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USING FISHPOND WATER TO ENHANCE SOIL FERTILITY AND REDUCE CLIMATE CHANGE IMPACTS

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Abstract

This study investigates the effects of fishpond water on the properties of irrigated soil and its potential role in mitigating climate change. By comparing fishpond water with traditional irrigation methods, the research analyzes various soil components and climate metrics. The experiment involved collecting soil samples before, during, and after irrigation to measure key factors such as nutrient levels, pH, organic matter, and moisture content. A descriptive-analytical approach and a complete random block design were used to evaluate the impacts of both fishpond water and climate variations in 2023. The results reveal that traditional irrigation water has higher conductivity and nitrate-nitrogen levels, as well as increased acidity, which influences its agricultural suitability. In contrast, significant differences were found between traditional water and fishpond water in terms of soil composition. Soil analysis showed variations in clay content, pH, and conductivity, all of which affect nutrient availability. Additionally, the type of water and its source played a crucial role in determining organic matter and nitrate-nitrogen levels, while soil texture significantly contributed to overall productivity. The climate analysis further highlighted substantial fluctuations in rainfall and temperature across different years and months. Based on these findings, the study concludes that using fishpond water for agricultural irrigation is a sustainable strategy for reducing the impacts of climate change. This method enriches the soil with organic matter and nutrients, improves its structure and water retention capacity, decreases reliance on harmful water sources, and enhances land resilience.

Keywords: Fishpond Water, Soil Texture, Sustainable Use, Climate Change.

1. INTRODUCTION

Addressing climate change requires sustainable water management. Traditional irrigation, reliant on dwindling arable water sources due to drought, heat, and pollution, is becoming less viable. Fishpond water, enriched with nutrients from fish waste and uneaten feed, offers a sustainable alternative that improves soil properties and helps mitigate climate change. A multidisciplinary approach and recognition of global and ethical responsibilities are essential. As Rossi et al., [1] emphasize, fostering a new "water culture" is crucial, integrating water's economic, social, and environmental roles into sustainable management practices.

Irrigation with nutrient-rich fishpond water can revitalize the soil, improve its structure and drainage, and boost biodiversity, ultimately resulting in higher crop production. However, it is important to be mindful of potential soil acidification caused by the high organic matter content [2]. Overall, fishpond water irrigation benefits both ecosystems and climate.

In Jordan, severe drought and declining groundwater levels are exacerbating water scarcity. To address this crisis, farmers need training in water-saving techniques, and groundwater management policies must be updated to prioritize conservation. Integrated aquaculture offers a promising solution, as it can help mitigate the impacts of drought, protect soil fertility, and provide a valuable source of irrigation water [3]. The loss of organic matter, erosion, and poor water management are leading to soil degradation, which threatens sustainable agriculture and food security. Al-Dala'een [4] suggested expanding fish farming in Jordan despite financial challenges, suggesting that improved expertise will increase long-term benefits. This could shift public and private sector interest toward providing affordable inputs. The national awareness program encourages both farmers and consumers to engage in the fish production sector. Al-Khraisat [5] identified six key constraints to fish farming in Jordan: production, technological, institutional, marketing, environmental, and social-cultural challenges, highlighting the need for multifaceted measures to ensure the sector's success and sustainability. On the other hand, Al-Burmawi [6] emphasized that climate change has affected water components, with some surpassing safe limits, necessitating prompt monitoring, treatment, and community efforts for water conservation. Similarly, El-Fawair [7] recommends adapting agricultural practices to climate change by carefully selecting irrigation water, performing regular soil analyses, and educating farmers to enhance soil quality and manage nutrient accumulation effectively.

The study aims to determine the potential advantages of utilizing fishpond water for irrigation purposes. It analyzes the chemical composition of the water, including its nutrient and organic matter content, and assesses its impact on soil properties. Additionally, the study investigates the potential role of fishpond water irrigation in mitigating climate change.

2. MATERIAL and METHODS

2.1 The Location

The study was conducted in the Shuna al-Shamalia area, located in Wadi al-Rayyan in Irbid Governorate, Jordan, with coordinates ranging from latitude 32.312°N to 32.769°N and longitude 35.855°E to 36.237°E (Figure 1). The site was selected for its representation of aquatic and agricultural ecosystems and includes both fishponds and agricultural lands.

