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PREFACE

The principal objective of irrigation and water management research is to determine how best the water resources, be it from underground, surface or rainfall can be utilized for crop production and how to minimize the harmful effect of this water. This inevitably demands research on how to exploit available sources of water, convey and distribute them to farms and apply the same to the individual crop field. The next important aim is to increase the crop water use efficiency in order to obtain maximum production per unit drop of water thereby increasing economic return and improving livelihood of the farmers. To achieve this goal, research need to be conducted on when and how much water should be applied, and when irrigation is not necessary at all.

The general objectives of the division are to conduct research on: a) proper irrigation scheduling and rain water management of the upland crops and drainage thereof, b) finding climate smart irrigation technologies for crop production, c) management of surface water and groundwater for sustainable agricultural use, d) water management in fragile ecosystems e) wastewater management f) micro irrigation, g) application of artificial intelligence and data science for irrigation planning and g) assessment of climate change on irrigated agriculture.

Amid climate change, many parts of the country are already facing water shortages threatening the sustainability of agriculture that could be overcome through demand management rather than supply management. The supply-side management is structure-oriented and costly as it focuses on providing water and related services to capture, store and deliver water to the field effectively. While demand management approach is non-structural and less costly, it focuses on development of water-efficient technologies, training, education and persuasion to the users. IWM division with its limited number of scientists have developed and are trying to develop water-efficient technologies addressing SDGs, BDP 2100, 2030 WRG, Perspective plan 2041 and 4AR as well.

There are great potentialities that need to be developed in the management of ground and surface water resources. In many crops improved irrigation system has the potential to double the production. Rice crop, on average, require 1000 mm of water for the growing season whereas most upland crops require 200 to 300 mm water when applied efficiently. All these indicate that there remains tremendous possibility of increasing crop production by bringing more upland crops under irrigation and by properly controlling and managing the available water resources.

Research and development activities of Irrigation and Water Management Division are directed towards the economic development of the country. The division is working to help the nation becoming self-sufficient in food, to generate employment in agriculture and to increase income of farmers through the development of appropriate water management practices and techniques widely acceptable to all categories of farmers. This report presents the findings of both on-station and on-farm studies conducted during 2024-25. This year, the division carried out researches in the areas of crop water requirement and irrigation scheduling, water application and distribution methods, on-farm water management, saline and wastewater management, groundwater management and dissemination of developed water saving technologies at the farmer's level and improvement of farmers' traditional irrigation practices.

Finally, I would like to express my sincere thanks to the scientists/staffs concerned with these studies and to all who helped in bringing out this report.

Dr. Md. Anower Hossain
Chief Scientific Officer (in-charge) and Head

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CHANGES IN CROP WATER REQUIREMENTS AND FUTURE IRRIGATION DEMAND WITH CLIMATE CHANGE IN THE SOUTHWEST COASTAL AREA

R. P. RANNU[1], K. K. SARKER[2], S. K. BISWAS[3], M. A. HOSSAIN[4]

ABSTRACT

Fresh water is limited for agricultural purposes in Bangladesh, especially in coastal areas. For the judicial use of this limited water, this study intended to estimate the irrigation water requirements through crop water requirements. The CROPWAT model was employed to estimate reference crop evapotranspiration, crop water need and irrigation requirement for the Boro rice in Khulna district. Results revealed that there is almost no increasing or decreasing trend annually for the long-term historical data period. Monthly variation of net irrigation requirements was also observed, and that could be due to ETo or rainfall variability. However, this is a partial study with one crop and for a historical period. The conclusion will be done once the full study is completed.

Introduction

Bangladesh is an agro-based country, growing different crops, with a major in rice, in different parts of the country. Around 79% irrigated agricultural land exists (World Bank, 2021), where groundwater provides 79% and surface water 21% in the agricultural sector (Dola and Mannan, 2023). But in the dry season, the country experiences a water shortage both in surface water and groundwater. In addition, saline water in the coastal zone is putting extra pressure on existing water resources.

In the coastal zone of Bangladesh, cropping intensity is low (around 148%) compared to the national average (198%) (BBS, 2023). Hence, to enhance cropping intensity, exploration of irrigation water requirement is crucial from the perspectives of both food security and sustainable water resources management.

Materials and Methods

Khulna district has been selected as the study area, which is located in the southwest part (near to Bay of Bengal) of Bangladesh. This area is mostly flat plains with deltaic silt deposits, an elevation range of 3-8 m and is prone to salinity due to its geographic location.

Long-term daily climatic data (Rainfall, maximum and minimum temperature, relative humidity, wind speed, sunshine hours) for 18 years (2000-2017) have been collected from the Bangladesh Meteorological Department. Soil type has been selected from the available reports. Crop coverage area of different crops has been collected from the BBS reports and selected those crops that are mostly covered in the study area. The duration of the Boro rice crop has been marked from the available reports. To estimate crop water requirements for the selected crops, CROPWAT 8.0 was used. The reference evapotranspiration (ETo) was computed based on the FAO Penman-Monteith method. ETo was the main factor to estimate crop evapotranspiration (ETc) (Alotaibi et al. 2023), and this ETc was calculated using Kc values for different crop growth stages by ETc=Kc*ETo. The net irrigation water requirement (NIWR) was calculated as:

NIWR= ETc-R_{eff}, where R_{eff} is effective rainfall (mm)

Results and Discussion

There is no remarkable trend (increase/decrease) in annual net irrigation requirements of Boro rice from 2000 to 2017, except slightly decreasing pattern. It varies from 612 mm to 856.2 mm, whereas total annual rainfall ranges from 1393-2627 mm, and ETo ranges from 1267-1505 mm. The slight decrease in net irrigation requirements in 18 years might be due to decreasing sunshine hours per day or monthly variation (temperature, rainfall). However, high evapotranspiration results in high irrigation water needs. Though there is comparatively higher rainfall for some years (2002, 2007, 2015-17), which could supplement irrigation water requirements, annual effective rainfall was less than the total rainfall and

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hence contributed less. Therefore, the irrigation requirement is more even when there is rainfall for the same year (Figure 1).

Monthly changes are found in irrigation water requirements over the year (Figure 2). In 2000, 176.4 mm in January, 174.8 mm in February, 122 mm in March and 239.2 mm in April, net irrigation was required, whereas in 2017, 172, 190, 73 and 199 mm net irrigation was required for January, February, March and April, respectively. These changes occurring might be due to the variation of monthly ETo and/or rainfall for those months.

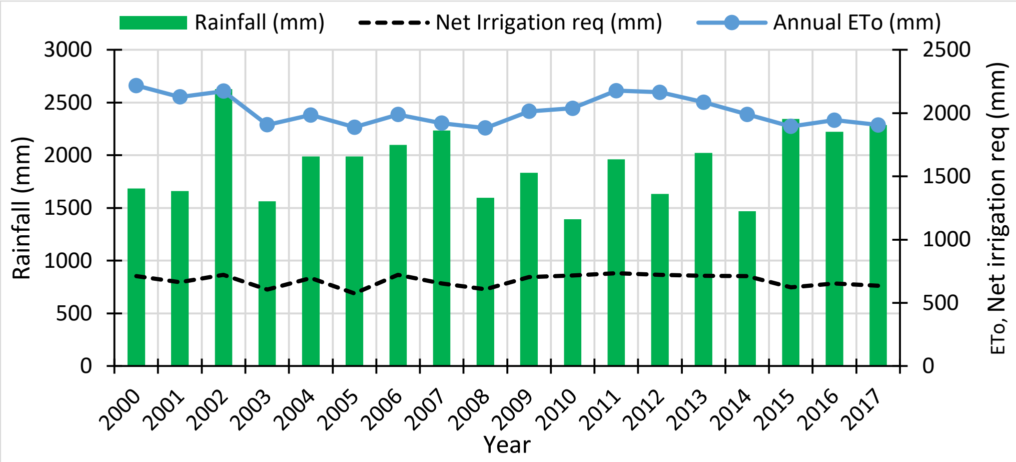

Figure 1. Annual rainfall, net irrigation requirements and reference evapotranspiration (ETo)

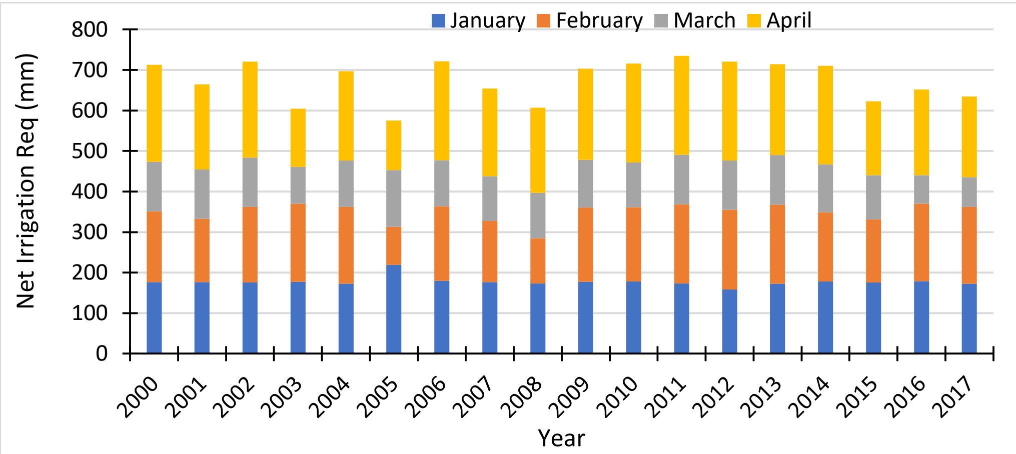

Figure 2. Seasonal change of net irrigation requirements for each year

Conclusion

This study shows there is almost no specific trend (increase/decrease) of net irrigation water requirements of Boro rice over the 18 years, and ETo is mostly responsible for the required amount of net irrigation. This is 1st year study. After completion, this study will help with decision-making to allocate water and select crops for the coastal zone in Bangladesh.

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RESPONSE OF PROSO MILLET TO DIFFERENT LEVELS OF IRRIGATION

C. R. PAUL[1], T. H. MUNMUN[2], K. K. SARKER[3], S. H. ANIK[4]

Abstract

Proso millet is a short-duration, drought-tolerant cereal with potential for cultivation in water-limited environments of Bangladesh. A field study was conducted during Rabi season in 2024–2025 at Gazipur, and RARS, BARI, Jamalpur to evaluate the effect of irrigation at different growth stages on growth, yield, and water productivity of proso millet. Six irrigation treatments at different growth stages were considered with three replications. The results showed that irrigation during the vegetative and flowering stages, treatment T_2, produced the highest yields, at 2.72 t/ha and 2.92 t/ha in Gazipur and Jamalpur, respectively. In contrast, no irrigation (T_0) resulted in the lowest yields at both locations. Yield and plant growth traits followed similar trends, with higher performance at Jamalpur compared to Gazipur, likely due to reduced stress conditions (biotic and abiotic). Although treatment T_5, three irrigations at vegetative, flowering and grain filling stages, enhanced vegetative growth, it did not result in higher grain yield, indicating that excessive irrigation promotes biomass production but lower grain yield. This study will be continued in the next year at both locations for the validation of these results.

Introduction

Proso millet (Panicum miliaceum L.) is a short-season crop with low water requirements and is highly tolerant to heat and drought. It contains higher nutritional values when compared to commonly consumed crops like rice and wheat. The proso millet is mainly grown in the char lands of the country. But this millet's cultivation has recently been expanded in the north, north-west, central parts and hilly regions. Water scarcity is a major problem in char lands. Although under drought conditions, proso millet gives higher yields than those of other crops and has the potential to produce food where other grain crops would fail (Jiaju, 1986). However, it is also observed that drought stress caused 55% reduction in its grain yield (Nematpour et al., 2019). This yield reduction can be mitigated with early planting dates under sufficient water supply and applying adequate irrigation at the more sensitive stages to water stress. Therefore, this study aims to determine the critical growth stages of proso millet concerning irrigation.

Materials and Methods

The field study was carried out with minor cereals, Proso millet (BARI China-2), in the research field of the Irrigation and Water Management Division of Bangladesh Agricultural Research Institute (BARI) in Gazipur and RARS, BARI, Jamalpur, during the rabi season of 2024-2025. The experiment followed a randomized complete block design (RCBD) with six treatments with three replications. The treatments were as follows: T_0= no irrigation, T_1= one irrigation at vegetative stage, T_2= two irrigations at vegetative and flowering stages, T_3= two irrigations at vegetative and grain filling stages, T_4= two irrigations at flowering stages and grain filling stages, T_5= three irrigations at vegetative, flowering and grain filling stages. The BARI recommended doses were: Urea, TSP, MoP, Gypsum, Zinc Sulphate @ 130, 100, 80, 50 & 3 kg/ha (BARI Agricultural Technology Handbook 2023). During land preparation, full doses of TSP, MoP, Gypsum, and Zinc Sulphate were applied at the field and the rest of the Urea was applied at 33 days after sowing. According to the treatments, soil samples were collected at different stages to measure moisture content, and irrigation was applied based on the calculated soil moisture levels. Various growth and yield-attributed data were recorded at harvest. Harvest index and water productivity were also calculated. The analysis and interpretation of data were performed using R software.

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Results and Discussion

The effect of irrigation treatments on proso millet varied significantly across both locations. As shown in Table 1, the highest grain yield was obtained from T_2, two irrigations at vegetative and flowering stages, producing 2.72 t ha^{-1} in Gazipur and 2.92 t ha^{-1} in Jamalpur. In contrast, the treatment T_0, (no irrigation) consistently resulted in the lowest yield in both sites. In Gazipur, less plant height, branch per plant, grain yield, straw yield was observed relative to Jamalpur, which occurred due to combined biotic and abiotic stresses. However, water productivity showed a reverse trend. The highest water productivity was recorded in T_1 (2.27 kg m^{-3}) at Gazipur, and T_0 (2.7 kg m^{-3}) at Jamalpur. Although T_5, three irrigations at vegetative, flowering & grain filling stages, produced highest vegetative growth, but grain yield was not superior in either location. This suggests that excessive irrigation may not be beneficial, as it could lead to unnecessary vegetative biomass at the expense of grain production.

Table 1. Effect of irrigation treatment on growth, yield and water productivity parameters of proso Millet

Treatment	Plant Height (cm)	Spike length (cm)	Brunch per plant (nos)	Spike per plant (nos)	Grain yield (t/ha)	Straw yield (t/ha)	1000 Grain weight (gm)	Total water use (mm)	Water productivity (kg/m3)
Gazipur (2024-2025)									
T_0	64.2b	19.5b	3.87c	7.76a	0.69c	1.8d	3.87c	37.7	1.84a
T_1	90.9a	22.7ab	5.46bc	8.76a	1.84b	3.02c	4.97ab	80.7	2.27a
T_2	100.0a	25.5a	7.21ab	7.87a	2.72a	4.56a	5.2a	125.45	2.16a
T_3	95.9a	24.9a	5.76bc	10.11a	2.21ab	3.92ab	4.53b	138.7	1.59a
T_4	89.6a	21.3ab	5.76bc	9.78a	1.93b	3.62b	4.43b	142.6	1.35a
T_5	100.4a	25.4a	8.53a	11.11a	2.66a	4.84a	5.3a	163.5	1.63a
Significance	*	NS	*	NS	*	*	*	-	NS
Jamalpur (2024-2025)									
T_0	95.3b	24.3ab	6.3a	7.3a	1.96d	3.2c	4.5abc	60.5	2.7a
T_1	102.0ab	23.3b	5.7a	7.7a	2.06d	3.8bc	4.6abc	90.5	2.3b
T_2	102.2ab	27.0a	7.3a	8.3a	2.92a	4.9a	4.8a	129.5	2.2b
T_3	98ab	25.7ab	6.7a	7.7a	2.52b	4.03b	4.4bc	147.5	1.7c
T_4	98.3ab	24.5ab	6.3a	7.3a	2.36c	3.6bc	4.3c	146.5	1.6c
T_5	107.3a	27.3a	6.7a	9.3a	2.8a	4.9a	4.7ab	162.5	1.7c
Significance	NS	*	NS	NS	*	*	*	-	*

*T_0=no irrigation, T_1=one irrigation (vegetative stage), T_2=two irrigation (vegetative & flowering), T_3= two irrigation (vegetative & grain filling), T_4=two irrigation (flowering & grain filling), T_5=three irrigation (vegetative, flowering & grain filling)

Conclusion

The results show that providing irrigation during the vegetative and flowering stages is crucial for proso millet production in both Gazipur and Jamalpur, as it enhances growth and yield. This study need to conduct in the next year in both locations as the crops faces some stresses in Gazipur and for the validation of these results.

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EFFECT OF IRRIGATION ON YIELD AND WATER PRODUCTIVITY OF FOXTAIL MILLET

T. H. MUNMUN[1], C. R. PAUL[2], K. K. SARKER[3], S. H. ANIK[4]

Abstract

Foxtail millet is an important crop for both cereal production and animal feed, but its water requirements have not yet been thoroughly studied. Therefore, this study aimed to examine the effect of irrigation at different growth stages on the yield and water productivity of foxtail millet. The research was conducted at Gazipur, and RARS, BARI, Jamalpur during Rabi season in 2024-2025. Six irrigation treatments with three replications were considered. The results showed that irrigation during the vegetative and flowering stages produced the highest yields, at 2.81 t/ha and 2.71 t/ha in Gazipur and Jamalpur, respectively. Conversely, a single irrigation at the vegetative stage resulted in the highest water productivity, at 2.28 kg/m³ and 1.88 kg/m³ in the two locations. Although maximum irrigation improved both growth and yield attributes, the overall findings indicated that the vegetative and flowering stages are the most critical for irrigation. However, for water-scarce areas, a single irrigation at the vegetative stage is preferable.

Introduction

Foxtail millet (*Seteria italica*) is an important cereal and fodder grain crop grown in various regions of the world. It is commonly known as "Kaon dana" in Bangladesh. It is one among the oldest cultivated and climate resilient crop species that plays a significant role in food security and nutrition. They are adapted to grow in gradual climate change like high temperature to drought and salinity, but they contain an immense nutritional profile almost five to ten times more nutritionally richer than more consumed rice or wheat (Singh & Prasad, 2020). In future, this crop may contribute to our food cycle and fill our nutrition demand among these hazardous climatic conditions. For this reason, the demand of cultivating these crop is increasing day by day in Bangladesh. But the growth and maximum yield is only obtained when an appropriate cultivation practice is provided for the crop. Among them, irrigation is a crucial factor of crop production for maximizing the yield. Excess or deficit irrigation decrease plant growth and yield. Therefore, it is necessary to find out the optimum water requirement and critical growth stages of foxtail millet for higher growth and yield. For this reason, this study is planned to find out the effect of irrigation on growth and yield of foxtail millet.

Materials and Methods

The experiment as conducted in the research field of the Irrigation and Water Management Division of Bangladesh Agricultural Research Institute (BARI) in Gazipur and RARS, BARI, Jamalpur during the rabi season of 2024-2025. The experiment followed a randomized complete block design (RCBD) with six treatments with three replications while the irrigation treatments were (T_0= no irrigation, T_1= one irrigation at vegetative stage, T_2= two irrigations at vegetative and flowering stages, T_3= two irrigations at vegetative and grain filling stages, T_4= two irrigations at flowering stages and grain filling stages, T_5= three irrigations at vegetative, flowering and grain filling stages. The sowing dates were 3 December 2024 at Jamalpur and 14 December 2024 at Gazipur. The recommended doses of TSP, MoP, Gypsum, Zinc Sulphate and half of the Urea applied during final land preparation and rest of the Urea applied at 35-40 day after sowing. BARI Kaon-4 variety was used, and standard crop establishment and management practices were followed. Soil samples were collected for moisture content measurement. Irrigation was calculated based on soil moisture and characteristics. Various growth and yield attributes were recorded at harvest. Harvesting was carried out on 11 April 2025 and 20 April 2025

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at Jamalpur and Gazipur, respectively. Harvest index and water productivity were also calculated. The data were analyzed statistically using R software.

Results and Discussion

The effect of irrigation treatments on foxtail millet varied significantly across both locations. From table 1. It was showed that in Gazipur, grain yield and water productivity were highest in treatments T_2 and T_1, with T_2 recording the highest grain yield (2.81 t/ha), while T_1 showed the best water productivity (2.28 kg/m³). Plant height, straw yield, biological yield, and harvest index were significantly improved under irrigated treatments compared to the control (T_0) where T_2 resulted the highest harvest index 31.11%. In Jamalpur, plant height and spike length were highest in T_5 and T_4, respectively, with the maximum grain yield (2.71 t/ha) recorded in T_2. However, water productivity declined with higher irrigation, with T1 showing the highest value (1.88 kg/m³). For both Gazipur and Jamalpur, 1000 grain weight demonstrated no significant distinctions among the different treatments. Overall, irrigation at vegetative and flowering stage enhanced growth, yield as well as water productivity across both sites, while excessive irrigation reduced water efficiency without significant yield gains.

Table 1. Effect of irrigation treatment on growth, yield and water productivity parameters of Foxtail Millet

Treatment	Plant Height (cm)	Spike length (cm)	1000 Grain weight (gm)	Grain yield (t/ha)	Biological Yield (t/ha)	Harvest Index (%)	Total water use (mm)	Water productivity (kg/m3)
Gazipur (2024-2025)								
T_0	64.67e	9.44b	1.95b	0.48d	3.48d	13.95c	42.7	1.13c
T_1	98.22d	16.55a	2.50a	2.19c	7.74c	28.38ab	96.3	2.28a
T_2	104.74cd	17.11a	2.51a	2.81a	9.05b	31.11a	161.4	1.74b
T_3	107.67bc	18.33a	2.45a	2.66ab	9.17b	29.07a	162.4	1.63b
T_4	114.56ab	16.88a	2.28ab	2.59b	9.28ab	27.94ab	166.3	1.55b
T_5	115.67a	15.33a	2.36a	2.48b	10.04a	24.86b	218.1	1.13c
CV(%)	**4.15**	**11.09**	**7.82**	**4.64**	**5.29**	**8.17**	**-**	**6.56**
LSD	**7.62**	**3.15**	**0.33**	**0.18**	**0.78**	**3.85**	**-**	**0.18**
Jamalpur (2024-2025)								
T_0	102.67d	11.67b	2.41b	1.28d	4.56d	28.11cd	80.5	1.59c
T_1	105cd	15.23ab	2.39b	2.15c	6.59c	32.65ab	114.5	1.88a
T_2	107c	15.67a	2.43b	2.71a	8.06b	33.67a	157.5	1.72b
T_3	111.89b	17.60a	2.67ab	2.55b	8.42b	30.41bc	188.5	1.35d
T_4	112.44b	17.90a	2.69ab	2.65ab	9.38a	28.34cd	224	1.18e
T_5	116.33a	18a	2.83a	2.61ab	9.88a	26.50d	266	0.98f
CV(%)	**1.44**	**12.58**	**8.35**	**3.10**	**5.24**	**4.54**	**-**	**3.76**
LSD	**2.86**	**3.66**	**0.39**	**0.13**	**0.74**	**2.47**	**-**	**0.099**

*T_0=no irrigation, T_1=one irrigation (vegetative stage), T_2=two irrigation (vegetative & flowering), T_3= two irrigation (vegetative & grain filling), T_4=two irrigation (flowering & grain filling), T_5=three irrigation (vegetative, flowering & grain filling)

Conclusion

The results show that providing irrigation during the vegetative and flowering stages is crucial for foxtail millet production in both Gazipur and Jamalpur, as it enhances growth, yield, and water productivity. In contrast, under water-limited conditions, prioritizing irrigation during the vegetative stage yields the best outcomes. Moreover, this research needs to be continued for one more year to validate these results.

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YIELD AND WATER PRODUCTIVITY OF CHIA TO DIFFERENT LEVELS OF IRRIGATION

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Abstract

This study investigated the impact of different irrigation treatments on BARI Chia-1 for the year 2023-24 and 2024-25 in Gazipur during Rabi season. Five treatments: T_1= irrigation at vegetative stage, T_2=irrigation at vegetative + flowering stage, T_3= irrigation at vegetative + grain filling stage, T_4= irrigation at flowering + grain filling stage, and T_5= irrigation at vegetative + flowering + grain filling stage. The study indicated that irrigation during the flowering stage and grain filling stage led to the highest seed yield and water productivity, followed by irrigation at the vegetative and grain filling stage. Overall results as well as water use of the treatments indicated that irrigation at the flowering stage and grain filling stage is the critical stage for irrigation.

