# EFFECT OF WATER AND NITROGEN MANAGEMENT PRACTICES ON WATER PRODUCTIVITY, AND RICE YIELD IN IRRIGATED RICE, EASTERN TANZANIA

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# EFFECT OF WATER, CROP AND NITROGEN MANAGEMENT PRACTICES ON WATER PRODUCTIVITY, YIELD AND GREENHOUSE GAS EMISSION IN IRRIGATED LOWLAND RICE, EASTERN TANZANIA


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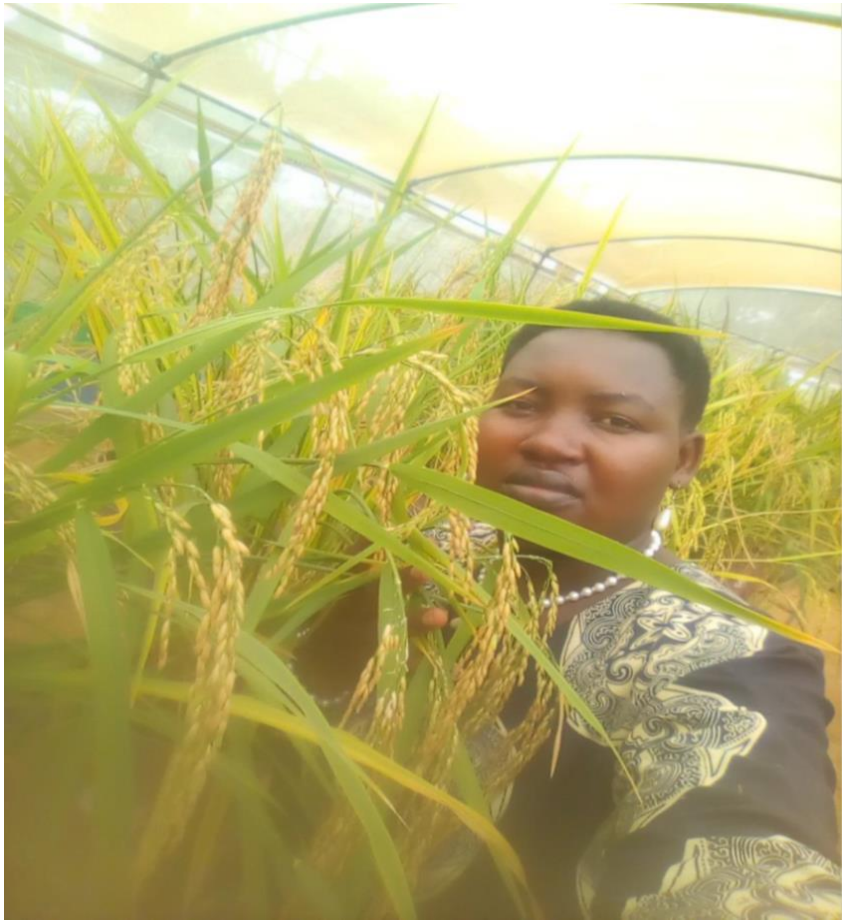


# INTRODUCTION

- Rice (*Oryza sativa* L.) is one of the most important grain crops for more than 50% of the world's population, providing approximately 20% of total energy intake for humans (Muthayya et al., 2014).

- Rice is also the largest consumer of water among all crops (Deng et al., 2021; Bouman and Tuong , 2001).

- The water productivity of rice is lower than those of other crops (Kumar and Rajitha, 2019).

- In Tanzania, about 90% of rice is grown under continuous flooding (CF), a practice that requires large amounts of water with less productivity (Katambara et al 2013; FAO, 2012) and contribute to emission of greenhouse gas emission ( Methane, carbon dioxide and nitrous oxide (Adounkpe et al .,2021).

- Water productivity of rice that ranges from 0.1 to 0.14 kg $m^{-3}$ has been recorded in Tanzania, which is lower when compared to 0.60–1.60 kg $m^{-3}$ in other parts of the world (Najmuddin et al .,2018).