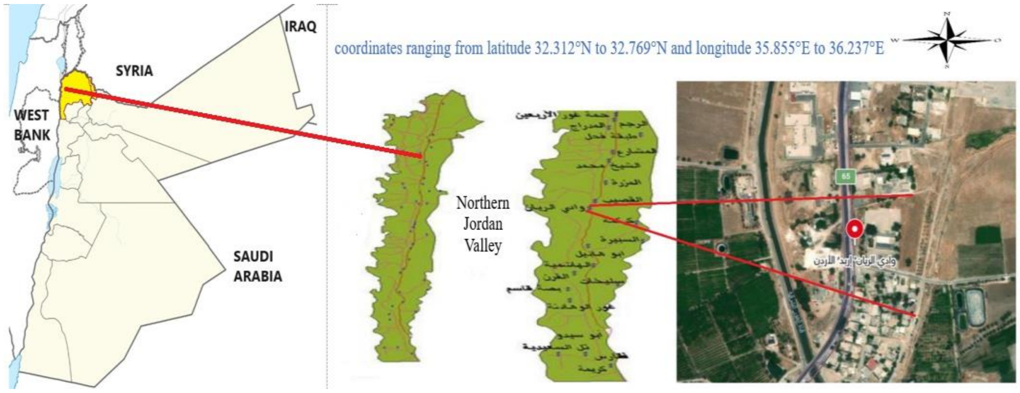


Figure 1: The study boundaries in Shuna al-Shamalia, Northern Jordan Valley

2.2 The Experiment

The study included two groups (eastern and western): the east group used fishpond water, while the group of the west relied on traditional water sources, with three replicates for each group, each covering 50 square meters. The samples were collected randomly at depths of 60 and 90 centimeters to assess nutrient availability. Over three months from June to August 2023, a total of 108 soil and 54 water samples were gathered and stored under temperature-controlled conditions. Soil samples were collected accurately using soil corers, while water samples were obtained with polarization bottles, and deep sampling devices to ensure representative sampling. The study focused on analyzing the key characteristics of fishpond water and traditional irrigation water, specifically examining factors such as electrical conductivity, pH, salt content, and nutrient levels. By comparing these water sources, the research aimed to identify their differences and assess their potential impacts on soil health. Additionally, the study explored how various factors, including water type, location, depth, and soil texture, influence soil composition. To gain a comprehensive understanding of the broader environmental influences, the analysis also included climate data, such as temperature, and precipitation.

2.3 Laboratory Work

Samples were stored in suitable containers and transported to the laboratory in cooler boxes to preserve their integrity. Laboratory procedures utilized apparatuses, incubators, microscopes, electronic balances, and specialized glassware for sample analysis. Where, water samples were analyzed at the Laboratories Directorate of the Jordan Valley Authority, while soil samples were processed at the National Center for Agricultural Research Laboratories. All analyses adhered to approved standards, and results were recorded systematically in Excel for statistical evaluation.

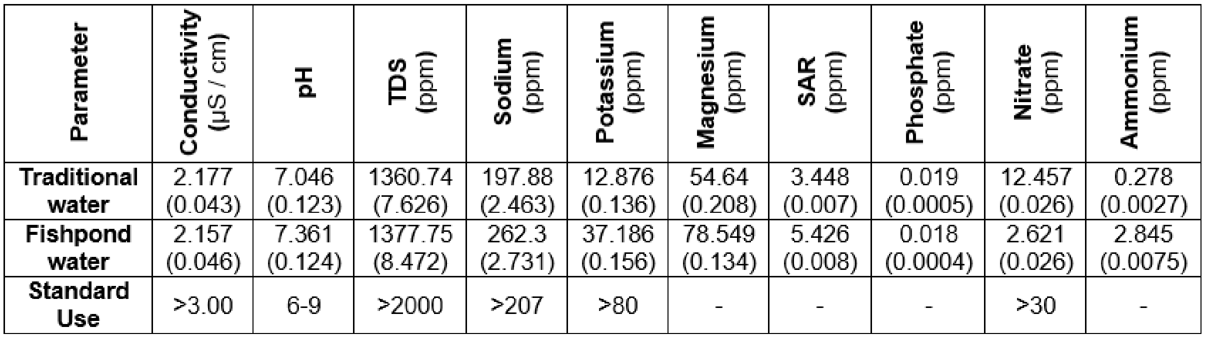
2.4 Statistical Analyses

A completely randomized block design was used to evaluate the impact of water type, sample location, depth, and soil texture. Soil and water samples were collected, organized in Excel, and analyzed using [8]. The effects of irrigation type, location, depth, and soil texture were assessed by calculating means and standard errors. A t-test compared fishpond water with traditional water, while an F-test analyzed differences in soil components. Additionally, variance analysis examined how climate variables were influenced by seasonal and annual changes from 2000 to 2019.