Introduction

Chia (Salvia hispanica L.) is an annual plant from the Lamiaceae family. In Bangladesh, it has recently been introduced, and its seeds are gaining importance for their high ω-3 fatty acid content, particularly ALA (alpha-linolenic acid), which offers various health benefits. Chia seeds are rich in protein, fats, carbohydrates, dietary fibre, antioxidants, minerals, and vitamins. They thrive in diverse soil and climatic conditions, suitable for rain-fed or irrigated fields (Muriithi et al., 2022). However, lack of soil moisture during the critical stage has hindered seed production. Effective irrigation management is crucial to enhancing chia yield. In addition, understanding the critical growth stages of a crop is essential for effective irrigation scheduling. Hence, our current research focuses on understanding the critical growth stages of chia under water stress.

Materials and Methods

The test crop was BARI Chia-1. The experiment was conducted using an RCBD design with three replications. Fertilisation was applied at 60 kg/ha nitrogen, 40 kg/ha phosphorus, 50 kg/ha potassium, and 8 kg/ha sulphur during land preparation. The unit plot size was 5.0 m × 3.0 m. Seeds were sown on 27 December, 2023 and were harvested on 18 April to 22 April 2024 for the 1st year and 12 December 2024 and were harvested from 08 April to 12 April 2025 for the 2nd year. The measured amount of water was applied to each plot as per requirement to maintain the soil moisture content in the root zone depth, using flood irrigation. Yield data was collected for each plot at harvest. Statistical analysis of the data was performed, and means were compared using the LSD test at a 5% significance level. The irrigation treatments were

T_1= One irrigation at vegetative stage (30-35 DAS)
T_2= Two irrigations at vegetative and flowering stages (60-65 DAS)
T_3= Two irrigations at vegetative and grain filling stages (80-85 DAS)
T_4= Two irrigations at flowering and grain filling stages
T_5= Three irrigations at vegetative, flowering and grain filling stages

Results and Discussion

In Table 1, the higher value of plant height (110.2 cm and 118.3), spike number/branch (11.3 and 13), spike length (16.1 cm and 18.5 cm), spike weight (2.6 gm and 3 gm), seed yield (999.6 and 1101.3 kg/ha) were obtained from treatment T_4 (irrigation applied at flowering and grain filling stages) for the

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year 1 and 2, respectively which is followed by T_3 (irrigation applied at vegetative and grain filling stages) and significantly similar to each other. The lowest results for all parameters were observed in treatment T_1 (irrigation applied at vegetative stage) with the lowest irrigation water. Treatment T_5, which received three irrigations, produced lower yields than T_3 and T_4, likely because chia might prefer less water and cannot tolerate excessive irrigation (could enhance vegetative growth rather than yield contribution). Among the five treatments, T_3 and T_4 were the most effective for chia yield.

The highest total water use was in treatment T_5, where more irrigation was applied at vegetative, flowering and grain filling stage for both years, but this treatment does not show higher water productivity due to high water use and lower yield. On the other hand, treatments T_4 and T_3 were in 2nd and 3rd position in terms of total water use, resulting in higher water productivity. However, in terms of yield and water productivity, treatment T_3 and T_4 performed better than the others for both years (Table 2). Both T_3 and T_4 included irrigation at the grain filling stage, indicating that this is a critical period for chia irrigation, which aligns with Diez et al. (2023).

Table 1. Yield and yield contributing characters of chia cultivation for 2023-24 and 2024-25

Treat-ments	Plant height (cm)		Spike number/br (no.)		Spike length (cm)		Spike wt. (gm)		Seed yield (kg/ha)	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T_1	89.3	92.0	8.3	9.0	10.4	11.9	1.8	2.3	684.1	700.5
T_2	99.5	100.7	8.0	8.7	11.7	12.0	1.9	2.6	687.2	769.0
T_3	102.5	107.3	9.7	10.0	16.1	18.0	2.6	3.0	823.7	940.4
T_4	110.2	118.3	11.3	13.0	16.0	18.5	2.4	2.9	999.6	1101.3
T_5	99.8	102.1	8.3	8.2	13.3	13.9	2.2	2.7	751.1	728.0
CV	4.2	3.8	2.7	2.3	3.9	3.5	3.3	3.0	5.1	7.2
LSD	9.2	8.4	0.9	1.1	3.1	5.1	0.37	0.7	63.7	95.4

Table 2. Irrigation water used and water productivity in different treatments for 2023-24 and 2024-25

Treat-ments	Water for plant estab. (mm)		Irri. water applied (mm)		Effective rainfall (mm)		Total water Used (mm)		Water productivity (kg/m^3)	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T_1	30	35	101	110	69.6	26	199	169	0.34	0.41
T_2	30	35	213	215	69.6	26	311	274	0.22	0.28
T_3	30	35	240	245	69.6	26	337	304	0.24	0.31
T_4	30	35	244	250	69.6	26	349	309	0.29	0.36
T_5	30	35	286	294	69.6	26	382	352	0.20	0.21

T_1= One irrigation at vegetative stage (30-35 DAS); T_2= Two irrigations at vegetative and flowering stages (60-65 DAS);
T_3= Two irrigations at vegetative and grain filling stages (80-85 DAS); T_4= Two irrigations at flowering and grain filling stages
T_5= Three irrigations at vegetative, flowering and grain filling stages

Conclusion

The both year findings indicate that irrigation during the flowering and grain filling stages is critical for chia cultivation, leading to improved yield and higher water productivity.

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TEMPERATURE FORECASTING USING BAYESIAN OPTIMIZATION TUNED MACHINE LEARNING ALGORITHMS

C. R. PAUL[1], T. H. MUNMUN[2], D. K. ROY[3]

Abstract

Accurate temperature predictions are crucial for agricultural planning and weather forecasting. This study explored soft computing techniques for predicting average daily temperatures using a dataset over 44 years (1980-2023) across two meteorological stations (Dhaka, and Ishurdi). The study developed and compared Artificial Neural Network (ANN), Extreme Learning Machine (ELM), Gaussian Process Regression (GPR), and Support Vector Regression (SVR) models. The optimal hyperparameters of these models were selected using Bayesian optimization to ensure their best performance. Results showed that prediction accuracy was influenced not only by the choice of algorithm but also by the characteristics of the training and testing datasets. In Dhaka, ELM consistently outperformed all models across all forecast horizons. In Ishurdi, SVR demonstrated superior performance for one-day-ahead and ELM for two, and three-day-ahead average temperature predictions (RMSE = 0.0495 °C and 0.0697 °C, respectively), as indicated by Shannon's Entropy-based decision theory. Therefore, ELM emerged as the most effective method in nearly all cases, except for the one-day-ahead prediction at Ishurdi, highlighting both its robustness and the importance of dataset-specific characteristics in predictive modelling.

Introduction

Weather forecasts have traditionally included temperature forecasts as the key component. The agricultural sector increasingly relies on weather forecasts, especially for average temperature predictions, which is crucial for crop growth, yield estimation, and irrigation planning. Recently, soft computing and machine learning methods have been increasingly used for temperature prediction because of their ability to handle nonlinear relationships and provide reliable results (Zhang et al., 2025). However, manual hyperparameter tuning is tedious and may not find the optimal parameters. Therefore, the present study implements an automatic parameter selection process using the Bayesian optimization algorithm to predict the multi-step ahead average temperatures.

Materials and Methods

Forty-four years of daily average temperature data (from Jan 1980 to Sep 2023) were collected from two meteorological stations located in Dhaka, and Ishurdi. The dataset passed through several preprocessing steps: missing data were imputed using the Piecewise Cubic Hermite Interpolating Polynomial (pchip) method, outliers were identified using the Generalized Extreme Studentized Deviate (gesd) method, and noisy data were smoothed using the Moving mean (movmean) method. Normalization was performed using the Z-score technique. After obtaining time series of the processed daily average temperature data, Partial Autocorrelation Function (PACF) approach was used to acquire time-lagged information from the time series data. Subsequently, the Minimum Redundancy Maximum Relevance (mRmR) approach was used to select the most significant input variables. The input-output dataset was partitioned into three sets: 60% of the data was used for training the models, 20% for the validation and the remaining 20% was employed to test the developed models. In this study, we developed and compared four soft computing techniques: ANN, ELM, GPR, and SVR. Optimal model parameters were selected through hyperparameter tuning using Bayesian optimization. Evaluation of the models performance was conducted using several performance metrics, aiming specifically on their ability to provide accurate multi-step ahead daily average temperature forecasts.

Results and Discussion

The four models optimized through Bayesian optimization demonstrated satisfactory performance, with high values of R, NS, and IOA, along with low RMSE, NRMSE, MAPRE, MAE, and MAD, indicating strong predictive agreement and minimal errors (Table 1 and 2). To identify the best model, a Shannon's

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Entropy–based ranking was applied, integrating eight performance indices. The ranking results revealed that, at Dhaka station, ELM was the best model across all horizons, followed by SVR, GPR, and ANN (ELM > SVR > GPR > ANN). At the Ishurdi station, SVR provided the best performance for the one-day-ahead forecast (SVR > ELM > ANN > GPR), while ELM ranked highest for both the two-day- and three-day-ahead forecasts (two-day: ELM > SVR > GPR > ANN; three-day: ELM > GPR > SVR > ANN). Overall, ELM emerged as the most robust and reliable model across both locations.

Table 1. Performance of the models on test dataset at location Dhaka

Models	Days ahead	Performance indices							
		RMSE (°C)	NRMSE	MAPRE (%)	MAE (°C)	MAD (°C)	R	NS	IOA
ANN	One	0.02128	0.00080	1.63266	0.01633	0.00815	0.99998	0.99996	0.99999
	Two	0.04275	0.00161	3.34272	0.03343	0.01646	0.99992	0.99983	0.99983
	Three	0.06400	0.00241	5.05473	0.05055	0.02466	0.99982	0.99962	0.99991
ELM	One	0.03199	0.00120	2.50468	0.02505	0.01215	0.99995	0.99998	0.99998
	Two	0.08347	0.00314	6.67531	0.06675	0.03334	0.99968	0.99936	0.99984
	Three	0.06963	0.00262	5.52456	0.05525	0.02659	0.99978	0.99955	0.99989
GPR	One	0.02140	0.00081	1.64273	0.01643	0.00805	0.99998	0.99996	0.99999
	Two	0.04297	0.00162	3.36093	0.03361	0.01625	0.99992	0.99983	0.99996
	Three	0.06495	0.00244	5.13631	0.05136	0.02457	0.99981	0.99961	0.99990
SVR	One	0.02769	0.00104	2.21145	0.02211	0.01090	0.99997	0.99993	0.99998
	Two	0.04703	0.00177	3.65501	0.03655	0.01779	0.99990	0.99980	0.99995
	Three	0.06548	0.00246	5.17064	0.05171	0.02474	0.99981	0.99960	0.99990

Table 2. Performance of the models on test dataset at location Ishurdi

Models	Days ahead	Performance indices							
		RMSE (°C)	NRMSE	MAPRE (%)	MAE (°C)	MAD (°C)	R	NS	IOA
ANN	One	0.02169	0.00085	1.66520	0.01665	0.00842	0.99999	0.99997	0.99999
	Two	0.04197	0.00165	3.29133	0.03291	0.01598	0.99995	0.99990	0.99998
	Three	0.06270	0.00247	4.94669	0.04947	0.02471	0.99989	0.99978	0.99995
ELM	One	0.03858	0.00152	2.99074	0.02991	0.01456	0.99996	0.99992	0.99998
	Two	0.04949	0.00195	3.90658	0.03907	0.01984	0.99993	0.99987	0.99997
	Three	0.06970	0.00274	5.50632	0.05506	0.02746	0.99987	0.99973	0.99993
GPR	One	0.02066	0.00081	1.58535	0.01585	0.00760	0.99999	0.99998	0.99999
	Two	0.04226	0.00166	3.31363	0.03314	0.01631	0.99995	0.99990	0.99998
	Three	0.06472	0.00254	5.11123	0.05111	0.02593	0.99989	0.99977	0.99994
SVR	One	0.06848	0.00269	5.48685	0.05487	0.02804	0.99988	0.99974	0.99994
	Two	0.04440	0.00175	3.51717	0.03517	0.01770	0.99995	0.99989	0.99997
	Three	0.06436	0.00253	5.07211	0.05072	0.02563	0.99989	0.99977	0.99994

Conclusion

The study demonstrated that ELM was the most reliable model for temperature prediction in Dhaka and Ishurdi, indicating its effectiveness for accurate forecasts. This study further highlights that the accuracy of predicting a given parameter depends not only on the choice of ML algorithms but also on the quality and characteristics of the data used for training and validation. In future work, data from additional meteorological stations will be incorporated to further evaluate and validate the performance of the models across diverse climatic conditions.

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ESTIMATION OF CROP WATER REQUIREMENT USING AN OPTIMIZATION ALGORITHM-TUNED FUZZY TREE APPROACH

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Abstract

Crop evapotranspiration (ETc) plays a vital role in making informed decisions for both real-time and future irrigation scheduling of major crops. Therefore, accurately predicting ETc is essential in the field of water resources management. This study investigates the effectiveness of a fuzzy tree (FT) approach, optimized using various algorithms, for predicting ETc during the initial, development, mid-season, and late-season growth stages of onion and potato crops in Gazipur. A total of 16 FT models were developed, and model performance was ranked using Shannon's Entropy (SE) method. For onion, the results showed that the FIS, GA-PSO, PSO-PSO, and FIS performed best during the initial, development, mid-season, and late-season stages, respectively. In contrast, for potato, the FIS model consistently outperformed other models across all growth stages. However, since the FT models were developed by optimizing tunable parameters, they are expected to outperform standalone FIS models when applied to unseen data. Overall, the study concluded that the FT model is highly effective for predicting seasonal ETc values for both onion and potato crops.

Introduction

For precise application of irrigation water, accurate irrigation scheduling is required. Crop water requirement is one of the vital parameters to accurately schedule irrigation. Because it has been demonstrated that the amount of water required for irrigation is largely dependent on crop water requirements, this poses a significant issue with exciting implications in agricultural research. Machine learning (ML)-based soft computing techniques have recently been considered one of the promising approaches to determine crop water requirement for developing precise irrigation scheduling (Sidhu et al., 2020). However, even with the right model, it is still a difficult scientific challenge to predict crop water requirement with the required level of accuracy (Roy et al., 2023). Additionally, selecting the optimal parameters for a ML-based model is a tedious and time-consuming task. To fill this research gap, the present study aims to utilize an optimization algorithm-tuned fuzzy tree approach to accurately predict growth stage based ET_c of the onion and potato.

Materials and Methods

The ETc values at different growth stages of onion and potato were calculated by multiplying the reference evapotranspiration (ET_0) and crop coefficient (kc) values for the respective growth stages. The ET_0 values were computed from the weather parameters using the Penman-Monteith equation. ETc values were subsequently calculated by multiplying the estimated ET_o with the growth stage–specific crop coefficient (Kc) values. The weather parameters and the corresponding ETc formed the input-output training patterns of the FT models. The FT models were constructed by integrating several FIS objects, with the inputs being the ranked input variables with the output (ETc). Eighty percent of the data were used for training, while the remaining 20% was used for testing. The optimal parameter sets of the proposed FT approach were determined through parameter tuning using optimization algorithms (GA, PSO, and their combinations). The parameter tuning was executed in two steps: in the first step, only the rule bases were optimized, whereas in the second step, both the rule bases and the membership functions were optimized. A total of 16 FT models were developed for the four growth stages and four combinations of the optimization algorithms (GA-GA, GA-PSO, PSO-PSO, PSO-GA). The performances of the optimization algorithm-tuned FT models were compared with those of an FIS model developed with the same dataset. Finally, the models were ranked based on their performances using the concept of Shannon's Entropy (Shannon, 1948).

Results and Discussion

The prediction performance of the optimization algorithm-tuned FT models was generally satisfactory, as evidenced by the R, NS, IOA, RMSE, MAE, and MAD values. The models provided higher values of R, NS, and IOA, as well as lower values of RMSE, MAE, and MAD. However, as it is difficult to

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decide on the best-performing model based on individual performance criteria, the models underwent a ranking process using SE that incorporated the six performance criteria instead of a single criterion. Based on SE, the FIS, GA-PSO, PSO-PSO, and FIS models turned out to be the top-performing models for predicting ET_c of onion during the initial, development, mid-season, and late-season stages. The SE-selected best model at the initial stage provided R, NS, IOA, RMSE, MAE, and MAD values of 0.98, 0.97, 0.99, 0.042 mm/d, 0.036 mm/d, and 0.017 mm/d, respectively. Similarly, at the development stage, the best model yielded R = 0.99, NS = 0.98, IOA = 0.99, RMSE = 0.059 mm/d, MAE = 0.036 mm/d, and MAD = 0.012 mm/d. The best model at the mid-season stage provided R = 0.99, NS = 0.97, IOA = 0.99, RMSE = 0.067 mm/d, MAE = 0.037 mm/d, and MAD = 0.013 mm/d. The best model at the late-season stage provided R = 0.98, NS = 0.97, IOA = 0.99, RMSE = 0.055 mm/d, MAE = 0.045 mm/d, and MAD = 0.023 mm/d (Table 1). In contrast, for potatoes, FIS model consistently emerged as the top-performing model across all growth stages (Table 2). However, the performance differences between the FT models and the FIS models were minimal, indicating that the FT models are strong candidates for ETc modeling across different growth stages. Furthermore, since the FT models were developed by optimizing tunable parameters, they are expected to outperform standalone FIS models when applied to unseen data.

Table 1. Performances of the selected best models at different growth stages of onion

Performance index	Best model at different growth stages			
	Initial (FIS)	Development (GA-PSO)	Mid-season (PSO-PSO)	Late-season (FIS)
R	0.986	0.992	0.99	0.987
NS	0.971	0.984	0.979	0.974
IOA	0.992	0.996	0.994	0.993
RMSE, mm/d	0.042	0.059	0.067	0.055
MAE, mm/d	0.036	0.036	0.037	0.045
MAD, mm/d	0.017	0.012	0.013	0.023

Table 2. Performances of the selected best models at different growth stages of potato

Performance index	Best model at different growth stages			
	Initial (FIS)	Development (FIS)	Mid-season (FIS)	Late-season (FIS)
R	0.953	0.989	0.993	0.974
NS	0.889	0.978	0.979	0.946
IOA	0.946	0.994	0.995	0.985
RMSE, mm/d	0.073	0.036	0.054	0.021
MAE, mm/d	0.016	0.028	0.036	0.016
MAD, mm/d	0.006	0.012	0.014	0.007

Conclusion

The optimization algorithm–tuned FT models performed well in predicting ETc for onion, demonstrating high R, NS, and IOA values, along with low RMSE, MAE, and MAD. SE-based ranking identified different top-performing models across onion growth stages, whereas the FIS model consistently outperformed others for potato. Since the FT models were developed by optimizing tunable parameters, they are expected to outperform standalone FIS models when applied to unseen data.

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PROJECTION OF MEDIUM-TERM WEATHER PARAMETERS USING DEEP LEARNING MODELS

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Abstract

Accurate forecasting of weather parameters and reference evapotranspiration (ET_0) is vital for effective irrigation planning and climate-resilient agriculture. This study evaluated the performance of three deep learning models—LSTM, Bi-LSTM, and Pro-LSTM—for projecting daily weather variables and ET_0 up to 730 days ahead at three stations in Bangladesh. Bi-LSTM showed the best performance on short-term predictions ($R \approx 0.999$–1.000; low NRMSE), but its accuracy declined over extended forecasts, likely due to its bidirectional structure. Pro-LSTM, by contrast, outperformed others in long-range projections, aided by its projected-layer design. Results highlight Pro-LSTM's robustness for medium-term forecasting, supporting data-driven agricultural water management.

Introduction

Weather forecasting plays a crucial role in agricultural water management, particularly in regions vulnerable to climatic variability. Traditional models often fail to capture nonlinear temporal patterns in meteorological data. Recently, deep learning models, especially recurrent neural networks (RNNs) such as Long Short-Term Memory (LSTM) (Hochreiter and Schmidhuber, 1997) and its variants, have demonstrated remarkable performance in time-series forecasting applications, including hydrological predictions (Chaki and Hasan, 2024; Diez-Sierra and del Jesus, 2020; Lateef et al., 2021). Bidirectional LSTM (Bi-LSTM) allows context from both past and future time steps, enhancing prediction accuracy. Projected-Layer LSTM (Pro-LSTM), a recent variant, integrates dimensionality reduction within the LSTM framework, improving computational efficiency and generalization. This study investigates and compares the medium-term forecasting capabilities of LSTM, Bi-LSTM, and Pro-LSTM in predicting daily weather variables and ET_0 for three key stations in Bangladesh.

Materials and Methods

Daily meteorological data from Gazipur, Barishal, and Ishurdi stations were collected and preprocessed. The target variables included maximum and minimum temperature, rainfall, relative humidity, sunshine duration, wind speed, and ET_0 (calculated using FAO Penman–Monteith). The models—LSTM, Bi-LSTM, and Pro-LSTM—were developed in MATLAB environment. The datasets were split into training and testing for evaluation of model performances, and model performance was evaluated using the correlation coefficient (R) and normalized root mean square error (NRMSE). Forecasts were extended beyond the available dataset (730 days) by resetting the network state and performances were assessed visually by observing the data trends.

Results and Discussion

The forecasting performance of LSTM, Bi-LSTM, and Pro-LSTM models was evaluated using R and NRMSE at Gazipur, Barishal, and Ishurdi stations. Bi-LSTM consistently delivered the highest short-term accuracy, with near-perfect R values (up to 1.000) and the lowest NRMSE across most weather variables. LSTM and Pro-LSTM performed reasonably well within the known dataset, especially for maximum and minimum temperatures, relative humidity, and ET_0 (R ranging from 0.720 to 0.967). However, their accuracy was lower for rainfall, sunshine duration, and wind speed. In long-term forecasting beyond the available data, Pro-LSTM outperformed the others due to its projected-layer architecture, followed by LSTM. Bi-LSTM, constrained by its bidirectional design, failed to generalize

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beyond the training window. Pro-LSTM demonstrated robust performance across all stations and weather parameters in extended forecasts. Table 1 summarizes the models' predictive accuracy within the test range, while Figure 1 illustrates Pro-LSTM's ET_0 projections beyond the available data.

Table 1. Performance indices of the deep learning models in predicting weather parameters at Gazipur station

Weather parameters	Performance indices					
	LSTM		Bi-LSTM		Pro-LSTM	
	R	NRMSE	R	NRMSE	R	NRMSE
Max. Temp.	0.889	0.053	1.000	0.003	0.888	0.053
Min. Temp.	0.889	0.053	1.000	0.003	0.888	0.053
Rainfall	0.343	2.580	0.997	0.196	0.346	2.582
Relative humidity	0.831	0.085	1.000	0.005	0.829	0.085
Sunshine duration	0.533	0.466	0.999	0.018	0.535	0.465
Wind speed	0.499	0.433	0.999	0.023	0.466	0.443
ET_0	0.790	0.203	0.999	0.015	0.778	0.206

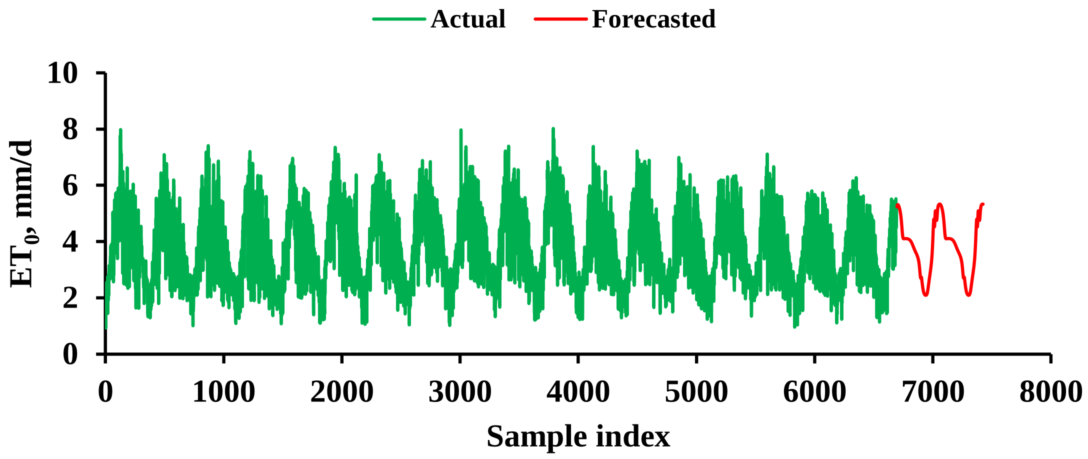

Fig. 1. Actual and projected ET_0 values produced by the Pro-LSTM model at Gazipur station

Conclusion

This study demonstrated that deep learning models, particularly Bi-LSTM and Pro-LSTM, offer reliable tools for medium-term forecasting of weather variables and ET_0. Bi-LSTM consistently delivered superior results across all weather parameters and stations, followed closely by Pro-LSTM. These findings underscore the potential of advanced deep learning models in supporting data-driven irrigation and climate adaptation strategies in agriculture.

