or restrict water supply. All irrigation water management organizations must work tirelessly to disseminate information, improve instruction and training at all levels, transfer technology, change decision-makers' minds, involve farmers in decision-making, and persuade funding organizations and governments to provide the necessary financial resources (Baye, 2011; Chartzoulakis & Bertaki, 2015; Dai & Li, 2013; Davis et al., 2017).

Fertigation

In modern irrigated agriculture, fertilization—the irrigation-based supply of nutrients—has gained popularity. Fertilizer can be applied with the help of localized irrigation systems, which have a high probability of being effective. Consequently, the irrigation system distributes the proper concentrations of soluble nutrients to the wetted soil volume. Inadequate irrigation design or operation can lead to uneven chemical distribution, over fertilization if irrigation is not based on crop needs, and excessive use of soluble fertilizers (Mainardis et al., 2021).

Deficit Irrigation Practices

Previously, crop irrigation needs were determined without considering water supply limits. The irrigation schedule was then developed based on the total water needs of the crop. However, growing urban and industrial water needs in arid and semiarid regions reduce the amount of available water for agriculture. Consequently, water is often insufficient to produce the best yields. For a more efficient and economical use of water, irrigation systems that are independent of the crop's total water requirements must be implemented. This procedure includes partially drying the roots, deficit watering, and subterranean irrigation (Hashem, El-Abedin, & Al-Ghobari, 2018).

Subsurface Drip Irrigation

Water is delivered through underground tubes using the low-volume, low-pressure irrigation technology known as subsurface drip irrigation (SDI). The water from the tubes is drained via suction from the soil matrix. Water spreads outward when the area around the tube becomes saturated. The following are potential advantages of SDI: Water efficiency, fertilizer effectiveness, consistent and highly efficient water application, elimination of surface infiltration issues and evaporation losses, flexibility in delivering frequent and light irrigations, reduced disease and weed issues, and reduced operational pressure are all benefits (Aydinsakir et al., 2021). The main drawbacks are the pricey initial installation expenses and the elevated clogging risk, especially when using subpar water. Subsurface irrigation is advantageous for the great majority of crops, especially for turfs, landscapes, and high-value fruits and vegetables. There are numerous tubes available, including porous tubes that emit water continuously and PE tubes with integrated emitters. The tube can be buried beneath the soil's surface by creating trenches or by employing specialized machinery pulled by a tractor. The installation depth may range from 15 to 20 centimeters for vegetable crops to 30 to 50 centimeters for tree crops, depending on the crop (Umair et al., 2019).

Agricultural Practices

Sustainable water management and environmental protection are reliant on soil management, fertilizer application, and disease and insect control. Use of fertilizers in modern agricultural practices distinguishes them. Farmers can use an empirical method to calculate the amount and type of fertilizer necessary for each crop, as opposed to soil and leaf testing (Chartzoulakis & Bertaki, 2015; Dai & Li, 2013). This method is detrimental to both the environment and the quality of groundwater, while dramatically increasing the price of agricultural products. Misuse of pesticides and herbicides is detrimental to the ecology and the quality of surface water. Plant protection agents, sometimes known as pesticides, are commonly used as a precautionary measure even when there is no actual danger present. Agricultural weed control can be accomplished by the use of both conventional and innovative technologies for water conservation and soil and crop management (e.g., limiting runoff, improving soil penetration rate, increasing soil water capacity, and decreasing soil water evaporation). In order to prevent additional ecological damage, pesticides and herbicides must be used with care (Dhawan, 2017; Dresselhaus & Hückelhoven, 2018; Du et al., 2015). Soil management approaches include: "soil surface tillage" refers to shallow tillage procedures that roughen the surface and temporarily concentrate excess rainwater in small depressions. Contour tillage is the process of cultivating the soil along the contour of a piece of land to limit water movement. Row crops and tiny grains can benefit from this erosion management method so long as the field slopes are not extremely steep. Wide-bed cultivation, which is often employed in horticulture for row crops, necessitates attention to the surface profile of the bed. Conservation tilling, also known as no-tilling and minimal-tilling, is a land management approach in which crop residue is left in the soil after planting. Mulches prevent precipitation from contacting the soil directly, preventing crusting and sealing (Gany et al., 2019; Gomiero et al., 2011; Harwood, 2020). Conservation tillage is particularly advantageous for boosting soil infiltration and decreasing soil erosion since it helps to maintain high organic matter levels in the soil. Agricultural waste can be used as surface mulch to shade the soil, limit water flow, increase infiltration, reduce evaporation losses, and aid in weed control, so reducing the quantity of water that is wasted. Increasing or preserving the organic matter content of the upper soil layers promotes soil aggregation, minimizes crusting or sealing on the soil's surface, and enhances water retention (Hashem et al., 2018; Lalehzari et al., 2016). Controlling deep percolation and enhancing soil water retention by adding micro particles or hydrophilic chemicals into sand or coarse soil low water retention capacity soils facilitate water accessibility. Similar to adding gypsum to acidic soils, liming can be utilized to reduce acidity. This method promotes deeper, more extensive rooting, enhanced crop development, and higher soil aggregation, resulting in a small improvement in the soil's water retention capacity. It is possible to reduce competition for water and transpiration losses by applying efficient weed management techniques (Nazari et al., 2018; Luis S Pereira et al., 2012; L. S. Pereira et al., 2020).

Conclusion

Long-term agricultural development requires water. In response to water shortage and climate change, many regulations have been enacted to improve water efficiency. Better management may achieve more with less water. Improved management usually includes increased water allocation and irrigation efficiency. Sustainable agricultural water management comprises soil management, irrigation, fertilizer, pest and disease control, and environmental preservation.

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