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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

# CONTENTS

# RESPONSE OF PROSO MILLET TO DIFFERENT LEVELS OF IRRIGATION

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

## Abstract

Proso millet is recognized for its short-season growth, low water requirements, and high tolerance to heat and drought. These qualities make it a promising crop in regions with water scarcity, particularly in drought-prone areas and char lands of Bangladesh. This study aimed to observe the effect of irrigation at different growth stages and to evaluate the performance of irrigation on yield and water productivity of proso millet. The research was carried out at the research field of IWM Division, BARI, Gazipur, during the 2023-24 growing season. Six irrigation treatments at different growth stages were considered with three replications. It is revealed from the study that treatment $T_1$, involving one irrigation at the vegetative stage, emerged with the highest grain yield and water productivity. However, a specific critical growth stage could not be identified due to light to moderate rainfall during the growing period. This study will be continued in the next year 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 a minor cereal, Proso millet (BARI Chenna-2), in the research field of the Irrigation and Water Management Division of Bangladesh Agricultural Research Institute (BARI) in Gazipur, during the rabi season of 2023-2024. 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. The seeds were sown on 27 December 2023 at a spacing of 25 cm line to line and crops were harvested on 9 April 2024. 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.

## Results and Discussion

The growth attributes of proso millet including plant height, spike length, tiller per plant, spikelet per spike, and spike per plant were significantly influenced by irrigation stages (Table 1). As plant height,

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spike length, 1000 grain weight are critical indicators of crop growth, demonstrated a significant difference between the different treatments. The $T_4$ treatment resulted in the highest average plant height 100.7 cm, while the shortest plant height 73.7 cm was observed with $T_0$ treatment, $T_4$ also demonstrated the highest, spike length, tiller per plant, spikelet per spike, and spike per plant. However, Table 1 demonstrates that different irrigation approaches had a non-significant influence on grain production. From the experiment, $T_1$ produced the highest grain yield 2.6 t/ha, whereas, $T_0$ resulted in the lowest output 2.0 t/ha, while $T_2$, $T_3$, $T_4$, and $T_5$ exhibited almost similar yield. Moreover, the findings indicated that different treatments had a significant impact on water productivity, as outlined in Table 2. In terms of water productivity $T_1$ showed the highest water productivity at 2.03 $kgm^{-3}$ while $T_5$ showed the lowest water productivity at 1.4 $kgm^{-3}$.

Table 1. Effect of irrigation level on growth and yield parameters of proso millet

| Treatments | Plant ht. (cm) | Spike length (cm) | Tiller per plant (nos) | Spikelet per spike (nos) | Spike per plant (nos) | Grain yield (t/ha) | Straw yield (t/ha) | 1000 Grain wt. (gm) |
|---|---|---|---|---|---|---|---|---|
| $T_0$ | 73.7d | 25ab | 2.7bc | 12a | 3.7b | 2.0b | 2.54b | 4.8c |
| $T_1$ | 87.7bc | 19.3c | 2.3c | 10.7ab | 3.7b | 2.6a | 3.77a | 5.1ab |
| $T_2$ | 79.7cd | 21.7bc | 3.3abc | 9.3bc | 4.7b | 2.4a | 3.27ab | 4.6c |
| $T_3$ | 86.3bc | 23abc | 3.7ab | 7.7c | 7.7a | 2.3ab | 2.96ab | 5.3ab |
| $T_4$ | 100.7a | 26.7a | 4.3a | 12.7a | 7.3a | 2.5a | 3.33ab | 5.7a |
| $T_5$ | 92.3ab | 26ab | 4.3a | 9.3bc | 7.3a | 2.2ab | 2.8b | 5.1bc |
| Significance | * | * | * | * | * | NS | NS | * |

Table 2. Effect of different irrigation treatments on water productivity of proso millet

| Treatments | Amount of irrigation (mm) | Effective rainfall (mm) | Soil water contribution (mm) | Total water use (mm) | Yield (t/ha) | Water Productivity $kg/m^3$ |
|---|---|---|---|---|---|---|
| $T_0$ | 0.0 | 66.8 | 54 | 120.8 | 2.0b | 1.7bc |
| $T_1$ | 20.2 | 66.8 | 40 | 127.0 | 2.6a | 2.03a |
| $T_2$ | 20.2 | 66.8 | 34 | 120.7 | 2.4a | 2.0a |
| $T_3$ | 70.2 | 66.8 | 27 | 164.0 | 2.3ab | 1.5c |
| $T_4$ | 50.0 | 66.8 | 22 | 138.4 | 2.5a | 1.8ab |
| $T_5$ | 70.2 | 66.8 | 20 | 157.2 | 2.2ab | 1.4c |
| Significance | - | - | - | - | NS | * |

## Conclusion

This study revealed that, treatment $T_1$, one irrigation at vegetative stage, produced higher yield and water productivity. However, the critical growth stage could not be determined due to shallow to medium rainfall occurred during the growing period. This study will be continued for the next year to validate the findings.

## References

Nematpour, A., Eshghizadeh, H. R., Zahedi, M., 2019. Drought-tolerance mechanisms in foxtail millet (Setaria italica) and proso millet (Panicum miliaceum) under different nitrogen supply and sowing dates. Crop and Pasture Science. 70. 442. 10.1071/CP18501.

Jiaju, C., 1986. Importance and genetic resources of small millets with emphasis on foxtail millet (Setaria italica) in China. In ‘Small millets in global agriculture’. (Eds A Seetharam, KW Riley, G Harinarayana).

# MULTI-STEP AHEAD TEMPERATURE FORECAST USING A BAYESIAN OPTIMIZATION TUNED LONG SHORT-TERM MEMORY NETWORK

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 three meteorological stations (Barishal, Gazipur, and Ishurdi). The study developed and compared Long Short-Term Memory (LSTM) networks, 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 indicated the superior predictive accuracy of ANN, ELM, GPR, and SVR models over LSTM for one-day ahead forecasts in Barishal. In addition, tuning of LSTM hyperparameters required extensive computation time compared to its counterparts. The SVR demonstrated superior performance for one, two, and three-days-ahead average temperature predictions compared to ANN, ELM, and GPR, as indicated by Shannon's Entropy-based decision theory. Due to LSTM's poor performance, the study will be continued next year employing the four alternative models for forecasting at the other two stations and across all time horizons.

## 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. In recent years, several soft computing techniques have been used to address temperature prediction issues. Most of these methods make use of neural computing methods, which are quick and produce reliable results (Paniagua-Tineo et al., 2011). Deep learning methods have gained significant attention in recent years for predicting daily average air temperatures (Shrivastava et al., 2023), nevertheless optimizing model parameters is still a challenging task. Current approaches often involve manual adjustment of the hyperparameters, which is a tedious task with the possibility of not finding the optimal model 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 three meteorological stations located in Gazipur, Barishal, 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 five soft computing techniques: LSTM, ANN, ELM, GPR, and SVR. Optimal model parameters were selected through hyperparameter tuning using Bayesian optimization. Evaluation of the models performance was

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conducted using several performance metrics, aiming specifically on their ability to provide accurate multi-step ahead daily average temperature forecasts.

## Results and Discussion

Of the three stations, the average daily temperature predictions for the Barishal station are presented in this report, as shown in Table 1. As shown in Table 1, the LSTM model demonstrated significantly poor performance for one-step-ahead forecasts. This is evidenced by its higher values of RMSE, NRMSE, MAPRE, MAE, and MAD, as well as lower values of $R^2$, NS, and IOA compared to the other four models (ANN, ELM, GPR, SVR). Moreover, optimizing the LSTM model through parameter tuning using Bayesian optimization is a time-intensive process, requiring at least 100 hours. In contrast, tuning the other four models (ANN, ELM, GPR, SVR) only took a couple of hours. For all three time horizons, SVR provided the superior performance among the four models, based on Shannon's Entropy-based decision theory. The trend across forecasting horizons and models showed that predictive performance generally decreases with increasing forecast horizon. Therefore, the LSTM model was developed solely for one-day ahead forecasts at the Barishal station due to its poor performance and extensive training time requirements. Subsequently, modeling will be conducted using the four models for all time horizons and for the remaining two stations.

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

| Models | Days ahead | Performance indices | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | RMSE (°C) | NRMSE | MAPRE (%) | MAE (°C) | MAD (°C) | $R^2$ | NS | IOA |
| ANN | One | 0.01968 | 0.00076 | 1.53158 | 0.01532 | 0.00762 | 0.99998 | 0.99997 | 0.99999 |
| | Two | 0.03942 | 0.00153 | 3.09025 | 0.03090 | 0.01544 | 0.99988 | 0.99988 | 0.99997 |
| | Three | 0.05924 | 0.00230 | 4.68505 | 0.04685 | 0.02344 | 0.99974 | 0.99970 | 0.99993 |
| ELM | One | 0.04129 | 0.00160 | 3.14890 | 0.03149 | 0.01485 | 0.99988 | 0.99987 | 0.99997 |
| | Two | 0.05870 | 0.00228 | 4.59327 | 0.04593 | 0.02372 | 0.99976 | 0.99974 | 0.99994 |
| | Three | 0.07088 | 0.00275 | 5.67655 | 0.05677 | 0.02863 | 0.99962 | 0.99962 | 0.99990 |
| GPR | One | 0.01934 | 0.00075 | 1.50658 | 0.01507 | 0.00733 | 0.99998 | 0.99997 | 0.99999 |
| | Two | 0.03936 | 0.00153 | 3.09780 | 0.03098 | 0.01523 | 0.99988 | 0.99988 | 0.99997 |
| | Three | 0.05974 | 0.00232 | 4.72368 | 0.04724 | 0.02366 | 0.99974 | 0.99973 | 0.99993 |
| SVR | One | 0.01948 | 0.00076 | 1.51583 | 0.01516 | 0.00759 | 0.99998 | 0.99997 | 0.99999 |
| | Two | 0.12366 | 0.00480 | 11.0829 | 0.11083 | 0.03916 | 0.99988 | 0.99884 | 0.99970 |
| | Three | 0.09206 | 0.00357 | 7.35797 | 0.07358 | 0.03769 | 0.99936 | 0.99936 | 0.99984 |
| LSTM | One | 1.84168 | 0.07147 | 179.784 | 1.79784 | 0.20189 | 0.99357 | 0.74370 | 0.93505 |

## Conclusion

This study demonstrated the superior predictive performance of the SVR model over others for one, two, and three-days ahead forecasts of average temperatures in Barishal. Due to poor performance of LSTM, the results for the other two stations will employ the other four ML algorithms across all forecast horizons. The study will be continued for the next year to provide findings for the other two stations.

## Reference

Paniagua-Tineo, A. & Salcedo-Sanz, Sancho & Casanova, Carlos & Ortiz-García, Emilio & Cony, Marco & Hernández-Martín, E. (2011). Prediction of daily maximum temperature using a support vector regression algorithm. Renewable Energy. 36. 3054-3060. 10.1016/j.renene.2011.03.030.

Shrivastava, V. K., Shrivastava, A., Sharma, N., Mohanty, S. N., & Pattanaik, C. R. (2023). Deep learning model for temperature prediction: A case study in New Delhi. Journal of Forecasting, 42(6), 1445–1460. https://doi.org/10.1002/for.2966.

# EFFECT OF IRRIGATION ON YIELD AND WATER PRODUCTIVITY OF FOXTAIL MILLET

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


## Abstract

This study aimed to observe the effect of irrigation at different growth stages and to evaluate the performance of irrigation on yield and water productivity of foxtail millet. The research was conducted at the research field of IWM Division, BARI, Gazipur during the 2023-24 growing season. Six irrigation treatment at different growth stages were considered with three replications. It is revealed from the study that one irrigation at vegetative stage ($T_1$) resulted in the best figures for both growth, yield and water productivity while no irrigation decreased these yield and higher irrigation showed lowest water productivity. Though maximum irrigation improves both growth and yield attributes but when water saving is the most priority, one irrigation at vegetative stage is suggested for foxtail millet cultivation as it produced the highest water productivity.


## 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 production 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, during the rabi season of 2023-2024. 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 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. Harvest index and water productivity were also calculated. The data were analyzed statistically using R software.

## Results and Discussion

The impact of various irrigation treatments at different growth stages of BARI Kaon-4 on the growth and yield characteristics is summarized in Table 1. These parameters encompassed factors such as

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plant height, spike length, grain and straw yield, Harvest Index and 1000 grain weight. From Table 1 plant height, spike length, 1000 grain weight which are a critical indicator of crop growth demonstrated no significant distinctions between the different treatments at a significance level of 0.05 throughout the crop growth cycle. The $T_5$ treatment resulted in the highest average plant height 174 cm, while the shortest plant height 148 cm was observed with $T_0$ treatment. In contrast, grain yield, straw yield and harvest index displayed notable variations among different irrigation treatments. Table 2 demonstrates that different irrigation approaches had a noteworthy influence on grain production. From the experiment $T_1$ produced the most substantial grain yield 3.99 t/ha, whereas, $T_0$ resulted in the lowest output 2.53 t/ha, while $T_2$, $T_3$, $T_4$, $T_5$ exhibited almost similar yield. Moreover, the findings indicated that different treatments had a noteworthy impact on water productivity, as outlined in Table 2. In terms of water productivity $T_1$ showed the highest water productivity at 2.39 $kgm^{-3}$ while $T_5$ showed the lowest water productivity at 1.26 $kgm^{-3}$.

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

| Treat-ment | Plant Height (cm) | Spike length (cm) | Grain yield (t/ha) | Straw yield (t/ha) | Biological Yield (t/ha) | Harvest Index (%) | 1000 Grain weight (gm) |
|---|---|---|---|---|---|---|---|
| $T_0$ | 148.67a | 21.33b | 2.53c | 6.8a | 9.33b | 27.45c | 4.80b |
| $T_1$ | 165ab | 23.33ab | 3.99a | 7.23ab | 11.22a | 35.63a | 4.99ab |
| $T_2$ | 173.23a | 23.97ab | 3.58b | 8.58a | 12.16a | 29.46bc | 5.57a |
| $T_3$ | 163.43ab | 24.76a | 3.62b | 6.75b | 10.37ab | 35.01ab | 5.26ab |
| $T_4$ | 167.43ab | 23.67ab | 3.75b | 7.1b | 10.85ab | 34.66ab | 5.27ab |
| $T_5$ | 174a | 24.76a | 3.78ab | 8.08ab | 11.87a | 31.94abc | 5.00ab |
| **Mean** | **165.31** | **23.64** | **3.54** | **7.42** | **10.97** | **32.26** | **5.15** |
| **CV(%)** | **6.624** | **6.96** | **3.47** | **10.15** | **8.54** | **9.97** | **7.33** |
| **Significance** | **NS** | **NS** | ***** | **NS** | ***** | **NS** | **NS** |

Table 2. Effect of different irrigation treatment on water productivity of Foxtail Millet

| Treatment | Total Irrigation (cm) | Total Effective rainfall (cm) | Soil water contribution (cm) | Total water use (cm) | Yield (t/ha) | Water productivity (kg/m3) |
|---|---|---|---|---|---|---|
| $T_0$ | 0 | 6.675 | 6.8 | 13.475 | 2.53c | 1.88b |
| $T_1$ | 4.05 | 6.675 | 5.95 | 16.675 | 3.99a | 2.39a |
| $T_2$ | 9.9 | 6.675 | 5.4 | 21.975 | 3.58b | 1.63c |
| $T_3$ | 13.5 | 6.675 | 4.9 | 25.075 | 3.62b | 1.44d |
| $T_4$ | 15.3 | 6.675 | 4.65 | 26.625 | 3.75b | 1.40d |
| $T_5$ | 19.35 | 6.675 | 3.8 | 29.825 | 3.78ab | 1.26e |
| **Mean** | **-** | **-** | **-** | **-** | **3.54** | **1.67** |
| **CV(%)** | **-** | **-** | **-** | **-** | **3.47** | **4.50** |
| **Significance** | **-** | **-** | **-** | **-** | ***** | ***** |

## Conclusion

This study found that different irrigation treatments significantly impacted on foxtail millet yield and water productivity. $T_1$ yielded the best results, while $T_2$, $T_3$, $T_4$ treatments also showed promising outcomes. However, the actual effect of irrigation at different growth stages could not be determined due to shallow to medium rainfall occurred during the growing period. Further research is needed to validate and expand upon these findings for foxtail millet cultivation.

## Reference

Singh, R.K., & Prasad, M. (2020). Foxtail Millet: A Climate-Resilient Crop Species with Potential to Ensure Food and Agriculture Security Amidst Global Climate Change. International Journal of Plant and Environment 6(3): 165-169.

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

T. H. MUNMUN[1], C. R. PAUL[2], M. P. HAQUE[3], D. K. ROY[4]

## Abstract

Crop evapotranspiration ($ET_c$) is a crucial element for making informed decisions on real-time and future irrigation scheduling of major crops. Therefore, accurate prediction of $ET_c$ is crucial in the water resources management discipline. This study evaluates the potential of an optimization algorithm-tuned fuzzy tree (FT) approach for the prediction of $ET_c$ during the initial, development, mid-season, and late-season stages of the sunflower crop in Gazipur. A total of 16 FT models were developed, and model ranking was performed utilizing Shannon's Entropy (SE). Evaluation outcomes for predicting $ET_c$ revealed the superiority of the hybrid PSO-PSO, GA-PSO, GA-PSO, and PSO-GA tuned FT models during the initial, development, mid-season, and late-season stages. The study concluded that the hybrid FT models, composed of several standalone FIS objects, is suitable for predicting seasonal $ET_c$ values.

## 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 sunflower crop.

## Materials and Methods

The $ET_c$ values at different growth stages of the sunflower were calculated by multiplying the reference evapotranspiration and crop coefficient values for the respective growth stages. The $ET_0$ values were computed from the weather parameters using the Penman-Monteith equation. The weather parameters and the corresponding $ET_c$ 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 ($ET_c$). 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

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higher values of R, NS, and IOA, as well as lower values of RMSE, MAE, and MAD. However, as it is difficult to 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 PSO-PSO, GA-PSO, GA-GA, and PSO-GA models turned out to be the top-performing models for predicting $ET_c$ during the initial, development, mid-season, and late-season stages. For instance, the best model at the development stage (GA-PSO) produced an entropy weight of 1, which is the highest compared to the other models (0.785, 0.631, 0.609, and 0.513 for the FIS, PSO-GA, PSO-PSO, and GA-GA, respectively) (Table 1). 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, 0.06 mm/d, 0.05 mm/d, and 0.02 mm/d, respectively. Similarly, at the development stage, the best model yielded R = 0.99, NS = 0.98, IOA = 0.99, RMSE = 0.18 mm/d, MAE = 0.14 mm/d, and MAD = 0.01 mm/d. The best model at the mid-season stage provided R = 0.96, NS = 0.92, IOA = 0.98, RMSE = 0.16 mm/d, MAE = 0.13 mm/d, and MAD = 0.06 mm/d. The best model at the late-season stage provided R = 0.98, NS = 0.96, IOA = 0.99, RMSE = 0.13 mm/d, MAE = 0.10 mm/d, and MAD = 0.04 mm/d (Table 2).

## Conclusion

The optimization algorithm-tuned FT models are able to predict sunflower growth stage-wise $ET_c$ values quite accurately. The experiment will be continued for the next year to apply the developed models to determine $ET_c$ values for other crops, such as tomato, potato, onion, and garlic.

Table 1. Performance ranking of the developed FT models based on Shannon's entropy

| Models | Weights and rankings of the models at different growth stages | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | | Development | | Mid-season | | Late-season | |
| | Weight | Ranking | Weight | Ranking | Weight | Ranking | Weight | Ranking |
| GA-GA | 0.633 | 5 | 0.513 | 5 | 0.870 | 5 | 0.789 | 4 |
| GA-PSO | 0.821 | 3 | 1.000 | 1 | 1.000 | 1 | 0.737 | 5 |
| PSO-GA | 0.754 | 4 | 0.631 | 3 | 0.896 | 4 | 0.999 | 1 |
| PSO-PSO | 1.000 | 1 | 0.609 | 4 | 0.941 | 2 | 0.956 | 2 |
| FIS | 0.944 | 2 | 0.785 | 2 | 0.927 | 3 | 0.827 | 3 |

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

| Performance index | Best model at different growth stages | | | |
|---|---|---|---|---|
| | Initial (PSO-PSO) | Development (GA-PSO) | Mid-season (GA-PSO) | Late-season (PSO-GA) |
| R | 0.983 | 0.992 | 0.960 | 0.979 |
| NS | 0.966 | 0.984 | 0.915 | 0.957 |
| IOA | 0.991 | 0.996 | 0.978 | 0.988 |
| RMSE, mm/d | 0.064 | 0.059 | 0.158 | 0.134 |
| MAE, mm/d | 0.050 | 0.036 | 0.131 | 0.103 |
| MAD, mm/d | 0.021 | 0.012 | 0.059 | 0.040 |

## Reference


Roy, D.K., Sarkar, T.K., Biswas, S.K., Datta, B., 2023. Generalized daily reference evapotranspiration models based on a hybrid optimization algorithm tuned fuzzy tree approach. Water Resour. Manag. 37(1), 193-218.

Sidhu, R.K., Kumar, R., Rana, P.S., 2020. Machine learning based crop water demand forecasting using minimum climatological data. Multimed. Tools Appl. 79, 13109–13124.

Shannon, C.E., 1948. A mathematical theory of communication. Bell Syst. Tech. J. 27, 379–423.

# GROWTH AND YIELD RESPONSES 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. Treatments included irrigation at vegetative stage, irrigation at vegetative + flowering stage irrigation, and irrigation at vegetative + grain filling stage, irrigation at flowering + grain filling stage, irrigation at vegetative + flowering + grain filling stage. The study indicated that irrigation during the flowering stage and grain filling stage led to the highest plant height (10.85 cm), spike number/branch (11.33), seed yield (999.56 kg/ha) and biomass (10.85 t/ha), followed by irrigation at vegetative and grain filling stage. Overall results as well as water use of the treatments indicated that irrigation at flowering stage and grain filling stage is the critical stage to irrigation. However, one irrigation at grain fillig stage is preferable for water scares area.

## Introduction

Chia (Salvia hispanica L.) is an annual plant from the Lamiaceae family. In Banglades, it is recently 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 fiber, 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 (Silva et al., 2018). Effective irrigation management is crucial to enhance 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. Fertilization was applied at 60 kg/ha nitrogen, 40 kg/ha phosphorus, 50 kg/ha potassium, and 8 kg/ha sulfur 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. 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

Table 1 presents the results for 2023-24. The higher value of plant height (110.17 cm), spike number/branch (11.33), spike length (16.11 cm), spike weight (2.57 gm), seed yield (999.56 kg/ha) and biomass (10.85 t/ha) were obtained from treatment $T_4$ and $T_3$, which were significantly similar to

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each other. However, there were no significant differences in root length and 1000-seed weight among the treatments. The lowest results for all significant parameters were observed in treatment $T_1$. 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. Among the five treatments, $T_3$ and $T_4$ were the most effective for chia yield. 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).