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AUTOMATION OF DRIP IRRIGATION USING ADVANCED SOIL SENSORS IN TOMATO (BARI TOMATO-21) CULTIVATION

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Abstract

Efficient irrigation management is critical for optimizing water use and maximizing crop yield, particularly for water-sensitive crops like tomato. This study evaluated the performance of different soil sensor-based automation systems for drip irrigation in the cultivation of BARI Tomato-21 at Gazipur. The experiment was laid out in a randomized complete block design (RCBD) with six treatments and three replications, comparing control and timer-based systems with four advanced sensor-based methods. Results showed that automation using multi-parameter and multi-layer soil moisture sensors effectively monitored soil conditions and controlled solenoid valves to initiate or terminate irrigation as required. Among the treatments, T_3 demonstrated the highest yield (82.69 t/ha) and superior fruit characteristics, while T_2 achieved the highest water productivity (21.89 kg/m^3) with the lowest seasonal water use. The findings confirm that sensor-based irrigation systems can enhance tomato yield and resource efficiency by enabling real-time, data-driven irrigation scheduling. This underscores the potential of precision irrigation technologies to support sustainable water management in tomato production.

Introduction

The increasing scarcity of freshwater resources necessitates the adoption of precision agriculture practices, particularly in irrigation management. Tomatoes, being shallow-rooted and highly sensitive to water stress, require precise water scheduling for optimal yield and quality (Patanè et al., 2011). Drip irrigation has proven superior to surface irrigation in conserving water and improving yields; however, automation can further optimize this method by responding to real-time soil conditions (Anjum et al., 2023). Soil sensors play a pivotal role in this context, enabling dynamic water application based on parameters like moisture, temperature, pH, EC, and nutrient availability (Kushwaha et al., 2024). The present study aims to compare the performance of various soil sensor technologies in automating drip irrigation for tomato cultivation under field conditions.

Materials and Methods

The experiment was conducted on tomato (BARI Tomato-21) using six irrigation treatments arranged in a randomized complete block design (RCBD) with three replications in the field of IWM Division, BARI, Gazipur. Each plot measured 5 m × 5 m, and sowing was performed on December 18, 2024. The treatments included T1 (control with manual irrigation every alternate day), T2 (timer-based irrigation), and four sensor-based automated systems: T3 (Teros LIIS 12 moisture sensor), T4 (LIIS SMPS sensor measuring pH, temperature, moisture, EC, and NPK), T5 (LIIS 2255 5-layer soil sensor), and T6 (LIIS 5254 tube-type 5-layer soil sensor). Fertilizers were applied based on BARI recommendations. Data on the number of fruits per plant, individual fruit weight, and total yield per hectare were collected for each treatment.

Results and Discussion

The comparative performance of six irrigation treatments during the 2024–25 growing season revealed notable differences in yield and water use efficiency of tomato. Among the treatments, sensor-based systems, particularly T_3 and T_2, demonstrated superior agronomic and water productivity outcomes. In terms of fruit production, T_3 recorded the highest fruit count (45.00), fruit length (56.33 cm), unit fruit weight (94.63 g), and yield (82.69 t/ha). T_2 closely followed with 81.67 t/ha, while T_6 also showed strong performance (81.13 t/ha). The lowest yield was recorded in T_5 (79.94 t/ha). Water use varied slightly, with irrigation amounts ranging from 244 mm (T_3) to 250 mm (T_1). Despite lower seasonal

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water use (373.11 mm), T_2 achieved the highest water productivity (21.89 kg/m³), followed by T_3 (21.86 kg/m³) and T_6 (21.43 kg/m³). Statistical analysis confirmed significant differences among treatments ($p < 0.005$), reinforcing the reliability of these results. These findings support earlier studies(e.g., Zheng et al., 2013), highlighting that sensor-based irrigation enhances efficiency and crop output by providing real-time soil moisture data for better scheduling decisions.

Table 1. Yield and yield contributing characters of tomato during 2024-25 growing season

Treatments	Number of fruits per plant, cm	Length of fruit, cm	Diameter of fruit, cm	Unit weight of fruit, g	Yield, t/ha
T_1	42.00	49.68	48.61	91.36	80.58
T_2	44.00	54.23	48.67	92.31	81.67
T_3	45.00	56.33	46.56	94.63	82.69
T_4	41.00	52.67	53.33	92.81	80.96
T_5	43.00	53.33	45.33	90.75	79.94
T_6	43.00	46.78	47.39	93.12	81.13
F	6.00	60.25	38.01	7.18	10.28
Prob.>F	0.0052	4.41×10^{-8}	5.95×10^{-7}	0.0025	0.0005

Table 2. Water use and water productivity of tomato in different treatments

Treatments	Amount of irrigation water, mm	Effective rainfall, mm	Soil water contribution, mm	Seasonal water use, mm	Yield, t/ha	Water productivity, kg/m³
T_1	250	113	17.92	380.92	80.58	21.15
T_2	248	113	12.11	373.11	81.67	21.89
T_3	244	113	21.23	378.23	82.69	21.86
T_4	247	113	25.17	385.17	80.96	21.02
T_5	245	113	18.67	376.67	79.94	21.22
T_6	246	113	19.54	378.54	81.13	21.43

Conclusion

The study demonstrated that sensor-based automated drip irrigation significantly improves tomato yield and water productivity compared to control and timer-based systems. Treatments T_3 and T_2, which utilized multi-parameter soil sensors, showed the highest yield and water use efficiency, respectively. These findings highlight the potential of precision irrigation technologies in enhancing crop performance while conserving water resources. This is 1st year study and will be continued in next year.

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ADVANCING WATER LIFTING FACILITIES AND IMPLEMENTING WATER-SAVING MICRO-IRRIGATION PRACTICES FOR SUSTAINABLE HILLTOP AGRICULTURE IN THE HILLY REGIONS OF BANDARBAN

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Abstract

In the hilly terrains of Bandarban, Bangladesh, limited water access and inefficient irrigation practices pose significant challenges to sustainable agriculture. This research aims to enhance water availability and crop productivity through advanced water lifting systems and water-saving micro-irrigation techniques. During the first two years of the project, two major objectives were successfully achieved: (1) the design and development of water lifting facilities, and (2) the implementation of micro-irrigation systems. A solar-operated 3 HP submersible pump was installed, lifting water from a depth of 550 ft, powered by eight 585 W solar panels (total 4680 W). Micro-irrigation systems were established for papaya and ber cultivation. The upcoming research year will focus on evaluating the socio-economic impacts of these interventions and developing sustainable adoption guidelines. Another 550 ft deep water lifting system (from the point of first lifting: double lifting) will also be installed. The findings aim to contribute to sustainable hill agriculture, improving livelihoods and climate resilience in the region.

Introduction

Agricultural productivity in the Bandarban hilly region is constrained by erratic water availability, topographic limitations, and unsustainable irrigation practices (Miah, 2025; Rasul et al., 2004). Traditional water management methods often lead to low irrigation efficiency, deep percolation losses, and degraded soil health, particularly in sloped terrains where runoff and erosion further reduce water retention and crop performance (Misbahuzzaman, 2016). Given the ecological sensitivity of hilly regions, sustainable water management technologies tailored to local topography and socio-economic conditions are essential (Miah, 2025; Uddin, 2018). This study, conducted under the PARTNER project of BARI, aims to address these issues by advancing solar-powered water lifting technologies and promoting micro-irrigation practices for water-efficient hill farming. The initiative builds on the premise that modern, site-specific interventions can significantly enhance agricultural outcomes and community well-being in hilly terrains (Rasul and Gurung, 2024).

Materials and Methods

The study was conducted in a hilltop area of Bandarban under the On-Farm Research Division (OFRD), BARI, as part of the PARTNER project, with the objective of enhancing sustainable agricultural practices through improved water management. During the first and second years (2023-24 & 2024-25), a solar-powered water lifting system was installed using a 3 HP submersible pump capable of lifting water from a depth of 550 feet, powered by eight solar panels each rated at 585 watts, totaling 4680 watts. This system supplied irrigation water to cultivated plots of papaya and ber, where micro-irrigation techniques such as drip irrigation were implemented to assess water use efficiency and crop performance. Various technical parameters such as water lifting efficiency, flow rate, water storage capacity, and energy use were monitored. Crop growth, yield, and water productivity were recorded and compared with traditional irrigation benchmarks. Data on soil moisture at various depths were also collected to evaluate the effectiveness of water application. In the upcoming year (2025-26), a second water lifting system will be established under similar conditions, and socio-economic surveys including structured interviews and focus group discussions will be conducted in the subsequent years to evaluate

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the impact of these technologies on farmer livelihoods, labor requirements, and income levels. A cost-benefit analysis will be conducted, which will quantify the economic feasibility of the interventions, while stakeholder workshops involving local farmers, extension agents, and community leaders will support the development of practical and locally appropriate guidelines for sustainable adoption.

Results and Discussion

The 2023-24 & 2024-25 implementations successfully demonstrated the feasibility and efficiency of solar-operated deep water lifting in steep hill terrain. The 3 HP submersible pump operated effectively with the 4680 W solar system, ensuring sustainable and eco-friendly irrigation access. Drip irrigation facilitated controlled water delivery and enhanced water use efficiency, significantly reducing water loss. Papaya and ber showed promising growth and yield under micro-irrigation conditions, indicating suitability for wider hilltop cultivation. Farmer feedback revealed increased interest in micro-irrigation due to observed water savings and reduced labor. These results confirm the potential of scaling up such interventions across similar hill farming communities. The next phase will provide insight into the broader socio-economic benefits, including improved income, job opportunities, and resilience to climate variability.

Fig. 1. Installed solar panels for water lifting through 3 hp submersible pump

Conclusion

The project successfully laid the foundation for sustainable hill agriculture in Bandarban by demonstrating effective solar-powered water lifting and micro-irrigation for high-value crops like papaya and ber. With the upcoming focus on socio-economic assessment and guideline formulation, the project is well-positioned to deliver comprehensive strategies for resilient hill farming. Expanding these innovations to other hilly regions may significantly contribute to food security and environmental sustainability. This ist 1st year study and will be continued in next year.

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EVALUATION OF BED AND FURROW IRRIGATION FOR YIELD AND WATER PRODUCTIVITY OF POTATO

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Abstract

Potato is traditionally grown with every furrow irrigation method, which increases irrigation water use and reduces water productivity (WP). Therefore, an experiment was conducted at Gazipur during Rabi season in 2024-25 to investigate yield, water use, WP, and the quality of potato tubers. The two-factor experiment included twelve combinations of four-ridge beds and furrow irrigation with three irrigation levels and two variable spacing. Double row ridge bed (70 cm) and furrow irrigation, row spacing 50 cm (DREFI50) significantly increase yields, reduce water use, and increase water productivity in potatoes. This system saved around 19% irrigation water compared to double row ridge bed (90 cm) and furrow irrigation with 60 cm (DRBFI60). Irrigation levels affect the quality of potato tubers. The results indicate that DREFI50 can be used for potato production in water-scarce areas.

Introduction

Water-saving irrigation methods are becoming increasingly popular in Bangladesh. Deficit irrigation, partial root-zone drying, alternated furrow irrigation (AFI), drip and sprinkler irrigation are promising techniques to save water (Sarker et al., 2019). Water-saving methods like sprinkler and drip irrigation are effective for saving water, but setting up these technologies is not easy due to the initial costs. Recently, the area and production of potatoes have increased. So, water-saving ridge bed and furrow irrigation is essential because of the scarcity of water in the dry season. This idea was taken from the concept of skip fixed AFI (Sarker et al., 2016). This water-saving technique has not been investigated in Bangladesh. Therefore, the method of ridge bed and furrow irrigation was evaluated for tuber yield, water use, WP and quality of potato.

Materials and methods

The study was conducted at the research field of IWM Division, BARI, Gazipur during the dry season (December-March) in 2024-25. The soil was silt clay loam with an average gravimetric field capacity (FC) of 28.5% (w/w) and bulk density of 1.49 g cm^{-3} over 0-30 cm soil profile. The 12 treatments consisted of four-ridge beds and furrow irrigation with two variable spacing and three irrigation levels. Ridge bed and furrow irrigation were (i) SREFI50: Single row ridge (30 cm) and every furrow irrigation, and plant row spacing 50 cm; (ii) DRBFI50: Double row ridge bed (70 cm) and furrow irrigation, plant row spacing 50 cm; (iii) SREFI60: Single row ridge (40 cm) and every furrow irrigation, plant row spacing 60 cm; (iv) DRBFI60: Double row ridge bed (90 cm) and furrow irrigation, plant row spacing 60 cm, and irrigation levels were**:** I_1: 100% FC, I_2: 20% less than I_1, I_3: 40% less than I_1. FRG 2018 and three irrigations at 20-25 days after planting (DAP), 40-45 DAP, and 60-65 DAP were used. BARI Alu-25 were planted on 4 December 2024 and harvested on 5 March 2025. The soil water balance approach was used to estimate the seasonal water use (Sarker et al., 2016; 2019). Adequate plant protection measures were taken whenever required. Data was statistically analysed to test the effects of ridge bed and furrow, and irrigation levels using R.

Results and Discussion

Table 1 presents the interaction effect of ridge bed furrow and irrigation levels on yield, WP and quality of potato tubers. The interaction effect of ridge bed furrow and irrigation levels had significant differences in potato (Table 1). SRRBFI and DRRBFI treatments with 50 cm row spacing technique produced significantly greater yield. The results indicated that DRRBFI with 50 cm row spacing produced significantly greater tuber yield than 60 cm row spacing of SRRFI60 and DRBFI60 (Table 1). Treatment mean values of TSS, DM and grade size are shown in Table 1. RBFI with row spacing significantly affected the treatments in TSS, DM and grade size (Table 2) of potato tubers. Similarly, the effect of irrigation levels was also significantly different except when the grade size is greater than 55 mm (Table 2). The interaction effect of

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ridge bed and furrow, and irrigation levels had no significant differences in TSS but significantly differed in DM (Table 2). RBFI and irrigation levels had significantly affected the treatments. WP was found to be significantly greater I_2 (20% less than 100% FC) than in other irrigation levels (Table 2). The interaction effect of RBFI, as well as irrigation level, indicated that double row ridge bed furrow irrigation with 50 cm spacing under I_2 irrigation level showed significant differences (Table 2), and irrigation water was saved up to 14-19% compared to SREFI50 (Table 2).

Table 1. Interaction effect of ridge bed furrow and irrigation levels on yield, yield components, and quality of potato tubers

*Treatment		Stem number, No./ m^2	Tuber number, no./m^2	Tuber weight, kg/m^2	Potato tuber yield, t/ha	TSS, °Brix	Dry matter, %	Potato tuber number, No. /m2			
								< 28 mm	28-<40 mm	40-<55 mm	> 55 mm
SREFI50	I_1	31.16ab	74.1a	3.18ab	31.80 ab	4.20d	17.45e	18.2a	29.9a	23.83ab	2.23ab
	I_2	26.7bcde	67.7b	3.12b	31.23 b	4.53bcd	19.58ab	15.1abc	28.5a	22.06abc	1.93bc
	I_3	30.9ab	58.3c	2.68c	26.83 c	4.90ab	19.53ab	13.3cde	20.9bcd	21.03bc	2.93a
DRBFI50	I_1	29.7abc	71.0ab	3.21a	32.18 a	4.56bcd	18.61cd	15.23abc	29.1a	24.96a	1.66bcd
	I_2	33.4 ab	70.2ab	3.12b	31.63 ab	4.66bcd	19.61ab	17.3ab	30.6a	21.1bc	1.16cd
	I_3	28.8bcd	51.6de	2.72c	27.25 c	4.73bc	20.19a	11.73def	22.7bc	15.8e	1.43bcd
SREFI60	I_1	23.7e	57.0cd	2.61d	26.16 d	4.30cd	19.28bc	11.56ef	23.8bb	19.4cd	2.16ab
	I_2	27.3bcde	55.4cd	2.58d	25.89 d	4.46bcd	19.70ab	14.5bcde	17.6de	21.2bc	2.13ab
	I_3	26.0cde	44.2fg	2.13f	21.39 f	4.36cd	19.71ab	8.50f	17.2de	17.3de	1.13
DRBFI60	I_1	27.8bcde	52.4de	2.499e	24.99 e	4.36cd	18.58d	12.50cde	23.06bc	16.10e	0.83
	I_2	24.9 de	49.6ef	2.50e	25.01 e	4.76bc	19.62ab	14.03bcde	19.6cde	14.9e	1.06
	I_3	23.5 e	42.5 g	2.19 f	21.97 f	5.36a	19.58ab	15.06abcd	16.7e	9.80f	0.93
CV		9.48	5.81	1.35	1.32	6.31	2.06	14.35	10.01	9.72	31.46
LSD		4.47	5.69	0.062	0.610	0.493	0.673	3.38	3.95	3.12	0.87
Mean		27.84	57.85	2.71	27.19	4.61	19.29	13.9	23.3	18.9	1.63

*Treatment: Ridge bed and furrow irrigation: **SREFI50**: Single row ridge (30 cm) and every furrow irrigation, and plant row spacing 50 cm; **DRBFI50**: Double row ridge bed (70 cm) and furrow irrigation, plant row spacing 50 cm; **SREFI60**: Single row ridge (40 cm) and every furrow irrigation, plant row spacing 60 cm; **DRBFI60**: Ridge bed (90 cm) and furrow irrigation, plant row spacing 60 cm. Irrigation level**:** I_1: 100% FC, I_2: 20% less than I_1, I_3: 40% less than I_1

Table 2. Irrigation event, seasonal water use, WP and water saving under different treatments

Irrigation Treatment		Irrigation event				Soil water contribution, mm	Water use, mm	WP, kg/m^3	Saving water, %
		PEIW	Irrigation 25 (25-30) DAP	Irrigation at 43 (40-45) DAP	Irrigation 65 (60-65) DAP				
I1	SREFI50	29	45	80	56	10	220	14.45e	-
	DRBFI50	18	47	78	55	8	206	15.16d	6.4
	SREFI60	24	44	75	58	14	215	12.47g	2.3
	DRBFI60	18	48	72	54	17	209	15.39d	5.3
I2	SREFI50	29	36	64	45	14	188	16.82ab	14.5
	DRBFI50	18	37.6	62.4	44	16	178	15.31d	19.1
	SREFI60	24	35	60	46	17	182	14.37e	17.3
	DRBFI60	18	38.4	57.6	43	20	177	14.63e	19.5
I3	SREFI50	29	27	48	33.6	28	165.6	12.92f	24.7
	DRBFI50	18	28.2	46.8	33	19	145	17.23a	34.1
	SREFI60	24	26	45	34.8	26	155.8	16.05c	29.2
	DRBFI60	18	29	43.2	32.4	29	151.6	14.49e	31.1

*Treatment description is shown below Table 1.

Conclusion

This study's first-year results indicate that the water-saving method of ridge bed furrow irrigation with 50 cm row spacing significantly increased tuber yield, WP, and saved water by 19% compared to the other treatments. Further study is needed to investigate the bed size and row spacing for maximum producing yield.

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OPTIMUM WATER MANAGEMENT OF DWARF SUNFLOWER AT VARIOUS TIME OF SOWING

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Abstract

Proper sowing along with appropriate use of irrigation at actual crop growth stages can minimise misuse of these costly inputs and can increase water productivity. Dwarf sunflower (BARI Surjamukhi–3) was grown during 2023-2025 Rabi season at IWM division field, Gazipur for three sowing dates (Factor A) using four irrigation combinations with full and 50% of full irrigation at 3 crop growth stages (Factor B). Due to seasonal rainfall variability, sowing date performed differently, consequently, in 2023-24, mid-December sowing gave the significantly highest seed yield and in the following year, 1st week of December sowing gave the significantly highest seed yield. Three irrigations at vegetative, pre-flowering, and flowering produced the highest yield. Higher irrigation water productivity (IWP) was found by mid-Nov sowing, and 50% of irrigation at vegetative, pre-flowering, and flowering which sacrificed 15% of yield. However, to meet our SDG goal we need to increase IWP just sacrificing 5% yield in situations of meeting demand of 17.12 crore people by focusing on limited water resources. Therefore, it can be difficult to conclude in case of sowing date because of rainfall variability. However, the dwarf sunflower can be irrigated at 50% of full irrigation at three growth stages to get higher IWP with 15% yield reduction compared to FI at the same crop growth stages in central Bangladesh.

Introduction

Water is an important input for the growth and development of most crops and efficient use of these resources can increase system efficiency and crop productivity. However, the sowing date is another parameter that also influences crop water use and yield. Dwarf sunflower is a promising new crop in Bangladesh, but there is still limited field evaluation of its yield potential for irrigated agriculture. Irrigation based on crop growth stages is an effective technique and easy to implement for all kind of stakeholders. However, the selection of this particular crop growth stage can save irrigation water and increase irrigation water productivity. Therefore, this study was conducted to optimise irrigation amount based on crop growth stage for increasing productivity.

Materials and Methods

The experiment was conducted at the experimental field of the IWM division, BARI, Gazipur during the Rabi season of 2023-24 and 2024-25. The experimental design was RCBD 2-factors with three replications; Factor A: Sowing date (16 Nov, 26 Nov and 18 Dec for year 1, and 26 Nov, 6 Dec and 16 Dec for year 2, respectively) and Factor B: Irrigation (full irrigation (FI) at vegetative, pre-flowering and flowering [I_1], 50% of I_1 [I_2], FI at vegetative, pre-flowering and grain filling [I_3], and 50% of I_3 [I_4]. Note that third sowing was delayed to 22 days because of heavy rain that destroyed the 6 Dec sown seeds.

Before sowing, half of urea with other fertilizers were applied. The rest half of the urea was divided into two equal splits; one was on days 24-25 and another was on days 40-42. BARI recommended fertilizer dose was: Urea, TSP, MoP, gypsum, $ZnSO_4$, H_3BO_3, $MgSO_4$, and cowdung @ 200 kg ha^{-1}, 180 kg ha^{-1}, 170 kg ha^{-1}, 170 kg ha^{-1}, 10 kg ha^{-1}, 12 kg ha^{-1}, 100 kg ha^{-1} and 10000 kg ha^{-1} (BARI Agricultural technology handbook 2020). The Basin irrigation method was used. Irrigation was applied based on soil moisture deficit up to field capacity at crop growth stages and the formula for calculating irrigation depth and volume was done by following Mila (2021). The sunflower crop was harvested on 18 February to 24 March 2024 and 9 March to 7 April 2025, respectively. During harvest 10 plants were collected to record yield and yield attributes. Soil moisture was collected at ~2 weeks' intervals. Finally, data were analysed using statistical software (Team, R.C., 2013).

Results and Discussion

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ANOVA results for two factors showed that yield and yield attributes were highly significant for the individual effect of irrigation and sowing dates for both years. The significant highest yield was recorded for FI at the V, PF and F stages followed by 50%FI at V, PF & F and FI at V, PF and GF stages (Fig. 2). In 2023-24, Mid-December sowing gave the significantly highest yield and yield attributes and its values gradually decreased for the previous two sowings (Fig. 2a). In the following year, 6 Dec sowing gave the significant highest yield followed by 26 November and lowest was recorded for 16 Dec sowing (Fig. 2b).