3. RESULTS

Significant variations in key water quality parameters between traditional water sources and fishponds, which may influence their uses and environmental impacts (Table 1).

Table 1: Estimation of averages and standard errors for some water components (traditional and Fishponds) used in the study site



Parameter	Conductivity (µS / cm)	pH	TDS (ppm)	Sodium (ppm)	Potassium (ppm)	Magnesium (ppm)	SAR (ppm)	Phosphate (ppm)	Nitrate (ppm)	Ammonium (ppm)
Traditional water	2.177 (0.043)	7.046 (0.123)	1360.74 (7.626)	197.88 (2.463)	12.876 (0.136)	54.64 (0.208)	3.448 (0.007)	0.019 (0.0005)	12.457 (0.026)	0.278 (0.0027)
Fishpond water	2.157 (0.046)	7.361 (0.124)	1377.75 (8.472)	262.3 (2.731)	37.186 (0.156)	78.549 (0.134)	5.426 (0.008)	0.018 (0.0004)	2.621 (0.026)	2.845 (0.0075)
Standard Use	>3.00	6-9	>2000	>207	>80	-	-	-	>30	-

µS / cm = microsiemens per centimeter; ppm=parts per million, it is equivalent to 1 milligram per liter (mg/L) for water-based solutions;

Values in parentheses represent standard errors. The T-test results show no significant conductivity, pH, phosphate differences between traditional and fishpond systems. However, significant differences were found in sodium, potassium, magnesium, Sodium Adsorption Ratio (SAR), nitrate, and ammonium, indicating marked changes in water chemistry in fishponds for these components. TDS shows a slight but non-significant variation (Table 2).

Table 2: Presents T-test estimates comparing water components between traditional and fishponds at the study site

Water Components	Conductivity (µS / cm)	pH	TDS (ppm)	Sodium (ppm)	Potassium (ppm)	Magnesium (ppm)	SAR (ppm)	Phosphate (ppm)	Nitrate (ppm)	Ammonium (ppm)
T-test	0.30	-1.80	-1.47	-18.4	-120.7	-93.4	-169.5	0.97	259.4	-309.5
Probability	0.763	0.075	0.144	0.001	0.001	0.001	0.001	0.335	0.001	0.001

µS / cm = microsiemens per centimeter; ppm=parts per million, it is equivalent to 1 milligram per liter (mg/L) for water-based solutions;

SAR = Sodium Adsorption Ratio.

Table (3) outlines soil component averages, highlighting conductivity, pH, phosphate, potassium, organic matter, and nitrate, with the soil mainly consisting of clay and silt. The ranges reflect variability across the site.

Table 3: Estimation of averages and standard errors for some soil components used in the study site

Soil Components	Conductivity (µS / cm)	pH	Phosphate (ppm)	Potassium (ppm)	Organic Matter (%)	Nitrate (ppm)	Clay (%)	Silt (%)	Sand(%)
Estimates	3.334 (0.043)	7.858 (0.034)	15.374 (0.227)	417.326 (6.052)	1.045 (0.015)	0.222 (0.010)	51.43 (0.30)	39.56 (0.26)	8.83 (0.16)
Ranges	0.17-7.13	4.44-10.85	6.85-28.19	170.40-699.48	0.30-2.36	0.01-1.05	25.36-82.98	14.56-72.73	2.03-6.44

µS / cm = microsiemens per centimeter; ppm=parts per million, it is equivalent to 1 milligram per liter (mg/L) for water-based solutions;

Values in parentheses represent standard errors; pH = potential of hydrogen.

Table (4) shows the variance of factors influencing soil components (EC, pH, P, K, OM, and N). Water type, location, sample depth, and soil texture all show significant effects.