Treatment $T_1$ used 198.77 mm of water, $T_2$ used 311.11 mm, $T_3$ used 337 mm, and $T_5$ used 348.83 mm during the cropping period. Treatment $T_5$, which received three irrigations, used the most water, while $T_1$, which received one irrigation, used the least water. Both treatments resulted in lower yields compared to $T_3$ and $T_4$, ultimately producing limited water productivity among the treatments with higher water use. Considering treatments with higher water use, $T_3$ and $T_4$ yielded the most and achieved the highest water productivity at 0.24 kg/m³ and 0.29 kg/m³, respectively.

Table 1. Yield and yield contributing characters of chia cultivation at IWMD research field

| Treatments | Plant height (cm) | Root length (cm) | No. of branches | Spike number/br | Spike length (cm) | Spike wt. (g) | 1000-seed wt. (g) | Seed yield (kg/ha) | Biomass (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 89.33 | 11.33 | 14.33 | 8.33 | 10.38 | 1.82 | 1.23 | 684.11 | 7.10 |
| $T_2$ | 99.5 | 11.33 | 13.5 | 8 | 11.72 | 1.99 | 1.19 | 687.23 | 7.63 |
| $T_3$ | 102.5 | 11 | 12.66 | 9.66 | 16.11 | 2.57 | 1.24 | 823.7 | 8.92 |
| $T_4$ | 110.17 | 11.11 | 12.83 | 11.33 | 16 | 2.42 | 1.20 | 999.56 | 10.85 |
| $T_5$ | 99.83 | 11 | 14.33 | 8.33 | 13.27 | 2.17 | 1.22 | 751.11 | 8.76 |
| CV | 4.17 | 3.12 | 3.56 | 2.73 | 3.87 | 3.29 | 4.32 | 5.14 | 4.22 |
| LSD | 9.24 | NS | 0.63 | 0.91 | 3.06 | 0.37 | NS | 63.72 | 2.35 |

Table 2. Irrigation water used and water productivity in different treatments

| Treatment | Number of Irri. applied | Water for plant estab. (mm) | Irri. water applied (mm) | Effective rainfall (mm) | Soil moisture contribution | Total water Used (mm | Water productivity (kg/m3) |
|---|---|---|---|---|---|---|---|
| $T_1$ | 1.00 | 30.00 | 100.84 | 69.60 | -1.67 | 198.77 | 0.34 |
| $T_2$ | 2.00 | 30.00 | 213.49 | 69.60 | -1.98 | 311.11 | 0.22 |
| $T_3$ | 2.00 | 30.00 | 239.66 | 69.60 | -2.26 | 337.00 | 0.24 |
| $T_4$ | 2.00 | 30.00 | 243.48 | 69.60 | -2.25 | 348.83 | 0.29 |
| $T_5$ | 3.00 | 30.00 | 285.70 | 69.60 | -2.89 | 382.41 | 0.20 |

## Conclusion

The findings indicate that irrigation during the flowering and grain filling stages is critical for chia cultivation, leading to improved growth and yield. However, in water scarce areas, the best time for irrigation is during the grain-filling stage.

## Reference

Diez, J., Orellana, F., Searles, P. and Acreche, M.M., 2023. Supplemental irrigation during the critical period for yield ensures higher radiation capture and use efficiency, water use efficiency, and grain yield in chia.

Muriithi, M.N., Masinde, P. and Mwenda, C.M., 2022. Influence of varying soil moisture on growth and yield of Chia (Salvia hispanica l.) in Meru County, Kenya. African Journal of Science, Technology and Social Sciences, 1(2), pp.26-35.

Silva, H., Arriagada, C., Campos-Saez, S., Baginsky, C., Castellaro-Galdames, G. and Morales-Salinas, L., 2018. Effect of sowing date and water availability on growth of plants of chia (Salvia hispanica L) established in Chile. Plos one, 13(9), p.e0203116.

# EFFECT OF IRRIGATION INTERVAL AND MULCHING ON GROWTH, FLOWERING AND CORM PRODUCTION OF GLADIOLUS IN WINTER SEASON

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**Abstract**

This research aimed to evaluate the influence of different irrigation intervals and mulching on the growth and yield of gladiolus (BARI Gladiolus-4). The treatments comprised different combinations of irrigation intervals (5, 10, 15, and 20 days, along with farmers practice) with and without mulching practices. The study found that the 10-days irrigation interval with mulching resulted in the highest plant height, spike length, and floret count. However, for corm production, the best results were obtained with a 15-days irrigation interval and no mulching. More frequent irrigation (every five days) led to excessive water use and reduced yield, while longer intervals (15 and 20 days) resulted in lower yields despite lower water consumption. Farmers' practice showed comparable results to the 15-days irrigation interval with mulching treatment in terms of spike yield, but its water usage resembled the more frequent irrigation approach.

## Introduction

Gladiolus (Gladiolus spp.) is a popular ornamental flower known for its vibrant colors and impressive spikes of blooms. It holds significant economic importance in the global floriculture industry, as well as being a favored choice for floral displays, decorations, and cut flower arrangements. To ensure consistent and robust production of Gladiolus during the winter season, factors such as irrigation management and mulching techniques play crucial roles in influencing plant growth, flowering, and corm production. This research aims to determine the best irrigation schedule and the impact of mulching on Gladiolus performance during the winter season. The results of this research will be highly beneficial to farmers who are interested in improving their gladiolus irrigation practices.

## Materials and Methods

Designed treatments for the experiment: $T_1$ = Irrigation up to FC at 5-days interval, $T_2$ = Irrigation with mulching up to FC at 5-days interval, $T_3$ = Irrigation up to FC at 10-days interval, $T_4$ = Irrigation with mulching up to FC at 10-days interval, $T_5$ = Irrigation up to FC at 15-days interval, $T_6$ = Irrigation with mulching up to FC at 15-days interval, $T_7$ = Irrigation up to FC at 20-days interval, $T_8$ = Irrigation with mulching up to FC at 20-days interval, $T_9$= Farmers practice (whenever top soil dried up), $T_{10}$= Farmers practice with mulching. The method of irrigation used was flood irrigation, and paddy straw was utilized as the mulching material. Recommended dose of fertilizers were applied @ 300 kg N, 375 kg P, 300 kg K, 30 kg S, 8 kg Zn, 12 kg B per hectare and cow-dung 1t/ha. During land preparation, full doses of P, K, S, Zn, B and cow-dung were properly mixed with the soil. Half of the nitrogen was applied at 25 days after planting and the rest half of the nitrogen was applied at flower initiation period. Corms were sown on 02 December, 2022 and 27 December, 2023 at a spacing of 15 cm plant to plant and 25 cm line to line. Flowers were harvested from 24 February to 05 March, 2023 and 06 March to 16 March, 2024 and corms and cormels were harvested from 03 June to 05 June, 2023 for both the years.

## Results and Discussion

The TDII treatments resulted in significantly improved growth, including plant height (64.33 cm), spike length (46.69 cm), rachis length (36.60 cm), number of florets (11.00), and spike weight (68.40 gm). This growth can be attributed to sufficient soil moisture achieved through 10-day interval irrigation. Adequate soil moisture and favorable environmental factors enhance gladiolus plants' commercial quality, increasing flower quantity, size, and stem length (Pereira et al., 2016). Excess or deficit moisture, on the other hand, can lead to lower plant growth (Yadav et al, 2020 and Mazzini-Guedes et al, 2017). Mulching, in particular, contributed to better results in all parameters compared

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to the no mulch as it helps preserve soil moisture, control weeds and pests, regulate soil conditions, and promote nutrient recycling and organic matter accumulation (Patra et al, 2022). Farmers practice was significantly comparable with treatment FTDII. However, treatment FTDII yielded the highest number of corms (4.16), corm weight (84.57 t/ha), corm diameter (60.44 mm), number of cormels (72.11), and cormel weight (19.76 g). Mulching treatment did not benefit corm production. Watering the plants every 10 days with 343.07 mm of water for spike and 711.20 mm for corm resulted in better yields. Mulching also improved yield with reduced water usage (302.57 mm for spike and 645.23 mm for corm). The farmer's practice yielded similarly to the FTDII treatment with or without mulching for spike yield, but their water utilization matched the FDII treatment.

Table 1. Effect of irrigation interval and mulching on vegetative and flowering charecteristics of gladiolus during 2022-23 and 2023-24

| Treat-ments | Plant peight (cm) | Spike length (cm) | Rachis length (cm) | No of florets | Spike wt. (gm) | No. of corm | Wt. of corm (gm) | Dia of corm mm | No. of cormel / plant | Wt. of cormel /plant, g |
|---|---|---|---|---|---|---|---|---|---|---|
| FDII | 62.06 | 40.63 | 29.56 | 10.67 | 52.34 | 3.43 | 71.65 | 58.61 | 49.71 | 14.44 |
| TDII | 64.33 | 46.69 | 36.6 | 11 | 68.4 | 3.85 | 75.61 | 59.5 | 57.23 | 14.86 |
| FTDII | 61.4 | 44.46 | 33.53 | 10.26 | 64.13 | 4.16 | 84.57 | 60.44 | 72.11 | 19.76 |
| TWDII | 57.47 | 39.04 | 28.27 | 8.34 | 57.34 | 1.92 | 67.65 | 54.1 | 42.9 | 11.13 |
| FP | 60.41 | 42.39 | 32.3 | 10.66 | 60.26 | 3.01 | 75.72 | 58.24 | 61.37 | 15.18 |
| CV | 2.87 | 1.64 | 2.3 | 3.15 | 3.82 | 17.96 | 9.24 | 8.76 | 13.67 | 14.49 |
| LSD | 1.31** | 1.07** | 1.14** | 0.42** | 3.15** | 0.43* | 7.65* | 3.89 | 8.10** | 3.54** |
| NM | 60.08 | 40.86 | 29.85 | 9.98 | 54.79 | 2.71 | 76.05 | 58.39 | 57.82 | 14.67 |
| PSM | 62.38 | 44.11 | 34.24 | 11.78 | 66.18 | 3.6 | 74.02 | 57.95 | 55.5 | 15.46 |
| CV | 2.23 | 3.16 | 4.01 | 4.44 | 4.74 | 20.2 | 8.51 | 9.03 | 11.61 | 15.89 |
| LSD | 1.53** | 0.57** | 0.65** | 0.34** | 2.11** | 0.42 | 4.55 | 4.21 | 3.94 | 1.88** |

*FDII= 5 days irrigation interval, TDII= 10 days irrigation interval, FTDII= 15 days irrigation interval, TWDII= 20 days irrigation interval, FP= farmers' practice, PSM= paddy straw mulch and NM= no mulch

## Conclusion

The research findings indicate that irrigation at 10-days intervals with mulching can be a promising approach for gladiolus cultivation, providing significant improvements in growth and yield while optimizing water usage.

## References


Mazzini-Guedes, R.B., Guedes Filho, O., Bonfim-Silva, E.M., Couto, J.C.C., Pereira, M.T.J. and da Silva, T.J.A., 2017. Management of corm size and soil water content for gladiolus flower production. Ornamental Horticulture, 23(2), pp.152-159.

Patra, S.K., Poddar, R., Pramanik, S., Gaber, A. and Hossain, A., 2022. Crop and water productivity and profitability of broccoli (Brassica oleracea L. var. italica) under gravity drip irrigation with mulching condition in a humid sub-tropical climate. Plos one, 17(3), p.e0265439.

Yadav, U., Agrawal, N., Katre, P., Tamrakar, S.K. and Tripathi, M.P., 2020. Effect of irrigation and fertigation on gladiolus crop water requirement, yield and water use efficiency in Chhattisgarh plain. International Journal of Current Microbiology and Applied Sciences, 9(6), pp.2913-23.

Pereira, M.T., da Silva, T.J. and Bonfim-Silva, E.M., 2016. Soil water content and wood ash fertilization on the cultivation of gladiolus. Revista Brasileira de Engenharia Agrícola e Ambiental, 20, pp.350-356.

# DESIGN AND DEVELOPMENT OF A LOW-COST SPRINKLER SYSTEM

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## 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 $ft^2$) 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. This high uniformity and efficient water distribution 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 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. Low-cost sprinklers distribute water uniformly across agricultural fields; ensuring crops receive the necessary moisture for growth while minimizing water wastage. Unlike traditional flood irrigation, which can lead to uneven water distribution and increased evaporation, sprinklers provide precise water application, particularly beneficial in water-limited regions where conservation is critical. 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 Saeed et al. (2022) 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 connecting with the domestic water supply line (gauge pressure: 5~6 psi). The distribution and uniformity of the system

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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 $ft^2$. 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.


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

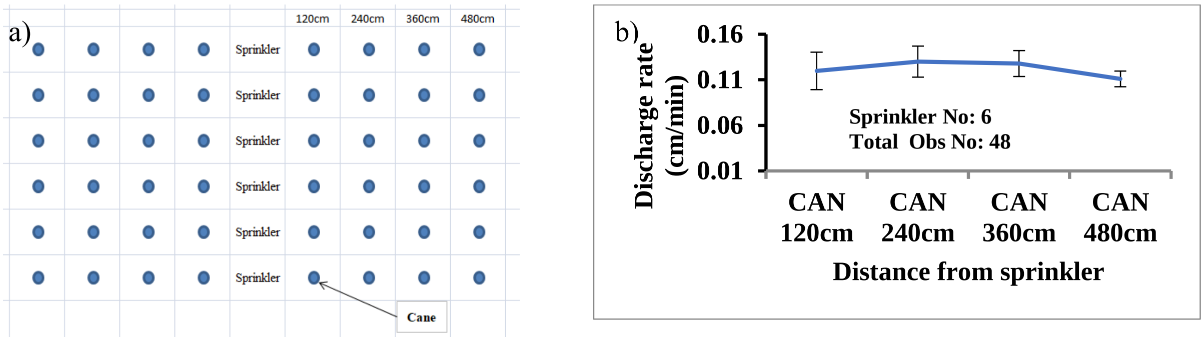


Figure 2. a) Arrangement of catch cans (48 nos) b) Discharge rate (cm/hr) vs distance from sprinkler

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.

## Conclusion

The low-cost sprinkler system 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. The adoption of such systems can significantly contribute to sustainable agricultural practices, water conservation, and improved livelihoods for farmers in water-scarce regions. The study should be continued in the next year.

## References

Saeed, Vakili, Rad., Lei, Gan., Jun, Ge, Dai., Shuai, Zhang., Liangliang, Huang., Linyan, Pan., Mohd, Raihan, Taha. (2022). Improved sprinkler irrigation layouts for smallholders. International Journal of Agricultural and Biological Engineering, doi: 10.25165/j.ijabe.20221502.6363

# IDENTIFICATION OF SURFACE IRRIGATION POTENTIAL ZONE IN BANGLADESH USING GIS TECHNIQUE

M. P. HAQUE[1], D. K. ROY[2] & S. K. BISWAS[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 study should be carried out in the next year (2024-25) to detect the surface water potential areas.


## Introduction

Bangladesh, with its predominantly agrarian economy, faces significant challenges in water management due to its geographic location and climatic conditions. Effective irrigation is crucial for enhancing agricultural productivity and ensuring food security in the country. Surface irrigation, the most common irrigation method, depends on the identification of suitable areas to optimize water use and increase crop yields. Geographic Information Systems (GIS) provide a powerful tool for analyzing spatial data to identify potential zones for surface irrigation. Surface irrigation systems are simple, low-cost methods widely used in developing countries, including Bangladesh. These systems rely on gravity flow to distribute water across agricultural fields, making the topography and soil characteristics critical factors in their effectiveness. Identifying suitable areas for surface irrigation involves analyzing various parameters such as land slope; soil type, land use, and proximity to water sources. GIS techniques offer significant advantages in managing and analyzing spatial data. By integrating multiple layers of information, GIS allows for the comprehensive assessment of potential irrigation zones. Previous studies have successfully utilized GIS for irrigation planning in various regions, demonstrating its efficacy in enhancing irrigation efficiency and sustainability (Birhanu et al., 2019). In Bangladesh, the application of GIS in identifying potential surface irrigation zones is still in its nascent stages. This research aims to bridge this gap by employing GIS techniques to identify suitable areas for surface irrigation across different regions of Bangladesh. By doing so, it seeks to contribute to the optimal utilization of water resources, support agricultural productivity, and promote sustainable water management practices. This study will focus on several key objectives: (1) to analyze the topographic and soil characteristics relevant to surface irrigation, (2) to integrate various spatial data layers using GIS, and (3) to delineate potential surface irrigation zones.

## Materials and Methods

This study was conducted in halda river basin, located in south-eastern region during 2023-24. 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

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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.

## 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 2). The Halda Basin has only a single rainfall gauge (Sitakundu, Chattogram), which may significantly limit our study. 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.

## 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.

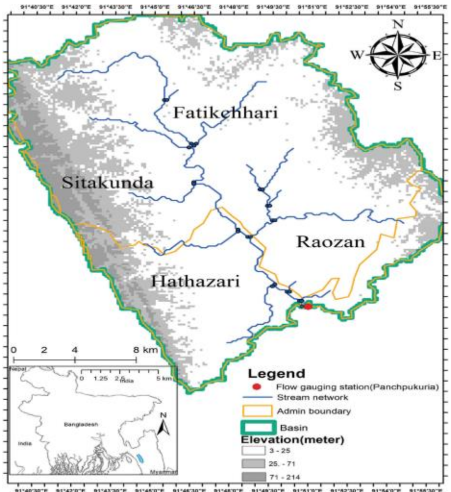


Figure 1. Catchment of Halda river basin.

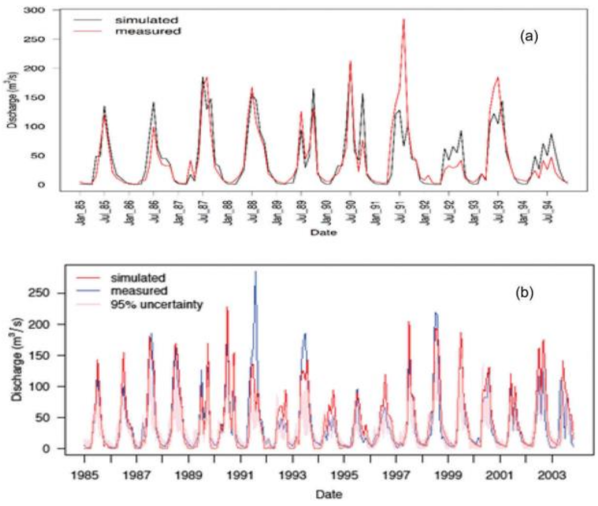


Figure 2. a) Monthly simulated and measured values b) Yearly simulated and measured values

## Reference

Birhanu, A., Murlidhar Pingale, S., Soundharajan, B.-S., and Singh, P. (2019) GIS-Based Surface Irrigation Potential Assessment for Ethiopian River Basin. *Irrig. and Drain.*, 68: 607–616. https://doi.org/10.1002/ird.2346.

# FEASIBILITY STUDY OF THE IOT BASED PRECISION AGRICULTURE FOR SUSTAINABLE CROP PRODUCTION IN BANGLADESH

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## Abstract

Sensor-based precision agriculture (PA) is not in general practice and its potential is yet to be adequately investigated. Therefore, this study has been taken to test the feasibility of the Internet of Things (IoT) based PA for predicting water and fertilizer. The field experiment was set up at BARI, Gazipur. Initial machine learning models-irrigation and fertilizer requirement and pest attack have been developed. A Mobile app has been developed for the end user. IoT-based PA practice ($T_1$) was evaluated by comparing with BARI recommended practices ($T_2$), drip fertigation ($T_3$) and traditional practice ($T_4$). The results indicated that the nutrient and water use efficiency was greater by $T_1$ than $T_4$. BCR of $T_1$ was lower than $T_4$ which indicates that $T_1$ system is not profitable in the first crop cycle.

## Introduction

Crop productivity often fluctuates due to the imbalanced use of water, fertilizer and pesticide in production practices. The common agricultural process is based on traditional surface broadcasting fertilizer, flooding irrigation and frequent pesticide application that uses excess fertilizer, water, pesticide and subsequently, decreases yield and overall efficiency and productivity. Considering the prevailing circumstances, this study aims to test the feasibility of Internet of Things (IoT) based precision agriculture for predicting water, fertilizer and pesticide use at field conditions. Therefore, the specific objectives were to (i) develop and test the IoT based machine learning PA system for improving crop productivity, (ii) monitor and evaluate the water and fertilizer use efficiency using IoT based precision agriculture, (iii) analysis the economic profitability and feasibility of IoT based PA for crop production.

## Materials and Methods

The field experiment was set up a randomized complete block design with four treatments at the research field of BARI, Gazipur. The performance of IoT-based PA practice ($T_1$) was evaluated by comparing with BARI recommended practices for eggplant production ($T_2$), drip fertigation ($T_3$) and traditional farmers practice ($T_4$). Focus group discussion (FGD) were done for setting the treatment $T_4$. The crop cycles of the field experiment were carried out at the research field of BARI in Gazipur during the Rabi season of 2021-22, 2022-23, 2023-24 and summer season of 2022 and 2023. The IoT based physical and networking system didn't set up during the first three crop cycles. Last two crop cycles, IoT systems including sensors and other necessary equipment were fully installed and successfully run the operation in the research field of BARI during 2023-2024. The data on the phenology of the eggplant, soil moisture content, irrigation water, fertilizers and pesticides, fruits yield and yield contributing characters of eggplant were taken. Nutrient (N,K) use efficiency, water productivity and benefit cost ratio (BCR) were also estimated for economic profitability and feasibility of the IoT based automated eggplant production. Database were created to from the experimental field to test the data in the IoT based machine learning program for precision eggplant production system. Some photographic images are shown in Fig. 1-3.

## Results and Discussions

The results indicated that the effect of treatment affected the fruits yield, plant height, water productivity, nutrient use efficiency and BCR among the treatments. IoT based automated using

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mobile app ($T_1$) and BARI recommended drip-fertigation system ($T_3$) produced nearly similar marketable yield and greater than traditional practices although applied less water, fertilizer (urea and potash) and pesticides than farmers' practices. The technique of $T_1$ and $T_3$ increased fruits yield, saved total water use around 62% and substantially improved water productivity without reduction in yield. Nutrient use efficiency ($NUE_{N, K}$) was found greater in $T_1$ and $T_3$ than other practices of $T_2$ and $T_4$. $T_1$ saved around 50% urea and 53% potassium and $T_3$ saved around 48% urea and 56% potassium than $T_4$ (farmers practices), respectively. Based on total cost, BCR of $T_1$ was lower than $T_4$ which indicates that this system is not economically profitable although this system saves labor, fertilizers, pesticides and water. Based on variable cost, BCR was greater in $T_1$ and $T_3$ than traditional practices due to less cost of labor, irrigation, fertilizer and pesticide. The results of the first crop cycle indicate that $T_1$ system is not profitable. After 2 or 3 crop cycles, $T_1$ system is profitable. Besides, IoT based real time daily weather parameters and field data like as soil moisture content can be monitored and recorded from anywhere and remotely controlled (Jawad et al., 2027).

