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Improving Water Use Efficiency

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Abstract

Over time, significant effort has been invested in introducing policies to enhance water use efficiency amid scarcity conditions. The core idea behind these policies is that better management can achieve more with less water. The main culprits of water consumption are agriculture and food production, which require a hundredfold more water than personal needs. Agriculture utilizes water for growing fresh produce and supporting livestock. On-farm water management and irrigation scheduling greatly profit from increased irrigation water efficiency. Factors like the irrigation technology employed, the environment, and the timing of water application all affect how successful irrigation water efficiency is. Irrigation scheduling essentially entails choosing the best time and volume of water to apply to an area. By precisely giving the required amount of water to restore the soil moisture to the optimum level, it is possible to maximize irrigation efficiency. This method gives farmers the ability to organize water rotation among fields, reducing crop water stress and maximizing yields. Furthermore, it leads to cost savings for farmers, reducing water usage and labour while making the most of soil moisture storage. It is a widely recognized fact that crop yield increases as water availability in the root zone rises, up to a certain "Saturation level." Beyond this point, additional water has little impact on the yield. The following adage encapsulates the essence of the matter:

"The success of crop growth doesn't solely depend on the quantity of water applied; it hinges on the intelligent application of water, where intelligence often outweighs the significance of water in all cases."

~Alfred Deakin, 1890

Keywords: Efficiency for water use, planning of irrigation, use of agricultural water, especially agronomic crops

Introduction

Enhancing water use efficiency becomes a critical solution as water becomes scarcer and scarcer. This includes the necessity to maintain sufficient water levels in rivers and lakes to support ecosystems and accommodate growing urban and industrial demand. Water usage efficiency was initially described by crop physiologists as the amount of carbon assimilated and crop yield per unit of transpiration, and it was then refined to the amount of biomass or marketable yield per unit of evapotranspiration. Global freshwater supplies are becoming increasingly scarce, polluted, and overused for environmental, recreational, household, industrial, and agricultural uses. Agriculture now consumes the most water, and if current patterns in food production and consumption hold true, total evapotranspiration from agricultural land worldwide might treble in the next 50 years.

According to Mubeen *et al*. (2013), climate and weather conditions have a substantial impact on the production and resource use efficiency of novel cultivars. High yields should be attained by the sustainable and effective use of natural resources, particularly water, in enhanced agricultural systems (Gadanakis *et al.*, 2015). Through suitable agronomic approaches, including timely planting, integrated nutrient management, and the selection of varieties and hybrids adapted to certain ecologies, efforts are made to boost yields, particularly with relation to irrigation water resources (Nasim *et al.*, 2017). Innovative techniques can provide economic advantages while lowering environmental burdens including water abstraction, energy use, and pollution. Irrigation systems are under pressure to produce more with less water (Levidow *et al.*, 2014). Adaptations of plants to different water regimes subsurface trickle irrigation emerges as one of the most advanced water-saving methods, as it has shown the ability to maintain or even increase the yield of various crops while requiring less water in many cases (Mo *et al*., 2017; Liu *et al*., 2017). Other reasons to improve agricultural water use efficiency include meeting the escalating demands for food due to changing dietary patterns of a growing, wealthier, and increasingly urbanized population, reallocating water from agriculture to urban and industrial sectors while ensuring environmental uses and climate change adaptation, and contributing to poverty reduction and economic growth for farmers (Molden *et al*., 2010).

Concept of water use efficiency

Efficiency is determined by the output to input ratio. The common definition of effectiveness is...

$$\text{Efficiency} = \frac{\text{Output from process}}{\text{Input to process}} \times 100$$

WUE is an acronym for water used equivalent. The unit of measurement is kg/ha cm.

$$\text{WUE} = \frac{\text{Y}}{\text{ET}}$$

Crop water use efficiency and field water efficiency are further definitions for water use efficiency. Crop water use effectiveness (a) It is the proportion of crop yield (Y) to the volume of water lost through evapotranspiration (ET).

$$\text{CWUE} = \frac{\text{Y}}{\text{ET}}$$

In this context, CWUE stands for crop water use efficiency.

Crop yield = Y

Evapotranspiration or ET

Consumptive water use efficiency (CWUE) is another name for CWUE. It is the proportion of crop yield (Y) to the total of water absorbed and utilised for crop growth (G), water directly evaporated from the soil surface (E), water transpired through leaves (T), and water consumed (Cu).