Table 4: Analysis of variance for some factors affecting the EC, pH, P, K, OM, and N of the soil used in the study site

Soil components / **Factors**	**EC**	**pH**	**P**	**K**	**OM**	**N**
	Means of squares					
Water type (traditional -fishponds**)**	395.61**	7.360**	21362.67**	8042982.23**	5.42**	15.37**
Location (east-west**)**	21.57**	11.696**	8100.57**	5386103.94**	49.05**	2.19**
Sample depth (60-90) cm	53.99**	6.847**	32.26**	1448996.22**	18.82**	0.12*
Soil texture (clay-silt**)**	87.98**	5.174**	165.14**	1131097.97**	12.92**	6.88**
Random error	0.577	0.823	4.010	875.71	0.035	0.025

** = high significant; * = significant; C = Conductivity; pH = potential of hydrogen; P = Phosphate;

K = Potassium; OM = Organic matter; N = Nitrate.

Table (5) presents the analysis of variance for soil texture, showing the mean square values for clay, silt, and sand percentages. Significant differences were observed in the silt and sand percentages, while no significant difference was found for clay.

Table 5: Analysis of variance for the texture of the soil used in the study site.

Soil components / Soil texture	clay%	silt%	sand%
	Means of Squares		
clay-Silt	65.310^{ns}	626.155**	173.826**
Random error	65.343	48.923	18.299

** = high significant; ns = non-significant.

Table (6) presents the variance analysis for climate elements at the study site. It demonstrates significant monthly variation for all climate factors. Yearly differences significantly affect temperature and humidity but do not affect rainfall significantly.

Table 6: Analysis of variance for some climate elements at the study site

Climate elements / Factors	RF	Tem	HTem	LTem	RH
	Means of squares				
Years	500.02^{ns}	6.96^{**}	12.40^{**}	19.15^{**}	62.44^{**}
Months	14379.52^{**}	778.77^{**}	892.07^{**}	944.25^{**}	678.82^{**}
Random error	538.98	1.92	6.12	4.39	16.23

RF= Rainfall; Tem= Temperature; HTem = Highest Temperature; LTem = Lowest Temperature;

RH = Relative Humidity. ** = high significant; ns = non-significant.

Figure (2) shows that temperatures rise from January to peak at around 30°C in July and August before declining. Precipitation is generally low but increases significantly from October to January, peaking in December and January. Figure (3) illustrates monthly rainfall trends from 2000 to 2019, showing large fluctuations with irregular rises and falls. The trend line indicates a slight, non-significant downward trend, with values remaining around a stable average. Figure (4) shows annual temperature changes from 2000 to 2019, with fluctuations ranging from high to low. The trend line indicates a slight increase in temperatures over time, despite ongoing annual variability.

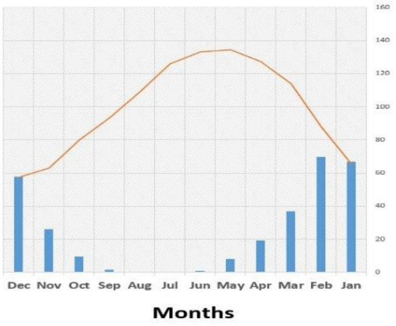


Figure 2: Average monthly rainfall and temperatures during the period 2000-2019

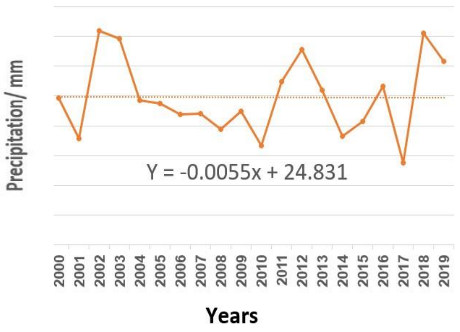


Figure 3: Average rainfall during the period (2000-2019)

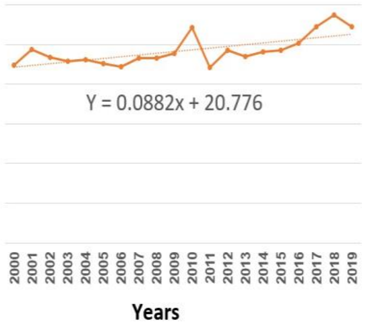


Figure 4: Average temperatures during the period (2000-2019)

4. DISCUSSION

Agricultural water analysis is vital for evaluating water quality, nutrients, and salinity, which boosts irrigation efficiency and plant health, leading to higher crop productivity [9]. Traditional water has higher EC, P, and N levels, with a lower pH, TDS, Na, K, Mg, SAR, and NH_4 than fishpond water (Table 1). The T-test shows significant differences in Na, K, Mg, SAR, N, and NH_4 levels (Table 2), while EC, pH, TDS, and P are non-significant. Fishpond water is a sustainable irrigation source, improving water quality and leveraging fish waste as fertilizer.