## Conclusion

Precision agriculture is a concept that may use the IoT for crop production. IoT based PA is not economically profitable although this system saves labor, fertilizers, pesticides and water. After two/three crop cycles, it is feasible. IoT system has a good prospect and might be an alternative option of automation for precision farming.

## Reference


Jawad, H. M., Nordin, R., Gharghan, S. K., Jawad, A. M., and Ismail, M., 2017. Energy-efficient wireless sensor networks for precision agriculture: A review. Sensors, 17(8), 1781.


**Fig. 1**. Photographic images of different activities in *Rabi* season of 2021-2022.

**Fig. 2**. Photographic images of monitoring team and honorable executive director and director of KGF with crop and water specialist visited the experimental field in 2023.

**Fig. 3.** Hon. Secretary (MoA), Executive Chairman (BARC), DG (DAE), DG (BARI), JS (MoA), ED (KGF), Directors (BARI, BARC, KGF), and other resource personnel's visited the IoT based eggplant production research field at IWM Division, BARI on 2024-02-08.

# DEVELOPMENT AND EVALUATION OF IOT BASED AUTOMATIC SMART SHED FOR SUMMER TOMATO PRODUCTION

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## Abstract

The Internet of Things (IoT) enabled sensors based summer tomato production is not common practice in Bangladesh. The most common practice is the traditional shed and flooding irrigation, which reduces crop productivity. Therefore, this study was attempted to develop a prototype of the IoT based automated smart shed and irrigation. The prototype of the smart shed was developed based on rain, temperature, and light sensor and automated irrigation($T_1$) and compared with the manually operated shed without sensor($T_2$), traditional shed($T_3$) and open field without shed ($T_4$). $T_1$ system was tested and deployed in the field to monitor the data and operate the shed ON-OFF. The fruit yield of summer tomato was significantly affected by the treatments. $T_1$ produced greater tomato yield than others. Sensor based automated smart shed ON-OFF needs further research and validation.

## Introduction

Summer tomato is one of the most important vegetable and growing interest on summer tomato are increasing in different regions of Bangladesh (Sarker et al., 2016). During summer season in Bangladesh, excess rainfall is a great problem and affects yields. The common cultivation practice is the use of traditional shed or open field which is practiced extensively in the region, leading to excessive uses of rain, temperature and consequently resulting in decreased aeration, and reduced system productivity. Among various technological options, the internet of things (IoT) based smart agriculture is one of the most updated technologies (Omar et al., 2029). Considering these, this research has been taken to develop a prototype of the IoT based automatic smart shed for auto-ON-OFF based on excess rain, temperature and light intensity for summer tomato production.

## Materials and Methods

The study was conducted at IWM Division research lab and field of BARI in Gazipur (Latitude: N23$^0$59$^/$15.06$^{//}$ and Longitude: E90$^0$24$^/$53.79$^{//}$). Soils were sandy loam. IoT based smart shed and irrigation system was developed through an integrated research approach that included lab and field experiment using IoT enabled sensors and mobile app. There were three parts: (i) hardware (Fig.1.a-e), (ii) software, and (iii) field experiment. First part was developed the prototype of an IoT based automated smart shed and irrigation. The system comprised an ESP32, solenoid valve, soil moisture, rain, light, temperature, air humidity, and water flow sensor. The microcontroller mapped sensor data. The mobile app using Blynk was used for the operation of real-time monitoring, operating the switch automatically ON-OFF of the smart shed and irrigation pump. User remotely saw the sensor values. When the sensor value crosses the threshold, the user is notified through the app. User takes actions from the app by pressing the switch. If the rain sensor becomes wet due to rain, it sends a notification to turn on the shed system. IoT enabled smart shed ($T_1$) was evaluated through field experiment and compared with manually operated shed ($T_2$), traditional fixed polythene shed ($T_3$), and open field without shed ($T_4$) for tomato production during summer season. The data was statistically analyzed to test the effects of shed system.

## Results and Discussion

Mobile app was used and enhanced the efficiency through real-time data monitoring and remotely controlled the shed ON-OFF. Data monitoring interface allowed manual and automatic shed and irrigation system based on sensor values. Two proximity sensors were used to sense the position of the shed system condition and scenario. Based on the shed's position, the motors were turned on or off and rotated clockwise or anti-clockwise. The proximity-2 sensor is positioned where the clothes

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are rolled with a roller. Proximity-1 is set on the opposite side. When the shed is closed, the proximity-2 value is one because the cloth is close to proximity-2. When any sensor value exceeded the reference limit (Table 1), the system checked the value to decide whether to turn on or keep off the shed. Table 1 depicts the automated shed and irrigation operation. The system checks the rain (=1), high-temperature (> 35°), or high-light (> 90k lux) conditions.
Treatments influenced the yield tomato are shown in Table 2. The treatments significantly affected the marketable fruits yield of tomato among the treatments. Marketable fruits yield in treatment $T_1$ was greater than other treatment. WP varied among the treatments (Table 2). TWU was almost similar but slightly differed between the treatments $T_1$ and $T_2$. $T_4$ system gave the lowest tomato yield and water productivity compared to other treatments.

## Conclusion

IoT-enabled sensor-based automated smart shed and irrigation was developed to automate ON-OFF the shed to prevent high rainfall, over temperature and automated irrigation for production. IoT based smart shed system may have option for producing off-season crops and use automated irrigation. Sensor-based automated smart shed needs further modification and validation.

Table 1. Cases of automated smart shed and irrigation operating system

| Input | | | | Output | |
|---|---|---|---|---|---|
| Case 1 (Moisture) | Case2 (Rain) | Case 3 (Temp.) | Case 4 (Light) | Shed System | Irrigation |
| Moisture < 15% | Rain = 0 | Temperature < 35° | Light < 90000 lux | Not applied | Applied |
| Moisture < 15% | Rain = 0 | Temperature > 35° | Light > 90000 lux | Applied | Applied |
| Moisture < 15% | Rain = 1 | Not considered | Not considered | Not applied | Not applied |
| Moisture > 15% | Rain = 1 | Not considered | Not considered | Applied | Not applied |
| Moisture > 15% | Rain = 0 | Temperature > 35° | Light < 90000 lux | Applied | Not applied |
| Moisture > 15% | Rain = 0 | Temperature < 35° | Light > 90000 lux | Applied | Not applied |
| Manual Switch ON | | | | Applied | Applied |

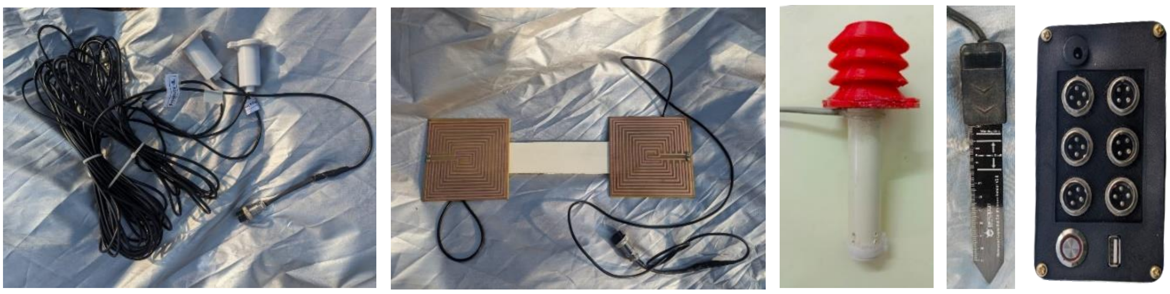
Table 2. Yield and yield contributing characteristics of summer tomato

| Treatment | Fruit length, Cm | Fruit dia, cm | Fruit number/Plant | Single fruit weight, g | Fruit yield, t/ha | TWU, mm | WP, kg/m3 |
|---|---|---|---|---|---|---|---|
| $T_1$ | 4.5 a | 4.8 a | 26.9 b | 74 a | 19.51 a | 190 | 10.3 a |
| $T_2$ | 3.9 b | 4.5 b | 27.3 a | 71 b | 19.09 a | 189 | 10.1 a |
| $T_3$ | 3.8 c | 4.3 c | 26.3 c | 68 c | 17.64 b | 227 | 7.8 b |
| $T_4$ | 3.4 c | 4.2 d | 20.3 d | 59 d | 11.69 c | 219 | 5.3 c |

## References


Omar, M., Samin, O. B., and Ihmed I., 2019. Smartshed: An Automatic Shed System Based on Rain, Temperature, and Light intensity. Proceedings of Academicsera 48th International Conference, Bangkok, Thailand, 5th-6th April, 2019.

Sarker, K.K., Akanda, M.A.R., Biswas, S.K., Roy, D.K., Khatun, A., Goffar, M.A. 2016. Field performance of alternate wetting and drying furrow irrigation on tomato crop growth, yield, water use efficiency, quality, and profitability. Journal of Integrative Agriculture 15(10): 2380–2392.

(a) (b) (c) (d) (e)

Fig.1 a-e. Customized IoT sensors proximity sensor (a), rain sensor (b), temperature-humidity (c), soil moisture sensor (d) and 3D-designed and printed the sensor node (e)

# YIELD AND WATER PRODUCTIVITY INDICES OF GARLIC VARIETIES UNDER SPRINKLER IRRIGATION

S. K. BISWAS[1], K. K. SARKER[2], D. K. ROY[3], M. A. HOSSAIN[4]

## Abstract

A field study was conducted to develop water – yield relationship for two garlic varieties with different irrigation regimes (0.6, 0.8, 1.0, 1.2 and 1.4 ETo) under sprinkler irrigation to quantify crop water productivity functions (CWPF) for optimum use of irrigation water. Marginal water productivity (MWP) and elasticity of water productivity (EWP) were calculated using the relationship between bulb yield and seasonal evapotranspiration (SET). A continuous increasing trend in yield was recorded with the increase in SET up to 1.2 ETo. The critical levels of SET ranged from 180 – 248 mm for BARI Rashun-3 and from 191 – 253 mm for BARI Rashun-5 for obtaining maximum WP and yield, respectively, indicating almost same irrigation practices is needed for cultivation of these two garlic varieties.

## Introduction

Garlic, a key spice, has an enormous importance all over the world for flavoring and seasoning various vegetables and meat dishes. In Bangladesh, it is the second most important bulb crop after onion belonging to family Alliaceae. Although the productivity of garlic is rising, every year the country has to import large quantity of garlic to meet the domestic demand due to an abysmal productivity scenario (6.28 t/ha) compared to the global productivity of 17.08 t/ha (FAOSTAT, 2020). The trail in productivity, among many factors, coupled with poor water and nutrient management. So, there is vast scope for increasing the productivity through innovations in agro-techniques and sustenance of productivity through better water management in the farm. With this view, this study was conducted to find out the comparative performance of two garlic varieties under sprinkler irrigation and to estimate the critical level of ET for obtaining maximum WP and maximum yield.

## Materials and Methods

A field study was carried out with two garlic varieties ($V_1$: BARI Rashun-3 and $V_2$: BARI Rashun-5) under sprinkler irrigation system during the winter season (November–March) of 2023 – 2024. A total of six irrigation treatments under each garlic varieties replicated thrice with split-plot design. The treatments were as follows: Sprinkler irrigation at 60% ETo ($I_1$), 80% ETo ($I_2$), 100% ETo ($I_3$), 120% ETo ($I_4$), and at 140% ETo ($I_5$). Cloves of garlic (cv BARI Rashun-2) were planted at 15 cm × 10 cm spacing on 12 November 2023. During land preparation, recommended dose of fertilizer ($N_{100}$, $P_{54}$, $K_{167}$, $S_{18}$ kg/ha) was properly incorporated with the soil. A light irrigation amounting 20 mm was applied after planting for proper germination and crop establishment. Following the treatments, irrigation was applied at 7- day intervals based on reference evapotranspiration (ETo). Seasonal evapotranspiration (SET) during the entire cropping period was calculated by using the field water balance equation as: $ET = IW + P + - D - R \pm \Delta SWS$, where P is precipitation (mm), IW is irrigation (mm), D is the drainage (mm), R the run-off and ΔSWS is the variation in water content of the soil profile. The bulb yields were recorded at harvested on 18 March 2024. The analysis and interpretation of data were done using the DMRT method of analysis of variance technique.

## Results and Discussion

Inter-cultivar variability of garlic in their functional responses to water deficit and well-watered conditions and its relationship with yield and water productivity was analyzed for two garlic varieties (Table 1 & Fig. 1). For both the varieties, the highest bulb yield (11.08 and 12.82 t/ha) was obtained under 120% ETo water regime and this was insignificant with the yields under the water regime of either 1.0 ETo or 1.4 ETo. In general, medium water regime (0.8-1.2ETo) treatments had higher WP

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than the lower and higher water regime treatments. This was due to the fact that the increase in yield was proportional to SET up to a certain level then onward the increasing rate was declined. In general, wetter water regime treatments had higher and drier treatments had lower SET values. To achieve maximum WP, 180-191 mm of SET would require for V1 and V2, respectively and to maximize yield, SET would need to be 248-253 mm, which is about 24% greater than the water use at maximum WP. Under a limited water supply condition, WP reached a maximum of 4.45 and 5.16 kg/m$^3$ when SET was equal to 180 and 191 mm, respectively for $V_1$ and $V_2$

Table 1. Yield, crop water use (CWU) and water productivity of garlic varieties during 2023 -2024

| Treatment | Yield (t/ha) | | CWU, mm | | Water productivity (kg/m$^3$) | |
|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_1$ | $V_2$ |
| $I_1$= 0.6ETo | 6.71c | 7.49c | 157 | 158 | 4.25 | 4.72 |
| $I_2$= 0.8ETo | 8.37b | 9.76b | 191 | 193 | 4.36 | 5.06 |
| $I_3$= 1.0ETo | 9.92ab | 11.64ab | 220 | 221 | 4.50 | 5.26 |
| $I_4$= 1.2ETo | 11.08a | 12.82a | 249 | 250 | 4.44 | 5.12 |
| $I_5$= 1.4ETo | 10.86ab | 12.74ab | 267 | 269 | 4.03 | 4.73 |

and the corresponding yield was 8.14 and 3.78 t/ha. If the water supply is not limited, then SET would need to be 248-253 mm to obtain maximum yield of 10.3-12.62 t/ha. The range of SET requirement between maximum WP and maximum yield was 180-248 mm for $V_1$ and 191-253 mm for $V_2$.

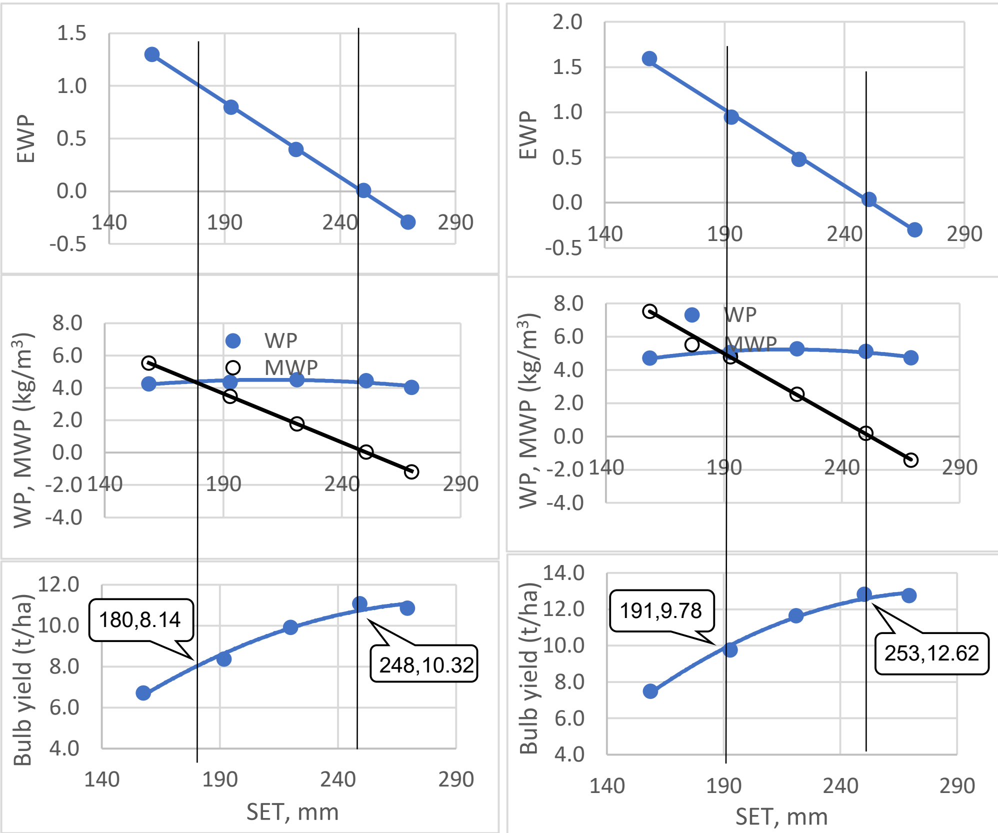


Figure 1. Relationships of yield, WP, MWP, EWP and SET for a quadratic ETPF for sprinkler irrigated garlic (Left: BARI Rashun-3and Right: BARI Rashun-5)

## Conclusion

The critical levels of SET obtained for maximum bulb yield or WP were slightly higher for $V_2$ than that of $V_1$ indicating almost same irrigation practices is needed for cultivation of these two garlic varieties.

## References


FAOSTAT, 2020. On line statistical database of Food and Agricultural Organization of United Nations. http://www.faostat.fao.org.

# OPTIMUM WATER MANAGEMENT OF DWARF SUNFLOWER AT VARIOUS TIME OF SOWING

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

## Abstract

Proper sowing along with appropriate use of irrigation at actual crop growth stages can minimise misuse of costly inputs and can increase water productivity. Dwarf sunflower (BARI Surjamukhi 3) was grown at three sowing dates of 16 Nov, 26 Nov and 18 Dec (Factor A) using four irrigation combinations with full and 50% of full irrigation at 3 crop growth stages (Factor B). 18 Dec 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 concluded that 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 IWM division, BARI, Gazipur during the Rabi season of 2023-24. The experimental design was RCBD 2-factors with three replications; Factor A: Sowing date (16 Nov, 26 Nov and 18 Dec) and Factor B: Irrigation (full irrigation (FI) at vegetative, pre-flowering and flowering [I1], 50% of I1 [I2], FI at vegetative, pre-flowering and grain filling [I3], and 50% of I3 [I4]. Note that third sowing was delayed to 12 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. 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).

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## Results and Discussion

ANOVA results for two factors showed that yield and yield attributes were highly significant for the individual effect of irrigation and sowing date. Their interaction was moderately to highly significant. 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. 2a). Mid-December sowing gave the significantly highest yield and yield attributes and its values gradually decreased for the previous two sowings.

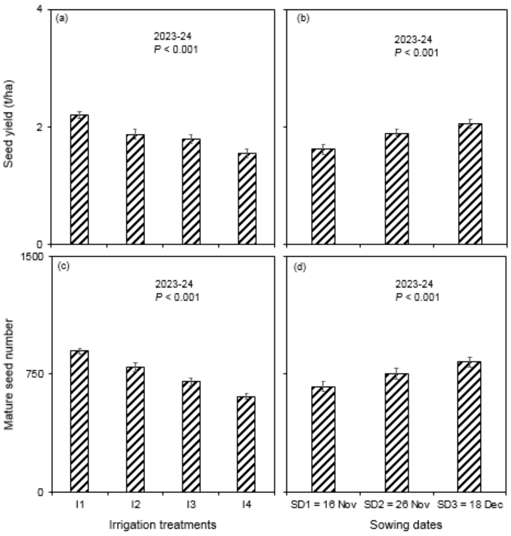


**Fig 1.** Seed yield and mature seed number against irrigation (a, c) and sowing dates (b, d). $SD_1$, $SD_2$ and $SD_3$ denotes 16 November, 26 November and 18 December sowing. Here, $I_1$= full irrigation (FI) at vegetative, pre-flowering and flowering, $I_2$= 50% of $I_1$, $I_3$ = FI at vegetative, pre-flowering and grain filling, and $I_4$ = 50% of $I_3$.

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 due to huge rain. Similarly, $SD_2$ received two irrigations either at PF and F or GF stages. On the other hand, $SD_3$ received three irrigations based on the design. 50%FI at V, PF & F needed comparatively lower amount of irrigation water and gave higher irrigation water productivity (Fig. 2c, 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.

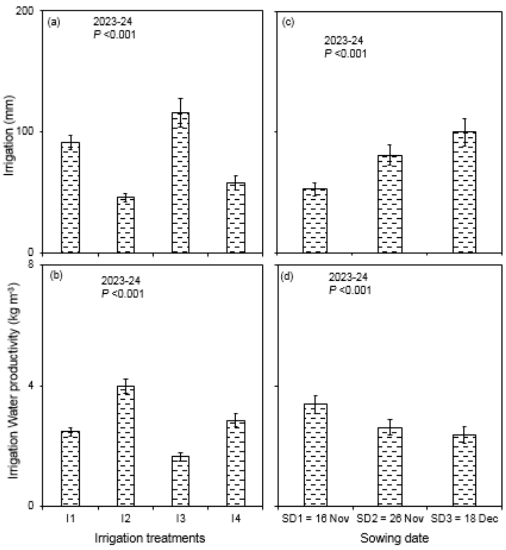


**Fig 2.** Irrigation, and irrigation water productivity against irrigation (a, b) and sowing date (c, d) for 2023-24 cropping season. The significance level with *p* values are shown. $I_1$ and $I_2$ means full irrigation (FI) and 50% of FI at vegetative (V), Pre-flowering (PF), and flowering (F), while $I_3$ and $I_4$ means FI and 50% of FI at V, PF, and grain filling (GF)

## Conclusion

The highest yield of 2.2 t $ha^{-1}$ was recorded for FI at vegetative, pre-flowering and flowering. While 50% of FI at vegetative, pre-flowering and flowering gave 15% lower yield and 62% higher irrigation water productivity than the highest yield treatment by saving 50% of irrigation water. 18 December sowing gave 9 to 26% higher seed yield than the previous sowings. This year 1 trial was mostly influenced by rainfall especially early sowings (16 and 26 November).

## References


BARI Agricultural technology handbook (2020) Oilseed crop: Sunflower. In: Azad AK, Miaruddin M, *Wahab MA*M, Shaque HR, Nag *BL* (ed) Description of BARI developed agricultural technology, 9th edn. Bangladesh Agricultural Research Institute, Gazipur, pp. 114-118.

Mila, A.J., 2021. Increasing the productivity of sunflower through efficient use of non-saline and saline water irrigation in the Ganges Delta (Doctoral dissertation, Murdoch University).

Team, R.C., 2013. R: A language and environment for statistical computing. Vienna, Austria.