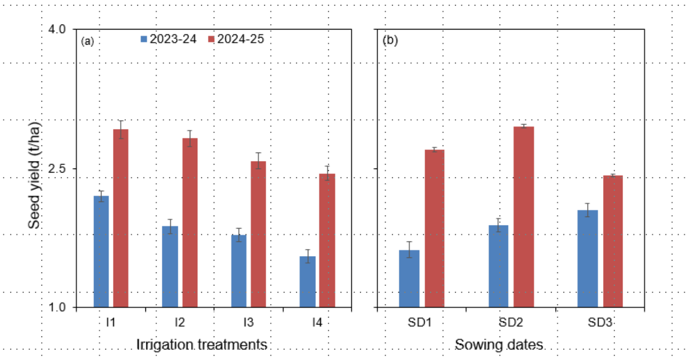

Fig 1. Yield against irrigation for three sowing dates. SD_1, SD_2 and SD_3 denotes 16 November, 26 November and 18 December for year 1, and 26 Nov, 6 Dec and 16 Dec for year 2. FI, V, PF, F and GF denotes full irrigation, vegetative, pre-flowering, flowering and grain filling, respectively.

Overall, SD_1 used comparatively lower amount of irrigation water and gave higher irrigation water productivity (Fig. 2a, b). SD_1 received only one irrigation either at F or GF stages with due to huge rain on day 22 and 23. SD_2 received two irrigations either at PF and F or GF stages with a total of 96 and 120 mm due to huge rain on day 12 and 13. Sowing date 3 received three irrigations based on design. On the other hand, 50%FI at V, PF & F needed comparatively lower amount of irrigation water and gave higher irrigation water productivity (Fig. 2c, d). However, in the following year, the plants for three sowing dates received all scheduled irrigation and provide better yield, and IWP (Fig. 2). Similarly, less was used treatment gave higher IWP and here I2 gave the highest followed by I4. In case of sowing date, SD1 gave higher IWP. (Fig. 2b, d). Relationship between % yield reduction compared to I_1 and IWP gave a best fit polynomial line with r^2 values of 1. based on this equation we estimated 5% yield reduction can obtain to IWP of 1.53.

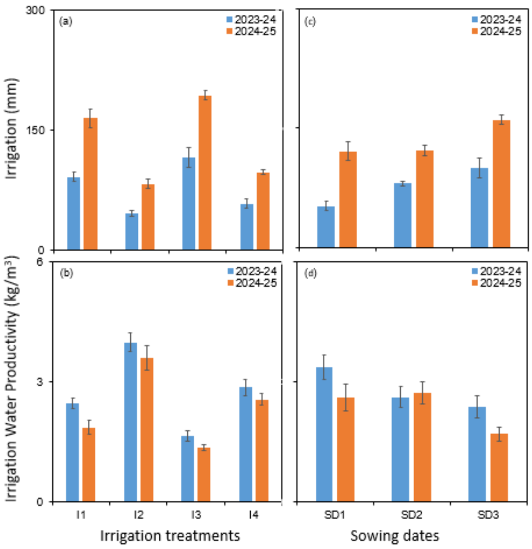

Fig 2. Irrigation, and irrigation water productivity (IWP) against irrigation (a, b) and sowing date (c, d) for 2023-24 and 2024-25 cropping seasons. I_1 and I_2 means full irrigation (FI) and 50% of FI at vegetative (V), Pre-flowering (PF), and flowering (F), while I_3 and I_4 means FI and 50% of FI at V, PF, and grain filling (GF).

Conclusion

Due to seasonal rainfall variability, sowing date performed differently and is difficult to conclude. However, from two years' trial, the mean highest yield of 2.2 t ha^{-1} was recorded for FI at vegetative, pre-flowering and flowering, while 15% lower yield was recorded by using 50% of less irrigation. 50% of less irrigation also gave 40 to 142% higher irrigation water productivity than other treatments. Therefore, for conformation of the results, the similar trial needs to be replicated in the following Rabi season.

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PARAMETERISATION, CALIBRATION AND VALIDATION OF APSIM-SUNFLOWER FOR IRRIGATION AT VARIOUS SOWING DATES

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Abstract

Optimum irrigation at specific crop growth stages through proper sowing can minimize yield reduction and can increase water productivity of dwarf sunflower. Dwarf sunflower (BARI Surjamukhi–3) was used to test the APSIM-Sunflower model for three time of sowing using four irrigations with full and 50% of full irrigation at 3 crop growth stages at Gazipur during Rabi season from 2023-2025. The APSIM model was parametrized using local environmental conditions (soil, climate etc.) and field experimental dataset. However, the work is not completed yet due to having some issues with the response of the APSIM-sunflower module to yield, biomass and soil water content. To solve this issue, need to recalibrate the model by revisiting the relevant parameters responsible for capturing the above response to the APSIM-sunflower module.

Introduction

Options for improved resource use efficiency for agricultural crop production can be assessed by using crop simulation models. Provided they are well-calibrated and validated, crop simulation models can obviate the need for large numbers of field experiments and can examine the long-term impacts of new technologies, varieties and cropping systems. Water is an important input for the growth and development of most crops and efficient use can increase system efficiency and profitability. APSIM is a platform for simulating biophysical processes of crops in cropping systems (Keating et al 2003, Gaydon et al. 2017). When well-calibrated, this model provides an accurate estimation of crop production in relation to climate, genotype, soil and farmer management factors (Keating et al 2003).
APSIM-Sunflower model was tested with the use of either full or deficit irrigation at various crop growth stages at various time of sowing. Sowing date has a direct impact on crop water use. In this case, water/irrigation water productivity can be important variables to know: which stage and amount of irrigation is important to get a good yield and higher water productivity of sunflower? Therefore, this study was conducted to calibrate the APSIM Sunflower model.

Materials and Methods

To test the APSIM-Sunflower model, a field experiment was conducted during 2023-24 and 2024-25 at the IWM division field at BARI, Gazipur. The crop was sown on 16 Nov, 26 Nov and 18 Dec using four irrigations: two were full irrigation (FI) at three crop growth (vegetative, pre-flowering and flowering or grain filling), and another were 50% of full irrigation. The detailed experimental procedure is explained in Mila et al. 2025 (Annual report). Long-term climate data were collected from local weather station. Soil physico-cheminal properties were collected from 5 soil layers (0-15, 15-30, 30-50, 50-80, and 80-120 cm) at around 10-15 days intervals. The model was parameterized with local input parameters of climate variables, soil physical and chemical characteristics, management impositions and inputs, etc. Then the parameterised model was calibrated for the chosen treatments (here used for all treatments) based on phenology, yield, biomass and soil water content.
APSIM-sunflower phenology has 11 stages. Yield data was collected during harvest. Biomass data were collected at the pre-flowering, flowering, and maturity stage. Soil water content were also collected.

Results and Discussion

Simulated and observed values of phenology, biomass and yield during the crop season are shown in Figures 1 and 2. At this stage SD_1 is perfectly match for phenology, biomass and yield. The 1:1 graph of the above three parameters are also shown in Figure 3. We found r^2 values of 98.9, 52, and 94.5% for

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phenology, yield and biomass for regression relationships between simulated and observed values (Fig.3). Our calibration process is ongoing for making the model more roust.

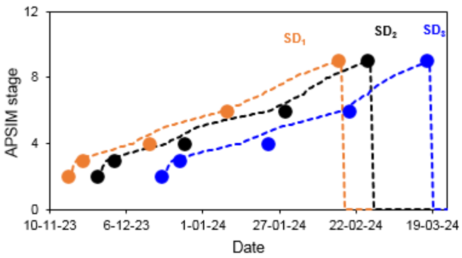

Fig. 1 APSIM simulated (dotted line) versus observed (filled circle) phenology of sunflower for three times of sowing during the crop season 2024. Here, orange, black and blue colour is used to denote SD_1, SD_2 and SD_3

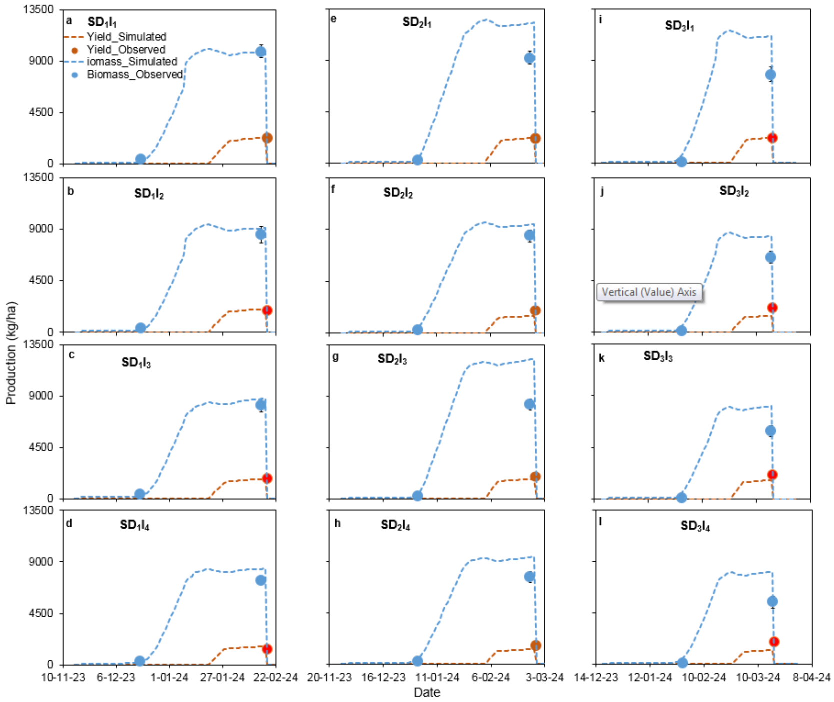

Fig. 2 Simulated (orange broken line) and observed (orange filled circle) seed yield, and Simulated (blue broken line) and observed (blue filled circle) biomass

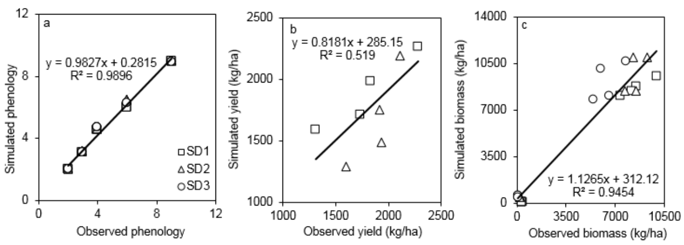

Fig. 3. Simulated vs observed phenology, yield and biomass

Conclusion

We are still working to calibrate the model and will validate the model in the next year using field experimental data.

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DESIGN AND DEVELOPMENT OF A LOW-COST SPRINKLER SYSTEM

M. P. HAQUE[1], D. K. ROY[2], K. K. SARKER[2] & M. A. HOSSAIN[3]

Abstract

Efficient water management is crucial for agricultural productivity, especially in regions facing water scarcity and climate variability. This study developed a low-cost sprinkler system using locally available materials in Bangladesh to provide small-scale farmers with an economical irrigation alternative. The system was constructed with UPVC-thread pipes (3/4 inch diameter), G.I. screws (1-1/2 inch), end plugs (3/4 inch), G.I. sockets (3/4 inch), and Teflon tape (1/2 inch). Tested on a 28 ft by 16 ft area (448 ft²) with a domestic water supply (5-6 psi), the system achieved a Coefficient of Uniformity (CU) of 88% (above the acceptable limit of 80%).The discharge rates varied from a maximum of 0.15 cm/min to a minimum of 0.09 cm/min, with peak at 360 cm from the sprinkler. The sprinkler system, equipped with a submersible 0.75 Hp DC solar pump, was also tested, and the coefficient of uniformity (CU) was relatively low (approximately 60%). This high uniformity and efficient water distribution with domestic water supply underscore the system's potential to optimize water use, conserve water, and enhance crop yields by maintaining optimal soil moisture. The system's low cost (850 Tk.) and ease of construction may make it accessible for smallholder farmers, promoting sustainable agricultural practices and improved livelihoods. For further confirmation, the study should be conducted for the next year.

Introduction

Efficient water management is crucial for enhancing agricultural productivity, particularly in regions facing water scarcity and climate variability. Low-cost irrigation systems, such as affordable sprinklers, are essential in optimizing water use and improving crop yields. These technologies provide small-scale farmers with a practical, economical alternative to traditional methods, increasing access to efficient irrigation. Various types of low-cost sprinklers cater to specific crop requirements and field conditions. Rotating sprinklers distribute water in a circular pattern, suitable for various crops, while fixed sprinklers are designed for smaller areas and can be adjusted to control water flow and coverage. These options allow farmers to select systems that best meet their irrigation needs, enhancing flexibility and efficiency. Low-cost sprinkler systems not only conserve water but also contribute to increased crop output. By maintaining optimal soil moisture levels, these systems support healthier plant growth and reduce the stress caused by drought conditions. Research by Smith et al. (2020) demonstrated that farms utilizing low-cost sprinklers experienced a significant increase in crop yields compared to those relying on traditional irrigation methods. This improvement is attributed to the uniform distribution of water, preventing water logging and soil erosion. Additionally, low-cost sprinklers reduce labor costs associated with manual irrigation, allowing farmers to allocate resources more effectively. The initial investment is relatively low, making these systems accessible to smallholder farmers who may not have the financial capacity for advanced irrigation technologies. Therefore, this study aimed to develop a low-cost sprinkler and its networking system for smallholder farmers.

Materials and Method

The locally available materials in Bangladesh were utilized to develop a low cost sprinkler system. The materials include i) UPVC- thread pipe ($\frac{3}{4}$ inch diameter) ii) G.I. screw ($1\frac{1}{2}$ inch) iii) End plug ($\frac{3}{4}$ inch) iv) G.I. socket($\frac{3}{4}$ inch) v) Taflon tape ($\frac{1}{2}$ inch size). The ten feet long upvc thread pipe was bored with 6mm drill bit in one side and the screw was attached centering the bored diameter with the other side (Figure 1). The drill was performed at the rate of 4ft apart along the length. The two thread pipe was joined with socket and the end of pipe was attached with plug. The total length of the system was 20ft and the bored hole was six in numbers. The sprinkler system was tested by connecting it to the domestic water supply line (gauge pressure: 5–6 psi) and also to a solar water pump with the following specifications: 24V, 0.75 Hp, maximum head of 45 meters, and a maximum flow rate of 50 liters per

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minute. The distribution and uniformity of the system was measured with a formula by coefficient of uniformity ($CU = [1 - \frac{x_i \sum f \times (z-m)}{\sum f \times z}] \times 100$; z is discharge of each catch can, m is the average of discharge, f is frequency). The catch can was placed at rate of 120cm from sprinkler in four numbers as shown in figure 2(a).

Results and Discussion

The low-cost sprinkler system developed for this study (Figure 1(a), Figure 1(b)) demonstrated effective irrigation over an area of approximately 28 ft by 16 ft, totaling 448 ft². The performance of the sprinkler system was assessed through the Coefficient of Uniformity (CU), a critical measure for evaluating the evenness of water distribution. The system achieved a CU of 88%, surpassing the acceptable threshold of 80%. The discharge rate of the sprinkler system was monitored to evaluate its efficiency in water delivery. The system exhibited a maximum discharge rate of 0.15 cm/min and a minimum discharge rate of 0.09 cm/min. This variation in discharge rates is a common characteristic of sprinkler systems, influenced by factors such as water pressure, nozzle design, and environmental conditions. Notably, the discharge rate increased gradually, reaching a peak of 360 centimeter per minute from the sprinkler. Beyond this point, the discharge rate began to decrease, as illustrated in Figure 2b. This pattern suggests that the system operates most efficiently up to a certain threshold, after which the performance may diminish due to potential factors like water pressure limitations or the physical constraints of the sprinkler design.

Figure 1: a) sprinkler system in a thread pipe (3/4 inch diameter) and b) Sprinkler (6mm bore with screw

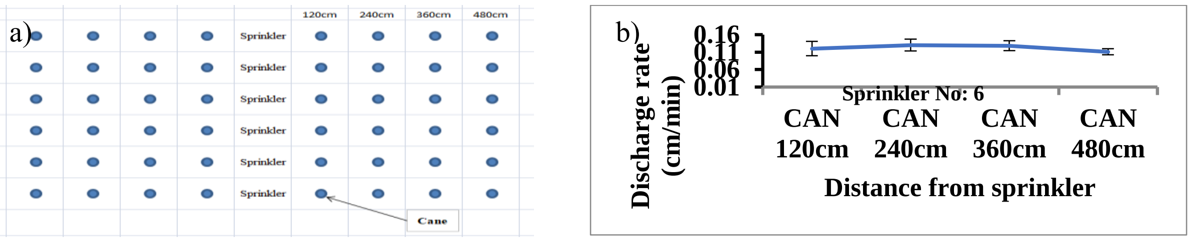

Figure 2: a) Arrangement of catch cans (48 nos) b) Discharge rate (cm/hr) vs distance from sprinkler

Conclusion

The low-cost sprinkler system with a domestic water supply (5-6 psi) developed in this study exhibits higher uniformity (CU=88%) and effective discharge rates (0.09-0.15 cm/min), making it a practical and efficient solution for small-scale irrigation. On the other hand, the sprinkler system with a submersible 0.75 Hp DC solar pump was lower CU (about 60%). Therefore, the study should be continued in the next year.

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IDENTIFICATION OF SURFACE IRRIGATION POTENTIAL ZONE IN BANGLADESH USING GIS TECHNIQUE

M. P. HAQUE[1], D. K. ROY[2], M. A. HOSSAIN[3]

Abstract

Bangladesh's agrarian economy faces significant water management challenges, necessitating efficient irrigation methods like surface irrigation to boost agricultural productivity and food security. This research employs Geographic Information Systems (GIS) to identify potential zones for surface irrigation in the Halda River basin, southeastern Bangladesh. The study utilizes DEM data from the Shuttle Radar Topography Mission, soil information from the Soil Research and Development Institute, land use data from Landsat 8, and hydrological data from the Bangladesh Water Development Board and Meteorological Department, integrating multiple spatial data layers in QGIS. The Soil and Water Assessment Tool (SWAT) Plus model was calibrated and validated using historical streamflow data, achieving Nash-Sutcliffe Efficiency (NSE) of 0.72 and 0.71, and R^2 values of 0.73 and 0.83 for calibration and validation periods, respectively. The results highlight the model's efficacy in simulating monthly runoff, despite some underestimation during peak flows, attributed to limited rainfall data from a single gauge. The estimated irrigation water requirement was highest for Boro rice (927 mm) and lowest for bean (10 mm). The study should be carried out in the next year.

Introduction

Bangladesh, with its agriculture-dependent economy, faces major water management challenges due to its geography and climate. Efficient irrigation—particularly surface irrigation—is vital for increasing crop productivity and ensuring food security. As a low-cost, gravity-based method, surface irrigation depends heavily on factors such as land slope, soil type, land use, and proximity to water sources. Geographic Information Systems (GIS) offer powerful tools to analyze these spatial parameters and identify suitable areas for irrigation. While GIS has been widely used for irrigation planning globally, its application in Bangladesh is still limited. This study aims to bridge that gap by using GIS to identify potential surface irrigation zones across various regions of Bangladesh. The key objectives are: (1) to analyze topographic and soil characteristics relevant to surface irrigation, (2) to integrate multiple spatial data layers using GIS, and (3) to delineate suitable zones for surface irrigation to support sustainable water use and agricultural productivity.

Materials and Methods

This study was conducted in halda river basin, located in south-eastern region during 2023-25. Data for this study were obtained from multiple sources to ensure comprehensive analysis: i) DEM data with a 30-meter resolution were sourced from the Shuttle Radar Topography Mission (SRTM) to assess topography and slope ii) Soil texture and type information were obtained from the Bangladesh Soil Research and Development Institute (SRDI) iii) LULC data were acquired from Landsat 8 satellite imagery and classified using supervised classification techniques. iv) River networks and water body's data were sourced from the Bangladesh Water Development Board (BWDB). v) Rainfall and temperature data were collected from the Bangladesh Meteorological Department (BMD). Data was processed using QGIS software. The streamflow of the Halda River and catchment delineation, as well as stream network, were calibrated and validated using the Soil and Water Assessment Tool (SWAT) Plus model linked to QGIS (Figure 1). The Halda Basin has only a single rainfall gauge (Sitakundu, Chattogram), which may significantly limit our study (Figure 2).

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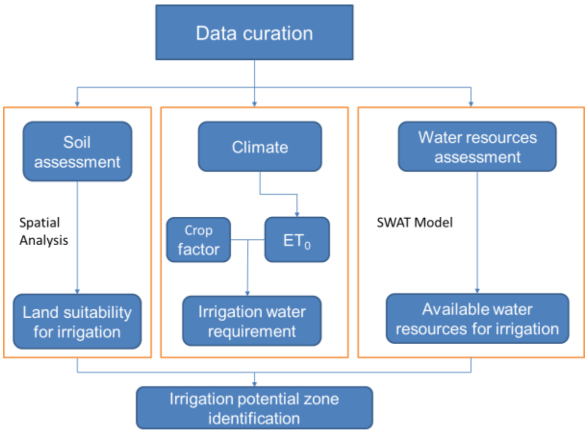

Figure 1: Methodological Framework

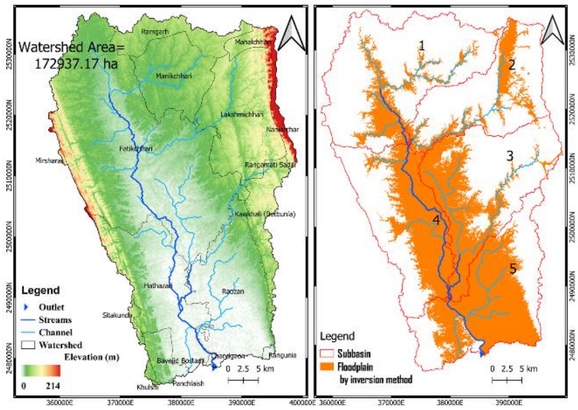

Figure 2: Catchment of Halda river basin

Results and Discussion

SWAT model was calibrated from 1985 to 1994 and validated from 1995 to 2004. For calibration, the Nash-Sutcliffe efficiency criterion (NSE) and the coefficient of determination (R^2) were 0.72 and 0.73, respectively. For validation, the values were NSE: 0.71 and R^2: 0.83.This study simulated the water balance in the Halda Basin and examined the performance and parameter sensitivity of the SWAT modeling platform, configured for a small basin in southeastern Bangladesh. The performance metrics of the calibrated model showed that it adequately simulated monthly runoff, despite underestimating and overestimating river flow during the calibration and validation periods, respectively. However, the calibrated model generally underestimated runoff during peak flows, which may be due to uncertainties associated with the rainfall data and the runoff generation process (Figure 4). Relying on data from just one gauge might be inadequate for accurately capturing the rainfall patterns across the watershed. Overall, the performance (NSE and R^2) of SWAT during calibration and validation was within the allowable limits. The highest average irrigation water requirement was recorded for Boro rice (927 mm), while the lowest was for bean (8 mm) (Figure 3). This significant variation reflects the diverse water needs of crops in the Halda River Basin, indicating that crop planning and water allocation strategies must be crop-specific to enhance water use efficiency.

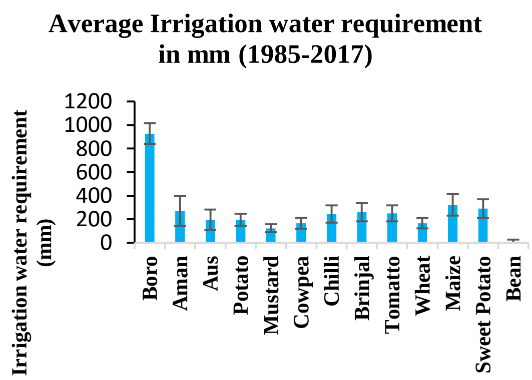

Figure 3: Average Irrigation Water Requirement (mm) in the Halda River Basin from 1985 to 2017

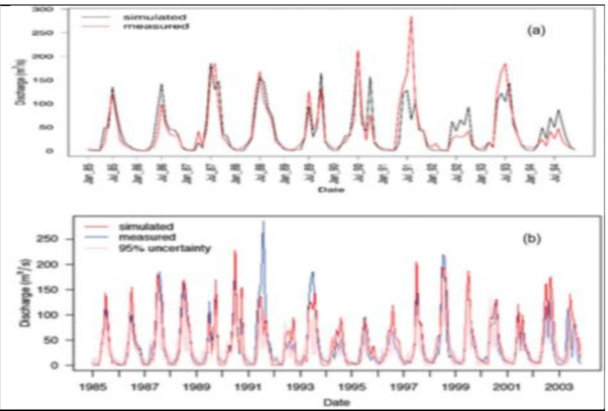

Figure 4: a) Monthly simulated and measured values b) Yearly simulated and measured values

Conclusion

The SWAT model was calibrated and validated in Halda river basin. The study might be conducted for the next year for confirmation and identifying potential zone of surface irrigation zones.