- On average, 2500 liters of water is used, ranging from 800 liters to more than 5000 liters to produce one kg of rice (Najmuddin et al .,2018;Bouman and Tuong 2001).

# Introduction

- By 2025, 15–20 million ha of irrigated rice is estimated to suffer from some degree of water scarcity (Bouman and Tuong, 2001).

- Alternate wetting and drying (AWD) irrigation practice has been demonstrated to provide advantages in terms of reducing water use and increasing crop productivity.

- In addition to water, nitrogen is one of the most important nutrients that determine rice yields (Zhang et al., 2021, Djaman et al., 2018; Saito et al., 2015); its deficiency is a limiting factor for sustainable rice production.

- However, the use of N fertilizer is generally inefficient, and the average apparent recovery efficiency of N fertilizer is about 33% for rice globally (Zhang et al., 2021).

# Objectives

- To evaluate the effect of alternate wetting and drying vs continuous flooding water management practices and nitrogen fertilization on paddy growth, yield and water productivity.

- To assess the effect of crop management practices and nitrogen fertilization on rice productivity and nitrogen use efficiency.

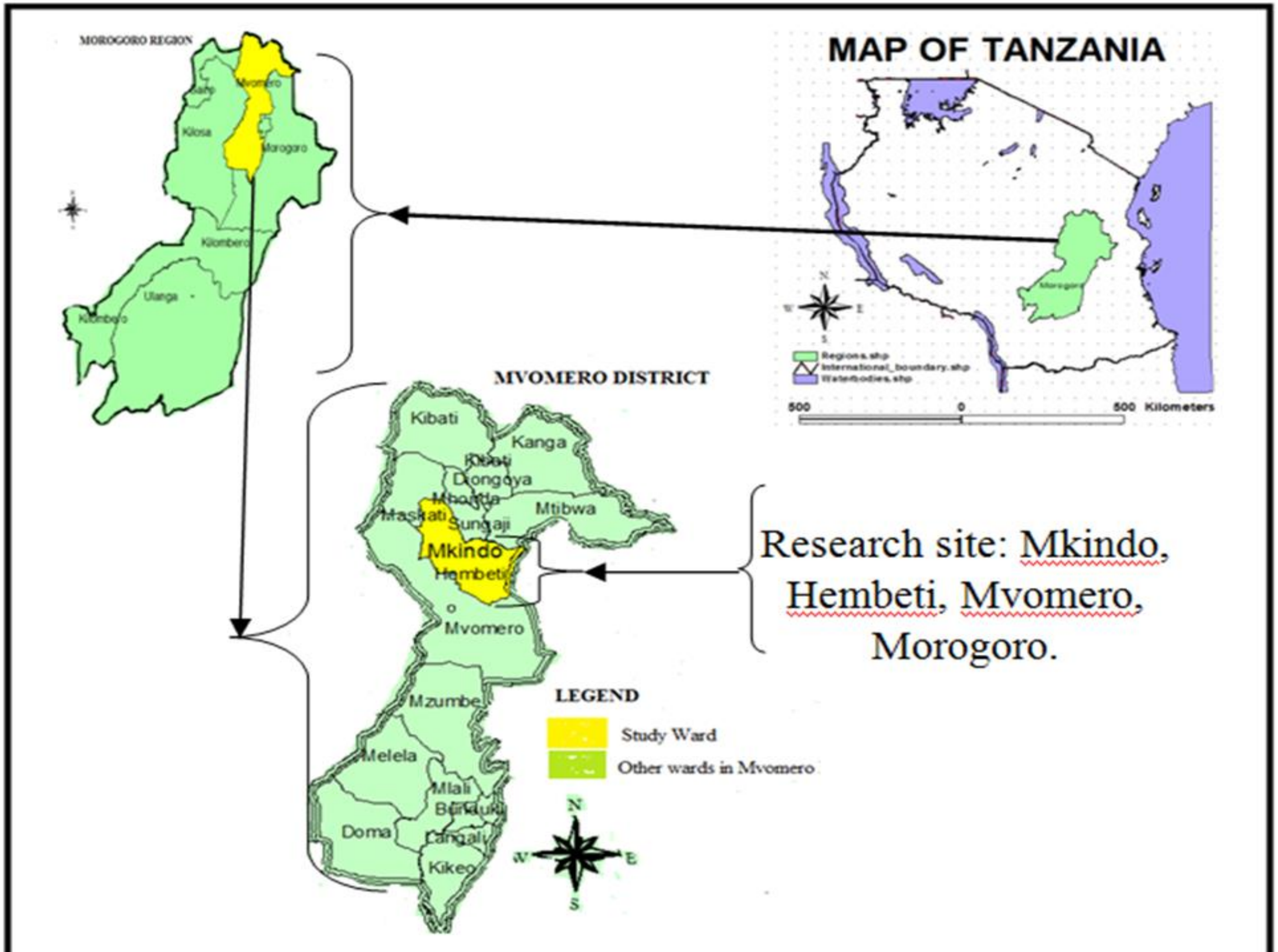
- To evaluate the mitigation potentials of crop management practices on greenhouse gas emission.