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

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

## Abstract

Optimize irrigation use of dwarf sunflower at various time of sowing by focusing on proper crop growth stages can minimize yield reduction and can increase water or irrigation water productivity. 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. We have made a good progress in parametrising APSIM using the field experimental dataset and setting up the APSIM for local environmental conditions (soil, climate etc.), however, the work is not completed yet. We are having some issues with the response of the APSIM-sunflower module to yield, biomass and soil water content. we are in the process of improving the calibration 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 with 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 irrigation 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 at the IWM division field, 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 Central report 2024 (Mila et al. 2024). 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 (not completed).

APSIM-sunflower phenology has 11 stages. Yield data was collected during harvest (See Fig. 2). Biomass data were collected at the pre-flowering and maturity stage. Soil moisture were also collected (not shown).

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## Results and Discussion

Simulated and observed values of phenology, biomass and yield during the crop season are shown in figure 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 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.

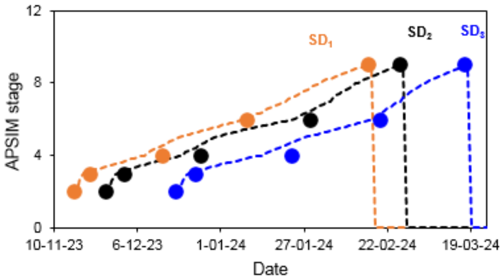


**Fig. 1** APSIM simulated (dotted line) and observed (filled circle) phenology of sunflower for three times of sowing during the crop season in 2024. Here, orange, black and blue colour is used to denote $SD_1$, $SD_2$ and $SD_3$.

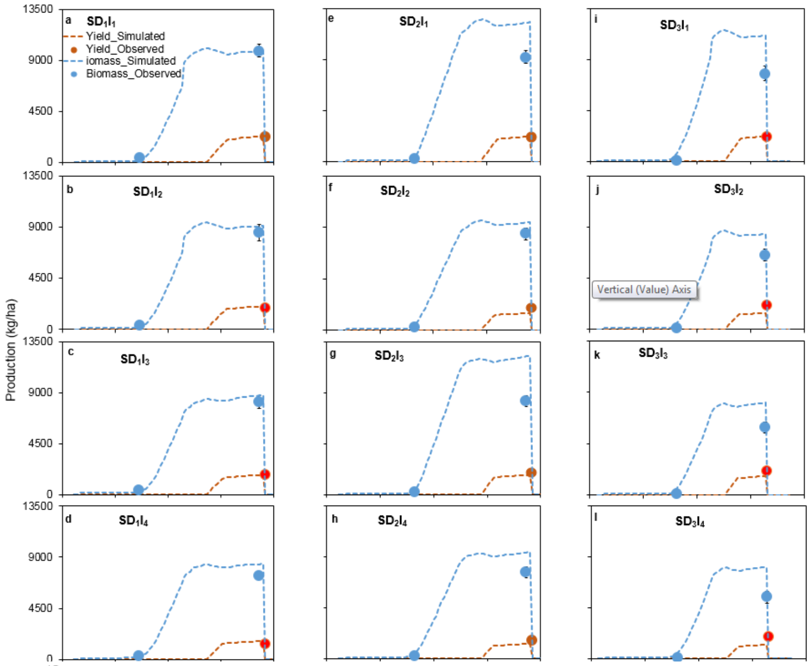


**Fig. 2** Simulated (orange broken line) and observed (orange filled circle) seed yield, and simulated (blue broken line) and observed (blue filled circle) biomass for 2023-24 cropping season.

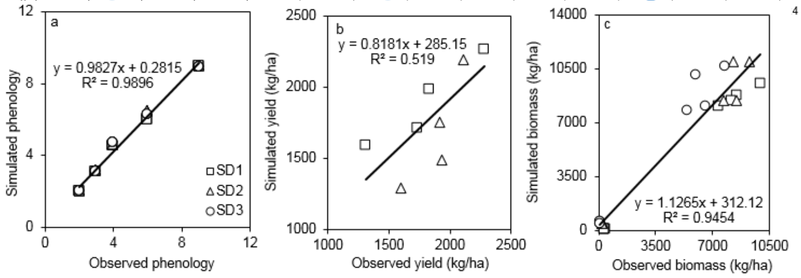


**Fig. 3.** Simulated vs observed phenology, yield and biomass.

## Conclusion

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

## References


Keating et al. 2003. An overview of APSIM, a model designed for farming systems simulation. *European journal of agronomy*, *18*(3-4), pp.267-288.

Gaydon et al. 2017. Evaluation of the APSIM model in cropping systems of Asia. *Field Crops Research*, *204*, pp.52-75.

# DETERMINATION OF OPTIMAL SURFACE DRAINAGE FOR POTATO IN SOUTHERN BANGLADESH

A. J. Mila[1], S. K. Biswas[2], R. W. Bell[3], M. A. Hossain[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. Therefore, surface drainage could be a potential option. This study was conducted at the farmer's field of Dacope upazila in Khulna district during 2022-23 and 2023-24 using potato crop, with three drainage depths (0 cm; no drain, 10, and 20 cm) replicated thrice. 24-hours of standing water was created artificially at the vegetative stage. We found that 20 cm depth of surface drainage gave the significantly highest seed yield than 10 cm drainage treatments. It released comparatively more water in less time than the 10 cm drainage depth. The SEW30 (sum of excess water within 30 cm of PVC pipe after drainage) was higher at no drain and gradually decreased with the increase of drainage depth. Therefore, a 20 cm depth of surface drainage technique can better facilitate the early establishment of the Rabi crop and increase sunflower yield in Southern Bangladesh.


## Introduction

Coastal region of Bangladesh is vulnerable due to the low-lying land, tidal effect, coastal flood, high temperature and high soil and water salinity. However, almost all of the land in this region remains fallow during the dry season (December-June) because of the late harvest of long-duration rice varieties. Late-sown winter crops are then at risk from elevated water and soil salinity, drought, and untimely heavy rainfall (Mila et al., 2021; Paul et al., 2021). This constraint can be partly overcome by early sown winter crops in the existing cropping pattern (CSI4CZ Annual Report 2020). However, early sowing (after monsoon) without surface drainage is also risky because of post-monsoon heavy rainfall on heavy textured clay soil. Therefore, this study was conducted to determine the optimum surface drainage depth through field experimentation.

## Materials and Methods

The field experiment was conducted in farmer's fields at Dacope, Khulna to grow potato during the winter season. The experimental field had a clay to clay loam texture. The experimental design was RCBD three treatments (0 cm; no drain, 10, and 20 cm) with three replications.

The Potato tuber (BARI Alu 72) was sown on 14 December 2022 using the zero tillage method with a spacing of 60 cm × 25 cm. While in 2023, it was sown on 21 December with a spacing of 50 cm × 25 cm. Then, cow dung was applied to cover the tuber, and fertilizer was used at a 115-130% of the BARI recommendation. During sowing, 50% of urea and 100% of other fertilizers were applied both sides of the potato tuber row at a distance of 10 cm. The tuber was successively covered by cow dung, water hyacinth and rice straw. 24-hrs of waterlogging was applied artificially at the vegetative stage. Intercultural operation and irrigation were done as necessary. One to four days after physiological maturity, the potato tuber was harvested on 18 March 23 and 23 March 2024.

During harvest, 10 plants were selected to record yield and yield attributes data of number and weight of total marketable and curl tuber. Finally, data were analysed using statistical software (Team, R.C., 2013).


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## Results and Discussion

Marketable tuber yield and yield attributes were affected due to the effects of drainage depth for both years (Fig. 1). The significant highest tuber yield was recorded for 20 cm depth surface drainage followed by 10 cm drainage depth. The undrain treatment had the lowest seed yield (Fig. 1a). Similar trend was observed for yield attributes of mature seed number (Fig. 1b).

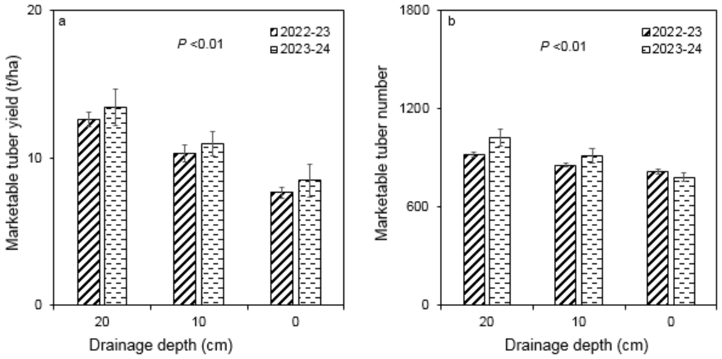
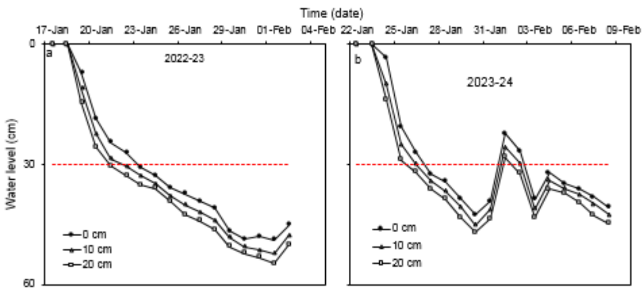



**Fig. 1** Yield and yield attributes due to the effects of drainage depth for 2022-23 and 2023-24 cropping season: a. marketable tuber yield, and b. marketable tuber number. Values plotted are the mean of all replicates with standard error and *P*–values indicated.

In 2022-23, 0 cm drainage depth kept the plot under waterlogged for 3-5 days, while 10 and 20 cm drainage depths were kept around 3 and 2-3 days, respectively (Fig. 2a and 2b). In 2023-24, 10 and 20 cm drainage depths were kept around 2-4 days. The $SEW_{30}$ was higher at no drain and gradually decreased with the increase of drainage depth (Fig. 3).



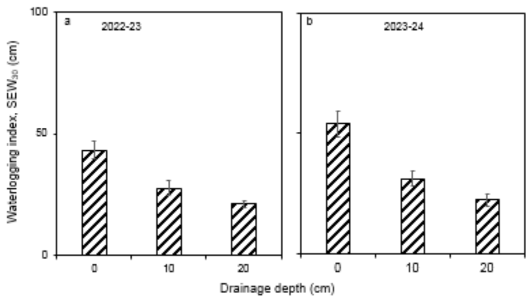




**Fig. 2.** Variation in water level over time after the release of 24-hr drainage water**.**

**Fig. 3.** Waterlogging indexes against individual effects of drainage depth.

## Conclusion

The surface drainage at 20 cm depth gave higher yield under waterlogging events during the vegetative stage than 10 cm drainage depth. Therefore, potato can be grown early using surface drainage at 20 cm depth to alleviate waterlogging and other abiotic stresses for increasing yield and improving farmer's livelihood in the southern Bangladesh.

## References

CSI4CZ Annual Report 2020. Cropping system intensification in the salt-affected coastal zones of Bangladesh and West Bengal, edited by M. Mainuddin. *Australian Centre for International Agricultural Research*.

Paul, P.L.C., Bell, R.W., Barrett-Lennard, E.G., Kabir, E. and Gaydon, D.S., 2021a. Opportunities and risks with early sowing of sunflower in a salt-affected coastal region of the Ganges Delta. *Agronomy for Sustainable Development*, *41*(3), p.39.

Mila, A.J., 2021. Increasing the productivity of sunflower through efficient use of non-saline and saline water irrigation in the Ganges Delta (Doctoral dissertation, Murdoch University).

Team, R.C., 2013. R: A language and environment for statistical computing. Vienna, Austria.

# FEASIBILITY OF SURFACE DRAINAGE FOR WINTER CROP FOR GREATER RESILIENCE OF SMALLHOLDER FARM INCOME AND FOOD SECURITY IN SOUTHERN BANGLADESH

A. J. Mila[1], P. L. C. Paul[2], A. K. Chaki[3], R. W. Bell[4], D. S. Gaydon[5]

## Abstract

Waterlogging at the end of the Kharif 2 season causes early Rabi crop establishment delay and faces plant other abiotic stresses that decrease yield. Therefore, surface drainage before early crop establishment would be a potential option. This study was conducted at the farmer’s field at Dacope, Khulna during 2022-23 and 2023-24 at two to three locations (Factor A) and three drainage depths (0, 15 and 30 cm) with farmer's practice (Factor B) replicated thrice. 30 cm surface drain gave the significantly highest yield for all locations followed by 15 cm drainage depth. It released comparatively more water in less time than the 15 cm drainage depth. The SEW30 (sum of excess water within 30 cm of PVC pipe after drainage) was higher at no drain and gradually decreased with the increase of drainage depth. Farmers of Bangladesh can increase smallholder farm income using this surface drainage technique, consequently increasing food security in Southern Bangladesh.

## Introduction

Late-sown winter crops are at risk from elevated water and soil salinity, drought and late-season heavy rainfall (Mila et al., 2021; Paul et al., 2021a, 2021b). This constraint can be partly overcome by sowing early maturing rice varieties. However, early sowing (after monsoon) without surface drainage is also risky because of post-monsoon heavy rainfall on heavy textured clay soil. The project aims to test the feasibility of surface drainage for sunflower through a crop simulation model by using field experimental data. It has two objectives: determine the optimal surface drainage depth for sunflower (Activity 1) and determine the long-term crop yield variability of sunflower (Activity 2). In this report field experimental results are shown.

## Materials and methods

The field experiment was conducted on sunflower during the winter season in farmer’s fields at Dacope, Khulna. The sunflower seed (Hysun 33) was sown on 9 and 27 December 2022 at two locations. While in 2023, it was sown on 15 and 21 December 2023 at three locations. Each experimental plot was prepared by inserting 3 internal and 1 external drain and isolated by polythene sheet. Three perforated pipes were installed within each experimental plot. At each site, there were three drainage depths (Factor A) 0, 15 and 30 cm in year 1 and with farmers practice in year 2 applied at two to three locations (Factor B) with 3 replications. Irrigation was applied based on the availability of surface and groundwater sources and their salinity. There was no heavy rainfall during the period of waterlogging. As a result, artificial waterlogging was applied for a day at the vegetative emergence, 12-14 and 24-32 days after vegetative emergence. An index of waterlogging, known as the SEW30 value, was calculated. The sunflower crop was harvested on 2 and 14 April 23 for two locations, and 29 March and 4 April 2024 for three locations, respectively. The data on yield and yield attributes were analysed using R software (R Core Team, R. 2013).

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## Results and discussion

30 cm surface drain gave the significantly highest seed yield for both locations followed by 15 cm drainage depth (Fig. 1a). The significantly lowest yield was recorded for no drain treatments. Similar trend was recorded for the 2023-24 cropping seasons when compared with the drainage depths only (Fig. 1b).

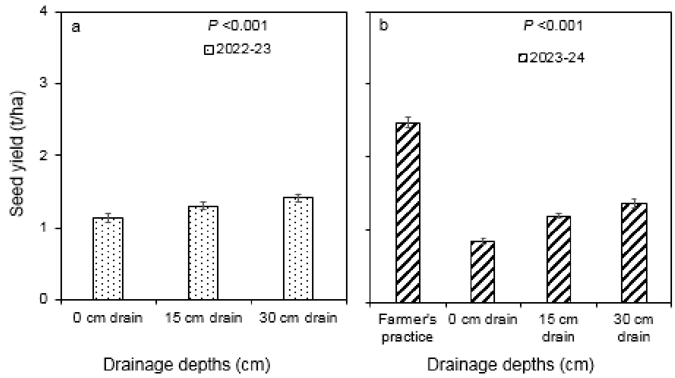


**Fig. 1.** Changes in seed yield due to the effect of drainage depths.

In 2022-23, 0 cm drainage depth kept the plot under waterlogged for 4-6 days, while 15 and 30 cm drainage depths were kept around 4-5 and 3-4 days, respectively (Fig. 2a-c). In 2023-24, Location 1 behave similarly with the previous season, while location 2 and 3 showed more waterlogged day for all three treatments due to scattered light to medium rain after $2^{nd}$ and $3^{rd}$ waterlogging. As a result, a 0 cm depth plot was waterlogged for 9 days, while 15 and 30 cm drainage depths were 6-9 and 5-8 days, respectively. The $SEW_{30}$ was higher at no drain and gradually decreased with the increase of drainage depth (Fig. 3).

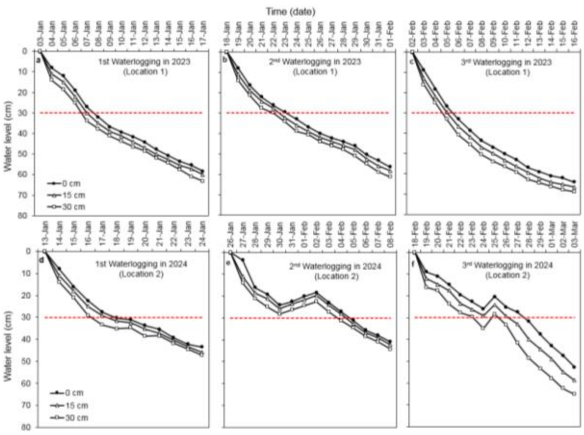


**Fig. 2.** Variation in water level over time after the release of drainage water

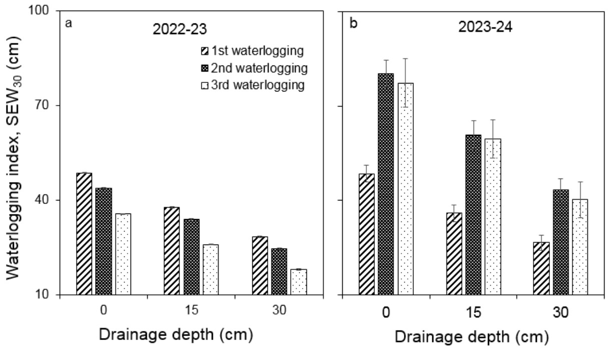


**Fig. 3.** Waterlogging indexes against individual effects of drainage depth and location.

## Conclusion

30 cm surface drain is the optimum drainage depth to get a comparatively higher yield under three waterlogging events during the vegetative stage. Therefore, sunflower can be grown early using 30 cm drainage depth to alleviate waterlogging stress along with other abiotic stresses to get an optimum yield in Southern Bangladesh.

## References


Mila, A.J., Bell, R.W., Barrett-Lennard, E.G. and Kabir, E., 2021. Salinity dynamics and water availability in water bodies over a dry season in the Ganges Delta. *Future of sustainable agriculture in saline environments*, pp.305-322.

Paul, P.L.C., Bell, R.W., Barrett-Lennard, E.G., Kabir, E. and Gaydon, D.S., 2021a. Opportunities and risks with early sowing of sunflower in a salt-affected coastal region of the Ganges Delta. Agron. Sustain. Dev., 41(3): 39.

Paul, P.L.C., Bell, R.W., Barrett-Lennard, E.G., Kabir, E., Mainuddin, M. and Sarker, K.K., 2021b. Short-Term Waterlogging Depresses Early Growth of Sunflower (Helianthus annuus L.) on Saline Soils with a Shallow Water Table in the Coastal Zone of Bangladesh. *Soil Systems*, *5*(4), p.68.

R Core Team, R. 2013. R: A language and environment for statistical computing. Vienna, Austria.

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

A. J. Mila[1], P. L. C. Paul[2], A. K. Chaki[3], R. W. Bell[4], D. S. Gaydon[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. Therefore, surface drainage could be a potential option. This study was conducted to test the APSIM-Sunflower by conducting experiment at the farmer's field of Dacope upazila in Khulna district using the sunflower, with three drainage depths (0 cm; no drain, 15, and 30 cm) replicated thrice. We have made good progress in parameterising APSIM using field experimental data and setting the model for local environmental conditions (soil, climate, etc.). We have started calibration but not been completed yet. In addition, successful calibration and validation of the model can generate more insight for researchers and policymakers about the risks of long-term use of this technique on seed yield, soil health and hydrology.

## Introduction

Coastal areas of Bangladesh is vulnerable due to waterlogging at the start of the Rabi season. In this study, we aimed to find the optimum surface drainage depth for the early establishment of sunflower and removing field water after heavy rainfall. Also, to optimize the specific drainage depth for a particular crop through a crop simulation model (APSIM-Agricultural Production Systems Simulator). APSIM 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. The aim is to test the feasibility of surface drainage for winter crops (i.e., sunflower) and using a crop simulation model calibrated by field experimental data to predict drainage requirements for greater resilience of smallholder farm income and food security in Southern Bangladesh. Therefore, the objective is to determine optimal shallow surface drainage for sunflower by testing variations in depth.

## Materials and Methods

To test the APSIM-Sunflower model, a field experiment was conducted during 2023 and 2024. The detailed experimental procedure is explained in Central report 2024 (Mila et al. 2024). Long-term climate data were collected from local weather station. Soil samples were collected in 5 soil layers (0-15, 15-30, 30-50, 50-80, and 80-120 cm) at around 10-15 days intervals and measured using oven dry method. Initial soil salinity ($EC_{1:5}$), pH (1:5 water), OC, boron, CEC, ESP, $NO_3$ and $NH_4$ for five layers were determined. Soil salinity ($EC_{1:5}$) was measured in 5 soil layers at around 10-15 day intervals during the season using an EC meter and Chloride deposition in ppm was calculated. APSIM-sunflower phenology has 11 stages. Yield data was collected during harvest (See Fig. 1). Finally, the APSIM-sunflower model was parameterised using the above climate, soil, and crop data.

## Results and Discussion

Simulated and observed values of phenology, biomass, and yield and soil water content during the crop season are shown in figure 1 and 2. At this stage 0 cm drainage depth treatment for both locations was selected, which showed fairly good 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 93, and 50 % for phenology, and yield for regression relationships between simulated and observed values (Fig.3). Similarly, soil water content and chloride content for 0-15, 15-30 and 30-50 cm soil depth for both

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locations showed fairly good (Fig. 2). However, it needs more work to complete the calibration process and making the model more roust.

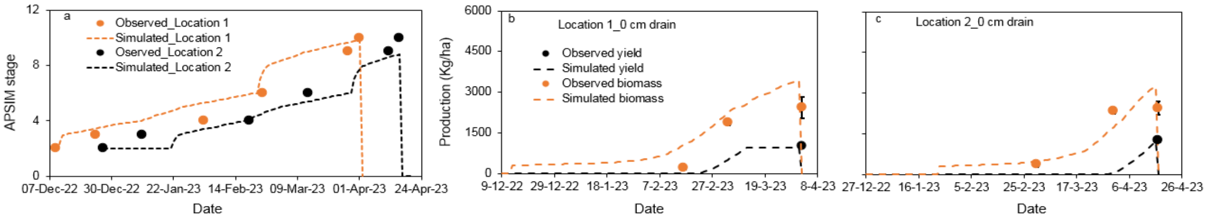


**Fig. 1** APSIM simulated and observed phenology and production (yield and biomass) of sunflower for three drainage depths and two locations at Dacope, Khulna during the crop season 2023.