SMART IRRIGATION BASED ON PAN EVAPORATION USING IOT-ENABLED ULTRASONIC SENSOR FOR BRINJAL PRODUCTION

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Abstract

Sensor-based smart irrigation (SI) is not in general practice, and its potential is yet to be investigated. Therefore, the objective of this study was to (i) develop and test the SI based on pan evaporation using IoT-enabled ultrasonic sensor for eggplant production. IoT-based smart irrigation practice (T_1) system was developed and tested in the lab and evaluated at field conditions of Gazipur in 2024-25. A mobile app was used to operate it. T_1 was partially evaluated by comparing it with BARI recommended practices (T_2), drip irrigation (T_3), and traditional practice (T_4). The results indicated that the water saved by T_1 was more than that of T_4. The treatments affected the fruit yield of eggplant. T_1 and T_3 produced a better yield than the others. IoT-enabled ultrasonic sensor-based pan evaporation method irrigation needs further validation.

Introduction

The Internet of Things (IoT)-enabled sensor-based smart irrigation is not in general practice due to the traditional surface flooding and frequent irrigation that uses excess water, subsequently decreasing yield and water productivity. Among various technological options, the IoT-based irrigation is one of the most updated technologies (Sarker et al., 2025, Omar et al., 2019). Presently, numerous soil moisture sensors offer advantages, but they also have more disadvantages, such as inaccuracies with soil types, sensitivity to environmental variables, and installation challenges. Pan evaporation can be used to optimize irrigation schedules, ensuring efficient water use and increasing yields. This method is widely used due to its simplicity. Therefore, this study aimed to develop and test the smart irrigation for eggplant production based on pan evaporation using an IoT-enabled ultrasonic sensor.

Materials and Methods

The research was conducted at IWM division research lab and field of BARI, Gazipur during in 2024-2025. Soils were sandy loam. IoT-based smart irrigation concept was developed through an integrated research approach that included lab and field experiments using IoT-enabled ultrasonic sensors based pan evaporation and a mobile app. There were three parts: (i) hardware, (ii) software, and (iii) field experiment. The hardware system comprised an ESP32, solenoid valve, ultrasonic sensor, pan-evaporimeter, water flow sensor, and water supply-related drip irrigation accessories (Fig.1a-b). The mobile app using Blynk was used for real-time monitoring, operating the switch automatically to turn the irrigation system oN-OFF. The user remotely saw the sensor values. When the sensor value crossed the threshold, the user was notified through the app. A user took action from the app by pressing the switch. Firstly, the innovative smart irrigation system (Fig.1a) was developed (T_1) and partially evaluated at field conditions, compared with BARI recommended practices (T_2), drip irrigation (T_3), and traditional farmers' practices (T_4). The field experiment was conducted in a randomized complete block design with four treatments. The IoT-based physical, and networking system was set up, and sensors and related equipment were installed to run the operation under lab and field. The data on the pan evaporation using IoT-enabled ultrasonic sensor, and irrigation using a solenoid valve for supplying water, fruit yield and yield contributing characters of eggplant were collected.

Results and Discussion

The relationship of manually operated reading and ultrasonic sensor-based reading is nearly similar (R^2 = 0.9913). The results indicated that sensor-based pan evaporation using ultrasonic sensor measurements is technically feasible. A manual and automatic smart irrigation system based on ultrasonic sensor values was made possible by the data monitoring interface. An ultrasonic sensor was

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used to sense the evaporation system. Based on the evaporation, the motor was turned on and off. The results indicated that the effect of treatment affected the fruits yield, saving water, and water productivity. The IoT-based smart irrigation using Blynk mobile app (T_1) operating system and BARI recommended drip irrigation practice (T_3) produced nearly similar marketable fruit yield and greater than traditional practices (T_4), although applied less water than farmers' practices (Table 1). The technique of T_1 and T_3 increased fruit yield, saved water around 60% and substantially improved water productivity without a reduction in yield (Table 1). The results of the first year crop yield indicate that T_1 system is promising irrigation scheduling. Besides, IoT-based real-time pan evaporation and field data like as soil moisture content can be monitored and recorded from anywhere and remotely controlled. Mobile app was used and enhanced the efficiency through real-time data monitoring and remotely control the irrigation ON-OFF.

Table 1. Yield contributing characteristics, yield, seasonal water use, and water use efficiency of eggplant

Treat ment	Fruit length, cm	Fruit dia, cm	Fruit number/Plant	Single fruit weight, g	Fruit yield,t/ha	TWU, mm	WUE, kg/m^3		Water saving, %
							WUE	IWUE	
T_1	24.6	3.1	13.2	125.8	23.25	140	16.6	21.1	60.0
T_2	25.4	2.97	13.5	123.4	23.59	284	9.2	8.3	18.8
T_3	24.5	3.2	13.4	126.9	24.48	142	22.2	17.2	59.4
T_4	22.2	2.89	13.8	115.5	22.14	350	6.3	6.7	-

*Treatment mean values. Pe indicates effective rainfall. TWU: total water use, WUE: water use efficiency, IWUE: irrigation water use efficiency, SWC: soil water contribution. T_1: IoT-based pan evaporation system with ultrasonic sensor (partially operated); T_2: BARI recommended eggplant production packages; T_3: BARI recommended drip-irrigation; T_4: Traditional practice (surface flooding irrigation). Transplanting and harvesting date: 19-12-2025 and 18 5 – 2025, respectively.

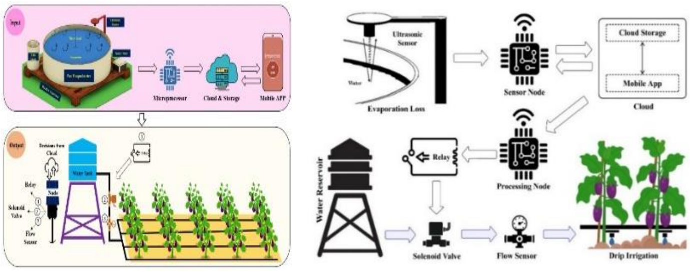

Fig. 1a. Schematic concept of the smart irrigation based on pan evaporation using IoT-enabled ultrasonic sensor for eggplant production

Fig. 1b. Photo images of the measuring pan evaporation using IoT-enabled ultrasonic sensor, irrigation water supply using solenoid valve.

Conclusion

Smart irrigation is a concept that may use pan evaporation using an IoT-enabled ultrasonic sensor for crop production. In the first year, an IoT-enabled ultrasonic sensor-based pan evaporation measurement system was developed and tested under laboratory conditions. More research is required to validate this creative smart irrigation system under field conditions.

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PARAMETERISATION, CALIBRATION, AND VALIDATION OF APSIM-SUNFLOWER FOR VARIOUS SURFACE DRAINAGE DEPTHS IN SOUTHERN BANGLADESH

A J MILA[1], D S GAYDON[2] R W BELL[3], A K CHAKI[4]

Abstract

In coastal saline area of Bangladesh, excess soil water at the end of the Kharif 2 season may cause a delay in the establishment of the following Rabi crops. In addition, unseasonal heavy rainfall during crop stages creates the situation worst. Therefore, surface drainage could be a potential option. This field study was conducted during 2022-23 and 2023-24 to simulate the APSIM-Sunflower for surface drainage depths (0 cm; no drain, 15, and 30 cm) at Dacope, Khulna, using the sunflower and long-term yield variability for changing climate. The model performed satisfactory in simulating observed crop, soil and salinity parameters with a high coefficient of determination (0.79-0.99) and acceptable RMSE values for both calibration and validation datasets. From the long-term yield prediction for seasonal total rainfall, 30 cm surface drainage showed more resilient than those for shallower or no drainage.

Introduction

Coastal areas of Bangladesh are vulnerable due to waterlogging at the start of the Rabi season. In addition, uncertainty of heavy rainfall during the crop season creates waterlogging and destroy crop yield. In this study, we aimed to simulate the surface drainage depths using APSIM-Sunflower model and long-term yield variability of sunflower for changing climate. The APSIM-Sunflower is a new sunflower simulation model for evaluating the performance of different cultivars under changing climates (Wang et al. 2001).

The APSIM-Agricultural Production Systems Simulator) is a platform for simulating biophysical processes of crops in cropping systems (Keating et al 2003, Gaydon et al. 2017). This kind of information would help to increase smallholder's farm income through cropping systems intensification while mitigating the risk of crop damage in this vulnerable landscape. Studies from literature found that the use of AquaCrop, DSSAT, and APSIM models for predicting crop productivity under a changing climate in coastal Bangladesh, India, and China (Gaydon et. al. 2021; Miao et al. 2025; Sarkar et. al. 2022, 2023). However, no work was done to simulate surface drainage depth to mitigate waterlogging and salinity stress, and the long-term yield variability of sunflower in terms of climate issues of RF variability during the Rabi seasons. Therefore, this study was conducted.

Materials and Methods

To collect model input data two years field experimentation was conducted during 2023 to 2024. The detailed experimental procedure is explained in Mila et al. (2024) (IWM Annual Report). Long-term climate data were collected from local weather station. Soil samples were collected in 5 soil layers (0-120 cm) at around 10-15 days intervals. Soil salinity ($EC_{1:5}$) was measured for the 5 soil layers using an EC meter. Salinity as a chloride content (in ppm) was calculated. APSIM-sunflower phenology has 11 stages. Yield data was collected during harvest. Finally, the APSIM-sunflower model was parameterised using the above climate, soil, and crop data. The model was calibrated using year 1 data and validated using following years' data. Then, long-term scenario analysis was done.

Results and Discussion

Both calibrated and validated model fits well in simulating the variables of crop (phenology, yield, and biomass), soil water content and soil salinity (chloride content) are shown in figure 1. The 1:1 graph shows a high coefficient of determination (0.79-0.99) with acceptable RMSE values for both calibration and validation datasets (Fig not shown). From the long-term yield prediction for seasonal total rainfall, 30 cm surface drainage showed more resilient than those for 15 cm and no drain treatments (Fig 2).

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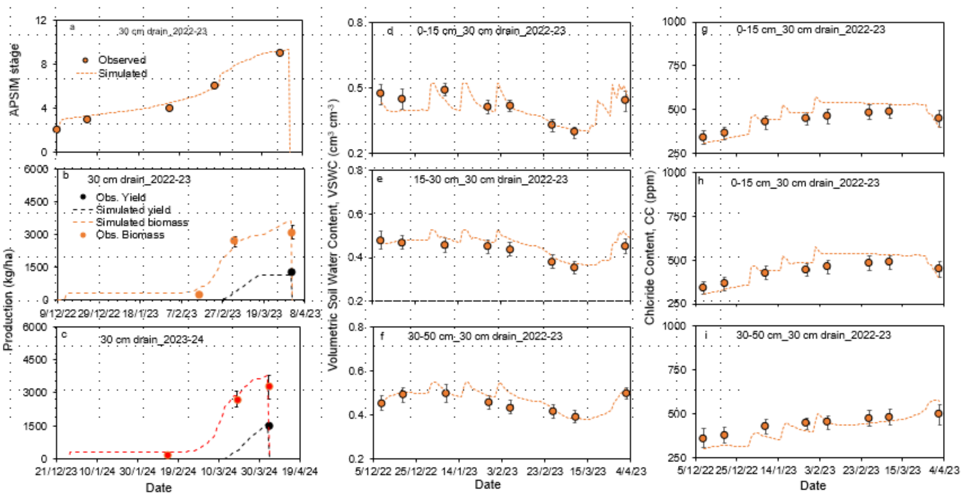

Fig. 1 APSIM simulated versus observed phenology (a), production (yield and biomass) (b, c), VSWC d-f), and CC (g-i) of sunflower for 30 drainage depths during 2022-2023 and 2023-24

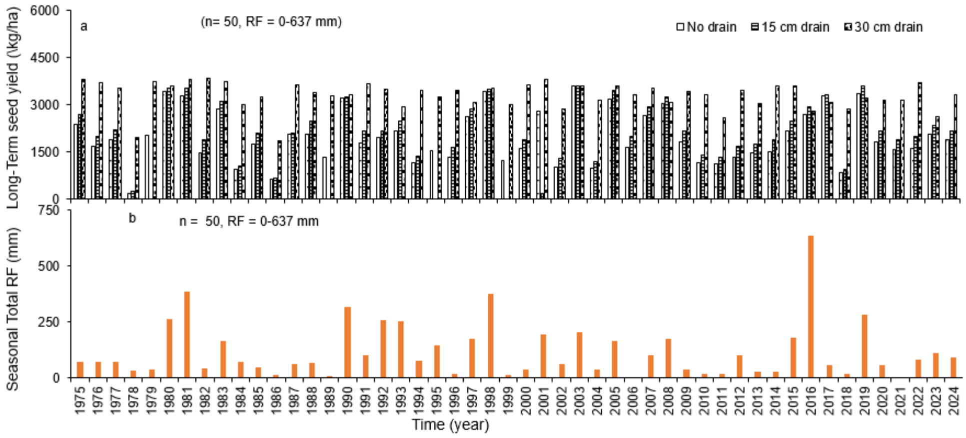

Fig. 2. Long-term (1975-2024 or 50 years) yield for three surface drainage depths (a) and seasonal total RF

Conclusion

The APSIM model performed robust in simulating crop (phenology), seed yield, biomass, soil water content, soil salinity (as Chloride content) for various surface drainage depths in coastal saline clay soil, climatic, and management options. A 30 cm surface drainage depth is more resilient and gives a higher yield for the long-term model simulation. This yield variability will help to make a decision on the investment in crop cultivation using the surface drainage depths. The experimental status is completed.

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PARAMETERISATION, CALIBRATION, AND VALIDATION OF APSIM-POTATO FOR VARIOUS SURFACE DRAINAGE DEPTHS IN SOUTHERN BANGLADESH

A J MILA[1], D S GAYDON[2], R W BELL[3], M A HOSSAIN[4], S. K BISWAS[5]

Abstract

In coastal saline area of Bangladesh, excess soil water at the end of the Kharif 2 season may cause a delay in the establishment of the following Rabi crops. In addition, unseasonal heavy rainfall during crop stages creates the situation worst. Therefore, surface drainage could be a potential option. This field study was conducted during 2022-23 and 2023-24 to simulate the APSIM-Potato for surface drainage depths (0 cm; no drain, 10, and 20 cm) at Dacope, Khulna, using the potato and long-term yield variability for changing climate. The model setup and calibration completed for the three surface drainage depth treatments. Model simulated crop (phenology, yield, and biomass), soil water content and soil salinity as chloride content. At this stages of model setup, yield and biomass match perfectly with R^2 values varied from 0.89-0.99. However, the validation is not completed yet but field data collection has been completed. After completion of validation, the model can perform long-term yield prediction for the climate change variabilities.

Introduction

Coastal areas of Bangladesh are vulnerable due to waterlogging at the start of the Rabi season. In addition, uncertainty of heavy rainfall during the crop season creates waterlogging and destroy crop yield. In this study, we aimed to simulate the surface drainage depths using APSIM-Potato model and long-term yield variability of potato for changing climate. The APSIM-potato was described in part by Brown et al. (2011) and developed using the Plant Modelling Framework (PMF) of Brown et al. (2014). Its performance is promising (Brown et al. 2011) to predict potato productivity (Borus et al. 2018) or to simulate yield, above-ground biomass, LAI, and irrigation requirement (Luo et al. 2024; Ojeda et al. 2020).

The APSIM-Agricultural Production Systems Simulator is a platform for simulating biophysical processes of crops in cropping systems (Keating et al 2003, Gaydon et al. 2017). This kind of information would help to increase smallholder's farm income through cropping systems intensification while mitigating the risk of crop damage in this vulnerable landscape. Studies from literature found that the use of AquaCrop, DSSAT, and APSIM models for predicting crop productivity under a changing climate in coastal Bangladesh, India, and China (Gaydon et. al. 2021; Luo et al. 2024; Ojeda et al. 2020; Sarkar et. al. 2022, 2023). However, no work was done to simulate surface drainage depth to mitigate waterlogging and salinity stress, and the long-term yield variability of potato in terms of climate issues of RF variability during the Rabi seasons. Therefore, this study was conducted.

Materials and Methods

To collect model input data two years field experimentation was conducted during 2023 to 2024. The detailed experimental procedure is explained in Mila et al. 2024 (IWM Annual Report). Long-term climate data were collected from local weather station. Soil samples were collected in 5 soil layers (0-120 cm) at around 10-15 days intervals. Soil salinity ($EC_{1:5}$) was measured for the 5 soil layers using an EC meter. Salinity as a chloride content (in ppm) was calculated. APSIM-potato phenology has 8 stages. Yield data was collected during harvest. Finally, the APSIM-potato model was parameterised using the above climate, soil, and crop data. The model was calibrated using year 1 data and validated using following years' data. Then, long-term scenario analysis was done.

Results and Discussion

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At this stages of model setup, the calibration was completed. However, the APSIM simulated versus observed phenology, yield and biomass is shown in Figure 1, that was satisfactory and indicates the need for validation. The 1:1 graph shows satisfactory with higher r^2 values and expectable RMSE. In addition, other variables of soil water content and soil salinity (chloride content) followed the similar pattern (not shown).

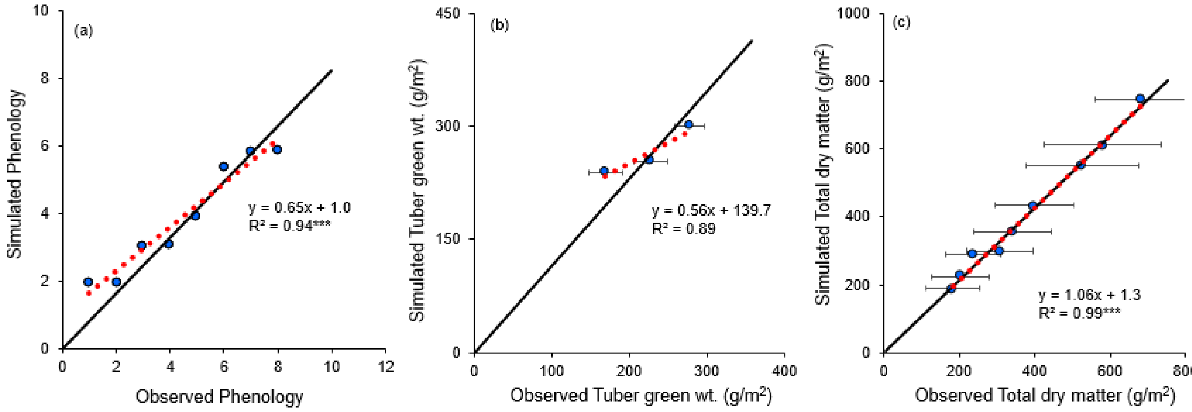

Fig. 1 APSIM simulated (dotted line) versus observed (filled circle) phenology, yield and biomass of potato for 20 cm drainage depths during 2022-2023

Conclusion

The APSIM model performed robust in simulating crop (phenology), yield, biomass, soil water content, and soil salinity (as Chloride content) for various surface drainage depths in coastal saline environment after successful validation of the model. From the field data, 20 cm surface drainage depth is more resilient and gives a higher yield for three sowing dates. Therefore, the experiment will be continued in the following year to complete the validation.

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PROJECTION OF GROUNDWATER LEVEL FLUCTUATIONS USING LONG SHORT TERM MEMORY NETWORKS IN A DROUGHT PRONE REGION OF NORTHWESTERN BANGLADESH

D. K. ROY[1], M. P. HAQUE[2], C .R. PAUL[2], M. A. HOSSAIN[3]

Abstract

This study investigates the capability of Long Short-Term Memory (LSTM) networks to forecast groundwater level (GWL) fluctuations in northwestern Bangladesh, a region particularly susceptible to drought. The performance of LSTM was benchmarked against traditional time series models, dynamic system response models and their hybrid forms. A total of eight models were evaluated using historical GWL data from 19 observation wells: LSTM, ARMA, three state-space models (n4sid, SSEST, SSREGEST), and three corresponding hybrid ARMA-state-space models. Model performance was assessed using key statistical indicators. Across most locations, the LSTM model consistently outperformed the others, achieving correlation values between 0.53 and 0.92. To identify the top-performing models, an integrated Entropy-EDAS decision-making framework was applied, further validating the dominance of LSTM. The best-performing models provided accurate GWL projections for five years beyond the available data, offering a practical tool for informed and sustainable groundwater management in drought-affected areas.

Introduction

Groundwater plays a vital role in ensuring water security, especially in regions like the Barind Tract of Bangladesh, where surface water availability is limited and groundwater is heavily relied upon for irrigation and domestic use (Altchenko & Villholth, 2013). However, increasing agricultural demand, climate variability, and over-extraction have led to significant stress on aquifers (Hasda et al., 2020). Accurate GWL forecasting is essential for sustainable resource management but remains challenging due to the dynamic and nonlinear nature of groundwater systems. Recent advances in machine learning (ML), particularly deep learning (DL), offer promising alternatives to traditional numerical models (Aderemi et al., 2023). This study explores DL and system modeling approaches to forecast GWL in northwestern Bangladesh and compares their performance using a robust decision-making framework.

Materials and Methods

The research was carried out in the Rajshahi district of northwestern Bangladesh, specifically within the semi-arid Barind Tract. Groundwater level (GWL) data, recorded at 15-day intervals, were collected from 19 observation wells managed by the Barind Multipurpose Development Authority. These data spanned several years and underwent quality control procedures, including outlier detection and interpolation, to ensure accuracy and consistency. Each model was trained using 90% of the available dataset, while the remaining 10% was used for validation. Forecasting beyond the observed data was performed using a closed-loop method, which iteratively used previous predictions as inputs for future projections. Model performance was evaluated using several statistical metrics. To determine the most effective model across different sites, a decision-making framework based on Shannon's Entropy and the Evaluation based on Distance from Average Solution (Entropy-EDAS) was employed. This multi-criteria approach enabled comprehensive model ranking and selection.

Results and Discussion

The LSTM model consistently outperformed other models at most observation wells, with high C (up to 0.92) and IOA values (up to 0.95), and low NRMSE (as low as 0.01). For example, at Bagha-Arani, LSTM achieved C = 0.779 and IOA = 0.86, outperforming ARMA (C = 0.366) and SSEST (C = 0.009)

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(Table 1). Hybrid models offered modest improvements over their standalone counterparts but generally lagged behind LSTM. The Entropy-EDAS ranking further confirmed LSTM as the best model at 12 of the 19 stations. Five-year GWL forecasts generated by LSTM showed either stable or declining trends, depending on the location (Figure 1), reflecting site-specific groundwater dynamics. The model's performance was found to be highly dependent on data quality and quantity, consistent with findings by Wu et al. (2023).