The soil was classified as clayey due to its predominant clay content, with a composition primarily of clay and silt particles rich in minerals and nutrients as shown in Table (3). This diversity underscores the need for tailored management strategies. By understanding these differences, more targeted interventions can be made to improve soil health and enhance crop productivity. Soil assessments show various soil components, providing critical insights for sustainable management practices [10].

Table (4) illustrates that factors such as water type (traditional vs. fishponds), sampling location (east or west), sampling depth (60-90 cm), and soil texture (clay vs. silt) have a significant impact on soil pH, Electrical Conductivity (EC), Phosphate and Potassium content, Soil Organic Matter and Nitrogen levels. Soil pH is essential for nutrient absorption and plant growth, and managing it effectively can enhance fertilization and productivity. The European Commission highlights that soil quality, which includes salts and minerals, affects the application of fertilizers and water, thereby improving plant health and yield [11].

Accurate measurement of soil Phosphorus is essential for plant growth, root development, and fruit formation, as it ensures proper fertilization and boosts agricultural productivity and crop quality. Similarly, Potassium levels, influenced by these factors, are crucial for plant growth, water regulation, root strength, and disease resistance. Proper estimation of potassium enhances fertilization and increases crop production [12]. Organic matter plays a key role in maintaining soil health, enhancing productivity, supporting plant growth, and preserving the environment. Measuring N levels is crucial for optimizing fertilization, as nitrogen is essential for plant growth, protein synthesis, and vegetative development. Accurate assessment of N enhances plant health, increases crop yields, and improves the quality of fruits and seeds [13].

Differences in silt and sand content between soil texture classes were significant, while no difference in clay content (Table 5). Clay improves soil structure by retaining water and providing air space for roots, enhancing plant health. Silt strengthens the soil, boosts water retention, and improves nutrient availability, while sand enhances aeration and drainage, reducing waterlogging and supporting root activity [14]. Understanding these soil components aids farmers in optimizing soil management, leading to better irrigation, fertilization, and overall agricultural production.

Climate element analysis identifies significant statistical variations in precipitation and temperature, with annual and monthly fluctuations. Monthly variations were found to have a statistical impact than annual variations (Table 6). This analysis detailed information on climate trends, highlighting the significant impact of monthly variations on weather conditions in the study area. Information climate provides valuable insights into observed climate patterns [15].

Figure (2) illustrates climate trends in Irbid Governorate, Jordan from 2000 to 2019, focusing on average monthly rainfall and temperatures. The data reveals notable variations that suggest a link between these factors and the potential influence of climate change on the local environment.

Figure (3) highlights fluctuations in rainfall patterns, showing some years with abnormally high or low rainfall, though overall annual rates remain stable. Figure (4) shows a gradual long-term temperature increase during the same period.

These figures provide a comprehensive view of the shifting climate patterns in Irbid Governorate, Jordan during this period. The observations point to increased rainfall intensity within shorter periods and changes in the timing of rainy seasons, likely influenced by climate change. Didovets et al., [16] call attention to the urgent need for coordinated climate action to address these emerging issues.

4.1 The Effect of high temperatures on the components of fishpond water.

Sodium levels in fishpond water are significantly higher than in traditional irrigation water (262.3). Elevated temperatures increase sodium levels due to evaporation, fish metabolism, and chemical reactions. High sodium content can enhance sodium availability in plants irrigated with fishpond water [17], [18].

Potassium levels in fishpond water are significantly higher than in traditional irrigation water (37.186). Elevated temperatures further increase potassium levels due to evaporation and algal growth. High potassium levels can pose risks to fish, making it crucial to monitor and adjust them [19].

Magnesium levels are significantly higher in fishpond water compared to traditional irrigation water (78.549). Elevated temperatures increase magnesium solubility, which can influence both the aquatic environment and fish health [20].