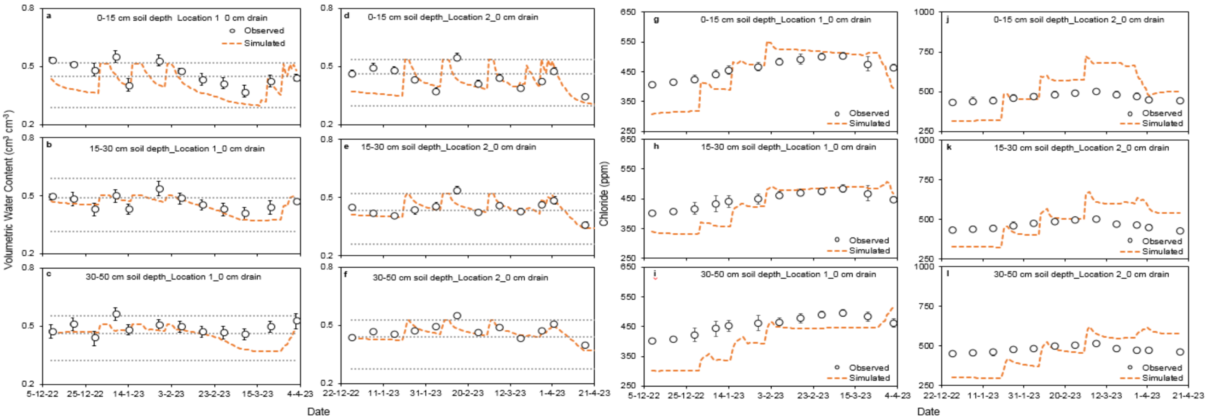


**Fig. 2** Simulated and observed volumetric soil water content (cm$^3$ cm$^{-3}$) and chloride (ppm) of sunflower for three drainage depths and two locations at Dacope, Khulna during the crop season 2023. a-c and g-i for location 1 0-50 cm soil depth soil water content and chloride content, d-f and j-l for location 1 0-50 cm soil depth soil water content and chloride content, respectively.

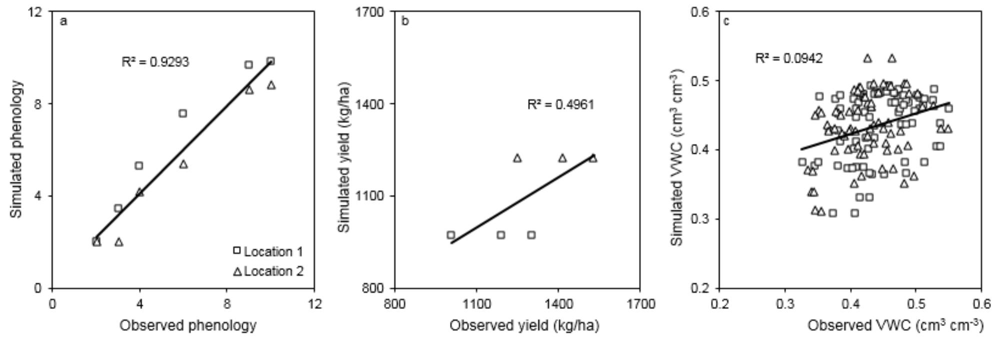


**Fig. 3.** Simulated vs observed phenology, yield and soil water content

## Conclusion

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

## References


Keating et al. 2003. An overview of APSIM, a model designed for farming systems simulation. *European journal of agronomy*, *18*(3-4), pp.267-288.

Gaydon et al. 2017. Evaluation of the APSIM model in cropping systems of Asia. *Field Crops Research*, *204*, pp.52-75.

# 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], S. K. BISWAS[3]

## Abstract

This study evaluates the impact of a small municipal solid waste dumpsite on groundwater quality in Konabari, Gazipur, Bangladesh. Specifically, it determines the travel time and direction of particles from the dumpsite to a pumping well and quantifies leachate migration into the subsurface system from the dumping site. The study utilizes finite difference-based numerical codes MODFLOW-MODPATH and MODFLOW-MT3DMS. In 2023–24, the methodology was developed using two pumping wells: one near the dumpsite and the other farther away. Results revealed that MODFLOW-MODPATH modeling effectively delineates the direction of water particles from the dumpsite to the pumping well, along with the required travel time. Similarly, MODFLOW-MT3DMS-based contaminant transport modeling simulates the migration of leachate from the dumpsite towards the well due to pumping. With satisfactory performance achieved, a more detailed modeling effort will be conducted next year for particle tracking and leachate migration quantification.

## 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. In the first year (2023-24), the methodology was developed using synthetic data but with the geometry of the real study area. As the methodology has now been developed, the modeling approaches will be utilized for the study area with real data obtained from relevant sources. Different leachate concentration scenarios will also be evaluated using the coupled MODFLOW-MT3DMS approach.

## 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

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direction of flow paths and the travel time depend largely on the rate of pumping from the well and the subsurface hydrogeology (Figure 1). 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 (Figure 2). Therefore, it can be inferred that the proposed methodology 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.

## Conclusion

The developed methodology can accurately track groundwater flow paths and predict the movement of contaminants. The study will continue next year to provide an in-depth analysis of the hydrogeology of the dumpsite and determine the impacts of different leachate scenarios on groundwater quality.

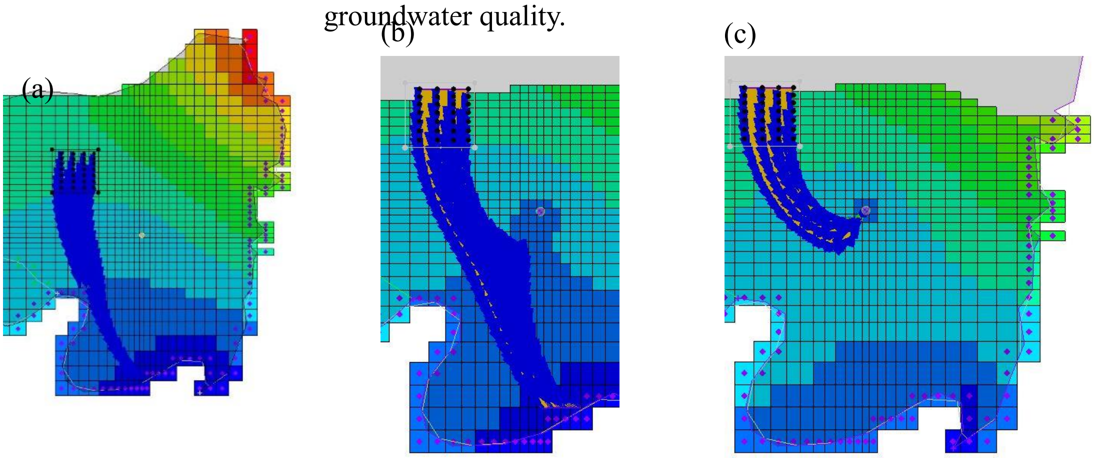


Figure 1. Movement of water particles toward the well from the landfill as a result of pumping: (a) 300 $m^3$/d, (b) 500 $m^3$/d, and (c) 600 $m^3$/d

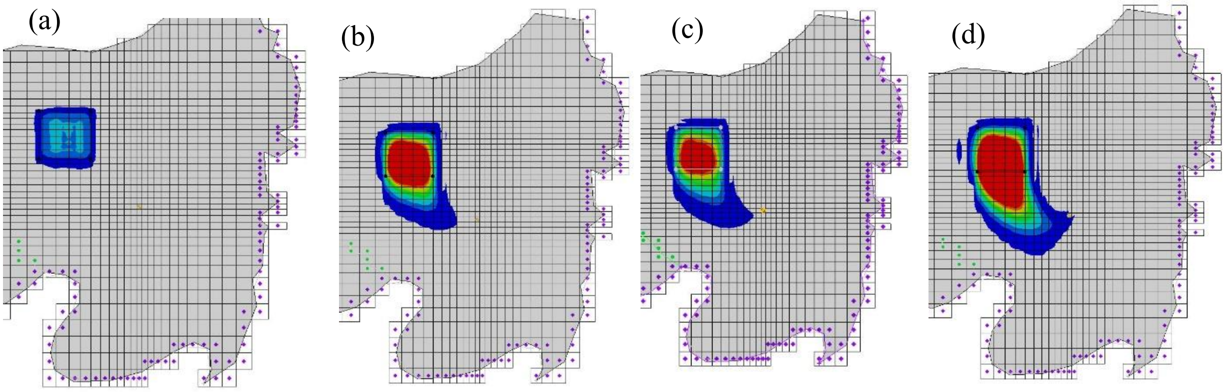


Figure 2. Movement of leachate toward the well from the landfill as a result of pumping: (a) after 500 days, (b) after 5000 days, (c) after 10000 days, and (d) after 15000 days

## Reference


Dagwar, P. P., Dutta, D., 2024. Landfill leachate a potential challenge towards sustainable environmental management. Sci. Total Environ. 171668.

Parvin, F., Tareq, S.M., 2021. Impact of landfill leachate contamination on surface and groundwater of Bangladesh: a systematic review and possible public health risks assessment. Appl. Water Sci. 11, 100.

Sun, X., Jiang, Y., Huang, Y., Su, Y., Miao, K., 2022. Modelling groundwater flow and contaminant migration in heterogeneous fractured media at a municipal solid waste landfill in Nanjing Lishui, China. Geofluids. 1, 8391260.

# DEEP LEARNING EMULATORS FOR SALTWATER INTRUSION MANAGEMENT MODELLING IN COASTAL AQUIFERS

D. K. ROY[1], S. K. BISWAS[2], B. DATTA[3]

## Abstract

The selected best DL-based emulators (DFFNN and FFNN) at various monitoring locations (MLs) were coupled with two optimization algorithms: CEMOGA and MOFEPSO. This approach utilized the coupled S-O-based optimization formulation, deriving Pareto-optimal solutions for optimal pumping. The precision of these optimal pumping schedules was verified through a numerical model, showing that the S-O approach with DL surrogates significantly reduced computational burden and provided reliable solutions. The best feasible bargaining solution from the Pareto front was selected using the SAW and TOPSIS methods. The findings indicated that the best DL-based emulators adequately provided optimal groundwater abstractions for both CEMOGA and MOFEPSO. Validation results suggested that MOFEPSO outperformed CEMOGA, with percentage RE values of 0 to 0.030% for CEMOGA and 0 to 0.025% for MOFEPSO.

## Introduction

Over-pumping of groundwater in coastal regions disrupts the natural equilibrium of fresh, brackish, and saline water, leading to saline water intrusion into freshwater zones of coastal aquifers. Assessing the consequences of this anthropogenic activity requires evaluation and mitigation through the development of an optimal pumping strategy. Optimal pumping from coastal aquifers can be achieved using a coupled simulation-optimization (S-O) approach, which provides multiple feasible solutions. To enhance computational efficiency in the S-O approach, simulation models are replaced with emulators. Previous studies employed either shallow learning algorithms or their ensembles to develop optimal pumping management models (Roy and Datta, 2020). To fill this research gap, the present study aims to propose a deep learning-based coupled S-O approach to prescribe optimal abstraction rates to control saltwater intrusion in coastal aquifers.

## Materials and Methods

A coupled S-O approach (Dhar and Datta, 2009) was the core constituent of this research. The study applied this approach to develop optimal pumping management schemes for a real world coastal aquifer system. A calibrated and validated numerical simulation model's output (which was developed and presented in the report of 2021-2022) was used to train, validate, and test DL-based emulators. The performance ranking of the DL models was conducted using Shannon's Entropy-based decision theory (Shannon, 1948). The selected best DL-based emulators (DFFNN and FFNN) at various monitoring locations were coupled with CEMOGA and MOFEPSO to address the coupled S-O-based optimization formulation and derive Pareto-optimal solutions for optimal groundwater pumping. The precision of the optimal pumping schedules derived from these DL-based emulators at different MLs was verified through a numerical model. Additionally, the best feasible bargaining solution from the Pareto front was selected using the SAW and TOPSIS methods (Hwang and Yoon, 1981), considering compromises between two competing objectives.

## Results and Discussion

The optimization routine using CEMOGA assessed 437,001 functions over 437 generations to attain the optimum solution, taking 24.2 hours to converge. For MOFEPSO, the total count of objective function evaluations was 100,107, with 176,227 constraint function evaluations, requiring 40 hours to attain optimum solutions. The Pareto fronts depicted in Fig. 1 offer various feasible solutions, illustrating the tradeoffs between two opposing objectives in the saltwater intrusion management

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problem. These solutions adhere to constraints on the highest admissible saline contents at specific MLs. Fig. 1's Pareto optimal front demonstrates the possibility of increasing groundwater abstraction from production wells (PWs) by concurrently raising water extraction from barrier wells (BWs). From these feasible alternatives, suitable combinations of water abstraction from PWs and BWs can be determined. For CEMOGA, the two methods (TOPSIS and SAW) provided different best solutions, with TOPSIS selecting the 211th solution as the superior option and SAW selecting the 56th solution (Fig. 1). In contrast, for MOFEPSO, both TOPSIS and SAW selected the 25th solution as the superior, albeit with varying weight values (TOPSIS: weight = 0.697, SAW: weight = 0.995). Validation results indicated that the simulation model's solutions closely aligned with the predictions made by DL-based emulators within the optimization formulation, as evidenced in Fig. 2. The percentage relative error values were less than 0.03% and 0.025% for CEMOGA and MOFEPSO, respectively, which are acceptable for the development of management model perspectives.

## Conclusion

The proposed approach provided optimal groundwater pumping schemes in the form of a Pareto optimal front with numerous alternative feasible solutions. The selection of the best solutions from the Pareto front enables decision-makers to choose the most suitable Pareto optimal solution. The findings indicate that optimizing groundwater pumping from the coastal aquifer can effectively control saltwater intrusion. Such analyses can assist in making informed decisions regarding coastal aquifer management.

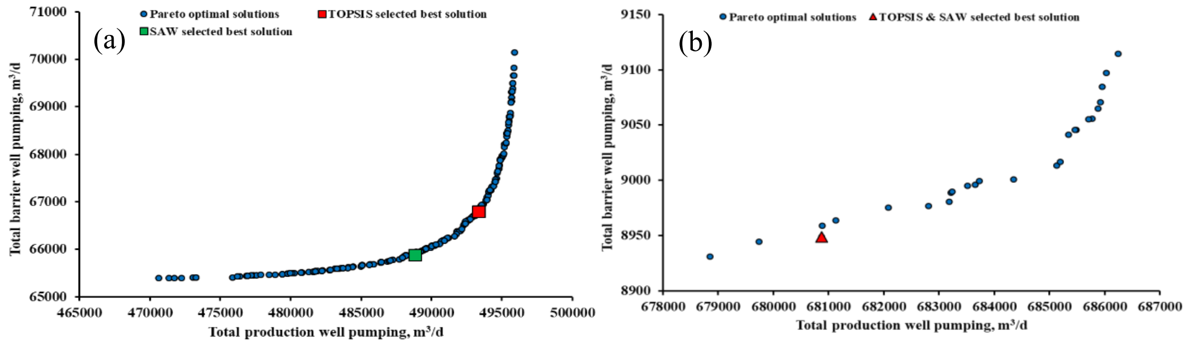


Figure 1. Pareto optimal front with the selected best solution using (a) CEMOGA, (b) MOFEPSO

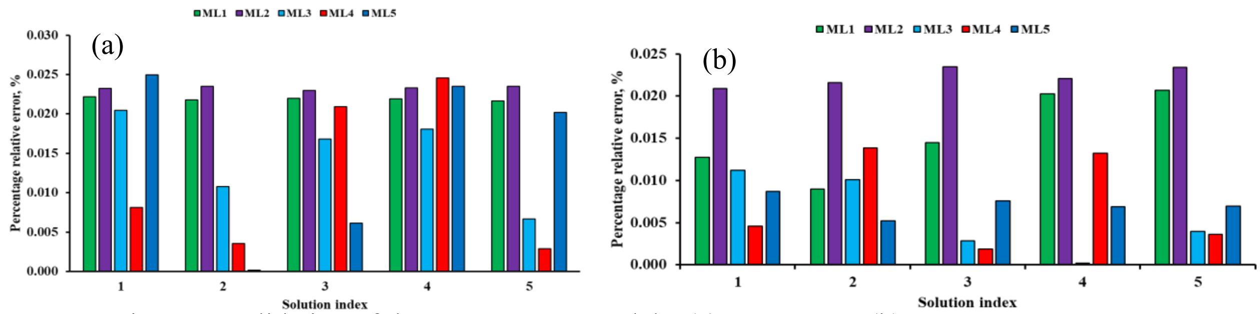


Figure 2. Validation of the management models: (a) CEMOGA, (b) MOFEPSO

## References

Dhar, A., Datta, B., 2009. Saltwater intrusion management of coastal aquifers. I: linked simulation-optimization. J. Hydrol. Eng. 14, 1263–1272.

Roy, D.K., Datta, B., 2020. Modelling and management of saltwater intrusion in a coastal aquifer system: A regional-scale study. Groundw. Sustain. Dev. 11, 100479.

Shannon, C.E., 1948. A mathematical theory of communication. Bell Syst. Tech. J. 27, 379–423.

Hwang, C.L., Yoon, K., 1981. Multiple attribute decision making: Methods and applications. Springer-Verlag, Berlin.

# INTERPRETABLE AND EXPLAINABLE MACHINE LEARNING ALGORITHMS FOR PREDICTING SALTWATER INTRUSION IN COASTAL AQUIFERS

D. K. ROY[1], S. K. BISWAS[2], M. A. HOSSAIN[3], B. DATTA[4]


## Abstract

Interpretability and explainability of the black-box models need to be explored to understand the relative importance of predictors in producing the output. Six interpretable and explainable machine learning models were developed to predict saltwater intrusion in coastal aquifers. These models provided adequate accuracies in predicting saltwater concentrations at designated monitoring locations, although they varied in their predictive abilities. The interpretability of the developed models was assessed through PDP, ICE, LIME, and Shapley plots. Results revealed that the adopted interpretability approaches can adequately interpret the model-predictor relationships in producing the desired output.


## Introduction

Saltwater intrusion processes in coastal aquifers are often predicted using machine learning (ML) algorithms, which are generally "black-box" in nature. While the prediction accuracies of these ML-based "black-box" algorithms are important, their interpretability and explainability remain unexplored, especially in saltwater intrusion prediction and management models. The main hindrance to using any ML-based model in real-world scenarios is the lack of transparency, explainability, interpretability, and trust due to the "black-box" nature of these models (Chakraborty et al., 2021; Dikshit and Pradhan, 2021). To overcome this limitation, this study aims to explore the interpretability and explainability of commonly used ML algorithms in predicting saltwater intrusion in coastal aquifers.

## Materials and Methods

A previously published saltwater intrusion simulation model (Roy and Datta, 2017) was used to generate the input-output patterns to train three "black-box" ML models. The input-output dataset was partitioned into two sets: 80% of the data was used for training the models, and the remaining 20% was used to test the developed models. The ML-based models developed were ANN, GPR, SVR, GAM, RT, and RTE. The optimal parameters of these models were obtained by optimizing the tunable parameters using Bayesian optimization. Three basic methods of model interpretability were used to explain the contribution of individual predictors to the predictions of the trained models. These were: (1) Local Interpretable Model-Agnostic Explanations (LIME); (2) Partial Dependence (PDP) and Individual Conditional Expectation (ICE); and (3) Shapley Values.

## Results and Discussion

The developed models provided acceptable performance based on commonly used statistical performance indices, although the performance varied among the models. Model interpretability with respect to PDP and ICE plots of the first input for the RTE model developed at ML3 is graphically illustrated in Figure 1. The x-axis minor ticks represent the unique values in inputs (0–1300, the lower and upper limits of groundwater pumping values). Figure 1a plots the partial dependence between the first input and the corresponding outputs for each unique value in the first input predicted using the RTE model. However, since a PDP finds averaged relationships, it does not reveal hidden dependencies, especially when outputs include interactions between inputs. Therefore, ICE plots are drawn to clearly show two different dependencies of outputs on the first input. ICE plots (Figure 1b) show the relationship between an input and the predicted outputs for each observation. Shapley and


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LIME plots for the RTE model developed at ML3 are graphically illustrated in Figure 2. The left figure shows the Shapley explanation with respect to the query point and average prediction for the first observation. The Shapley values indicate how much each predictor deviates from the average prediction at the point of interest, indicated by the vertical line at zero. The second figure shows the LIME coefficient values for the first 20 important variables. LIME was used to approximate the complex RTE model in the neighborhood of the prediction of interest with a simple, interpretable linear model. The linear model was then used as a surrogate to explain how the original RTE model works.

## Conclusion

The proposed models demonstrated acceptable but varying degrees of performance. Interpretability analyses using PDP, ICE, Shapley, and LIME plots provided valuable insights into the relationships between inputs and outputs, enhancing the transparency and understanding of the "black-box" models.