Table 1. Performances of different models on test dataset at Bagha-Arani station

Model	Performance indices							
	C	IOA	a-20	NRMSE	MAE, m	MAD, m	MBE, m	FPE
LSTM	0.779	0.86	0.696	0.185	0.868	0.375	-0.462	
ARMA	0.366	0.495	0.357	0.348	1.869	1.213	-1.768	0.151
n4sid	0.200	0.476	0.314	0.370	2.002	1.296	-1.924	0.187
SSEST	0.009	0.463	0.271	0.389	2.115	1.316	-2.059	0.153
SSREGEST	0.148	0.475	0.314	0.37	1.999	1.32	-1.920	0.169
ARMA-n4sid	0.146	0.466	0.257	0.389	2.118	1.249	-2.071	0.144
ARMA-SSEST	0.246	0.468	0.257	0.389	2.132	1.266	-2.080	0.145
ARMA-SSREGEST	0.172	0.473	0.286	0.380	2.061	1.318	-2.000	0.154

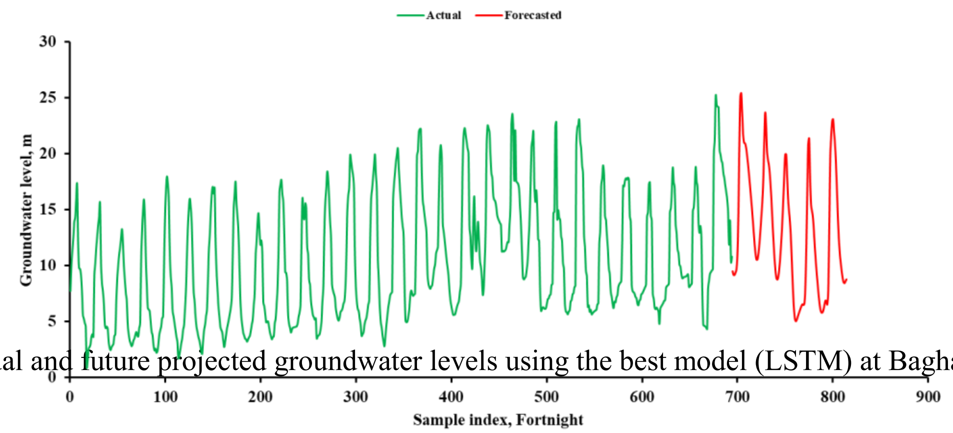

Figure 1. Actual and future projected groundwater levels using the best model (LSTM) at Bagha-Auchpara

Conclusion

This study highlights the effectiveness of LSTM models in forecasting GWL fluctuations in drought-prone regions. Compared to traditional ARMA and dynamic system models, LSTM demonstrated superior accuracy, robustness, and adaptability. The results emphasize the importance of adopting DL-based approaches for groundwater management, particularly in data-limited and climate-vulnerable regions like northwestern Bangladesh. Future research should focus on extending these methods to other regions and incorporating real-time data for dynamic forecasting.

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INVESTIGATION OF GROUNDWATER LEVEL FLUCTUATIONS IN RELATION TO RAINFALL AT KUSHTIA DISTRICT

M. M. MORSHED[1], R. P. RANNU[2], M. A. HOSSAIN[3]

Abstract

This study examines 30 years of rainfall and groundwater data from Kushtia District, Bangladesh, to evaluate rainfall–groundwater interactions. A moderate negative correlation (r = –0.28) was found between rainfall and groundwater depth, with the strongest effect at a two-month lag (r = –0.65), showing delayed recharge. High annual rainfall variability (CV > 1.0) was linked to deeper groundwater, indicating reduced recharge efficiency under irregular rainfall. Regression analysis revealed that 61% of fluctuations were explained by current and lagged rainfall. These findings underscore the role of consistent rainfall in aquifer replenishment and emphasize the need for adaptive irrigation and sustainable groundwater use.

Introduction

Groundwater sustains nearly 2.5 billion people worldwide and supports over 40% of irrigated agriculture (UNESCO, 2022). In Bangladesh, it supplies more than 70% of irrigation water (Shamsudduha et al., 2019). Kushtia District, a key agricultural area, depends heavily on groundwater because surface water is limited. However, unsustainable extraction (Rahman & Zahid, 2019) and irregular rainfall (Ahmed et al., 2021) threaten long-term sustainability. Seasonal and interannual rainfall variability strongly affect recharge, yet detailed long-term studies are scarce. This research examines 30 years of rainfall and groundwater data to assess trends, recharge lags, and variability impacts, supporting sustainable groundwater management strategies.

Materials and Methods

The study was conducted in Kushtia District, located in southwest Bangladesh, an alluvial floodplain characterized by sandy loam soils and a subtropical monsoon climate. Groundwater serves as the primary source of irrigation in the area. Weekly groundwater depth data and monthly rainfall records covering 1994–2023 were obtained from the Bangladesh Water Development Board (BWDB). The datasets were pre-processed by removing obvious errors and inconsistencies, then aggregated into monthly averages for analysis. Several approaches were applied, including descriptive trend assessments to identify long-term changes, Pearson's correlation to evaluate the rainfall–groundwater relationship, and lag correlation (0–6 months) to detect delayed recharge responses. Rainfall variability was assessed using the coefficient of variation (CV), which reflects the irregularity of rainfall distribution. To capture the combined influences of current and lagged rainfall as well as variability, a multiple regression model was employed. This model quantified the extent to which fluctuations in rainfall explained changes in groundwater depth. All statistical analyses and graphical visualizations were carried out in Python, utilizing widely used scientific computing and plotting libraries, ensuring both transparency and reproducibility of the research workflow.

Results and Discussion

Rainfall and groundwater in Kushtia showed distinct seasonal patterns, with shallow groundwater during monsoon and deeper levels in dry months. Correlation analysis indicated a moderate negative relationship (r = –0.28), with the strongest at a two-month lag (r = –0.65), reflecting delayed recharge. Rainfall variability (CV) significantly influenced groundwater depth, as irregular rainfall years coincided with deeper water levels. Regression analysis explained 61% of groundwater fluctuations through current and lagged rainfall and variability. Figures 1–3 highlight these trends, showing that consistent rainfall supports effective recharge, while intense, irregular events and excessive dry-season extraction worsen groundwater depletion.

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Figures

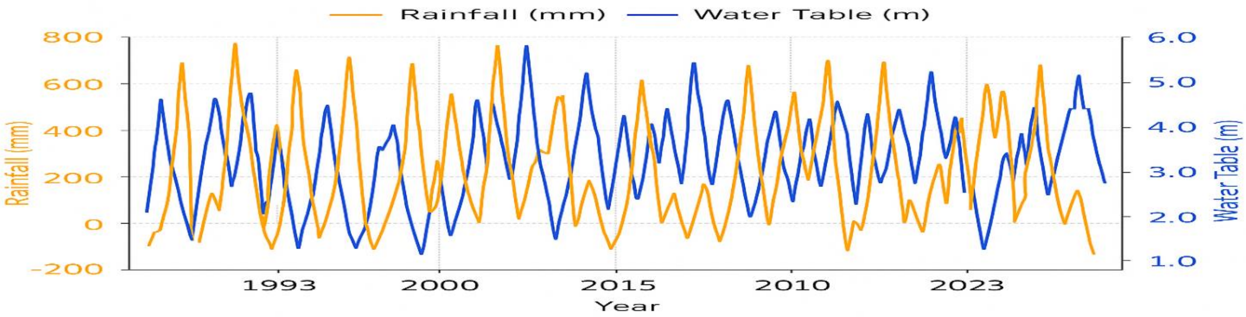

Fig. 1: Monthly water table depth and rainfall

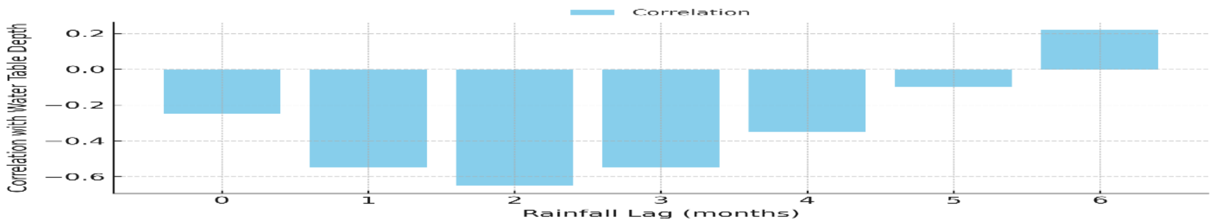

Fig. 2: Correlation between rainfall and groundwater depth at different lags

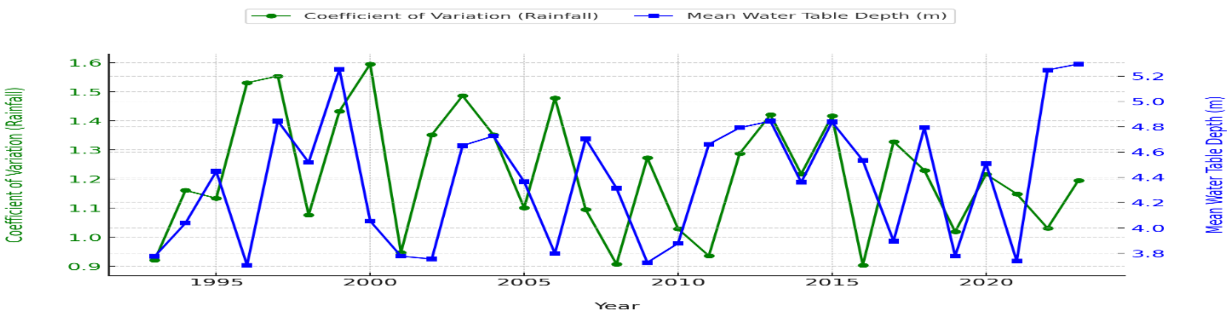

Fig. 3: Annual rainfall variability and groundwater level trends

Conclusion

Groundwater in Kushtia responds to monsoonal rainfall with a 1–2-month recharge lag. High variability worsens stress, while consistent rainfall supports recharge, highlighting the need for adaptive, sustainable irrigation management.

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MONITORING OF GROUND WATER LEVEL AT DIFFERENT BARI STATIONS

M. A. HOSSAIN[1], D. K. ROY[2], S. K. BISWAS[3], M. S. HOSSAIN[4], M. MORSHED[5], M. A. RAHMAN[6], M. M. RAHMAN[7], M. S. HOSSAIN[8], ROKKONUZAMAN[9] AND M. A. MOTTALIB[10]

Abstract

This study has been conducted at the research fields of Irrigation and water Management Division (IWM), RARS, Rahmatpur, Barisal, and RARS Ishurdi, Pabna, SRC, Bogura, BSPC, Debigonj, RARS, Jamalpur and RARS, Jessore of Bangladesh Agricultural Research Institute (BARI) from 2019-20. The maximum depletion of groundwater level was found (156.11ft) at IWM Field of BARI, Gazipur in 7th September, 2025 followed by RARS, BARI, Ishurdi (32 ft) in 26th April 2025. The lowest depletion of groundwater level was observed 14.9 ft at BSPC, Debigonj. Variation of maximum depletion of date at different locations may be caused by variations in rainfal, soil type, soil characteristics and other factors.

Introduction

Variations in water storage, including surface water, snow and ice, soil moisture, and groundwater, are essential for understanding a wide range of hydrologic, climatic, and ecologic processes and are important for water resources and agricultural management. Water scarcity is a global concern, with an estimated 1.1 billion people lacking access to clean water (Salman, 2005). Increasing demand for water requires more accurate information needed on water resources. While monitoring networks for precipitation and rivers exist in most regions, monitoring of subsurface water reservoirs (soil moisture and groundwater) is inadequate. However, groundwater represents a much larger fraction (~30%) of global fresh water resources than rivers (~0.006%) (Dingman, 2002). In addition, depletion of groundwater resources has increased substantially in the last several decades, particularly in places where groundwater-based irrigation has expanded (Scanlon et al., 2007). However, monitoring of groundwater storage in Bangladesh is extremely limited. Lack of information on groundwater storage changes inhibits development and execution of effective water management plans. Many countries with severe groundwater depletion problems have limited information on spatial and temporal variability in groundwater storage (Strassberg et al., 2009), as monitoring networks are generally limited and it is difficult to regionalize point-based measurements. To improve water resources management, it is critical to develop monitoring systems that provide accurate and timely information on the status of water reservoirs, including water in soil and aquifers. Therefore, an experiment was proposed with a view to meet the following objectives:

1) Installation of observation well at different BARI stations
2) Regular monitoring of groundwater level at 7 days' interval
3) To determine the depletion of groundwater level

Materials and Methods

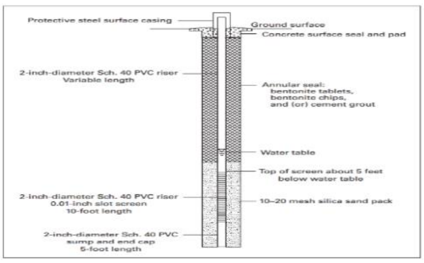

Fig 1. Schematic diagram of groundwater observation well

Methodology

Six observation wells were installed at IWM Division, BARI, Gazipur; RARS, Rahmatpur, Barishal; SRC, Bogura; BSPC, Debigonj; RARS, Jamalpur and RARS Jessore. On the other hand, an existing well was used at RARS, Ishurdi, Pabna to monitor groundwater level fluctuations. A schematic representation of the groundwater observation well is presented in Fig-1. The information of location (latitude, longitude and height above MLS), date of installation, depth of installation and strainer length are given in Table 1.

[1]CSO (In-charge), IWM Division BARI, Gazipur, [2]SSO, IWM Division BARI, Gazipur, [3]PSO FRC, Binodpur, Rajshahi, [4]CSO, BSPC, Debigonj, Panchagarh, [5]SO, PSC, Ishurdi, [6]CSO, RARS, Rahmatpur, Barishal, [7]SO, RARS, Pabna, Ishurdi, [8]SO, RARS, Jamalpur, [9]SO, RARS, Jessore, and [10]SO, SRC, Shibgonj, Bogura

Table-1. Information of server observation wells at different stations of BARI

Location	IWM Field Gazipur	RARS, Barishal	RARS, Pabna, Ishurdi	SRC Bogura	BSPC Debigonj	RARS Jamalpur	RARS Jessore
Date of installation	08 January 2020	25 Feb. 2020	01 March 2021	15 Dec. 2022	15 Sept. 2021	07 May 2023	22 April 2022
Latitude & longitude	25.99^0N 90.41^0E	22.79^0N 90.29^0E	24.07N 89.08^0E	24.97N 89.33^0E	26.099^0N 28.769^0E	24.936^0N 89.912^0E	23^0.18 N 90.18 E
Height above MSL	36 ft	33 ft.	52.48 ft	65 ft	194 ft	82 ft	60 ft
Depth of installation	210 ft	860 ft.	120 ft	65 ft	48 ft	128 ft	120 ft
Strainer length	20 ft	20 ft.	20 ft	26 ft	10 ft	20 ft	20 ft

Results and Discussions

Groundwater level fluctuation date of seven different observations well studded at different RARS and centres of BARI have been measuring at 7 days' interval since the installation of the observation well. The peak period of groundwater level of seven different locations from installation to upto date are shown in Table 2.

Table-2. Maximum depletion of groundwater table of server different station of BARI in 2025

Location	IWM Field Gazipur	RARS, Barishal	RARS Ishurdi	SRC Bogura	BSPC Debigonj	RARS Jamalpur	RARS Jessore
Maximum fluctuation	156.92 ft	25.42 ft	32 ft	25.56 ft	14.9 ft	29.8 ft	26 ft
Date	07/09/2025	25/03/2025	26/04/2025	28/04/2025	21/06/2025	21/03/2025	15/04/2025

The maximum depletion of groundwater level was found (156.11ft) at IWM Field of BARI, Gazipur in 7th September, 2025 followed by RARS, BARI, Ishurdi (32 ft) in 26th April 2025. The lowest depletion of groundwater level was observed 14.9 ft at BSPC, Debigonj. Variation of maximum depletion of date at different locations may be caused by variations in rainfal, soil type, soil characteristics and other factors.

Conclusions

The maximum depletion of groundwater level was found (156.11ft) at IWM Field of BARI, Gazipur in 7th September, 2025 followed by RARS, BARI, Ishurdi (32 ft) in 26th April 2025. The lowest depletion of groundwater level was observed 14.9 ft at BSPC, Debigonj. Variation of maximum depletion of date at different locations may be caused by variations in rainfal, soil type, soil characteristics and other factors. During 2025-26, observation well will be installed at RARS, Burirhat, RARS, Hathazari, RARS Cumilla and RARS, Abkarpur depend on the fund availability.

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IMPACT OF A SMALL MUNICIPAL SOLID WASTE DUMPSITE ON GROUNDWATER QUALITY: A CASE STUDY IN GAZIPUR CITY

D. K. ROY[1], M. P. HAQUE[2], M. A. HOSSAIN[3]

Abstract

This study evaluates the impact of a small municipal solid waste dumpsite on groundwater quality in Konabari, Gazipur, Bangladesh. Specifically, it assesses the travel time and direction of particle movement from the dumpsite to a pumping well and quantifies leachate migration into the subsurface system. The study employs finite difference-based numerical models: MODFLOW-MODPATH and MODFLOW-MT3DMS. Two pumping wells used for beneficial purposes were considered—one located near the dumpsite and the other farther away. The results show that MODFLOW-MODPATH effectively delineates the flow direction of water particles from the dumpsite to the pumping well, as well as the associated travel time. The average flow length and travel time to the nearest well were 429.41 meters and 5,163.57 days, respectively. Likewise, MODFLOW-MT3DMS-based contaminant transport modeling successfully simulates leachate migration from the dumpsite toward the well as a result of pumping.

Introduction

Leachate leakage from an improperly managed dumpsite results in groundwater contamination, impacting water quality due to its high concentrations of organic and inorganic compounds, heavy metals, toxic elements, and other dangerous chemicals (Dagwar and Dutta, 2024). When contaminants travel through the vadose zone and reach groundwater, they can mix with the aquifer system. The Gazipur City Corporation area, spanning 330 sq. km and housing approximately 4 million people, produces about 4,000 to 7,500 tons of municipal solid waste daily. The increased waste generation and disposal have led to significant groundwater pollution, rendering the soil unsuitable for farming (Parvin and Tareq, 2021). Therefore, regular monitoring of groundwater contamination with quantitative measurements of various contaminants is a priority for managing groundwater pollution. Numerical simulation modeling is a proven approach to quantify contaminant concentration, migration distance, and the extent of the area affected by leachate infiltration (Sun et al., 2022). Consequently, this study aims to determine the travel time and direction of particles from a dumpsite to a set of pumping wells and to investigate and quantify leachate migration into the subsurface system from the dumping site.

Materials and Methods

Coupled MODFLOW-MODPATH and MODFLOW-MT3DMS modeling with local hydrological data around an open dumping site constitute the central part of this study. Groundwater flow modeling was performed using MODFLOW-2005, incorporating data on groundwater levels, recharge, and aquifer properties. MODPATH, in association with the developed flow model using MODFLOW-2005, was used for tracing particle movement to and from the dumping site and wells, while MT3DMS, in conjunction with MODFLOW-2005, was used for delineating the leachate plume in the subsoil.

Results and Discussion

Results revealed that the MODFLOW-MODPATH modeling effectively delineates the direction of water particles from the dumpsite to the pumping well and determines the required travel time. The direction of flow paths and the travel time depend largely on the rate of pumping from the well and the subsurface hydrogeology (Figure 1). Figure 1(a) shows the study area, while Figure 1(b) illustrates the model domain. Figure 1(c) presents the flow direction and movement of water particles toward the well from nearby sinks. Figure 1(d) depicts the flow length and travel time of water particles. The average

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flow length and travel time to the nearest well were 429.41 meters and 5,163.57 days, respectively. Similarly, MODFLOW-MT3DMS-based contaminant transport modeling successfully simulates the migration of contaminants from the dumpsite towards the well due to pumping activities. The contaminant plume migrates further with increased groundwater abstraction from the wells and duration of pumping (Figure 2). Figures 2(a), 2(b), and 2(c) show the movement of the leachate plume after 5,000, 7,500, and 10,000 days, respectively, under a constant pumping rate of 200 m³/d. This pumping rate and duration affected the nearest well, while the well farthest from the dumpsite remained unaffected. Therefore, it can be inferred that the proposed modelling approach provides a reliable prediction of contaminant behavior in groundwater systems, highlighting the impact of leachate migration on water quality and the influence of pumping wells on contaminant dispersion.

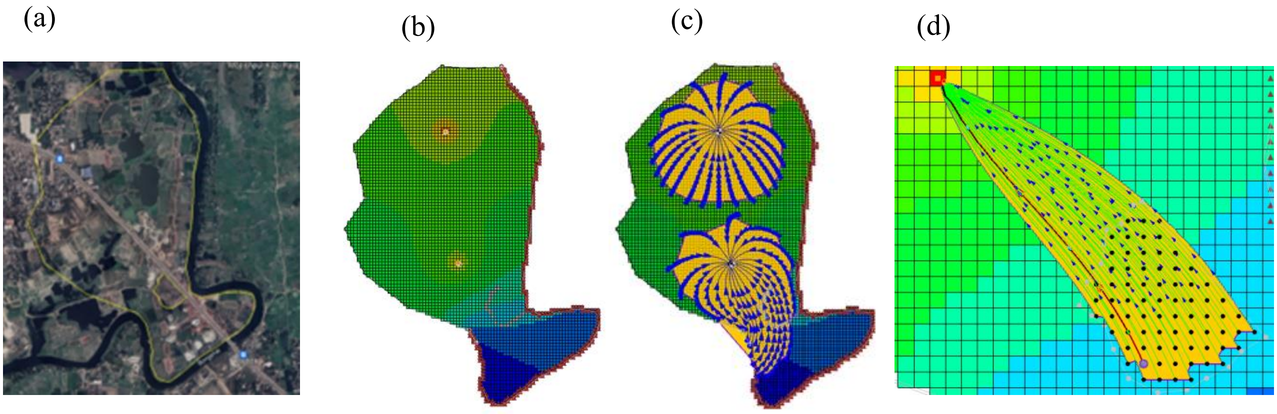

Figure 1. Study area (a), model domain (b), the movement of water particles from the well (c), and length of flow paths (d) because of pumping near a dumpsite

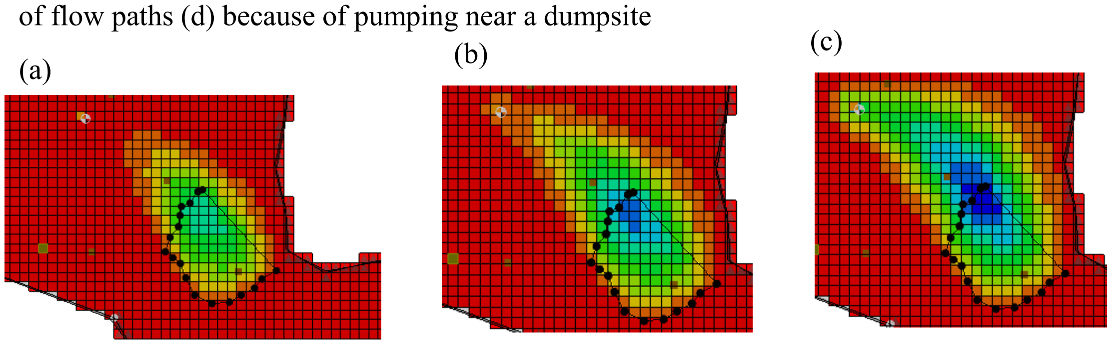

Figure 2. Movement of leachate after 5000 days (a), after 7500 days (b), and after 10000 days (c) towards the well from the landfill

Conclusion

This study demonstrates that a small municipal solid waste dumpsite can pose a long-term threat to nearby groundwater sources. Numerical modeling using MODFLOW-MODPATH and MODFLOW-MT3DMS effectively simulated groundwater flow and leachate migration, revealing significant particle travel toward the nearest pumping well. The findings highlight the need for careful monitoring and management of waste disposal sites to protect groundwater quality.

