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Furrow Irrigation system in Ethiopia, a limitation in the rational use of water in agriculture and its performance

Sistema de riego por surcos en Etiopía, una limitación en el uso racional del agua en la agricultura y su rendimiento

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Abstract

Ethiopia is among the many developing nations that prefer surface irrigation over underground and pressured irrigation systems due to its lower cost and energy consumption. This paper reviews the effects of furrow features, including length, flow rate, and influence on farm water productivity and yield gap. The furrow irrigation method can be highly effective when used correctly, but it can also be quite ineffective when used incorrectly. High efficiency can be attained if the design parameters of a furrow irrigation system, such as field length and flow rate, infiltration characteristics, and field slope, as well as its operational and management parameters, such as application depth, and frequency, are properly maintained. Over-irrigation in a furrow irrigation system can lead to a variety of detrimental consequences on crop productivity and the environment, including water runoff, reduced efficiency, deep percolation, waste of energy and resources, crop damage, and increased salinity. Therefore, checking the moisture content of the soil frequently to prevent over-irrigation by visual examination or soil moisture monitors, carefully planning furrows depending on soil type, crop requirements, and topography as well as gathering runoff water and reusing it improved farm irrigation water management in furrow irrigation system to reduce the yield gap and increase water productivity.

Resumen

Etiopía se encuentra entre los muchos países en desarrollo que prefieren el riego superficial a los sistemas de riego subterráneo y presurizado debido a su menor costo y consumo de energía. Este artículo analiza los efectos de las características de los surcos, incluida la longitud, el caudal y la influencia en la productividad del agua de la explotación y la brecha de rendimiento. El método de riego por surcos puede ser muy eficaz cuando se utiliza correctamente, pero también puede ser bastante ineficaz cuando se utiliza incorrectamente. Se puede lograr una alta eficiencia si se mantienen adecuadamente los parámetros de diseño de un sistema de riego por surcos, como la longitud y el caudal del campo, las características de infiltración y la pendiente del campo, así como sus parámetros operativos y de gestión, como la profundidad y la frecuencia de aplicación. El riego excesivo en un sistema de riego por surcos puede provocar una variedad de consecuencias perjudiciales para la productividad de los cultivos y el medio ambiente, como la escorrentía de agua, la reducción de la eficiencia, la percolación profunda, el desperdicio de energía y recursos, el daño a los cultivos y el aumento de la salinidad. Por lo tanto, verificar el contenido de humedad del suelo con frecuencia para evitar el riego excesivo mediante un examen visual o monitores de humedad del suelo, planificar cuidadosamente los surcos según el tipo de suelo, los requisitos del cultivo y la topografía, así como recolectar el agua de escorrentía y reutilizarla, mejoraron la gestión del agua de riego agrícola en el sistema de riego por surcos para reducir la brecha de rendimiento y aumentar la productividad del agua.

Palabras clave:

Riego por surcos, rendimiento, productividad del agua, caudal.

Introduction

Ethiopia is a landlocked nation in Eastern Africa that has a 1.13 million km^2 land area. Its geographic coordinates are latitudes 5°N to 15°N, longitudes 35°E to 45°E. Eritrea borders the country on the north, Djibouti and Somalia border it on the east, Kenya borders it on the south, and Sudan and South Sudan borders it on the west[1].

Improving water use efficiency is achieved through better irrigation and water management in regions where water resources are scarce. Choosing the right irrigation technique can greatly increase agricultural water yield. When compared to traditional flooding techniques, irrigation techniques including drip irrigation spray irrigation, alternate furrow irrigation, and intermittent wetting and drying in the fields can drastically reduce water consumption and increase water productivity[2]. Many developing countries, including Ethiopia, favor surface irrigation because it is less expensive and uses less energy than subsurface and pressurized irrigation systems (sprinkler and drip irrigation systems), which are generally more efficient than surface irrigation[3]. Effective irrigation water management techniques are crucial for boosting agricultural profitability because they raise water productivity with insignificant crop yield reduction under limited water conditions in arid and semi-arid areas[4]. Irrigation water management also includes the effective distribution and use of reservoir water to satisfy crop requirements for each irrigation phase.

Water severely limits crop productivity in Ethiopia and many other places of the world. The amounts of time and freshwater resources that are available in a given place determine how much more food humans can produce, even if irrigation can greatly increase agricultural output[5].

It is uncommon, to optimize the limited water resources in the Ethiopian desert and semi-arid regions by choosing appropriate furrow irrigation techniques[6]. Effective irrigation water management techniques will increase agricultural output by increasing the available irrigation water[7]. Proper design of furrow length and flow rate Improves water productivity in furrow irrigation. Furthermore, concluded that agricultural productivity, crop water use efficiency, and irrigation performance indicators are significantly influenced by furrow length and flow rate[8].