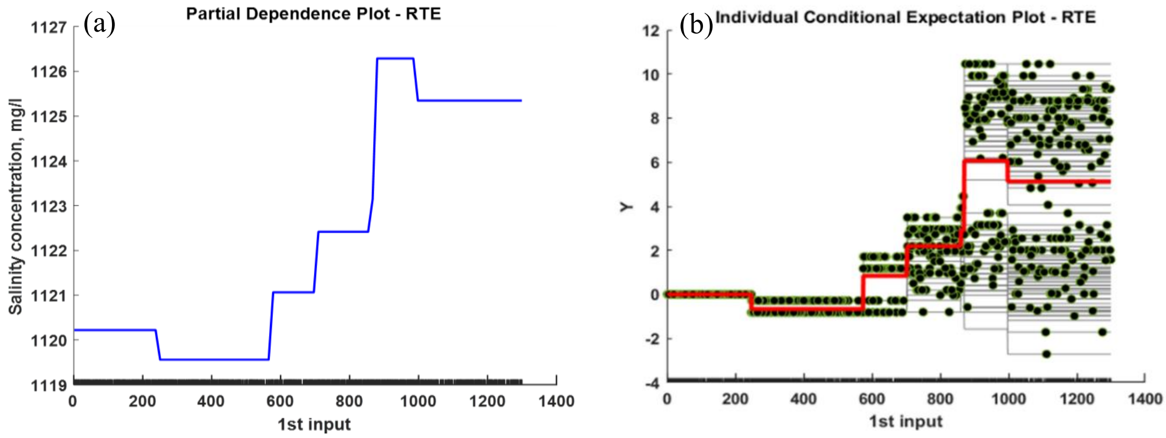


Figure 1. PDP and ICE plots for the black box RTE model at monitoring location ML3

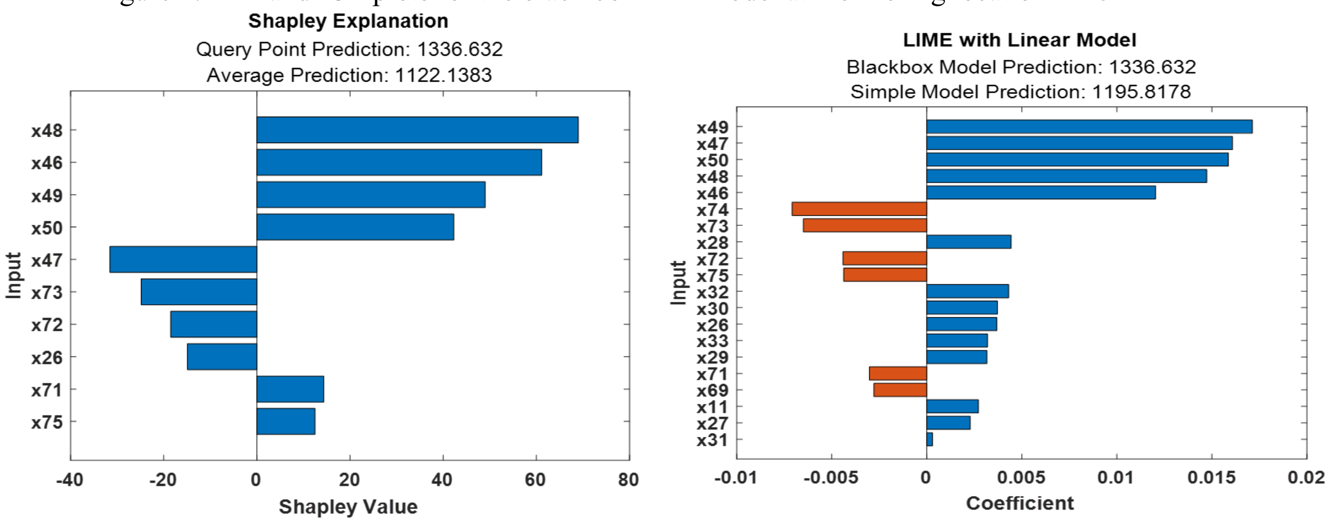


Figure 2. Shapley and LIME plots for the black box RTE model at monitoring location ML3

## Reference

Chakraborty, D., Başağaoğlu, H., Winterle, J., 2021. Interpretable vs. noninterpretable machine learning models for data-driven hydro-climatological process modeling. Expert Syst. Appl. 170, 114498.

Dikshit, A., Pradhan, B., 2021. Interpretable and explainable AI (XAI) model for spatial drought prediction. Sci. Total Environ. 801, 149797.

Roy, D.K., Datta, B., 2017. Fuzzy C-Mean Clustering Based Inference System for Saltwater Intrusion Processes Prediction in Coastal Aquifers. Water Resour. Manag. 31.

# ACCURACY AND COMPUTATIONAL TIME OF GA AND PSO BASED MULTI-OBJECTIVE OPTIMIZATION ALGORITHMS FOR SALTWATER INTRUSION MANAGEMENT MODEL IN COASTAL AQUIFERS

D. K. ROY[1], S. K. BISWAS[2], B. DATTA[3]

## Abstract

The top-performing heterogeneous ensemble model was externally linked to two algorithms: CEMOGA and MOFEPSO. The CEMOGA algorithm employed a population of 2,597, a maximum generation of 32,000, a crossover fraction of 0.92, a function tolerance of 0.0001, and a constraint tolerance of 0.000001. It took 498 seconds to converge to optimal solutions. In contrast, the MOFEPSO algorithm utilized a swarm size of 2,000, a maximum iteration of 32,000, an increment factor of 0.3, a velocity initialization factor of 0.3, and a boundary tolerance of 0.01. It converged to optimal solutions in 461 seconds. Results indicated that the MOFEPSO algorithm outperformed CEMOGA in terms of convergence time and the value of the optimal beneficial pumping. The CRITIC method was used to select the optimal bargaining solution from the Pareto optimal front, assisting decision-makers in choosing the best solution. The optimal solutions from both algorithms were verified using a numerical simulation model, confirming their credibility with relative error values of less than 5%.

## Introduction

The accuracy and robustness of any emulator-based multi-objective saltwater intrusion management model depend largely on the accuracy of the emulators and the search capabilities of the optimization algorithm. Although the accuracy of this approach has been investigated in recent studies with either a standalone model (Lal and Datta, 2018) or a heterogeneous ensemble of a few models (Roy and Datta, 2020), the robustness, computation time, and stochastic nature of the multi-objective optimization algorithms have not yet been evaluated for saltwater intrusion management problems. To fill this research gap, the present study aims to: (i) determine the accuracy and robustness of multiple objective optimization algorithms in a coupled simulation-optimization framework; and (ii) the stochastic nature of multi-objective optimization algorithms in obtaining global optimal solutions.

## Materials and Methods

The top-performing heterogeneous ensemble model developed last year was linked separately to two multi-objective optimization algorithms: CEMOGA and MOFEPSO. The optimal parameters for both algorithms were selected after several trials, ensuring the best combination for the optimization routine. The time required to obtain the global optimal solution was recorded. The multi-objective optimization provided a set of feasible alternative solutions in the form of a Pareto optimal front. A post-Pareto analysis was then performed using the CRITIC method (Diakoulaki et al., 1995) to help decision-makers select the best alternatives from the feasible options in the Pareto optimal front. The validity of the obtained optimal solutions was verified using a numerical simulation model. Randomly selected optimal solutions were fed into the simulation model to obtain salinity concentrations at designated monitoring locations. These concentrations were then compared with those predicted by the ensemble model within the optimization routine to ensure accuracy.

## Results and Discussion

The proposed multiple objective optimization algorithm for pumping optimization in saltwater intrusion management in coastal aquifers provided a set of equally probable alternative solutions in the form of a Pareto optimal front (Fig. 1). The Pareto optimal fronts in Fig. 1 showed that the MOFEPSO algorithm offered higher values of total production well (PW) pumping for beneficial purposes compared to the CEMOGA algorithm. The CEMOGA algorithm proposed a certain amount

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of total PW pumping when total barrier well (BW) pumping was close to zero. In contrast, the MOFEPSO algorithm proposed higher values of total PW pumping along with higher values of total BW pumping. As the goal of the saltwater intrusion management problem is to maximize beneficial pumping from the aquifer without causing harm, the solutions proposed by the MOFEPSO algorithm are deemed superior to those proposed by the CEMOGA algorithm. Additionally, the MOFEPSO algorithm (461 seconds) took less time to converge compared to the CEMOGA algorithm (498 seconds). Another important aspect is selecting the best alternative bargaining solution from the Pareto optimal solutions to aid decision-makers. The CRITIC method was employed for this purpose, with the best solution marked by a red triangle for the CEMOGA-derived Pareto front and a red diamond for the MOFEPSO-derived Pareto front (Fig. 1). The optimal solutions from both algorithms were verified using a numerical simulation model, confirming their credibility with relative error values of less than 5% (Fig. 2).

## Conclusion

The CEMOGA- and MOFEPSO-assisted coupled S-O approaches are able to provide optimal groundwater pumping values that minimize saltwater intrusion in coastal aquifers. However, a closer look at the optimal solutions reveals the superiority of the MOFEPSO-based optimization approach, which can be employed to develop a regional-scale saltwater intrusion management model.

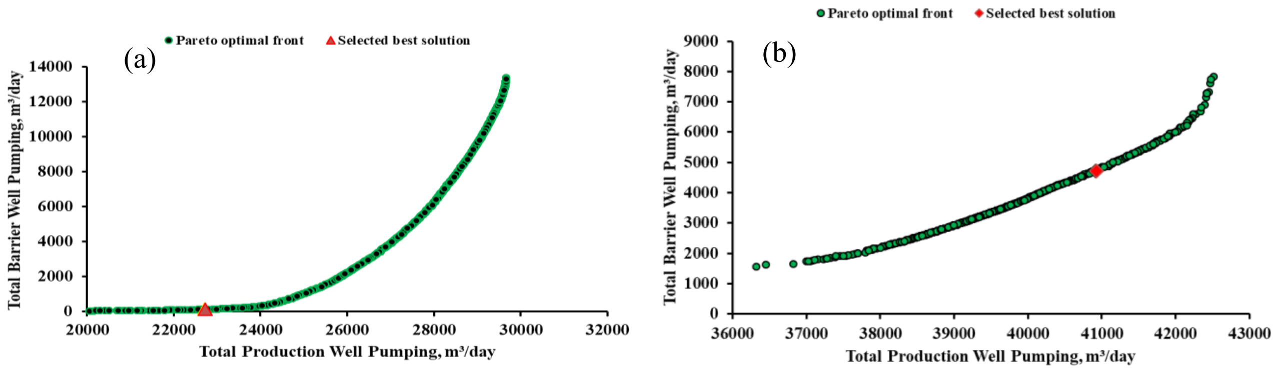


Figure 1. Pareto optimal front with the selected best solution using (a) CEMOGA, (b) MOFEPSO

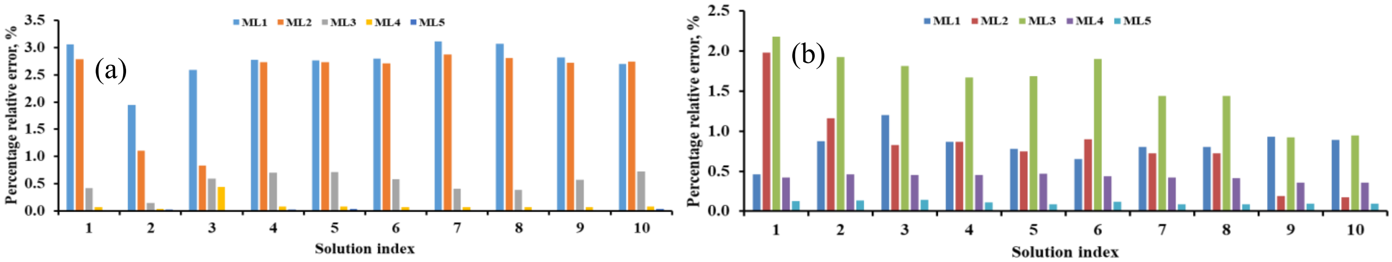


Figure 2. Percentage relative errors of salinity concentrations between simulation and ensemble models: (a) CEMOGA, (b) MOFEPSO

## Reference


Diakoulaki, D., Mavrotas, G., Papayannakis, L., 1995. Determining objective weights in multiple criteria problems: The critic method. Comput. Oper. Res. 22(7), 763-770..

Lal, A., Datta, B., 2018. Development and implementation of support vector machine regression surrogate models for predicting groundwater pumping-induced saltwater intrusion into coastal aquifers. Water Resour. Manag. 32, 2405–2419.

Roy, D.K., Datta, B., 2020. Saltwater intrusion prediction in coastal aquifers utilizing a weighted-average heterogeneous ensemble of prediction models based on Dempster-Shafer theory of evidence. Hydrol. Sci. J. 65, 1555–1567.

# MONITORING OF GROUND WATER LEVEL AT DIFFERENT BARI STATIONS

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## 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 (153.08 ft) at IWM Field of BARI, Gazipur in 6th October, 2024 followed by RARS, BARI, Jamalpur (30.17 ft) in 15th May 2024. The lowest depletion of groundwater level was observed 16.67 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

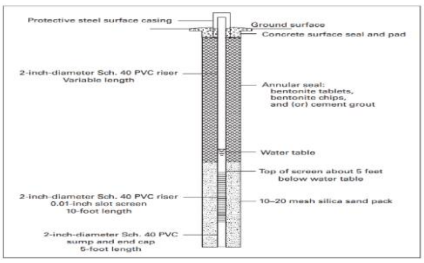


Fig 1. Schematic diagram of groundwater observation well

### 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.

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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 December 2022 | 15 September 2021 | 07 May 2023 | 22 April 2022 |
| Latitude & longitude | $25.99^0$N $90.41^0$E | $22.79^0$N $90.29^0$E | 24.07N $89.08^0$E | 24.97N $89.33^0$E | $26.099^0$N $28.769^0$E | $24.936^0$N $89.912^0$E | $23^0$.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

| Location | IWM Field Gazipur | RARS, Barishal | RARS Pabna | SRC Bogura | BSPC Debigonj | RARS Jamalpur | RARS Jessore |
|---|---|---|---|---|---|---|---|
| Maximum fluctuation | 153.08 ft | 25.25 ft | 36 ft | 22.40 ft | 16.67 ft | 30.08 ft | 29 ft |
| Date | 06/10/2024 | 14/03/2024 | 15/05/2024 | 05/09/2024 | 20/05/2024 | 30/01/2024 | 27/04/2024 |

The maximum depletion of groundwater level was found (153.08 ft) at IWM Field of BARI, Gazipur in $6^{th}$ October, 2024 followed by RARS, Pabna (36 ft) in $15^{th}$ May 2023. The lowest depletion of groundwater level was observed 16.67 ft at BSPC, Debigonj of date at different location may be caused rainfall aquifer characteristics and also other factors.

## Conclusions

The maximum depletion of groundwater level was found (153.08 ft) at IWM Field of BARI, Gazipur in $6^{th}$ October, 2024 followed by RARS, Pabna (36 ft) in $15^{th}$ May 2024. The lowest depletion of groundwater level was observed 16.67 ft at BSPC, Debigonj. Variation of maximum depletion of date at different locations may be caused by variations in rainfall, soil type, soil characteristics and other factors. During 2024-25, observation well will be installed at HARS, Khagrachari, RARS, Burirhat, RARS, Hathazari, RARS Cumilla and RARS, Abkarpur depend on the fund availability.

References

Dingman, S. L. (2015). *Physical hydrology*. Waveland press.

Salman, S. M. (2005). United Nations General Assembly Resolution: International Decade for Action, Water for Life, 2005–2015: A Water Forum Contribution. *Water international*, *30*(3), 415-418.

Scanlon, B. R., Jolly, I., Sophocleous, M., & Zhang, L. (2007). Global impacts of conversions from natural to agricultural ecosystems on water resources: Quantity versus quality. *Water resources research*, *43*(3).

Strassberg, G., Scanlon, B. R., & Chambers, D. (2009). Evaluation of groundwater storage monitoring with the GRACE satellite: Case study of the High Plains aquifer, central United States. *Water Resources Research*, *45*(5).

# ASSESSMENT OF GROUNDWATER QUALITY FOR IRRIGATION AND DRINKING PURPOSES IN SOME SELECTED BARI RESEARCH STATION

S. K. BISWAS[1], D. K. ROY[2], AND M.A. HOSSAIN[3]

## Abstract

The present investigation is aimed at understanding the temporal and spatial variability of groundwater quality for its use in irrigation and drinking purposes in different regional station of BARI. Water quality indices, namely sodium adsorption ratio (SAR), exchangeable or soluble sodium percent (SSP or %Na), residual sodium carbonate (RSC) and Kelly's ratio (KR) were calculated for STWs, DTWs and HTWs that used for irrigation and domestic uses. Besides, the composite influence of different water quality parameters on the overall quality of water was also assessed using water quality index (WQI). According to the WQI values, all the samples were found to be "excellent" except few were found "good" in post-irrigation season. Thus, the majority of the area is occupied by good water in both pre- and post-irrigation season.

## Introduction

Assessment of groundwater quality is essential to identify its suitability for various purposes such as domestic, irrigation and industrial uses. Groundwater quality in an area is influenced mainly by two processes like rock/soil-water interaction during recharge and groundwater flow, and time when it is supplied through improper canals for irrigation and drinking purposes. Temporal changes in the constitution and origin of the water recharged, and human factor, frequently cause periodic changes in groundwater quality. Poor quality water affects human health and damages the crop yield in several ways. Therefore, it is necessary to perform a regular assessment to check its suitability prior to its use in any purposes. In view of this, this study is proposed to analyze the groundwater quality of some research stations of BARI to determine the physico-chemical parameters with special emphasis on its irrigation and drinking suitability.

## Materials and Methods

In this investigation, groundwater samples of HTWs, STWs and DTWs were collected during the pre-irrigation season (November – December) and the post-irrigation (April – May) season. Each of the groundwater samples was analyzed for various physicochemical parameters such as pH; electrical conductivity at $25^0$C; total dissolved solids (TDS); major cations—sodium ($Na^+$), potassium ($K^+$), calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$); major anions—bicarbonate ($HCO_3^-$), chloride ($Cl^-$), nitrate ($NO_3^-$) and sulphate ($SO_4^{2+}$); components such as iron (Fe), manganese (Mn), arsenic (As) and zinc (Zn). Groundwater suitability for irrigation and drinking purposes were assessed using SAR (Sodium Adsorption Ratio), RSC (Residual Sodium carbonate), SSP (Soluble Sodium percentage) and KR (Kelly's ratio). Besides, to get a comprehensive picture of overall quality of groundwater, the water quality index (WQI) was determined. The computed WQI values are classified into five categories: excellent water (WQI < 50); good water (WQI = 50–100); poor water (WQI = 100–200); very poor water (WQI = 200–300); and water unsuitable for irrigation (WQI > 300).

## Results and Discussion

### Suitability of groundwater for irrigation and drinking purposes

Groundwater of the study areas were classified into different categories by using different quality indices such as SAR, SRC, SSP, KR and WQI (Table 1). As per SAR values, all samples collected from DTWs, STWs and HTWs were fall in excellent category both in pre-irrigation and post-irrigation seasons as SAR values determined as <10. As per RSC values of all samples except one STW of Rajshahi fall into excellent category in both pre- and post-irrigation seasons. Water quality of Barishal were found not suitable for irrigation as SRC value was greater than 2.5. But all other samples of DTWs, STWs and HTWs were found suitable for irrigation purpose in both pre- and post-irrigation season. In respect of sodium hazards (SSP), all water samples were fall under excellent category. Irrespective of DTW, STW or HTW, KR values of all groundwater samples were less than 1.0 indicate low Na+ ion in water; hence it was suitable for irrigation (Ehya and Saeedi, 2018). The estimation of water quality index (WQI) of all

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samples collected in pre- and post-irrigation seasons showed that almost all HTWs, STWs and DTWs water was excellent, except water samples of Rajshahi which was found good for irrigation. None of the samples were exceed the allowable limit for drinking purposes (WHO, 1997; DoE, 1989).

Table 1. Water quality indices for suitability assessment of different water sources for irrigation

| Location | Source | Pre-irrigation | | | | Post-irrigation | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SAR | RSC | SSP | KR | SAR | RSC | SSP | KR |
| Bogura | DTW | 0.27 | 2.02 | 13.68 | 0.164 | 0.28 | 2.13 | 14.13 | 0.170 |
| | STW | 0.23 | 1.41 | 10.39 | 0.118 | 0.23 | 1.75 | 10.65 | 0.122 |
| | HTW | 0.25 | 1.96 | 11.54 | 0.133 | 0.25 | 1.95 | 11.20 | 0.129 |
| Ishurdi | DTW-1 | 0.28 | 1.99 | 14.02 | 0.166 | 0.31 | 2.26 | 15.98 | 0.195 |
| | DTW-2 | 0.26 | 1.46 | 11.57 | 0.133 | 0.33 | 2.28 | 16.77 | 0.206 |
| | HTW | 0.27 | 2.49 | 13.41 | 0.158 | 0.28 | 2.64 | 13.81 | 0.163 |
| Barishal | DTW | 0.38 | 3.22 | 16.15 | 0.195 | 0.41 | 3.56 | 16.86 | 0.205 |
| | STW | 0.37 | 2.74 | 26.05 | 0.194 | 0.40 | 2.78 | 27.36 | 0.208 |
| Jashore | DTW | 0.26 | 2.43 | 23.56 | 0.320 | 0.26 | 2.44 | 23.06 | 0.409 |
| | STW | 0.27 | 2.01 | 14.06 | 0.311 | 0.27 | 1.51 | 13.50 | 0.339 |
| Range | | 0.23-0.37 | 1.41-3.22 | 11.77-26.05 | 0.139-0.320 | 0.26-0.40 | 1.51-3.56 | 10.65-27.36 | 0.114-0.409 |
| Average | | 0.284 | 2.17 | 15.44 | 0.189 | 0.302 | 2.33 | 16.33 | 0.214 |

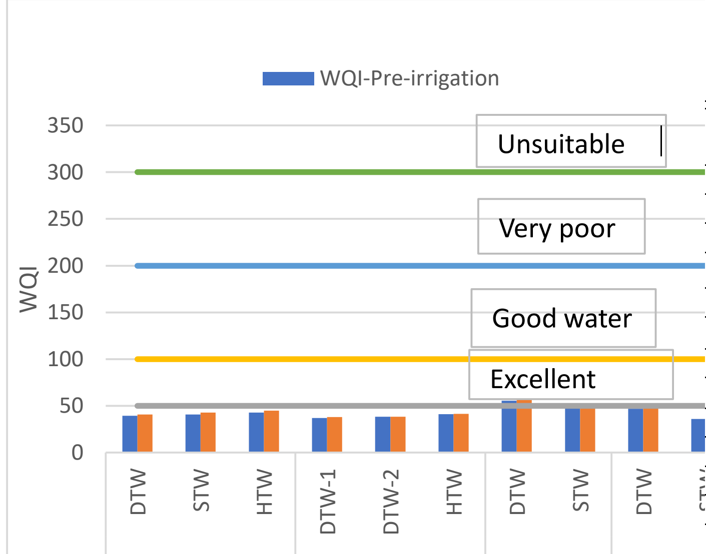


Figure 1. Water quality index (WQI) of groundwater at different location of the study area (solid line represents the range of different categories of water quality)

Table 2: Comparision of the groundwater samples with WHO (1997) and DoE (1989) for drinking water purposes

| Parameter | WHO (1997) | (DoE, 1989) | Average |
|---|---|---|---|
| pH | 6.5-8.5 | 6.5-8.5 | 7.34 |
| EC | 400 | - | 383.0 |
| TDS | 500-1000 | 500-1500 | 255.0 |
| Na | 200 | 200 | 5.67 |
| K | 12 | 12 | 1.18 |
| Ca | 75-200 | 75-200 | 31.60 |
| Mg | 50-150 | 30-50 | 1.32 |
| Cl | 250 | 150-600 | 1.69 |
| $SO_4$ | 250 | 400 | 7.41 |
| $NO_3$ | 50 | 10 | 0.74 |
| $HCO_3$ | 125-350 | - | 227.0 |
| Fe | 0.3 | 0.3-1.0 | 0.16 |
| Zn | 0.01-3.0 | 1.0 | 0.011 |

## Conclusions

In respect of all evaluating criteria, groundwater of the study area was found suitable and can safely be used for both irrigation and drinking purposes.

## References

Ehya, F., Saeedi, F., 2018. Assessment of groundwater quality in the Garmez area (Southeastern Khuzestan province, SW Iran) for drinking and irrigation uses. Carbonates Evaporites. https://doi.org/10.1007/s13146-018-0481-7.

DoE, 1989. Environmental Quality Standard. Department of Environment, Bangladesh.