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ADAPTIVE TRIALS ON WATER-SAVING IRRIGATION TECHNOLOGIES IN WATER-SCARCE REGIONS OF BANGLADESH

D. K. ROY[1], M. A. HOSSAIN[2], K. K. SARKER[1], A. J. MILA[3], M. P. HAQUE[4], C. R. PAUL[4]

Abstract

This study evaluates the performance of various water-saving irrigation technologies through adaptive field trials conducted in farmers' fields across water-scarce regions of Bangladesh during the 2024–2025 growing season. A total of 71 demonstrations were implemented across multiple sites, comprising 22 trials of alternate furrow irrigation, 8 trials of conjunctive use of fresh and saline water, 16 trials of deficit irrigation, 7 trials of drip irrigation, 5 trials of solar-powered drip irrigation, 7 trials of sprinkler irrigation, and 6 trials of solar-powered sprinkler irrigation. These technologies were applied to diverse crops and soil types representative of the region. Key performance indicators included water use efficiency, crop yield, and water productivity. Results showed that alternate furrow irrigation reduced water use by up to 33% (e.g., potato: 0.30 m to 0.20 m, water productivity 9.79 kg/m^3; cauliflower: 0.26 m to 0.17 m, water productivity 11.83 kg/m^3) without compromising yield. Deficit irrigation saved 15–20% water while improving water productivity (e.g., mustard: 0.15 m to 0.12 m, water productivity 1.21 kg/m^3; maize: 0.33 m to 0.26 m, water productivity 3.85 kg/m^3). Conjunctive use maintained stable yields (e.g., maize 10.00 t/ha, potato 19.10 t/ha) but showed no significant water savings. Drip irrigation achieved high yields for high-value crops such as tomato (80.00 t/ha) and brinjal (50.00 t/ha), while solar-powered systems reduced operational costs and improved energy sustainability. Sprinkler irrigation performed well for moderate water-requirement crops like onion (18.00 t/ha) and garlic (8.00 t/ha). Farmers perceived these technologies as effective strategies for addressing water scarcity, enhancing yields, and lowering operational costs, with strong interest in continued adoption. The study will extend for the next three years, evaluating these irrigation methods under varying agro-ecological conditions to further validate their long-term benefits.

Introduction

Water scarcity has emerged as one of the most pressing challenges for agriculture in Bangladesh, particularly in regions prone to seasonal aridity and irregular rainfall patterns. In many parts of the country, including coastal and drought-prone zones, declining groundwater reserves, salinity intrusion, and erratic precipitation increasingly threaten the reliability of irrigation water supply. These factors collectively undermine agricultural productivity, reduce farm incomes, and jeopardize national food security, especially in the context of a rapidly growing population and increasing climate variability.

Traditional irrigation practices in Bangladesh—such as uncontrolled surface flooding and inefficient canal or tube well distribution systems—are characterized by excessive water application, significant conveyance losses, and high energy consumption. Such practices not only accelerate groundwater depletion but also increase production costs for farmers. The situation is further aggravated by limited access to renewable energy sources, which heightens dependence on diesel and electricity for pumping, thereby adding financial and environmental burdens.

In recent years, there has been a growing emphasis on innovative irrigation technologies that prioritize water conservation while sustaining or enhancing crop yields. Globally, methods such as drip irrigation, sprinkler systems, alternate furrow irrigation, deficit irrigation, and conjunctive use of multiple water sources have demonstrated substantial potential to reduce water use, improve water productivity, and lower operational costs. In Bangladesh, however, widespread adoption of these

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technologies remains limited, primarily due to the lack of localized field evaluations, farmer awareness, and tailored recommendations for specific agro-ecological contexts.

Against this backdrop, the present study introduces adaptive trials of seven advanced irrigation technologies—alternate furrow irrigation, conjunctive use of fresh and saline water, deficit irrigation, drip irrigation, solar-powered drip irrigation, sprinkler irrigation, and solar-powered sprinkler irrigation—implemented directly in farmers' fields across water-scarce regions. By conducting 71 demonstrations during the 2024–2025 growing season, this research seeks to evaluate the performance of these technologies under real-world conditions, encompassing diverse crop types, soil textures, and water quality scenarios. The assessment focuses on three key performance indicators: water use efficiency, crop yield, and water productivity. The overarching objective is to generate practical, evidence-based recommendations that can facilitate the transition from traditional high-water-use practices to modern, resource-efficient irrigation systems. In doing so, this study aims to contribute to sustainable agricultural intensification, improved climate resilience, and the long-term water security of Bangladesh's farming communities.

Materials and Methods

The study was carried out during the 2024–2025 growing season in selected water-scarce regions of Bangladesh, encompassing a range of agro-ecological zones and climatic conditions. Field sites were located in Gazipur, Kishoreganj, Manikganj, Faridpur, Patuakhali, Satkhira, Bogura, and Rangpur, representing diverse soil types, water availability scenarios, and cropping patterns. The research adopted an adaptive trial approach, integrating innovative irrigation technologies directly into farmers' fields to evaluate their performance under real-world conditions. A total of 71 demonstrations were implemented, distributed among seven water-saving irrigation technologies as follows: alternate furrow irrigation (22 trials), conjunctive use of fresh and saline water (8 trials), deficit irrigation (16 trials), drip irrigation (7 trials), solar-powered drip irrigation (5 trials), sprinkler irrigation (7 trials), and solar-powered sprinkler irrigation (6 trials). Each technology was applied to representative crops grown in the respective locations, selected according to local cropping practices and farmer preferences. The tested crops included maize, potato, sunflower, wheat, cauliflower, mustard, watermelon, papaya, brinjal, onion, garlic, malta, and cabbage.

Trials were managed under standard agronomic practices, with the only variable being the irrigation technology. Crop yield (t/ha) was measured at harvest using calibrated weighing scales, and water use was quantified based on volumetric measurements of irrigation applications for both traditional and water-saving methods. Water productivity (kg/m^3) was calculated by dividing total crop yield by the corresponding volume of water applied. The research strictly complied with ethical guidelines for on-farm experimentation. Farmers were fully informed about the objectives, procedures, and potential impacts of the trials, and their consent was obtained prior to implementation. All activities were designed to minimize disruption to regular farming operations, ensuring that the trials complemented rather than hindered ongoing agricultural activities.

Results and Discussion

The adaptive trials revealed distinct variations in yield, water requirement, and water productivity across different crops and irrigation technologies in water-scarce regions of Bangladesh (Table 1). Drip and solar-powered irrigation demonstrated high productivity for horticultural crops. Watermelon yielded 41.30 t/ha with a traditional water requirement of 0.30 m, while brinjal achieved 50.00 t/ha using 0.42 m of water. Tomato recorded the highest yield in this group (80.00 t/ha) with a relatively low water requirement of 0.34 m, indicating the suitability of drip irrigation for water-efficient production of high-value crops. Malta, although having a lower yield (20.00 t/ha), required 1.20 m of water due to its perennial nature. Cabbage (58.00 t/ha, 0.32 m) and papaya (60.00 t/ha, 1.50 m) also performed well, suggesting that drip and solar-powered systems can sustain both seasonal and perennial crops under limited water conditions. Sprinkler and solar-powered irrigation were tested on onion and garlic, producing yields of 18.00 t/ha and 8.00 t/ha, with water requirements of 0.27 m and 0.25 m, respectively. These results confirm that sprinkler systems are suitable for crops with moderate water needs, offering potential for energy savings when combined with solar power.

Table 1. Yield, water requirement, and water productivity of different crops under various irrigation technologies

Irrigation technology	Crops	Yield, t/ha*	Water requirement (Traditional), m	Water requirement (water-saving technology), m	Water productivity, kg/m^3
Drip and solar-powered irrigation	Watermelon	41.30	0.30	-	-
	Brinjal	50.00	0.42	-	-
	Tomato	80.00	0.34	-	-
	Malta	20.00	1.20	-	-
	Cabbage	58.00	0.32	-	-
	Papaya	60.00	1.50	-	-
Sprinkler and solar-powered irrigation	Onion	18.00	0.27	-	-
	Garlic	8.00	0.25	-	-
Alternate furrow irrigation	Potato	19.10	0.30	0.20	9.79
	Sunflower	1.50	0.34	0.22	0.69
	Cauliflower	20.00	0.26	0.17	11.83
	Wheat	3.51	0.26	0.17	2.08
	Maize	10.00	0.33	0.21	4.73
Conjunctive use	Maize	10.00	0.34	0.34	2.99
	Sunflower	1.50	0.26	0.26	0.58
	Potato	19.10	0.30	0.30	6.37
	Mustard	1.40	0.15	0.15	0.97
Deficit irrigation	Mustard	1.40	0.15	0.12	1.21
	Maize	10.00	0.33	0.26	3.85
	Wheat	3.51	0.26	0.21	1.69

*Average yield at different locations

Alternate furrow irrigation showed clear water savings compared to traditional methods. For potato, the water requirement reduced from 0.30 m to 0.20 m, maintaining a high yield of 19.10 t/ha and achieving a water productivity of 9.79 kg/m^3. Sunflower recorded a yield of 1.50 t/ha, with water use reduced from 0.34 m to 0.22 m, though water productivity remained low (0.69 kg/m^3), suggesting limited economic return under this method. Cauliflower achieved a yield of 20.00 t/ha with water productivity of 11.83 kg/m^3, highlighting its strong response to reduced water application. Wheat and maize also benefited, with maize reaching 4.73 kg/m^3 water productivity and wheat 2.08 kg/m^3 under reduced water use.

Conjunctive use (combining different water sources) showed stable yields but no water savings compared to traditional application rates, as the water requirement remained the same. For example, maize yielded 10.00 t/ha with 0.34 m of water (2.99 kg/m^3 productivity), while potato maintained 19.10 t/ha yield with 6.37 kg/m^3 productivity. Mustard and sunflower under conjunctive use recorded lower water productivity (0.97 kg/m^3 and 0.58 kg/m^3, respectively), indicating that this approach may be more suited for reliability of supply than for improving water use efficiency.

Deficit irrigation proved highly effective for certain crops. Mustard maintained the same yield (1.40 t/ha) with water reduced from 0.15 m to 0.12 m, with a water productivity of 1.21 kg/m^3. Maize yield remained at 10.00 t/ha, with water use reduced from 0.33 m to 0.26 m, boosting water productivity to 3.85 kg/m³. Wheat also benefited, with productivity rising to 1.69 kg/m³ under reduced water application.

Overall, the results indicate that alternate furrow irrigation and deficit irrigation consistently improve water productivity without significant yield loss, particularly for potato, cauliflower, and maize. Drip irrigation offers the highest yield potential for high-value horticultural crops, while sprinkler systems are well suited for moderate water-requirement crops like onion and garlic. Conjunctive use maintains yield reliability but does not necessarily improve water savings. These findings support the targeted adoption of water-saving technologies based on crop type and water availability, which is critical for sustaining agriculture in water-scarce regions of Bangladesh.

Conclusion

The adaptive trials conducted during the 2024–2025 growing season provide strong evidence that water-saving irrigation technologies can play a pivotal role in addressing the dual challenges of water scarcity and sustainable agricultural intensification in Bangladesh. By evaluating seven advanced irrigation methods across diverse crops, soil types, and water availability scenarios, the study demonstrated that significant water savings can be achieved without compromising crop yields. For instance, alternate furrow and deficit irrigation techniques consistently reduced water use by 15–33% while maintaining or even enhancing water productivity, and drip systems achieved exceptional yields for high-value horticultural crops with comparatively low water inputs. These results reinforce the critical importance of transitioning from traditional, high-water-demand irrigation methods to modern, resource-efficient systems that align with the realities of Bangladesh's water-limited environments. The demonstrated improvements in water productivity, operational cost reduction, and crop performance underscore the practical and economic benefits of these technologies for smallholder farmers. Given the promising outcomes of this initial phase, the program will continue for the next three years, expanding trials to additional agro-ecological zones and incorporating a broader range of crops. This extended research will enable the refinement of technology-specific recommendations, facilitate wider farmer adoption, and contribute to long-term strategies for ensuring water security, improving climate resilience, and sustaining agricultural growth in the country's most vulnerable regions.

WATER-EFFICIENT IRRIGATION MANAGEMENT FOR ENHANCING CROP PRODUCTION IN CHAR AREAS OF NORTHERN BANGLADESH

M. A. HOSSAIN[1], D. K. ROY[2], M. P. HAQUE[3]

Abstract

This study investigated the performance and economic viability of modern, water-efficient irrigation technologies in the water-scarce char regions of northern Bangladesh. Field trials of drip fertigation, sprinkler irrigation, and solar-powered alternate furrow irrigation (AFI) were conducted across four char locations to improve crop productivity and resource use efficiency. Results showed that these technologies significantly reduced water (30–50%), fertilizer (20–40%), and energy use while increasing crop yields (20–35%). The solar-powered AFI system had the shortest payback period (0.7–0.8 years), demonstrating strong potential for rapid adoption. Overall, the study highlights the effectiveness of integrating climate-smart irrigation practices with renewable energy for sustainable agricultural intensification in marginal ecosystems.

Introduction

Bangladesh's char areas represent a vast but underutilized agricultural resource due to their isolation, sandy-loam soils, and unreliable water infrastructure. Traditional irrigation practices in these regions often result in low productivity and inefficient resource use. Modern irrigation systems such as drip, sprinkler, and alternate furrow irrigation (AFI) have shown promise in improving water efficiency and crop yields globally (Yang et al., 2023; Chauhdary et al., 2024). These systems can be particularly beneficial in climate-vulnerable regions like char lands when integrated with solar power (Ashraf & Jamil, 2022). This study aimed to validate these technologies under local conditions, assess their agronomic and economic feasibility, and develop scalable solutions for climate-resilient agriculture in Bangladesh's char regions.

Materials and Methods

Field experiments were conducted in four char sites: Char Gunai (Rangpur), Char Begumganj (Kurigram), Char Gugunda (Lalmonirhat), and Char Haldia (Gaibandha), using randomized block designs with three replications. Drip fertigation was tested on chili, sweet gourd, and pointed gourd; sprinkler irrigation on onion, groundnut, and leafy vegetables; and solar-powered AFI on maize. Control plots using hand-pipe irrigation were included for comparison. Soil moisture, water use, crop yields, and input costs were recorded, and economic analysis was performed using benefit-cost ratio (BCR) and payback period. Farmer surveys assessed perception and adoption potential. Data were analyzed using ANOVA and descriptive statistics in R Studio and Excel.

Results and Discussion

Modern irrigation methods significantly outperformed traditional systems across all metrics. In Char Gunai, drip irrigation reduced irrigation water by 35–45% for chili and sweet gourd while increasing yields by 15–30%, with water productivity improving up to 13.77 kg/m^3. At Char Begumganj, sprinkler irrigation on mixed vegetables reduced water use by 17% and increased yield by 25%, resulting in a BCR increase from 1.02 to 1.39 (Fig. 1). Solar-powered AFI used in maize cultivation consistently reduced water use by 30–35% and improved yields by 15–20%. The payback period analysis showed AFI systems had the shortest recovery time (0.7–0.8 years), while sprinkler systems showed longer recovery periods (6–10 years), especially in crops like groundnut. Drip systems showed moderate payback periods (2.7–6.1 years) depending on crop value and location. Across all sites, the improved

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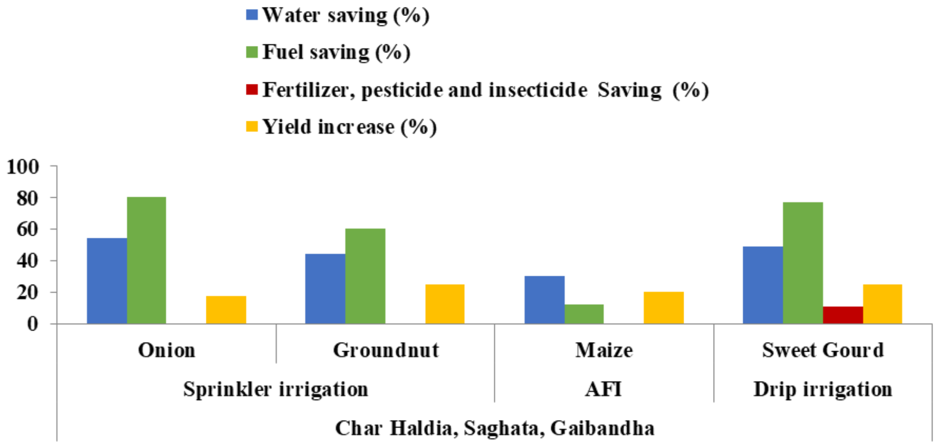
systems not only enhanced productivity and input efficiency but also offered greater economic returns, validating their suitability for the socio-environmental conditions of char areas.



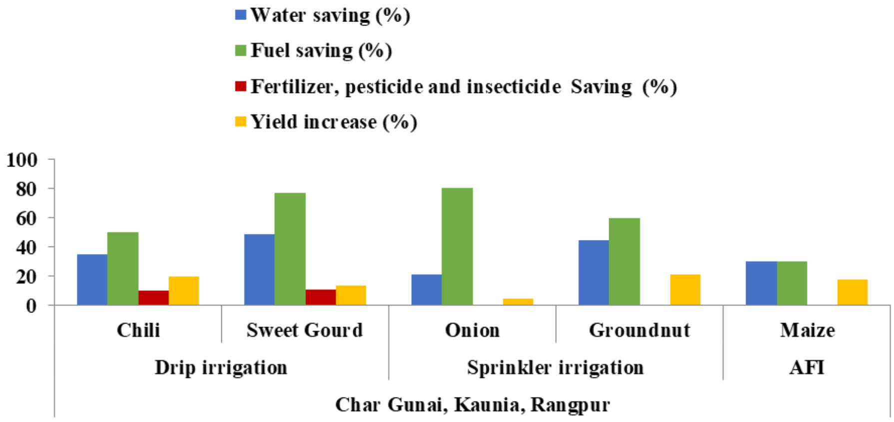


Figure 1. Water, fertilizer, and fuel savings and yield increase under water saving irrigation technologies at Char Haldia, Saghata, Gaibandha & Char Gunai, Kaunia, Rangpur

Conclusion

The integration of drip fertigation, sprinkler, and AFI technologies—particularly when powered by solar energy—significantly improved crop yields, resource use efficiency, and farm profitability in char areas of northern Bangladesh. These findings support the broader adoption of water-saving irrigation technologies for sustainable agriculture in marginal environments. The success of farmer group–based implementation models further suggests the potential for large-scale replication with appropriate policy and institutional support.

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VALIDATING SPRINKLER AND SUBSURFACE DRIP IRRIGATION SYSTEMS FOR SUSTAINABLE CROP PRODUCTION IN CHAR AREAS OF BANGLADESH

M. A. HOSSAIN[1], D. K. ROY[2], K. K. SARKER[2]

Abstract

In Bangladesh, where agricultural land is dwindling due to population pressure, innovative irrigation techniques are critical for maximizing crop production on underutilized char lands. This study validates and refines sprinkler and subsurface drip irrigation (SDI) systems for growing high-value crops under the challenging conditions of sandy loam soils in the char areas of Rajbari, Dhaka, and Tangail districts. Field and tank experiments were conducted from October 2024 to April 2025 using crops such as brinjal, pumpkin, onion, and ground nut. The sprinkler system showed enhanced yields for shallow-rooted crops, while SDI demonstrated substantial water and fertilizer savings. Preliminary results indicate increased water productivity and techno-economic feasibility, suggesting these irrigation technologies can play a significant role in ensuring sustainable agriculture in vulnerable char ecosystems.

Introduction

Bangladesh faces increasing pressure on its agricultural resources due to land fragmentation and climate variability. Cultivating fallow char lands through improved irrigation methods offers a sustainable solution to enhance food production (Shahid et al., 2021; Rahman et al., 2020). Micro-irrigation technologies like sprinkler and subsurface drip irrigation have proven effective in improving water use efficiency and crop yields in water-scarce regions (Narayanamoorthy, 2004). However, their applicability to the unique soil and hydrological conditions of Bangladeshi char lands remains understudied. This research aims to validate and adapt these systems for char areas to improve productivity, reduce water losses, and enhance resilience to climate variability.

Materials and Methods

The study was conducted in char areas of Rajbari, Dhaka, and Tangail, using crops like onion, groundnut, brinjal, and pumpkin to compare farmer practices with sprinkler, surface drip, and subsurface drip irrigation (SDI) systems. A preliminary tank experiment helped refine SDI emitter placement. Solar-powered pumps supplied water, with irrigation scheduled based on crop evapotranspiration. Sprinkler was applied every 7–10 days, surface drip every 3 days, and SDI every 5 days. Standard agronomic practices were followed, and yield and water productivity were recorded for each treatment to evaluate efficiency and feasibility.

Results and Discussion

Preliminary observations from the field experiments indicated that both sprinkler and subsurface drip irrigation (SDI) systems significantly improved crop performance compared to traditional farmer practices. Onion and groundnut grown under sprinkler irrigation showed higher yields, particularly in the char areas of Rajbari and Dhaka, where water distribution was more uniform and frequent. Brinjal and pumpkin cultivated under SDI demonstrated better root zone moisture retention, reduced water loss, and increased productivity. The SDI system, in particular, achieved notable reductions in water and fertilizer use—by approximately 60–70% and 50–60%, respectively—while increasing yields by up to 50%. These systems minimized evaporation losses and supported consistent crop growth under the sandy loam soils of the char areas. Farmers noted healthier crops and improved soil moisture management, which contributed to better harvest quality. Although economic analysis is ongoing, early

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results suggest strong potential for improving resource-use efficiency and promoting sustainable agriculture in vulnerable char lands through these modern irrigation technologies.

Fig. 1. Photographic views of sprinkler irrigation system for onion production at char area of Banglabazar, Nowabganj, Dhaka

Fig. 2. Photographic views of solar-powered sub-surface and surface drip irrigation system for brinjal production at char area of Bhuapur, Tangail

Conclusion

The preliminary findings support the adoption of sprinkler and subsurface drip irrigation systems for sustainable crop production in char areas. These technologies improve water productivity, reduce input use, and support climate-resilient agriculture. With further economic analysis and capacity building, these systems hold promise for transforming underutilized char lands into productive agricultural zones. This is 1st year study and will be continued in next year.

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PROJECT (SACP-IWM PART):

DISSEMINATION OF WATER SAVING TECHNOLOGIES FOR NON-RICE CROPS IN SALINE PRONE AREAS OF BANGLADESH

D. K. ROY[1], M. P. HAQUE[2], M. A. HOSSAIN[3]

Location wise demonstrations and crop/variety details during 2024-2025 growing season

Sl. No.	Title of the adaptive trial	Technology Used	Farmers' name	Farmers' address (Vill., Union, Dist.)	Mobile No.	Area covered
01	Dissemination of Water Saving Technologies for Non-Rice Crops in Saline Area	Solar-powered Drip Irrigation System	Md. Abdur Rahim	Holdebariya, Kalapara, Patuakhali	01613093063	33 decimals
02	Do	Solar-powered Drip Irrigation System	Md. Abdul Hi	Omitpur, Kalapara, Patuakhali	01753739149	33 decimals
03	Do	Solar-powered Drip Irrigation System	Wasim Shikari	Monoharpur, Kalapara, Patuakhali	01610065037	33 decimals
04	Do	Solar-powered Drip Irrigation System	Dilip Gain	Monoharpur, Kalapara, Patuakhali	01779615706	33 decimals
05	Do	Solar-powered Drip Irrigation System	Md. Malek Akon	Khajura, Kalapara, Patuakhali	01725962397	33 Decimals
06	Do	Solar-powered Drip Irrigation System	Md. Delowar Hossain	Char Jabbar, Subarnochar, Noakhali	01851550521	40 decimals
07	Do	Solar-powered Drip Irrigation System	Md. Moin Uddin	Char Hasan, Char Jabbar, Subarnochar, Noakhali	01840212143	50 decimals
08	Do	Solar-powered Drip Irrigation System	Md. Jahirul Islam	Patakata, Amtoli, Barguna	01747688391	45 decimals

In this project, the solar-powered drip irrigation system developed by the IWM division was used to irrigate different crops at various locations in the salt affected areas of Bangladesh. Although the installation cost of the system was a little higher, the cost was less than an LLP (Low Lift Pump) installation cost. Farmers can use the portable solar panel for multiple purposes including household use, electricity storage in batteries to use electric bulbs and fans, and irrigating vegetables grown in the homestead garden. The specification and cost of the solar irrigation system (excluding tanks, main and lateral lines, and drippers) are as follows: a 300 watts' solar panel will cost Tk. 12000, a 180 watts DC pump would cost around Tk.7000, and the accessories would cost around Tk. 1000. Therefore, the total cost of the solar panel system will be Tk. 20000.