Y/(G + E + T) = CWUE

In this case, Cu = (G + E + T)

In other words, since very little water is utilized for agricultural development, ET is really Cu.

Y/(CU) = CWUE

The unit of measurement is kg/ha/mm or kg/ha/cm.

(b) Field Water Use Efficiency: This metric measures how much water is utilized per unit of agricultural output (Y) in a field.

Y/WR = FWUE

Where, FWUE stands for field water use effectiveness.

Factors affecting efficient use of water of crops

Water use efficiency (WUE) is a critical aspect affected by the interplay of soil, plant, and environmental factors. This ratio is significantly influenced by various genetic, environmental, and cultural practices applied to crops. Improvements in both the numerator, representing crop yield dependent on soil, plants, and environmental factors, and the denominator, reflecting water supply, can boost WUE. Manipulating water supply under field conditions offers another avenue for increasing WUE. The effect of all the above mentioned factors on efficient use of water of crop is briefly discussed as under;

A. Climatic factors: Plant transpiration and soil evaporation, both of which are regulated by various climate conditions, have a substantial impact on the water use efficiency (WUE) of crops. The rate of evapotranspiration is significantly influenced by temperature, wind speed, relative humidity, sunlight hours, and rainfall. Higher temperatures and wind velocity tend to increase evapotranspiration, leading to reduced WUE. Conversely, evaporation is inversely proportional to humidity, resulting in reduced water consumption and increased WUE. Moreover, an abundance of light positively influences photosynthesis, leading to greater crop production and, consequently, an enhanced WUE. In this study, we explore the complex interplay between these climatic and photoperiodic variables and how it affects crop water usage efficiency.

B. Nature of crops: The growth and photosynthetic capacity of crops are closely linked to their canopy structure, with taller canopies generally exhibiting higher photosynthesis and yield, consequently leading to increased water use efficiency (WUE). In contrast, crops with shallow and underdeveloped root systems absorb less water and nutrients, resulting in reduced growth and lower WUE. Based on the carboxylation reactions that occur during photosynthesis, crops can be divided into two primary classes, C_3 and C_4. C_3 crops, such as wheat, barley, oats, pulses, and oilseeds, exhibit lower WUE due to their respiration even in the presence of light, leading to diminished production. On the other hand C_4 crops, including sugarcane, maize, and Jowar, display minimal or no respiration under light, contributing to higher WUE and consequently greater production. It is noteworthy that there are considerable variations in WUE among different plant species, as they produce varying amounts of dry matter per unit of water utilized. Furthermore, even within the same crop species, different varieties may exhibit differences in WUE.

C. Wetness in the soil: The availability of appropriate soil moisture plays a critical role in determining water use efficiency (WUE) and crop productivity. Both inadequate and excess moisture supply to crops can have detrimental effects on plant growth, resulting in reduced WUE. In this study, we investigate the consequences of insufficient and excessive soil moisture on plant development and productivity, with a focus on understanding their implications for water use efficiency.

D. Fertilizers: Irrigation exerts a significant demand for plant nutrients. For most crops, nutrient availability is optimal when water tension is low. Numerous pieces of evidence suggest that adequate irrigation, coupled with appropriate fertilization, substantially enhances yields while only slightly increasing evapotranspiration (ET), resulting in a remarkable improvement in water use efficiency (WUE).

E. Plant population: Achieving the higher yield potential facilitated by favorable irrigation, enriched soil fertility from substantial fertilizer application, and the genetic potential of new crop varieties and hybrids necessitates the precise adjustment of the plant population.

Management factors for improving water use efficiency

Efficient crop management (Agronomic) practices

i. Time sowing: The timing of sowing represents a non-monetary input that plays a crucial role in achieving higher yields and maximizing the efficient utilization of resources. By shifting the sowing time of crops from periods of high evaporative (ET) demand to those with lower demand, optimal results can be attained. Crops sown at the appropriate time exhibit greater production and consequently higher water use efficiency (WUE). Conversely, crops grown at later dates tend to experience reduced growth and development, leading to lower yields and, consequently, diminished WUE.

ii. Method of sowing: The sowing method directly influences yield, solar energy capture, and soil water evaporation, consequently affecting water use efficiency indirectly. Compared to the broadcasting method, line sowing of crops demonstrates enhanced utilization and absorption of nutrients, water, and light, resulting in higher production and, consequently, higher water use efficiency (WUE). The N-S direction of planting has also demonstrated to boost grain yield in crops including wheat, oats, and pearl millet, which helps in raising yields and decreasing the overall irrigation water required for crops.