Fishpond water typically has a higher Sodium Absorption Ratio (SAR) than traditional irrigation water, averaging 5.426. This increase in SAR is attributed to elevated temperatures in fishponds, which lead to higher concentrations of dissolved minerals. To ensure effective management, it is important to monitor and regulate temperature, sodium levels, and algal growth, thereby maintaining SAR within safe limits [21], [22].

The concentration of nitrogen in fishpond water is significantly higher than in traditional irrigation water (2.621). Elevated temperatures stimulate bacteria that produce nitrate-nitrogen, leading to reduced water quality, increased disease risk, and slower growth rates [23].

Ammonium levels in fishpond water are significantly higher than in traditional irrigation water, averaging 2.845. This increase is associated with elevated temperatures in fishponds, which enhance ammonium-nitrogen production. High ammonium levels can cause fish toxicity, impair growth, and raise disease risk. Thus, managing ammonium levels is crucial for fish health and optimal growth in aquaculture systems [24], [25].

That emphasizes the importance of monitoring and managing water quality in fishponds to ensure optimal conditions for fish health and growth. It highlights the need for effective regulation of temperature, nutrient levels, and algal growth to prevent adverse effects on aquatic ecosystems.

4.2 The effect of high temperatures on the components of agricultural soil.

Fishpond water significantly increases EC due to organic matter, nutrients, salts, and minerals (3.334). Higher temperatures accelerate organic matter decomposition, further influencing EC [26].

The pH of soil irrigated with fishpond water is slightly alkaline (7.858). Increasing temperatures contribute to higher pH levels due to chemical and biological factors [27].

Fishpond water increases phosphorus levels in the soil, particularly under higher temperatures (15.374). This enhances phosphorus availability for plants and influences soil structure [28].

Potassium levels are elevated in fishpond-irrigated soil influenced by temperature (417.326), organic matter decomposition, and other factors [29].

Fishpond water and aquatic life contribute to higher organic matter content in the soil (1.045). Higher temperatures accelerate organic matter breakdown, improving nutrient availability [30].

Nitrate-nitrogen levels are low in fishpond-irrigated soil (0.222), likely due to temperature-influenced microbial activity and nitrogen compound dynamics [31].

Fishpond water may improve soil composition by enhancing root aeration and water availability. However, higher temperatures can affect silt (51.43%) and sand (39.56%) content through drying and clay clumping [32], [33].

That highlights the complex interactions between temperature, fishpond water, and soil properties. Monitoring these factors is crucial for understanding and managing the long-term effects of fishpond water irrigation on soil health and agricultural productivity.

4.3 Using fishpond water for irrigation to boost soil fertility and combat climate change effects

Using fishpond water for irrigation helps mitigate the impacts of climate change on soil fertility by increasing the levels of sodium, potassium, and magnesium in the soil, which enhances its quality and supports agricultural sustainability [34]. The higher sodium absorption capacity in fishpond water improves soil flexibility, reducing the adverse effects of climate change [35]. Additionally, the improved uptake of phosphorus, nitrates, and ammonium from fishpond water contributes to maintaining soil fertility and promoting sustainable agricultural systems [36]. These improvements enhance soil resilience and mitigate climate change effects.

5. CONCLUSIONS and RECOMMENDATIONS

Traditional water exhibits higher conductivity and N levels compared to fishpond water, and its low pH may affect its properties and agricultural use. Fishpond water, as a sustainable irrigation source, provides environmental benefits and essential nutrients for plants.

Soil composition varies, particularly in clay content, emphasizing the need for soil analysis to improve fertilization and land management. pH and EC affect nutrient availability and agricultural quality. Assessing P and K levels boosts productivity, while water type and location affect soil composition. Nutrient assessment is crucial for effective land management and sustainable productivity, with organic matter and N being key to soil health. Soil texture also critically influences soil properties and management strategies.

Rainfall and temperature fluctuate notably across years and months, with monthly variations being crucial in climate effects. From 2000 to 2019, there has been a marked acceleration in changes to both rainfall patterns and temperatures, reflecting the influence of climate change.

This study recommends using fishpond water for sustainable irrigation to mitigate climate change effects. This method provides a reliable water source, enriches soil with nutrients, improves water retention, and boosts plant productivity. It also enhances environmental resilience and supports agricultural sustainability.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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