- To assess the impact of crop management practices and nitrogen fertilization on nutrients uptake and grains quality

Objective 1.

**To evaluate the effect of alternate wetting and drying vs continuous flooding water management practices and nitrogen fertilization on paddy growth, yield and water productivity.**

# Methodology



- The greenhouse pot experiment involving soil collected from Mkindo farmer-managed irrigation scheme located in Eastern Tanzania was conducted

- **Table 1. Treatment details**

| Treatment combinations | Water management | Nutrient application rates | | | | | |
|---|---|---|---|---|---|---|---|
| | | kg $ha^{-1}$ | | | g $pot^{-1}$ | | |
| | | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| AWD + ABC | Alternate wetting and drying | 0 | 0 | 0 | 0 | 0 | 0 |
| AWD + N0 | | 0 | 60 | 60 | 0 | 9.56 | 3.84 |
| AWD + N60 | | 60 | 60 | 60 | 4.17 | 9.56 | 3.84 |
| AWD + N90 | | 90 | 60 | 60 | 6.26 | 9.56 | 3.84 |
| AWD + N120 | | 120 | 60 | 60 | 8.35 | 9.56 | 3.84 |
| AWD + N150 | | 150 | 60 | 60 | 10.44 | 9.56 | 3.84 |
| CF + ABC | Continuous flooding | 0 | 0 | 0 | 0 | 0 | 0 |
| CF + N0 | | 0 | 60 | 60 | 0 | 9.56 | 3.84 |
| CF + N60 | | 60 | 60 | 60 | 4.17 | 9.56 | 3.84 |
| CF + N90 | | 90 | 60 | 60 | 6.26 | 9.56 | 3.84 |
| CF + N120 | | 120 | 60 | 60 | 8.35 | 9.56 | 3.84 |
| CF + N150 | | 150 | 60 | 60 | 10.44 | 9.56 | 3.84 |

# Water management

- The irrigation water treatments comprised two water regimes, alternate wetting and drying (AWD) and continuous flooding (CF) (main factor)
- In AWD, irrigation water was applied to maintain the soil at a saturated condition instead of ponding.

- Irrigation was applied 1–3 days after the disappearance of water from the soil surface.

- Continuously- flooded pots were given water to maintain a ponded water layer of 1–5 cm depth during the entire vegetative stage until one week before harvest.