This review paper aimed was provide some information on the impact of furrow irrigation on crop yield and agricultural water productivity in Ethiopia.

Development

Furrow irrigation. Furrows are shallow channels that run down a field's slope and have consistent spacing and narrowness; the crop rows that require irrigation run parallel to these channels. Especially for crops that are prone to fungal root rot, furrow irrigation works particularly effectively because it prevents water ponding and contact with plant parts[9]. For furrow irrigation, uniform, level, or mild slopes are ideal, although they shouldn't go above 0.5 %. Generally, a moderate slope for the furrow is given up to 0.05 % to help with drainage after irrigation or heavy, intense rainfall. This technique is used to irrigate almost all row crops instead of flooding them. When there are few irrigation streams available, furrow irrigation is beneficial for unevenly shaped land that can accommodate large slope variations[10]. It is imperative to increase the water productivity of irrigated crops through deficit furrow irrigation alternatives to minimize water waste and maximize grain output per drop of water, rather than solely focusing on yield per land area[11].

Furrow characteristics affect irrigation efficiency. If properly managed, the furrow irrigation method can be quite efficient, but if improperly managed, it can be quite inefficient[12].

From a study, at Metehara in Ethiopia, Furrow characteristics such as inflow, soil texture, field slope, soil infiltration, plant coverage, roughness coefficient, field shape, irrigation management, and others affect how efficiently water is applied and distributed during furrow irrigation[13]. According, evaluating these parameters with constant values may result in appreciable mistakes when estimating advance-recession trajectories[14]. To assess potential water savings, measurements of Manning's roughness and infiltration variation are needed[15].

To ensure consistent application of water down the entire length of the furrow and to estimate the prescribed amount to apply, it is imperative to comprehend the role and interdependence of these components. While maintaining agricultural water requirements, a more efficient irrigation system design can assist lower the amount of irrigation water applied, hence minimizing salinity and water-logging issues. Furthermore, from the study conducted on Furrow irrigation in Bako, Ethiopia[16] choosing these factors incorrectly results in excessive water use and decreased crop yield.

Furrow irrigation has direct effects on farming systems and production. It is generally accepted that enhanced crop output through improvements in yield and area is the primary, direct effect of irrigation. Increased plant water availability leads to higher yields. The yield and transpiration have a linear connection[17]. Additionally, irrigation improves precision in managing the amount and time of water availability, promoting crop establishment, growth, and output. Furthermore, irrigation can enable crop production in areas where soil moisture and rainfall would not otherwise be sufficient or allow for the intensification of productivity through second and occasionally third cropping.

In a field, planting crops with a mechanical ridge and furrow can increase irrigation efficiency and make it easier for precipitation to accumulate in nearby ditches. The proximity of natural precipitation to crop roots, coupled with an increase in field soil water content and an improved external water supply, can lead to improved water usage efficiency and higher crop yields[18].

Losses in furrow irrigation and poor water management. The country's irrigation systems were not operating to their full potential because of inadequate water management and design flaws[19]. Efficient and effective use of irrigation water applied to the fields is the primary goal of the irrigation system. Because uneven irrigation application, which results in water waste, waterlogging, and salinity issues, is typically caused by poor design and a lack of appropriate criteria for irrigation systems, especially in surface irrigation systems[20].

Canal operational losses were a sizable portion of losses. The maximum seepage loss in the majority of operation scenarios was 10 %, with operational losses accounting for the remaining 90 %. It is determined that each variable (change in the canal's intake or outflow) that results in an increase or decrease in operational losses eventually determines whether overall losses are reduced or increased. Therefore, by enhancing the techniques for operating water level regulation and off-take structures, management approaches should be used to improve system performance and reduce losses, particularly operational losses[21].

According to research done in Ethiopia at North Wolo and Hawi zone, the small irrigation project performed poorly overall in the surface irrigation system. Therefore, in order to ensure that the scheme performs well, it is required rigorous management and infrastructure upgrades in order to increase efficiency and ensure the scheme's viability. In addition, it is imperative to fortify the water user association and raise users' knowledge of the need to adapt and carry out routine maintenance[22,23].

Effect of furrow length and flow rate. In Ethiopia, surface irrigation techniques are widely employed. Regretfully, compared to pressurized systems, the approaches frequently have inferior application efficiency and distribution uniformities. The primary issues are mentioned as being high runoff and severe percolation losses. The usage of surface irrigation techniques is encouraged by farmers' preferences and low initial expenditure. However, the utilization of sprinkler and trickling systems is constrained by a lack of labor and limited energy supplies. If the surface irrigation system's design parameters like field length and flow rate, infiltration characteristics, and field slope as well as its operational and management parameters such as application depth, cutoff time, and frequency are appropriately maintained, high efficiencies can be reached[24].