WHO, 1997. Guidelines for drinking water quality. World Health Organization, Geneva.

**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], S. K. BISWAS[3]**

**Location wise demonstrations and crop/variety details during 2023-2024 growing season**

| Sl. No. | Title of the adaptive trial | Technology Used | Farmers' name | Farmers' address (Vill., Union, Dist.) | Mobile No. | Area covered under adaptive trial |
|---|---|---|---|---|---|---|
| 01 | Dissemination of Water Saving Technologies for Non-Rice Crops in Saline Area | Solar-powered Drip Irrigation System | Md. Al Amin | Fasipara, Latachapli, Patuakhali | 01774938831 | 33 decimals |
| 02 | Do | Solar-powered Drip Irrigation System | Md. Abdul Hi | Omitpur, Nilgonj, Patuakhali | 01753739149 | 33 decimals |
| 03 | Do | Solar-powered Alternate Furrow Irrigation Method | Md. Kabir Hossain | Fasipara, Latachapli, Patuakhali | 01712440390 | 33 decimals |
| 04 | Do | Solar-powered Alternate Furrow Irrigation Method | Abdul Aziz | Fasipara, Latachapli, Patuakhali | 01752912102 | 33 decimals |
| 05 | Do | Solar-powered Alternate Furrow Irrigation Method | Md. Abdul Hi | Omitpur, Nilgonj, Patuakhali | 01753739149 | 33 Decimals |

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[2] SO, IWM Division, BARI, Joydebpur, Gazipur
[3] PSO, FRC, Binodpur, Rajshahi

| | | | | | | |
|---|---|---|---|---|---|---|
| 06 | Do | Solar-powered Drip Irrigation System | Md. Jahurul Haque | Char Showallia Kieya, Noakhali | 01641105295 | 50 decimals |
| 07 | Do | Solar-powered Alternate Furrow Irrigation Method | Md. Mosaraf Hossain | Char Darvash, Char Wabdha, Noakhali | 01784308342 | 25 decimals |
| 08 | Do | Solar-powered Alternate Furrow Irrigation Method | Md. Abdul Kader | Char Jobbar | 01856547490 | 25 decimals |
| 09 | Do | Solar-powered Drip Irrigation System | Liton Sikder | Ghotkhali, Amtoli, Barguna | 01767402551 | 20 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 this 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.

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

### Abstract

Traditionally farmers irrigate watermelon by carrying water in a container from a small pond which is laborious work and labor-intensive. Therefore, field demonstrations were conducted with solar-powered drip irrigation system to mitigate the laborious work of water application, save water and energy for irrigation. There were two treatments with four replications: solar-powered drip irrigation system ($T_1$) and farmer's practice as a control treatment ($T_2$). The demonstrations were conducted from 2019-20 to 2023-24 growing seasons. The results revealed that treatment $T_1$ was highly responsive to yield and more profitable than $T_2$. The solar powered drip irrigation treatments provided the highest BCR for the consecutive growing seasons. The farmers were benefited and interested in using this promising water and energy saving irrigation technology.

### Introduction

Soil as well as water salinity is a major problem in the coastal region during the dry period. Farmers grow T. Aman during July-December and the lands remain fallow due to salinity development and scarcity of water during other periods of the year. To minimize water application losses and increase water use efficiencies in the saline areas of Bangladesh, BARI developed modern irrigation technologies that are suitable for non-rice crops should be disseminated in the farmer's field. The promising water management technologies are: (i) drip fertigation that is recommended for high value vegetable and fruit crops, and (ii) alternate furrow irrigation suitable for both field crops and vegetables planted in rows. Consequently, the present study aims to disseminate drip fertigation technology to cultivate watermelon in the Kuakata and Noakhali districts in Bangladesh.

## Materials and Method

The field demonstrations were conducted at Patuakhali, Borguna, Bhola, Noakhali, and Khulna regions. In Patuakhali district, there were three drip irrigation demonstrations in 2019-2020 whereas 3 drip irrigation demonstrations were carried out in 2020-2021. The two solar-powered drip system was demonstrated in Patuakhali during 2023-2024 for water melon production. There were two drip irrigation demonstrations conducted in 2021-2022. At Borguna district there were one drip irrigation experiment in 2019-2020, 2020-2021, and 2021-2022 growing seasons. Although two drip irrigation demonstrations were conducted in the Khulna district during 2019-2020, there were no drip irrigation demonstrations in the Khulna district in 2020-2021. In Bhola district, 3 solar-powered drip irrigation demonstrations were conducted during both the 2020-2021 and 2021-2022 growing seasons. One solar-powered drip irrigation demonstration was also conducted in Noakhali district during 2020-2021, 2021-2022 ,2022-2023, and 2023-2024 growing seasons. In addition, 6 solar powered irrigation pumps and 6 solar panels were provided to 30 farmers of the Kaliganj upazila, Satkhira district to facilitate irrigation in the Gher boundaries, and during 2021-2022, and 2022-2023 six sets of drip irrigation systems were provided to Kaliganj upazila, Satkhira to facilitate the irrigation in Gher boundaries. During 2023-2024, three watermelon demonstrations were conducted using a solar-powered drip irrigation system—one in the Noakhali district and two in Kuakata. There were two irrigation treatments with four replications in the demonstrations: (i) irrigation with solar-powered drip system ($T_1$), and (ii) Farmer's practice ($T_2$) as control treatment.

## Results and Discussion

The findings obtained from the demonstrations for 2019-2020, 2020-2021, 2021-2022, 2022-2023and 2023-2024 growing seasons are presented in Tables 1 and 2. Table 1 presents the yield and yield attributing characters while the profitability of the demonstrations is shown in Table 2. The vine length, number of fruits per plant, individual fruit weight, and yield were found comparatively high at treatment $T_1$. Drip irrigation performed better than conventional irrigation in all demonstrations in the farmer's fields. The vine length and yield of watermelon were found statistically significant at a 5% level of significance between the treatments. Also, the water productivity of the treatment $T_1$ was higher than that obtained from treatment $T_2$. The BCR of the drip irrigated treatments was also found higher than the conventional irrigation method.

Table1.Yield and yield components of Watermelon from 2019-20 to 2023-24

| Treatment | Vine Length (cm) | Number of Fruits/ Plant | Individual Fruit Weight (kg) | Yield (t/ha) | Water productivity (kg/m$^3$) |
|---|---|---|---|---|---|
| ***Year: 2019-2020*** | | | | | |
| $T_1$ | 292.47a | 1.83a | 6.18a | 35.51a | 6.79 |
| $T_2$ | 280.17b | 1.40a | 5.41a | 29.91b | 4.41 |
| CV (%) | 0.57 | 12.62 | 7.14 | 2.78 | |
| LSD(5%) | 5.73 | - | - | 3.20 | |
| ***Year: 2020-2021*** | | | | | |
| $T_1$ | 287.33 | 1.96 | 6.23 | 36.63 | 6.11 |
| $T_2$ | 281.67 | 1.64 | 5.89 | 28.98 | 4.02 |
| F | 4.66 | 21.53 | 1.71 | 346.1 | |
| Prob.>F | 0.097 | 0.0097 | 0.2616 | 0.00049 | |
| ***Year: 2021-2022*** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $T_1$ | 281.67 | 1.85 | 5.12 | 32.53 | 5.61 |
| $T_2$ | 263.85 | 1.77 | 4.00 | 22.59 | 3.40 |
| F | 14.76 | 0.83 | 57.93 | 124.8 | |
| Prob.>F | 0.0184 | 0.4131 | 0.0016 | 0.0004 | |
| ***Year: 2022-2023*** | | | | | |
| $T_1$ | 295.52a | 1.95a | 6.25a | 36.12a | 5.95 |
| $T_2$ | 270.05b | 1.35a | 5.75a | 28.35b | 4.58 |
| CV (%) | 0.6 | 12.01 | 6.95 | 3.05 | |
| LSD (5%) | 5.7 | - | - | 3.25 | |
| ***Year: 2023-2024*** | | | | | |
| $T_1$ | 290.65a | 1.95a | 6.25a | 37.42a | 5.7 |
| $T_2$ | 260.58b | 1.35a | 5.75a | 29.15b | 4.45 |
| CV (%) | 4.6 | 12.01 | 6.95 | 26.13 | |
| LSD (5%) | 10.3 | - | - | 7.58 | |

Table 2. Benefit-Cost Ratio (BCR) of Watermelon from 2019-20 to 2023-24

| Treatment | Land preparation (tk./ha) | Seed (tk./ha) | Fertilizer (tk./ha) | Pesticide (tk./ha) | Irrigation (tk./ha) | Labor (tk./ha) | Total Cost (tk./ha) | Total return (tk./ha) | BCR |
|---|---|---|---|---|---|---|---|---|---|
| ***2019-2020*** | | | | | | | | | |
| $T_1$ | 11250 | 16875 | 32400 | 30000 | 14600 | 75000 | 180125 | 400000 | 2.22 |
| $T_2$ | 11250 | 16875 | 32400 | 30000 | 28000 | 95000 | 213525 | 311300 | 1.46 |
| ***2020-2021*** | | | | | | | | | |
| $T_1$ | 11475 | 17213 | 33048 | 30600 | 14892 | 76500 | 183728 | 412000 | 2.24 |
| $T_2$ | 11475 | 17213 | 33048 | 30600 | 28560 | 96900 | 217796 | 320639 | 1.47 |
| ***2021-2022*** | | | | | | | | | |
| $T_1$ | 11878 | 17213 | 33048 | 30600 | 15892 | 78500 | 187131 | 381743 | 2.04 |
| $T_2$ | 11878 | 17213 | 33048 | 30600 | 28960 | 97900 | 219599 | 268194 | 1.22 |
| ***2022-2023*** | | | | | | | | | |
| $T_1$ | 12370 | 17213 | 33048 | 30600 | 16390 | 79000 | 188621 | 429283 | 2.28 |
| $T_2$ | 12370 | 17213 | 33048 | 30600 | 29460 | 97900 | 220591 | 378897 | 1.72 |
| 2023-2024 | | | | | | | | | |
| $T_1$ | 12370 | 17213 | 33048 | 30600 | 16390 | 79000 | 188621 | 421515 | 2.34 |
| $T_2$ | 12370 | 17213 | 33048 | 30600 | 29460 | 97900 | 220591 | 303390 | 1.42 |

## 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 ALTERNATE FURROW IRRIGATION METHOD FOR SUNFLOWER AND MAIZE CULTIVATION IN SALINE PRONE AREAS OF BANGLADESH (KUAKATA AND NOAKHALI)


## Abstract

Farmers usually apply irrigation water with flooding and furrow methods in sunflower production requiring more water which is a rarely attainable goal in the saline prone areas of Bangladesh. Therefore, to motivate farmers to use water saving irrigation technologies, a demonstration of solar-powered Alternate Furrow Irrigation (AFI) was carried out with BARI Surjomukhi-2 and Maize (Hybrid Provat-1) in the Kuakata district of the southern Bangladesh during 2019-20 to 2023-24 growing seasons. Two treatments were selected: (i) alternative furrow irrigation ($T_1$) and (ii) farmer's practice ($T_2$). Results revealed the superiority of treatment $T_1$ than treatment $T_2$ in terms of profitability and water saving. AFI treatments provided the highest BCR for the consecutive growing seasons. The farmers were benefited and interested in using this promising water and energy saving irrigation technology.


## Introduction

Soil as well as water salinity is a major problem in the coastal region during the dry period. Farmers grow T. Aman during July-December and the lands remain fallow due to salinity development and scarcity of water during other periods of the year. To minimize water application losses and increase water use efficiencies in the saline areas of Bangladesh, BARI developed modern irrigation technologies that are suitable for non-rice crops should be disseminated in the farmer's field. The promising water management technologies are: (i) drip fertigation that is recommended for high value vegetable and fruit crops, and (ii) alternate furrow irrigation suitable for both field crops and vegetables planted in rows. Consequently, the present study aims to disseminate solar-powered alternate furrow irrigation technology to cultivate sunflower in the Kuakata and Noakhali districts in Bangladesh.

## Materials and Method

Field demonstrations were conducted at Kalapara and Fasipara, Patuakhali regions. In Kalapara, Patuakhali district, there was one Alternate Furrow Irrigation (AFI) demonstration in 2019-2020 whereas 3 AFI demonstrations were conducted during 2020-2021, 2021-22, 2022-2023, and 2023-2024 growing seasons, respectively at Fasipara, Patuakhali. In Noakhali, two demonstrations were conducted during 2023-2024. There were two irrigation treatments with four replications in the demonstrations: (i) irrigation with solar-powered AFI ($T_1$), and (ii) Farmer's practice ($T_2$) as control treatment. BARI Surjonikhi-2 and maize (local variety in 2023-24) was used for the demonstration of the AFI method. BARI recommended fertilizers were applied for the development of the sunflower crop. Insects and pests were controlled by using BARI recommended insecticides and pesticides.

## Results and Discussion

Table 1 shows the yield and yield components of sunflower (BARI Surjomukhi – 2) from 2019-20 to 2023-24 growing seasons. The plant population, plant height, head diameter, number of seeds per head, 1000 seed weight, and yield were found comparatively higher in treatment $T_1$ than treatment $T_2$. The AFI technique performed better than conventional irrigation methods at both locations and for all demonstrations during 2019-20 to 2023-24 growing seasons. The head diameter, number of seed per head, 1000 seed weight, and yield were statistically significant at the 5% level of significance. Significantly higher yield was obtained from treatment $T_1$ (1.89 t/ha) than treatment $T_2$ (1.69 t/ha) during 2022-23 growing season. Table 2 showed that the BCR of sunflower production using AFI was more profitable (BCR>1) than the farmer's practice. For instance, during 2023-24 growing season, the BCR of treatment $T_1$ (1.07) was slightly higher than that of treatment $T_2$ (0.89). AIF method ($T_1$) for maize production in 2023-24 was also higher BCR with comparison to traditional methods ($T_2$) (Table 1A and Table 2A). The demonstration will be continued for the 2024-25 growing season.

## Conclusion

Solar powered AFI method was found more water productive and profitable than farmers' practice. The farmers were benefited and interested in using this promising water and energy saving irrigation technology. Therefore, we need to disseminate AFI method covering a range of locations within the salt affected southern parts of Bangladesh.

Table 1. Yield and yield components of sunflower from 2019 to 2024

| Treatment | Plant Population/m$^2$ | Plant Height (cm) | Head Diameter (cm) | Number of Seed/ Head | 1000 Seed Weight (gm) | Yield (t/ha) |
|---|---|---|---|---|---|---|
| ***2019-2020*** | | | | | | |
| $T_1$ | 7.00 | 143.57a | 59.47a | 464.67a | 88.00a | 1.99a |
| $T_2$ | 6.67 | 139.90a | 50.35b | 420.00b | 77.67b | 1.73b |
| CV (%) | - | 4.62 | 5.11 | 0.74 | 5.81 | 2.09 |
| LSD (5%) | - | - | 9.85 | 11.47 | 16.91 | 0.14 |
| ***2020-2021*** | | | | | | |
| $T_1$ | 6.85 | 145.61 | 60.12 | 471.24 | 89.56 | 2.31 |
| $T_2$ | 6.38 | 139.85 | 53.98 | 455.32 | 81.02 | 2.12 |
| F | 3.44 | 230.6 | 153.01 | 229.85 | 114.24 | 3.09 |
| Prob.>F | 0.1374 | 0.0001 | 0.0002 | 0.0001 | 0.0004 | 0.1536 |
| ***2021-2022*** | | | | | | |
| $T_1$ | 6.80 | 144.16 | 60.21 | 471.42 | 89.65 | 2.11 |
| $T_2$ | 6.31 | 138.15 | 53.89 | 455.23 | 81.02 | 2.02 |
| F | 3.44 | 230.6 | 153.01 | 229.85 | 114.24 | 3.09 |
| Prob.>F | 0.1374 | 0.0001 | 0.0002 | 0.0001 | 0.0004 | 0.1536 |
| ***2022-2023*** | | | | | | |
| $T_1$ | 7.00 | 142.11a | 60.01a | 463.88a | 89.02a | 1.89a |
| $T_2$ | 6.67 | 140.05a | 51.15b | 417.00b | 75.70b | 1.65b |
| CV (%) | - | 4.7 | 5.13 | 1.2 | 6.02 | 3.98 |
| LSD (5%) | - | - | 9.85 | 11.47 | 16.91 | 0.14 |
| ***2023-2024*** | | | | | | |
| $T_1$ | 6.90 | 141.11a | 69.13a | 465.01a | 90.51a | 1.98a |
| $T_2$ | 6.77 | 140.55a | 50.05b | 418.15b | 77.2b | 1.75b |
| CV (%) | - | 2.34 | 5.56 | 3.12 | 7.8 | 5.4 |
| LSD (5%) | - | - | 5.22 | 12.1 | 15.8 | 0.23 |

Table 1A. Yield and yield components of Maize during 2023-2024

| Treatments | Plant height (cm) | No. of grains per cob | 1000 seed wt. (g.) | Grain yield (ton per ha) |
|---|---|---|---|---|
| T1 | 238.0a | 712.0a | 390.0a | 9.4a |
| T2 | 222.4b | 560.0b | 430.0b | 8.5b |
| CV (%) | 3.95 | 6.29 | 3.46 | 5.92 |
| LSD (5%) | 10.2 | 15.33 | 9.65 | 0.61 |

Table 2. Benefit-Cost Ratio (BCR) of Sunflower from 2019 to 2024

| Treatment | Land preparation (tk/ha) | Seed (tk/ha) | Fertilizer (tk/ha) | Pesticide (tk/ha) | Irrigation (tk/ha) | Labor (tk/ha) | Total Cost (tk/ha) | Total return (tk/ha) | BCR |
|---|---|---|---|---|---|---|---|---|---|
| ***2019-2020*** | | | | | | | | | |
| $T_1$ | 9375 | 3000 | 23400 | 0 | 24000 | 18800 | 78575 | 99500 | 1.27 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $T_2$ | 9375 | 3000 | 23400 | 0 | 28000 | 20000 | 83775 | 86500 | 1.03 |
| ***2020-2021*** | | | | | | | | | |
| $T_1$ | 9563 | 3060 | 23868 | 2040 | 24480 | 19176 | 82187 | 102485 | 1.25 |
| $T_2$ | 9563 | 3060 | 23868 | 2040 | 28560 | 20400 | 87491 | 89095 | 1.02 |
| ***2021-2022*** | | | | | | | | | |
| $T_1$ | 9658 | 3060 | 23868 | 2040 | 25480 | 20176 | 84282 | 93611 | 1.11 |
| $T_2$ | 9658 | 3060 | 23868 | 2040 | 29560 | 21400 | 89586 | 84892 | 0.95 |
| ***2022-2023*** | | | | | | | | | |
| $T_1$ | 9760 | 3060 | 23868 | 2040 | 24480 | 19176 | 82384 | 84294 | 1.023 |
| $T_2$ | 9760 | 3060 | 23868 | 2040 | 28560 | 20400 | 87688 | 73203 | 0.835 |
| **2023-2024** | | | | | | | | | |
| $T_1$ | 9760 | 3060 | 23868 | 2040 | 24480 | 19176 | 82384 | 88308 | 1.07 |
| $T_2$ | 9760 | 3060 | 23868 | 2040 | 28560 | 20400 | 87688 | 77639.55 | 0.89 |

Table 2A. Benefit-Cost Ratio (BCR) of Maize during 2023-2024

| Treatment | Land preparation (tk/ha) | Seed (tk/ha) | Fertilizer (tk/ha) | Pesticide (tk/ha) | Irrigation (tk/ha) | Labor (tk/ha) | Total Cost (tk/ha) | Total return (tk/ha) | BCR |
|---|---|---|---|---|---|---|---|---|---|
| T1 | 9375 | 2200 | 23400 | 2000 | 24000 | 15800 | 76775 | 197400 | 2.571149 |
| T2 | 9375 | 2200 | 23400 | 2000 | 28000 | 15800 | 80775 | 178500 | 2.209842 |

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


### Abstract

Farmers irrigate brinjal fields mostly with furrow irrigation methods, which need more irrigation water. Therefore, field demonstrations were performed with a solar-powered drip irrigation system to minimize water loss and save energy. The demonstrations were conducted during 2020-21 to 2023-24 growing seasons in the southern region of Bangladesh. There were two irrigation treatments with four replications: (i) solar-powered drip irrigation system ($T_1$) and (ii) farmer's practice ($T_2$) as a control treatment. The results revealed that treatment $T_1$ was highly responsive to yield and more profitable than $T_2$. The solar powered drip irrigation treatments provided the highest BCR (~2.0) for the consecutive growing seasons. The farmers were benefited and interested in using this promising water and energy saving irrigation technology.


### Introduction

Soil as well as water salinity is a major problem in the coastal region during the dry period. Farmers grow T. Aman during July-December and the lands remain fallow due to salinity development and scarcity of water during other periods of the year. To minimize water application losses and increase water use efficiencies in the saline areas of Bangladesh, BARI developed modern irrigation technologies that are suitable for non-rice crops should be disseminated in the farmer's field. The promising water management technologies are: (i) drip fertigation that is recommended for high value vegetable and fruit crops, and (ii) alternate furrow irrigation suitable for both field crops and vegetables planted in rows. Consequently, the present study aims to disseminate drip fertigation technology to cultivate brinjal in the Barguna district in Bangladesh.

## Materials and Method

Field demonstrations were conducted using brinjal (bt. Brinjal-2) at Ghotkhali, Amtali, Barguna during 2020-2021, 2021-22, 2022-23, and 2023-24 growing seasons. There were two irrigation treatments with four replications in the demonstrations: (i) irrigation with solar-powered drip system ($T_1$), and (ii) Farmer's practice ($T_2$) as control treatment. BARI recommended fertilizers were applied for the development of the brinjal crop. Insects and pests were controlled by using BARI recommended insecticides and pesticides.

## Results and Discussion

The findings obtained from the demonstrations for 2020-2021, 2021-2022, 2022-2023, and 2023-2024 growing seasons are presented in Tables 1 and 2. Table 1 presents the yield and yield attributing characters while the profitability of the demonstrations is shown in Table 2. The length of fruit, diameter of fruit, unit weight of fruit, and yield were found comparatively high at treatment $T_1$ than treatment $T_2$. Drip irrigation performed better than conventional irrigation in all demonstrations at the farmer's fields. The yield and yield attributing characters were found statistically significant at a 5% level of significance between the treatments. Also, the water productivity of the treatment $T_1$ was higher than that obtained from treatment $T_2$. The BCR of the drip irrigated treatments was also found higher than the conventional irrigation method.