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DISSEMINATION OF SOLAR-POWERED DRIP IRRIGATION SYSTEM FOR WATERMELON CULTIVATION IN SALINE PRONE AREAS OF BANGLADESH (PATUAKHALI, NOAKHALI, AND BARGUNA)

Abstract

Traditionally, watermelon farmers irrigate by manually carrying water from small ponds, a process that is both labor-intensive and time-consuming. To address this challenge and improve resource efficiency, field demonstrations were conducted using a solar-powered drip irrigation system. The study included two treatments with three replications: solar-powered drip irrigation (T_1) and the farmers' conventional practice as the control (T_2). Trials were carried out during the 2024–25 growing season at Holdebariya and Omitpur in Kalapara, Patuakhali; Char Jabbar in Subarnochar, Noakhali; and Patakata in Amtoli, Barguna. Results indicated that T_1 consistently produced higher yields and significantly improved water productivity compared to T_2. The adoption of solar-powered drip irrigation not only reduced the labor burden of water application but also saved water and energy, making it an attractive and sustainable option for farmers.

Introduction

Soil and water salinity pose significant challenges to agricultural production in the coastal regions of Bangladesh, particularly during the dry season. In these areas, farmers typically cultivate T. Aman rice from July to December, after which the land often remains fallow due to increased soil salinity and acute water scarcity during the remaining months of the year. This prolonged fallow period not only limits cropping intensity but also reduces farm income and overall land productivity.

To address these constraints, it is essential to adopt irrigation practices that minimize water losses and enhance water use efficiency, particularly in saline-prone environments. The Bangladesh Agricultural Research Institute (BARI) has developed several modern irrigation technologies tailored for non-rice crops in such challenging conditions. Among these, drip fertigation has emerged as a highly promising water management technology, especially for high-value vegetable and fruit crops. This method delivers both water and nutrients directly to the plant root zone in precise quantities, thereby reducing evaporation losses, limiting salt accumulation in the root zone, and improving crop yields while conserving water and energy.

Given the growing demand for water-efficient and climate-resilient agricultural practices, the present study was undertaken to promote and evaluate the performance of BARI's drip fertigation technology for watermelon cultivation in the coastal districts of Kuakata, Noakhali, and Barguna. The overarching aim is to assess its potential for improving productivity, water use efficiency, and farmer profitability in saline-affected areas, thereby contributing to sustainable intensification of agriculture in coastal Bangladesh.

Materials and Method

The field demonstrations were carried out in three coastal districts of Bangladesh—Patuakhali, Noakhali, and Barguna—during the 2024–25 growing season to evaluate the performance of solar-powered drip irrigation for watermelon cultivation under saline-prone conditions. In the Patuakhali district, two demonstration sites were established, located at Holdebariya and Omitpur in Kalapara upazila. In Noakhali, a single demonstration was conducted at Char Jabbar in Subarnochar upazila, while in Barguna, one demonstration was implemented at Patakata in Amtoli upazila.

Each demonstration was laid out using a randomized complete block design (RCBD) with two irrigation treatments and three replications. The treatments were: T_1 – Irrigation with a solar-powered drip irrigation system, designed to deliver water directly to the plant root zone in a controlled manner, thereby reducing evaporation losses and improving water use efficiency. T_2 – Farmer's practice (control), in which irrigation water was applied manually by carrying water from nearby ponds in containers and applying it to the crop basins.

Plot sizes, plant spacing, and other agronomic practices such as land preparation, seedling establishment, fertilization, and pest management were kept uniform across treatments to ensure that differences in crop performance could be attributed primarily to the irrigation method. In the T_1 plots, the solar-powered drip system was operated based on crop water requirements, determined from local evapotranspiration estimates and growth stage-specific needs. In T_2 plots, irrigation was applied according to the farmers' conventional practice without scheduled water management.

Key parameters recorded included vine length, number of fruits per plant, individual fruit weight, total yield (t/ha), and water productivity (kg/m³). Water productivity was calculated by dividing the total yield by the volume of irrigation water applied. Data from each location were analyzed to compare treatment effects on crop growth, yield components, and water use efficiency.

Results and Discussion

The results of the field demonstrations on watermelon cultivation in three coastal districts during the 2024–25 growing season are summarized in Tables 1, 2, 3, and 4. Across all locations, a clear and consistent trend was observed—Treatment 1 (T_1), which used the solar-powered drip irrigation system, outperformed Treatment 2 (T_2), the farmer's conventional practice, in most growth parameters, yield components, total yield, and water productivity.

Table 1. Yield and yield components of watermelon during 2024-25 growing season at Holdebariya, Kalapara, Patuakhali

Treatment	Vine Length (cm)	Number of Fruits/ Plant	Individual Fruit Weight (kg)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	292.33	1.96	6.21	35.63	6.11
T_2	280.67	1.46	5.59	29.98	4.08
F	21.87	13.07	3.75	7.77	-
Prob.>F	0.0095	0.0225	0.1248	0.0494	-

In terms of vegetative growth, vine length was notably greater under T_1 across all sites, ranging from 281.33 cm at Omitpur to 295.12 cm at Char Jabbar, compared to T_2 values of 265.58–280.67 cm. These differences were statistically significant in all locations, suggesting that the improved and more uniform water supply under drip irrigation promoted better vegetative development. Longer vine growth is often associated with enhanced leaf area, increased photosynthetic capacity, and improved fruiting potential, which may have contributed to the observed yield differences.

Table 2. Yield and yield components of watermelon during 2024-25 growing season at Omitpur, Kalapara, Patuakhali

Treatment	Vine Length (cm)	Number of Fruits/ Plant	Individual Fruit Weight (kg)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	281.33	1.83	5.23	32.63	5.11
T_2	267.85	1.79	4.19	32.63	4.1
F	81.43	0.15	8.27	0.005	-
Prob.>F	0.0008	0.7194	0.0452	0.9983	-

Fruit number per plant also tended to be higher in T_1, with values reaching 1.96 fruits/plant at Holdebariya compared to 1.39 fruits/plant for T_2 at Patakata. Although statistical significance for fruit count varied between sites, the numerical advantage for T_1 was consistent, indicating that the drip irrigation method may have supported better flower retention and fruit set.

For individual fruit weight, T_1 maintained modest but consistent numerical advantages over T_2 across the sites, with maximum values of 6.21 kg (Holdebariya) compared to 5.59 kg (T_2 at the same site). While these differences were not statistically significant in most cases, the trend suggests that improved water and nutrient availability in T_1 may have supported better fruit filling and uniformity.

The most substantial improvements were seen in total yield and water productivity. Yields under T_1 ranged from 32.63–36.42 t/ha, with the highest recorded at Patakata (36.42 t/ha), while T_2 yields ranged from 29.84–32.63 t/ha. Yield improvements of approximately 10–20% were observed in T_1 compared to T_2, with statistically significant differences in most locations. This suggests that the precision and consistency of water application in T_1 reduced plant stress during critical growth stages, leading to higher productivity.

Table 3. Yield and yield components of watermelon during 2024-25 growing season at Char Jabbar, Subarnochar, Noakhali

Treatment	Vine Length (cm)	Number of Fruits/ Plant	Individual Fruit Weight (kg)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	295.12	1.93	6.15	36.09	5.91
T_2	273.05	1.45	5.69	29.93	4.35
F	107.63	4.05	0.89	23.68	-
Prob.>F	0.0005	0.1145	0.3993	0.0082	-

Water productivity showed the most pronounced differences between treatments. T_1 values often exceeded 5.7 kg/m^3—peaking at 6.11 kg/m^3 in Holdebariya—while T_2 values frequently remained below 4.5 kg/m^3, with the lowest recorded at Omitpur (4.10 kg/m^3). This reflects a 15–40% improvement in the efficiency of converting irrigation water into marketable yield for T_1. The superior water productivity under drip irrigation is consistent with previous studies in saline-prone areas, which report reduced non-beneficial water losses and improved crop water use efficiency under localized irrigation methods.

Table 4. Yield and yield components of watermelon during 2024-25 growing season at Patakata, Amtoli, Barguna

Treatment	Vine Length (cm)	Number of Fruits/ Plant	Individual Fruit Weight (kg)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	289.62	1.92	6.05	36.42	5.74
T_2	265.58	1.39	5.73	29.84	4.46
F	103.57	18.4	0.24	38.3	-
Prob.>F	0.0005	0.0128	0.6485	0.0035	-

Overall, these findings indicate that solar-powered drip irrigation not only enhances yield but also significantly improves water use efficiency in saline-prone coastal environments. This technology's ability to deliver water directly to the root zone at controlled rates appears to mitigate the adverse effects of salinity and water scarcity, offering a sustainable and resource-efficient solution for watermelon production in coastal Bangladesh.

Conclusion

Solar powered drip irrigation system was found more water productive and profitable than farmers' practice. The findings not only provide a valuable insight regarding crop production under water scarcity but also motivate the farmers of the project site in using water saving irrigation technologies to achieve higher yields.

DISSEMINATION OF SOLAR-POWERED DRIP IRRIGATION SYSTEM FOR PUMPKIN CULTIVATION IN SALINE PRONE AREAS OF BANGLADESH (PATUAKHALI AND NOAKHALI)

Abstract

Pumpkin fields are typically irrigated by farmers using manual techniques, drawing water from nearby sources, which often leads to excessive water use. To address this issue, field trials utilizing a solar-powered drip irrigation system were carried out to reduce water wastage and improve energy efficiency. These trials took place during the 2024-25 growing season in several locations across southern Bangladesh, including Monoharpur and Kalapara in Patuakhali, as well as Char Hasan, Char Jabbar, and Subarnochar in Noakhali. The experiment consisted of two irrigation treatments, each replicated three times: (i) a solar-powered drip irrigation system (T_1) and (ii) conventional farmer practices (T_2) serving as the control. Findings showed that T_1 outperformed T_2 in both yield and water productivity. The technology also garnered positive interest from farmers due to its potential for saving both water and energy.

Introduction

Soil and water salinity represent major obstacles to agricultural productivity in the coastal regions of Bangladesh, particularly during the dry season when freshwater availability declines and salt accumulation intensifies. These saline conditions drastically limit the range of crops that can be cultivated, compelling farmers to predominantly grow T. Aman rice between July and December—the monsoon season—when rainfall helps to somewhat mitigate salinity effects. However, during the dry months, increasing soil and water salinity combined with scarcity of irrigation water results in large tracts of land remaining fallow. This extended fallow period not only decreases the overall utilization and productivity of arable land but also adversely affects the economic well-being and food security of the farming communities that depend on agriculture for their livelihoods.

Addressing these challenges requires innovative and sustainable agricultural practices tailored to the unique conditions of saline-prone coastal areas. Recognizing this need, the Bangladesh Agricultural Research Institute (BARI) has developed and promoted a range of modern irrigation technologies aimed at enhancing water management and enabling the cultivation of non-rice crops that are better suited to saline environments. One of the most promising among these is drip fertigation—a system that combines drip irrigation with the precise application of fertilizers. By delivering water and nutrients directly to the root zone of plants, drip fertigation significantly reduces losses caused by evaporation, deep percolation, and surface runoff, thereby improving water use efficiency and nutrient uptake.

This technology is particularly well-suited for high-value vegetable and fruit crops, which have the potential to increase farm income and diversify cropping systems in coastal regions. Pumpkin, as a nutritious and economically important crop, is well positioned to benefit from such advanced irrigation methods. With this context, the present study is designed to promote the dissemination and adoption of drip fertigation technology for pumpkin cultivation in selected coastal districts of Bangladesh, including Monoharpur and Kalapara in Patuakhali, as well as Char Hasan, Char Jabbar, and Subarnochar in Noakhali. The overarching goal is to demonstrate how this efficient irrigation practice can improve crop yield, enhance water productivity, and contribute to sustainable agricultural development in areas affected by salinity stress.

Materials and Method

Field demonstrations were conducted during the 2024-25 growing season to evaluate the performance of pumpkin cultivation under different irrigation strategies in the saline-prone coastal areas of Bangladesh. The selected experimental sites included Monoharpur and Kalapara in the Patuakhali district, as well as Char Hasan, Char Jabbar, and Subarnochar located in the Noakhali district. These locations represent typical coastal environments where soil and water salinity significantly challenge crop production. To ensure robust and statistically reliable outcomes, two distinct irrigation treatments were established, each replicated three times following a randomized design.

The first treatment (T_1) involved the use of a solar-powered drip irrigation system. This modern irrigation technology is designed to enhance water use efficiency by precisely delivering water directly to the root zone of the plants, thereby minimizing water loss due to evaporation, surface runoff, and deep percolation. The use of solar energy to power the system also offers an environmentally sustainable and cost-effective solution for farmers in off-grid or energy-scarce areas. In contrast, the second treatment (T_2) followed the conventional irrigation practices commonly adopted by local farmers, typically relying on manual watering methods such as bucket or furrow irrigation, which are often less efficient in water use.

Throughout the entire growing season, pumpkin plants under both treatments received fertilization based on the guidelines provided by the Bangladesh Agricultural Research Institute (BARI). These fertilizer applications were carefully timed and dosed to meet the nutritional requirements of the crop, supporting optimal growth and maximizing yield potential. Additionally, integrated pest management practices were employed to protect the crop from insect pests and diseases. BARI-recommended insecticides and pesticides were applied judiciously, ensuring that crop health was maintained without causing undue environmental harm.

The primary objective of these demonstrations was to compare the two irrigation methods with respect to key performance indicators such as water use efficiency, total crop yield, fruit quality, and overall resource utilization. The study also aimed to explore the potential of solar-powered drip irrigation as a sustainable agricultural practice that could improve productivity and resilience for farmers facing the dual challenges of salinity and water scarcity in Bangladesh's coastal regions.

Results and Discussion

The results from the field demonstrations conducted during the 2024-25 growing season across Monoharpur, Kalapara (Patuakhali), and Char Hasan, Char Jabbar, Subarnochar (Noakhali) are summarized in Tables 5, 6, and 7. For pumpkin cultivation, the benefits of the solar-powered drip irrigation system (T_1) were consistently evident across all locations. Specifically, T_1 resulted in higher fruit counts per plant, reaching up to 4.93 fruits, compared to the farmer's traditional irrigation method (T_2), which produced between 3.56 and 4.16 fruits per plant. This increase in fruit number directly contributed to the overall productivity improvement under T_1.

Table 5. Yield and yield components of pumpkin during 2024-25 growing season at Monoharpur, Kalapara, Patuakhali-1

Treatment	Number of Fruits / Plant	Individual fruit Weight (kg)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	4.93	5.12	36.83	7.96
T_2	3.67	3.86	29.85	6.61
F	7.75	7.59	54.93	-
Prob.>F	0.0496	0.0511	0.0018	-

In addition to producing more fruits, the individual fruit weights under T_1 were also greater, ranging from 4.79 to 5.12 kg, whereas T_2 fruits weighed between 3.56 and 4.16 kg. This indicates that the solar-powered drip system not only increased the quantity but also enhanced the quality and size of the pumpkins. The combined effect of more fruits per plant and heavier fruits resulted in substantially higher yields for T_1, which varied between 34.61 and 36.83 tons per hectare. In contrast, the yields under T_2 were significantly lower, ranging from 29.13 to 30.12 tons per hectare. The differences in yield between the two treatments were statistically significant at all trial sites, highlighting the effectiveness of the drip irrigation technology in improving crop productivity under saline and water-limited conditions.

Table 6. Yield and yield components of pumpkin during 2024-25 growing season at Monoharpur, Kalapara, Patuakhali-2

Treatment	Number of Fruits / Plant	Individual fruit Weight (kg)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	4.73	5.08	35.67	7.67
T_2	3.59	4.16	29.13	6.27
F	7.33	3.05	42.12	-
Prob.>F	0.0536	0.1555	0.0029	-

Table 7. Yield and yield components of pumpkin during 2024-25 growing season at Char Hasan, Char Jabbar, Subarnochar, Noakhali

Treatment	Number of Fruits / Plant	Individual fruit Weight (kg)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	4.13	4.79	34.61	7.81
T_2	3.57	3.56	30.12	6.55
F	2.39	10.22	30.25	-
Prob.>F	0.1968	0.033	0.0053	-

Water productivity, defined as the amount of crop produced per unit of water used, was also markedly better in T_1. The drip irrigation treatment achieved water productivity values between 7.67 and 7.96 kg/m^3, whereas the conventional farmer practice yielded 6.27 to 6.61 kg/m^3. This improvement demonstrates that the higher yields attained with T_1 were not the result of increased water consumption but rather due to more efficient water use. The precise delivery of water and nutrients through the drip system minimized losses from evaporation and runoff, making it a sustainable option for water-scarce coastal environments. Overall, the findings clearly suggest that adopting solar-powered drip irrigation can significantly enhance pumpkin production in salinity-prone coastal areas of Bangladesh, providing both higher yields and better water use efficiency. This technology holds promise for improving agricultural productivity and resource conservation in similar challenging agro-ecological zones.

Conclusion

Solar powered drip irrigation system was found more water productive and profitable than farmers' practice for pumpkin cultivation. It provided the highest yield and water productivity. The findings provided a valuable insight regarding crop production under water scarcity and motivate farmers of the project area.

DISSEMINATION OF SOLAR-POWERED DRIP IRRIGATION SYSTEM FOR BRINJAL CULTIVATION IN SALINE PRONE AREAS OF BANGLADESH (PATUAKHALI)

Abstract

In many coastal areas, brinjal growers still rely on manually transporting water from nearby ponds, a method that demands considerable labor and time. To overcome these limitations and enhance the efficient use of resources, field demonstrations were implemented featuring a solar-powered drip irrigation system. The experimental setup consisted of two treatments with three replications: solar-powered drip irrigation (T_1) and the traditional farmer's method (T_2) as the control. A field demonstration was conducted during the 2024–25 growing season at Khajura in Kalapara, Patuakhali. Results revealed that, T_1 consistently delivered greater yields and markedly higher water productivity than T_2. Moreover, the solar-powered drip system reduced the physical effort required for irrigation while conserving both water and energy, making it a promising and sustainable technology for local farming communities.

Introduction

Soil and water salinity are among the most pressing constraints to agricultural production in the coastal regions of Bangladesh, particularly during the dry season. High evapotranspiration rates, combined with tidal intrusion and poor drainage, lead to the accumulation of salts in both soil and irrigation water, severely limiting crop growth. Farmers in these areas typically cultivate T. Aman rice between July and December, when monsoon rains dilute salinity levels. However, during the remaining months of the year, agricultural lands often remain fallow due to the dual challenges of increased salinity and limited freshwater availability. This prolonged fallow period not only reduces overall cropping intensity but also curtails farm income and food supply.

Addressing these challenges requires the adoption of water-efficient irrigation practices that can minimize application losses, optimize water use, and support the cultivation of crops that can withstand moderate salinity. The Bangladesh Agricultural Research Institute (BARI) has developed a range of modern irrigation technologies designed specifically for non-rice crops in saline-prone areas. Among these, drip fertigation has emerged as a particularly promising option for high-value vegetables and fruit crops. This technique delivers water and soluble fertilizers directly to the plant root zone in controlled quantities, reducing evaporation and percolation losses, enhancing nutrient uptake, and helping to manage salt accumulation around the root zone.

Given the need to expand cropping opportunities in the coastal dry season, the present study was undertaken to promote and evaluate BARI's drip fertigation technology for brinjal (eggplant) cultivation in saline-affected environments. The demonstration was conducted at Khajura in Kalapara, Patuakhali district, with the objective of assessing its potential to improve crop performance, water productivity, and economic returns compared to traditional farmer practices. By introducing this technology at the farmer level, the study also aims to encourage the adoption of climate-smart and resource-efficient irrigation solutions in coastal Bangladesh.

Materials and Method

Field demonstrations on brinjal (hybrid variety) cultivation were carried out during the 2024–25 growing season at Khajura, Kalapara, Patuakhali, a coastal region characterized by moderate soil salinity during the dry period. The primary objective was to evaluate the performance of a solar-powered drip irrigation system compared to traditional farmer practices under saline-prone conditions.

The experimental layout followed a randomized complete block design (RCBD) with two irrigation treatments and three replications. The treatments were: T_1 – Solar-powered drip irrigation system: Water was delivered directly to the plant root zone through a network of drip lines powered by a solar pump, ensuring uniform and precise water application based on crop water requirements. T_2 – Farmer's practice (control): Irrigation water was applied manually following conventional local methods, without specific scheduling or precise application control.

Each plot received BARI-recommended fertilizer doses for brinjal, applied in split applications to match the crop's nutrient uptake pattern. In the T_1 plots, soluble fertilizers were applied through the drip system (fertigation), enabling efficient nutrient delivery directly to the roots. In the T_2 plots, fertilizers were broadcast and incorporated into the soil manually, following the farmers' customary practices. Crop protection measures were implemented uniformly across treatments. BARI-recommended insecticides and pesticides were applied to manage insect pests and diseases, ensuring optimal plant health and preventing yield loss. Standard agronomic practices, including land preparation, seedling transplanting, staking, and weeding, were carried out consistently across all plots to minimize non-treatment-related variability. Key parameters recorded included fruit length, fruit diameter, individual fruit weight, total yield (t/ha), and water productivity (kg/m^3). Water productivity was calculated as the ratio of total yield to the volume of irrigation water applied. Data collected from the demonstrations were analyzed to determine treatment effects on crop growth, yield performance, and irrigation water use efficiency.

Results and Discussion

The results of the field demonstration on brinjal cultivation at Khajura, Kalapara during the 2024–25 growing season are presented in Table 8. The findings clearly indicate that Treatment 1 (T_1), which used solar-powered drip irrigation, provided measurable advantages over Treatment 2 (T_2), the farmer's conventional irrigation practice, in several crop performance parameters.

Table 8. Yield and yield components of brinjal during 2024-25 growing season at Khajura, Kalapara, Patuakhali

Treatment	Length of Fruit (cm)	Diameter of Fruit (cm)	Unit Weight of Fruit (g)	Yield (t/ha)	Water Productivity (kg/m^3)
T_1	8.43	7.11	448	31.28	6.14
T_2	7.02	6.27	421	28.67	4.87
F	11.45	1.29	16.69	5.43	-
Prob.>F	0.0277	0.3201	0.015	0.0802	-

In terms of fruit size, T_1 produced significantly longer fruits, averaging 8.43 cm, compared to 7.02 cm under T_2. Similarly, individual fruit weight was significantly greater in T_1 (448 g) than in T_2 (421 g). These improvements suggest that the uniform and controlled water delivery under drip irrigation created more favorable conditions for fruit development, potentially reducing physiological stress and supporting better fruit filling. Increased fruit size and weight are particularly important for marketability and consumer preference, thereby contributing to higher potential income for farmers. Although total yield in T_1 (31.28 t/ha) was higher than in T_2 (28.67 t/ha), the difference was not statistically significant. This lack of statistical significance may be attributed to yield variability within the plots or environmental factors such as soil salinity variations and pest pressure. Nevertheless, the numerical yield advantage for T_1 still represents an approximate 9% improvement, which is meaningful from a production and economic standpoint, especially when combined with other quality improvements.

The most notable difference between treatments was in water productivity. T_1 achieved 6.14 kg/m^3, substantially higher than T_2's 4.87 kg/m^3, reflecting a 26% improvement in irrigation water use efficiency. This outcome underscores the ability of the solar-powered drip irrigation system to optimize water delivery and minimize non-beneficial losses such as evaporation and deep percolation. In saline-prone coastal areas where freshwater is scarce, such gains in water productivity are critical for sustainable crop production. Overall, the results demonstrate that adopting solar-powered drip irrigation for brinjal not only enhances fruit size and weight but also significantly improves water use efficiency, even if total yield gains are modest. The technology therefore holds considerable promise for improving both resource sustainability and economic returns in coastal Bangladesh.

Conclusion

Solar powered drip irrigation system was found more water productive and profitable than farmers' practice. It provided the highest yield and water productivity for the brinjal crop. The findings provided a valuable insight regarding crop production under water scarcity and motivate farmers of the project area.

Overall Conclusion

When considering all crops and sites together, the pattern indicates that T_1 not only improves yield but also enhances water productivity across different environments and crop types. In most cases, yield gains of 10–20% were observed for $T_1$1 over T_2, accompanied by water productivity improvements of 15–40%. This suggests that T_1's cultivation practices or inputs—whether related to irrigation strategy, nutrient management, or another factor—are more effective in maximizing both productivity and resource use efficiency. The few instances where differences were statistically non-significant (e.g., individual fruit weight in some watermelon sites, brinjal yield) still showed a numerical advantage for T_1, indicating a consistent agronomic benefit even if variability at certain sites reduced statistical confidence. Overall, the data strongly support T_1 as the superior treatment for achieving higher yields with better water use efficiency, making it a favorable option for farmers in water-limited coastal agricultural zones.