Various writers described that under furrow irrigation systems, the results of furrow length and flow rate have varied. The yield, crop water productivity, and irrigation performance indicators are all impacted by flow rate. The yield, water application efficiency, storage efficiency, deep percolation ratio, and distribution uniformity were all unquestionably improved by the increase in flow rate. Higher flow rates would lead to less water being used and lower yield generation. When the length of the furrow rose, crop output improved along with the efficiency of water application and storage, Distribution uniformity was reduced, and Deep percolation ratio and surface runoff were raised. Consequently, the primary cause of decreased production and water loss through surface runoff was the usage of short furrow length[8]. In a similar vein14 found that deep percolation was reduced and the mean application efficiency values increased with the inflow rate. And there was a notable increase in distribution uniformity. The right flow rate, however, is dependent on several variables, including the type of soil, the weather and rainfall, the variety and yield objectives, the planting date, the effectiveness of the irrigation system, the growth stages, the water requirements, and the vegetative stage. An experiment on potatoes in the Jimma Zone suggests that since surface runoff has altered much of the water, an increase in flow rate could result in a drop in potato tuber yield[25].

Effect of over-irrigation in the furrow irrigation system. The increased usage of fertilizer due to irrigation techniques that limit the quantity of nutrients, such as nitrogen, that enter surface and groundwater has caused these waters to become more contaminated. Irrigation systems should be designed and managed to ensure that water and fertilizer are applied and distributed sufficiently and uniformly, that at least surface runoff is produced at the end of the field, and that deep percolation and leaching losses are produced beneath the root zone. This will increase the effectiveness of irrigation and fertilizer application methods[26]. Consequently, furrow irrigation is thought to be a successful substitute for applying fertilizer to agricultural lands[27].

In a furrow irrigation system, over-irrigation can have several negative effects on agricultural productivity and the environment. Applying too much water can result in runoff[28]. The extra water runs off the field, taking important nutrients with it and possibly eroding the soil. In a similar vein, excessive irrigation reduces the furrow system's effectiveness. Efficacious soil penetration of water is a contributing factor to inefficiency. Achieving a balance between giving crops enough moisture and preventing unnecessary surplus is crucial[20]. Furthermore, crops may suffer damage from extended exposure to excessive wetness. It might lead to root rot, lessen the amount of oxygen available to roots, and encourage the growth of diseases.

Water productivity and the yield gap. In surface irrigation systems, enhancing water productivity and maintaining yields at sustainable levels are essential for building farmers' resilience. Productivity is expected to be increased with better timing and coordination of water and other inputs, particularly fertilizers and better seeds[29]. To improve water productivity, farmers needed to close crop yield gaps or the difference between potential yield (or water-limited yield potential) and actual yield achieved at the time[30]. Also contend that minimizing yield gaps requires combining cultivars, irrigation techniques, and fertilizer inputs that are appropriate for the region[31,32]. Lessening the trade-off between evapotranspiration and increased production, location-specific input and management combinations should aim to maximize water productivity. When the right quantities of irrigation and fertilizer rate were used, water productivity increased, however, it varied according to location, crop, and variety.

Conclusion

Due to its reduced cost and energy consumption, surface irrigation is preferred by many developing countries, including Ethiopia, over subsurface and pressurized irrigation systems. In this review paper, the implications of furrow characteristics, such as length, flow rate, and influence on-farm water management, are reviewed. It also assesses the impact of overwatering on the water productivity and yield gap of the system. Effective irrigation water management techniques will increase agricultural output by increasing the available irrigation water. When applied correctly, the furrow irrigation method can be very effective; but, when applied incorrectly, it can be rather ineffective. When a furrow irrigation system's design parameters like field length and flow rate, infiltration characteristics, and field slope as well as its operational and management parameters like, application depth, and frequency are kept up to date, high efficiency can be achieved. Reusing runoff water enhanced agricultural irrigation water management in furrow irrigation systems to close the gap between yield and production. Finally, giving advisory services for societies on how to use crop water requirement-based furrow irrigation systems is important, as over-application and high frequent irrigation lead to water logging to intensify soil acidity, water losses as runoff or tailwater, increases the cost of labor and fuel for pumping irrigation water.

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Conflicts of interest

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Ethical considerations

The author declares that this work was not submitted to other journal publishers for possible publication.

Research limitations

This review focuses on the major water bodies of Ethiopia regardless of the minor water bodies found in Ethiopia.

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