## Conclusion

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

Table 1. Yield and yield components of brinjal during 2020-21 to 2023-24

| Treatments | Length of fruit, cm | Diameter of fruit, cm | Unit weight of fruit, g | Yield, t/ha |
|---|---|---|---|---|
| ***2020-2021*** | | | | |
| $T_1$ | 7.53 | 6.52 | 435 | 30.64 |
| $T_2$ | 6.98 | 6.19 | 412 | 27.37 |
| F | 41.63 | 5.32 | 10.73 | 84.85 |
| Prob.>F | 0.003 | 0.0823 | 0.0306 | 0.0008 |
| ***2021-2022*** | | | | |
| $T_1$ | 8.09 | 7.02 | 452 | 31.46 |
| $T_2$ | 7.02 | 6.05 | 427 | 29.07 |
| F | 116.11 | 15.87 | 12.98 | 52.84 |
| Prob.>F | 0.001 | 0.0163 | 0.0227 | 0.0023 |
| ***2022-2023*** | | | | |
| $T_1$ | 8.59 | 7.12 | 450 | 31.64 |
| $T_2$ | 7.12 | 6.35 | 425 | 29.37 |
| F | 116.11 | 15.87 | 12.98 | 52.84 |
| Prob.>F | 0.001 | 0.0163 | 0.0227 | 0.0023 |
| ***2023-2024*** | | | | |
| $T_1$ | 7.83 | 6.83 | 465 | 30.14 |
| $T_2$ | 7.11 | 6.15 | 413 | 28.73 |
| F | 51.03 | 7.88 | 11.01 | 81.03 |
| Prob.>F | 0.001 | 0.0163 | 0.0227 | 0.0023 |

Table 2. Benefit-Cost Ratio (BCR) of Brinjal during 2020-21 to 2022-23

| Treatment | Land preparation (tk/ha) | Seed (tk/ha) | Fertilizer (tk/ha) | Pesticide (tk/ha) | Irrigation (tk/ha) | Labor (tk/ha) | Total Cost (tk/ha) | Total return (tk/ha) | BCR |
|---|---|---|---|---|---|---|---|---|---|
| ***2020-2021*** | | | | | | | | | |
| $T_1$ | 10455 | 2550 | 17228 | 5610 | 17850 | 54876 | 108569 | 309165 | 2.85 |
| $T_2$ | 10455 | 2550 | 17228 | 5610 | 25296 | 66096 | 127235 | 264823 | 2.08 |
| ***2021-2022*** | | | | | | | | | |
| $T_1$ | 10955 | 2550 | 17228 | 5610 | 18750 | 55825 | 110918 | 302520 | 2.73 |
| $T_2$ | 10955 | 2550 | 17228 | 5610 | 26225 | 68090 | 130658 | 253101 | 1.94 |
| ***2022-2023*** | | | | | | | | | |
| $T_1$ | 10000 | 2550 | 17228 | 5610 | 17850 | 54876 | 108114 | 304250 | 2.81 |
| $T_2$ | 10000 | 2550 | 17228 | 5610 | 25296 | 66096 | 126780 | 282422 | 2.23 |
| ***2023-2024*** | | | | | | | | | |
| $T_1$ | 10000 | 2550 | 17228 | 5610 | 17850 | 54876 | 108114 | 289827 | 2.61 |
| $T_2$ | 10000 | 2550 | 17228 | 5610 | 25296 | 66096 | 126780 | 250140.8 | 1.91 |

# PARTNER-DLI4: ADAPTIVE TRIALS ON WATER-SAVING IRRIGATION TECHNOLOGIES IN WATER-SCARCE REGIONS OF BANGLADESH

**D. K. ROY[1], S. K. BISWAS[2], K. K. SARKER[3], A. J. MILA[4], M. P. HAQUE[5], C. R. PAUL[6]**

## Abstract

This study demonstrates the efficacy of various water-saving irrigation technologies through field trials conducted on farmers' fields. The study consists of 300 adaptive trials using 7 different efficient irrigation technologies across farmers' fields in the water-scarce regions of Bangladesh. During the growing season of 2023-2024, the adaptive trial involved 34 demonstrations across multiple sites, with the following distribution: alternate furrow irrigation (6 trials), conjunctive use of fresh and saline water (3 trials), deficit irrigation (3 trials), drip irrigation (7 trials), solar-powered drip irrigation (4 trials), sprinkler irrigation (8 trials), and solar-powered sprinkler irrigation (3 trials). These techniques were applied across representative crop types and soil conditions of the region. Key performance indicators included water use efficiency, crop yield, and water productivity. Preliminary results indicate that drip, sprinkler, and solar-powered drip and sprinkler systems significantly reduced water usage and energy costs while maintaining or enhancing crop yields. Alternate furrow and deficit irrigation demonstrated promising water-saving capabilities but with variable impacts on crop performance. Conjunctive use of fresh and saline water optimized water resources by balancing the utilization of both types of water while maintaining crop yield. Farmers perceived the new irrigation technologies as promising solutions for mitigating water scarcity and reducing operational costs. They particularly appreciated the potential for increased crop yields and the sustainable use of water resources offered by these advanced methods. The study will continue for the next four years using similar irrigation technologies in different study locations.

## Introduction

Water scarcity poses a significant challenge to agriculture in Bangladesh, particularly in its arid regions, where erratic rainfall patterns and depleting groundwater reserves intensify the vulnerability of crops. Efficient water management is crucial not only for sustaining crop production but also for ensuring food security amidst a growing population. Traditional irrigation methods, characterized by their high water and energy requirements, exacerbate the scarcity issue and strain local resources. In response, innovative irrigation technologies that prioritize water conservation while enhancing agricultural productivity have emerged as vital solutions. This study seeks to address these challenges through adaptive trials of seven advanced irrigation systems, aiming to assess their effectiveness across diverse crop types and soil conditions. By evaluating key performance indicators such as water use efficiency, crop yield, and water productivity, this research aims to promote sustainable irrigation practices suitable for the water-scarce regions of Bangladesh.

## Materials and Methods

The study was conducted during the growing season of 2023-2024 in water-scarce regions of Bangladesh. It encompassed adaptive trials of seven water-saving irrigation technologies across various locations: Gazipur, Kishoreganj, Manikganj, Faridpur, Patuakhali, Satkhira, Bogura, and Kurigram. Thirty-four demonstrations were implemented across multiple farmers' fields, distributed as follows: alternate furrow irrigation (6 trials), conjunctive use of fresh and saline water (3 trials), deficit irrigation (3 trials), drip irrigation (7 trials), solar-powered drip irrigation (4 trials), sprinkler irrigation (8 trials), and solar-powered sprinkler irrigation (3 trials). Each trial was conducted under typical crop types and soil conditions prevalent in the region. Therefore, crops such as potato, tomato, chili, pumpkin, onion, garlic, brinjal, and mixed vegetables were used for conducting the adaptive

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[4] SSO, IWM Division, BARI, Joydebpur, Gazipur
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[6] SO, IWM Division, BARI, Joydebpur, Gazipur

trials under the seven irrigation technologies. Data on crop productivity and water productivity were collected from the adaptive trials. The study strictly adhered to ethical guidelines regarding the use of farmers' fields for research purposes, ensuring minimal disruption to ongoing agricultural activities and obtaining informed consent from participating farmers.

## Results and Discussion

The adaptive trials of seven water-saving irrigation technologies conducted across multiple regions of Bangladesh during the 2023-2024 growing season yielded insightful results across various performance indicators. Drip and solar-powered drip irrigation demonstrated significant improvements in water use efficiency and maintained high crop yields across crops such as tomato, chili, and pumpkin. Similarly, sprinkler and solar-powered sprinkler irrigation system showed effective water management capabilities, reducing water consumption while achieving competitive crop yields of onion, garlic, and mixed vegetables. It was revealed, as anticipated, that solar-powered systems showed promise in reducing energy consumption compared to traditional irrigation methods, contributing to sustainability goals by utilizing renewable energy sources. The results highlight the potential of advanced irrigation technologies in mitigating water scarcity challenges and enhancing agricultural sustainability in Bangladesh's water-scarce regions. Farmers perceived the water-saving irrigation technologies as highly adaptable solutions that could effectively address water scarcity while improving crop yields. They expressed optimism about integrating these technologies into their farming practices to enhance productivity and sustainability in Bangladesh's challenging agricultural landscape.

## Conclusion

The adaptive trials of various water-saving irrigation technologies underscore their potential to mitigate water scarcity challenges and enhance agricultural sustainability in Bangladesh. The findings highlight the importance of adopting efficient irrigation practices to enhance crop yield in water-scarce regions. The study will continue for the next four years to conduct additional adaptive trials in other locations.

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

| Irrigation technology | Crops | Yield, kg/ha* | Water requirement, m | Water productivity, kg/m$^3$ |
|---|---|---|---|---|
| Drip and solar-powered irrigation | Sweet gourd | 39700 | 0.21 | 19.25 |
| | Cucumber | 30000 | 0.14 | 21.82 |
| | Tomato | 80000 | 0.18 | 43.42 |
| | Pointed gourd | 30000 | 0.11 | 27.27 |
| | Papaya | 60000 | 0.83 | 7.27 |
| | Onion | 18000 | 0.19 | 9.52 |
| Sprinkler and solar-powered irrigation | Garlic | 8000 | 0.18 | 4.57 |
| | Mixed leafy vegetables | 60000 | 0.32 | 19.05 |
| | Potato | 21850 | 0.20 | 11.21 |
| Alternate furrow irrigation | Tomato | 77000 | 0.22 | 35.36 |
| | Maize | 10000 | 0.21 | 4.73 |
| | Tomato | 69000 | 0.34 | 20.60 |
| Conjunctive use | Onion | 17000 | 0.27 | 6.30 |
| | Potato | 19100 | 0.30 | 6.37 |
| | Brinjal | 50000 | 0.42 | 11.90 |
| | Mustard | 1400 | 0.12 | 1.21 |
| Deficit irrigation | Sunflower | 1500 | 0.21 | 0.72 |
| | Chili | 20000 | 0.25 | 7.94 |
| | Potato | 18050 | 0.24 | 7.52 |
| | Sweet gourd | 39700 | 0.21 | 19.25 |

*Average yield at different locations

## PARTNER-DLI3: DEVELOPMENT OF ARTIFICIAL INTELLIGENCE (AI) AND SENSOR BASED EFFICIENT IRRIGATION TECHNOLOGIES FOR SUSTAINABLE CROP PRODUCTION

**D. K. ROY[1], C. R. PAUL[2], M. P. HAQUE[3], S. K. BISWAS[4]**

### Abstract

The application of AI and Machine Learning (ML) in sensor-based micro-irrigation systems facilitates automation in agriculture. This study integrates the forecasting capabilities of AI and ML into these systems to automate irrigation using drip and sprinkler methods. Initially, an LSTM network was developed to forecast weather parameters and reference evapotranspiration ($ET_0$). Before employing the LSTM for forecasting, the training and test performances were evaluated using the RMSE criterion. The minimal differences in RMSE values between the training and testing phases indicated that the model was not over fitted. Additional performance indices were computed on the test dataset to further evaluate the LSTM models' testing phase performance. The LSTM models were benchmarked against ARIMA and four system dynamic models, with results showing that the LSTM models consistently outperformed the benchmarks. Following satisfactory training and testing, the LSTM and the benchmark models were used to forecast weather parameters and $ET_0$ values for up to two years beyond the training and test datasets. The results demonstrated that the LSTM models effectively captured the historical data trends and provided better forecasts compared to their benchmarked counterparts.

### Introduction

ML and sensor-based irrigation technologies are revolutionizing agriculture by optimizing water management. These systems use sensors to measure soil moisture and weather conditions, calculating the precise amount and timing of irrigation (Seyar and Ahamed, 2024). This automation saves farmers time and resources while ensuring optimal crop growth. ML algorithms further enhance efficiency by analyzing data to develop predictive models for real-time irrigation scheduling (Gu et al., 2021; Del-Coco et al., 2024). Nevertheless, accurate $ET_0$ forecasting is crucial because $ET_0$, combined with crop coefficients, determines the $ET_c$ needed for irrigation scheduling. Common practices in $ET_0$ modeling involve using ML and deep learning approaches for prediction within known datasets or multi-step ahead forecasting for short-term future predictions. However, it is essential to develop novel approaches for long-term $ET_0$ forecasting beyond available datasets. To address this gap, this study proposes an LSTM-based deep learning approach to forecast weather parameters and $ET_0$ up to two years beyond the existing data. These forecasts will be used to accurately quantify future $ET_c$ for automated irrigation scheduling systems in conjunction with soil sensors. Additionally, drip and sprinkler irrigation system inputs will be optimized using a coupled simulation-optimization approach. Finally, the potential of nitrate leaching through the subsoil will be investigated using a 3D vadose zone model.

### Materials and Methods

A Recurrent Neural Network-based LSTM, ARIMA, and four system dynamic models were developed to forecast weather parameters and the resulting $ET_0$ essential for computing $ET_c$ and determining crop water requirements. Weather and other relevant data were collected from appropriate sources and the collected data underwent a thorough QA/QC process. Missing entries were imputed using the Modified Akima cubic Hermite interpolation method. The corrected weather data were used to compute $ET_0$ using the Penman-Monteith equation. Time series data of individual weather parameters and $ET_0$ were used to train and test the LSTM and benchmark models. Several performance indices were employed to compare the models' performances. The best model was then used to forecast future values up to two years beyond the available data. The credibility of the

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proposed best forecasting model was assessed by comparing the forecasted values with actual data over the forecasting period.

## Results and Discussion

The LSTM and other models were trained and tested using the available data where 80% of the data served as training data and the remaining 20% served as the test data. Results revealed, based on the computed performance evaluation indices, that the LSTM model outperformed the benchmark models (ARIMA and the system dynamic models) (Table 1). After proper training and testing, the LSTM and the benchmark models were employed to forecast future values of up to 2 years. Results revealed that the benchmark model forecasts were unable to capture the true trends of the weather parameters and $ET_0$ time series except for the minimum temperature for which the ARIMA model was able to capture the historical data trends. In contrast, the LSTM forecasts accurately captured the true trends of the historical time series of all weather parameters and $ET_0$. Comparison with the available data revealed the suitability of the LSTM models in forecasting 2 years beyond the available data. The model will be retrained up to the present time data and the model will be used for forecasting for the next 4 years. The forecasted $ET_0$ values will then be integrated with crop coefficient values to determine the crop evapotranspiration ($ET_c$).

## Conclusion

The proposed LSTM model accurately predicted weather parameters and $ET_0$ values, as demonstrated by the performance indices. It effectively captured the true trends of the historical time series for these parameters. The study will continue for the next four years to calibrate soil sensors for irrigation scheduling, model nitrate leaching in the subsoil, and optimize micro-irrigation system parameters.

Table 1. Performance indices of the models on test dataset

| | LSTM | ARIMA | nSid | SSEST | SEREGEST |
|---|---|---|---|---|---|
| R | 0.664 | 0.227 | 0.147 | 0.146 | 0.142 |
| MAE, mm/d | 0.648 | 1.067 | 2.805 | 2.785 | 2.447 |
| NRMSE | 0.236 | 0.354 | 0.840 | 0.835 | 0.748 |

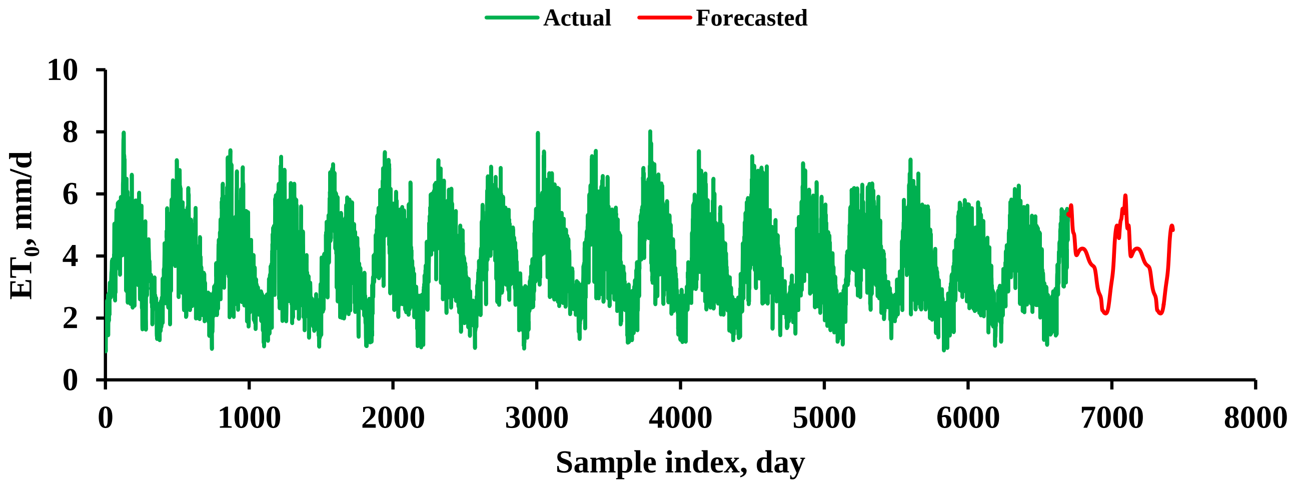


Figure 1. $ET_0$ projection for two years beyond the available data using the best LSTM model

## Reference


Del-Coco, M., Leo, M., Carcagnì, P., 2024. Machine Learning for Smart Irrigation in Agriculture: How Far along Are We?. Information, 15(6), 306.

Gu, Z., Zhu, T., Jiao, X., Xu, J., Qi, Z,. 2021. Neural network soil moisture model for irrigation scheduling. Computers and Electronics in Agriculture, 180, 105801.

Seyar, M.H., Ahamed, T., 2024. Optimization of Soil-Based Irrigation Scheduling Through the Integration of Machine Learning, Remote Sensing, and Soil Moisture Sensor Technology. In: IoT and AI in Agriculture. Springer, Singapore.

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

**S. K. BISWAS[1], D. K. ROY[2], M. P. HAQUE[3]**

### Abstract

This study highlights the effectiveness of various water-efficient irrigation technologies through field trials conducted on farmers' fields in the char areas of northern Bangladesh. The research involved several adaptive trials utilizing three distinct irrigation methods: alternate furrow irrigation, drip irrigation, and sprinkler irrigation. During the 2023-2024 growing season, 10 demonstrations were conducted across multiple sites, with three trials on alternate furrow irrigation, four on drip irrigation, and three on sprinkler irrigation. These technologies were applied to representative crops: onion and mixed vegetables for sprinkler irrigation; chili, pumpkin, and pointed gourd for drip irrigation; and maize for alternate furrow irrigation. The trials accounted for the diverse soil conditions in the region. Farmers viewed these technologies as promising for addressing water scarcity and reducing operational costs. They particularly recognized the potential for increased crop yields and the sustainable use of water resources that these advanced methods offer. The study will continue into the next rabi season, with additional trials planned at the same locations, further evaluating the performance of these irrigation technologies.

### Introduction

The char areas of Northern Bangladesh, characterized by sandy soil and erratic water availability, face significant challenges in sustaining agricultural productivity. Water-efficient irrigation management offers a potential solution to optimize crop yield in these vulnerable regions. By implementing strategies such as precision irrigation, deficit irrigation, and scheduling based on crop water requirements, farmers can reduce water wastage and enhance soil moisture retention. This study focuses on developing sustainable irrigation practices tailored to the unique conditions of char lands, with the goal of increasing crop production, improving water-use efficiency, and promoting resilience to water scarcity in Bangladesh's agricultural sector.

### Materials and Methods

The study was conducted during the 2023-2024 growing season in the char areas of northern Bangladesh. It involved adaptive trials of three water-efficient irrigation technologies at three locations: Char-gunai in Kaunia, Rangpur; Begumganj Char in Ulipur, Kurigram; and Haldiar Char in Saghata, Gaibandha. A total of 10 demonstrations were carried out across farmers' fields, including three trials using alternate furrow irrigation, four with drip irrigation, and three with sprinkler irrigation. The trials were designed to reflect the typical crop types and soil conditions in the region, focusing on maize, pumpkin, onion, pointed gourd, chili, and mixed vegetables. Data on crop productivity and water efficiency were collected throughout the trials. The study adhered to ethical research practices, ensuring minimal disruption to the farmers' ongoing activities and securing informed consent from all participants. These adaptive trials offer practical insights into the impact of advanced irrigation methods on crop yield and water resource management in the char areas.

### Results and Discussion

The adaptive trials of three water-efficient irrigation technologies, conducted across multiple char regions of northern Bangladesh during the 2023-2024 growing season, produced valuable results. Drip irrigation showed marked improvements in water use efficiency while maintaining high crop

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yields, particularly for pointed gourd, chili, and pumpkin. Similarly, the sprinkler irrigation system demonstrated effective water management, reducing water consumption while delivering competitive yields for crops like onion and mixed vegetables. These outcomes highlight the potential of advanced irrigation technologies in addressing water scarcity and promoting agricultural sustainability in the char regions. Farmers found these water-saving technologies to be highly adaptable and practical solutions for mitigating water shortages while boosting crop productivity. They expressed optimism about adopting these methods into their agricultural practices to improve both yields and sustainability in Bangladesh's challenging farming environment.

## Conclusion

The adaptive trials of various water-saving irrigation technologies emphasize their potential to address water scarcity and improve agricultural sustainability in the char areas of northern Bangladesh. The results underscore the critical need to adopt efficient irrigation practices to boost crop yields in these vulnerable regions. Building on these promising findings, the study will extend into the next season, conducting additional adaptive trials in similar locations with different crops. This continued research aims to further refine irrigation strategies and enhance water use efficiency for long-term agricultural resilience in the char areas.

Table 1. Completed adaptive trials on different crops under various irrigation technologies

| Locations | Technologies | Number of demonstrations | Crop | Area coverage |
|---|---|---|---|---|
| Char-gunai, Kaunia, Rangpur | Drip irrigation | 1 | Pumpkin | 20 decimals |
| Do | Alternate Furrow Irrigation | 1 | Maize | 40 decimals |
| Do | Alternate Furrow Irrigation | 1 | Maize | 30 decimals |
| Do | Alternate Furrow Irrigation | 1 | Maize | 35 decimals |
| Do | Sprinkler irrigation | 1 | Onion | 40 decimals |
| Do | Drip irrigation | 1 | Chili | 20 decimals |
| Begumganj char, Ulipur, Kurigram | Drip irrigation | 1 | Pointed gourd | 30 decimals |
| Do | Sprinkler irrigation | 1 | Mixed vegetables | 20 decimals |
| Haldiar char, Saghata, Gaibandha | Sprinkler irrigation | 1 | Onion | 30 decimals |
| Do | Drip irrigation | 1 | Pumpkin | 40 decimals |

Table 2. Additional adaptive trials to be performed next season

| Location | Crops | IR Technoloy |
|---|---|---|
| Char-gunai | Onion, Garlic | Sprinkler |
| | Chili, Pumpkin | Drip |
| | Maize | AFI |
| Haldiar char, Saghata, Gaibandha | Onion, Garlic | Sprinkler |
| | Pumpkin | Drip |
| Begumganj char, Ulipur, Kurigram | Maize | AFI |
| | Mixed vegetables | Sprinkler |
| | Pointed gourd | Drip |