iii. Depth of sowing: Crops whose seeds are sown at optimum depth have greater growth since germination and hence higher production resulting in greater WUE.

iv. Row spacing and seed rate: It is possible to boost yields and water use efficiency by reducing the distance between rows, a practice known as narrow row spacing. This is due to the decreased soil water evaporation associated with higher planting density. To optimize results, it is advisable to adopt a planting density that can be sustained by the available moisture until the economic part of the crop's production is reached.

v. Tillage practices: Increases infiltration, which raises water storage. Deep tillage and subsoiling promote root development and soil moisture absorption.

vi. Use of antitranspirants: Antitranspirants are substances that, when sprayed on plants, effectively reduce transpiration. Well-known examples of antitranspirants include kaolin, phenyl mercuric acetate, and abscisic acid. The application of antitranspirants on plants leads to a decrease in transpiration rates, which subsequently reduces their water consumption, Increasing water usage efficiency (WUE) is the end outcome.

vii. Use of growth retardants: Multiple experiments have provided compelling evidence that numerous chemical substances, such as cycocel (CCC), phosphon, and others, can be applied to plants to promote good production even under water-deficient conditions. Consequently, these substances contribute to higher water use efficiency (WUE).

viii. Use of mulch: Mulches are either natural or artificial materials applied to the soil surface with the aim of minimizing evaporation and weed growth. By doing so, mulches facilitate the enhanced utilization of light, fertilizers, air, and water by crops, leading to increased production and, in turn, higher water use efficiency (WUE).

ix. Method of irrigation: The use of sprinkler and drip irrigation techniques greatly lowers water loss through evaporation and infiltration in comparison to flooding irrigation techniques. An improvement in water use efficiency (WUE) is the outcome of this effective water management, which increases agricultural yield while consuming less water.

	
Flood irrigation (High water consumption & low yield)	**Furrow irrigation (Low water consumption & increase yield)**

x. Management of nutrients: Crop growth and output have been demonstrated to be improved by mixing chemical fertilizers with organic nutrient sources or bio-fertilizers. When fertilizers are administered effectively and at the right time, crops grow and develop more rapidly, which ultimately increases their water use efficiency (WUE).

xi. Weed control: Weeds generally demand more water compared to crop plants and consistently compete for water, nutrients, air, and light. Consequently, it is crucial to effectively control weeds through appropriate methods to ensure the proper growth of crops and achieve higher water use efficiency (WUE).

xii. Insect-pest and disease control: Ensuring effective management of insect-pests and diseases at the appropriate time is essential for achieving a successful crop production. If crops are not protected from these threats, their growth and development can be adversely affected, leading to a reduction in water use efficiency (WUE).

xiii. Use of shelter belts: In regions with hot and high-velocity winds, there is a considerable loss of irrigation water through evaporation. However, installing shelter belts in certain locations can significantly lower evaporation loss, increasing water usage efficiency (WUE). Numerous additional elements, in addition to those already listed, also have a big impact on how well crops perform under adverse conditions. Crop rotation, soil testing, seed treatment, soil and water management techniques, the addition of organic matter to the soil, and the type of soil are a few of these. Each of these elements has an impact on how effectively crops use water overall.

Conclusion

The concept of "crop productivity" or "value per drop of water" has expanded greatly in the context of water use efficiency (WUE), reflecting the overall socioeconomic and environmental advantages of using water in agriculture. Up to a certain point, increased water availability tends to boost water productivity, but it also increases fertilizer use efficiency by increasing the availability of applied nutrients. The creation of crop varieties with a higher harvest index proven to be a very effective method for raising land and water productivity during the period of the green revolution. The productivity growth since then has slowed down. Alternatively, in large low-productivity rain-fed regions, the application of dry-spell mitigation strategies and efficient soil-fertility management has the potential to more than quadruple on-farm yields. The plant's ability to draw water from a bigger reservoir is increased by fertilizers since they play a crucial part in encouraging stronger root development. Additionally, a larger canopy and longer-lasting growth increase the need for water by plants. It is essential and within farmers' power to properly regulate fertilizer rates, especially those for secondary and micronutrients, in response to available water supplies. Achieving synchronization between nutrient delivery and crop demand without excess or deficiency under different moisture regimes, especially lowland paddy fields, is essential for optimizing trade-offs between yield, profit, and environmental protection.

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