# Results

## Table 2. Water use, percentage water saved, water productivity, and number of irrigation.

| Treatment | Water use (L pot$^{-1}$) | Number of irrigation (n) | Water productivity (kg kg m$^{-3}$) | Equivalent amount used to produce 1 kg of rice (L kg$^{-1}$) | (%) Water saved relative to CF (%) |
|---|---|---|---|---|---|
| **Water management** | | | | | |
| AWD | 62.4 | 25.6 | 1.2 | 781 | −2 |
| CF | 61.2 | 25.9 | 1.1 | 868.1 | |
| L.S.D (p = 0.05) | NS | NS | NS | | |
| SE | 0.19 | 0.31 | 0.06 | | |
| **N fertilizer levels** | | | | | |
| ABC | 36.7 $^{a}$ | 18 $^{a}$ | 0.6 $^{a}$ | 1683.5 | |
| 0 N | 36.4 $^{a}$ | 19 $^{a}$ | 0.7 $^{a}$ | 1523 | |
| 60 N | 71.8 $^{b}$ | 28 $^{b}$ | 1.4 $^{b}$ | 705.3 | |
| 90 N | 76.2 $^{b}$ | 31 $^{b}$ | 1.3 $^{b}$ | 753.7 | |
| 120 N | 77.8 $^{b}$ | 31 $^{b}$ | 1.3 $^{b}$ | 747.4 | |
| 150 N | 71.8 $^{b}$ | 28 $^{b}$ | 1.4 $^{b}$ | 729.7 | |
| L.S.D (p = 0.05) | 6.89 | 2.72 | 0.28 | | |
| SE | 2.34 | 0.92 | 0.09 | | |
| **Interaction water management × N levels** | | | | | |
| AWD × ABC | 36 $^{a}$ | 17.0 $^{a}$ | 0.6 | 1558.4 | 3.5 |
| AWD ×0N | 37 $^{a}$ | 18.0 $^{a}$ | 0.6 | 1615.7 | −3.4 |
| AWD ×60N | 68 $^{bc}$ | 27.0 $^{bc}$ | 1.5 | 659.6 | 10.2 |
| AWD ×90N | 71.7 $^{cd}$ | 29.0 $^{bcde}$ | 1.4 | 692.8 | 11.2 |
| AWD ×120N | 79.3 $^{de}$ | 32.0 $^{e}$ | 1.4 | 730.2 | −3.9 |
| AWD ×150N | 82.3 $^{e}$ | 31 $^{cde}$ | 1.5 | 696.3 | 34.3 |
| CF× ABC | 37.3 $^{a}$ | 19.0 $^{a}$ | 0.6 | 1810.7 | - |
| CF× 0N | 35.8 $^{a}$ | 19.0 $^{a}$ | 0.7 | 1437.8 | - |
| CF× 60N | 75.7 $^{cde}$ | 30.0 $^{cde}$ | 1.3 | 753.2 | - |
| CF× 90N | 80.7 $^{de}$ | 32.0 $^{e}$ | 1.2 | 817.6 | - |
| CF× 120N | 76.3 $^{cde}$ | 29 $^{bcde}$ | 1.3 | 766.1 | - |
| CF× 150N | 61.3 $^{b}$ | 26.0 $^{b}$ | 1.3 | 780.9 | - |
| SE | 3.02 | 1.23 | 0.13 | | |
| L.S.D (p = 0.05) | 20.16 | 3.603 | NS | | |

# Table 3:Yield characteristics as influenced by water management and nitrogen fertilizer

| Treatment | Panicle weight pot$^{-1}$ (g) | Panicle length (cm) | 1000 grains weight (g) | Straw yield pot$^{-1}$ (g) | Grain yield pot$^{-1}$ (g) | % GY increase due to N application pot$^{-1}$ | Grain harvest index |
|---|---|---|---|---|---|---|---|
| **Water** | | | | | | | |
| AWD | 87.2 | 22.6 | 28.4 | 70.2 | 79.9 | - | 0.5 |
| CF | 70.1 | 21.5 | 27.0 | 65.0 | 70.5 | - | 0.5 |
| L.S.D (p = 0.05) | 5.9 | 0.9 | 1.35 | 1.57 | 8.4 | - | NS |
| SE | 1.78 | 0.15 | 0.28 | 0.26 | 3.44 | | 0.01 |
| **N fertilizer levels** | | | | | | | |
| ABC | 25.3 $^{a}$ | 19.7 $^{a}$ | 27.8 $^{bc}$ | 22.3 $^{a}$ | 21.8 $^{a}$ | - | 0.49 $^{ab}$ |
| 0 N | 28.5 $^{a}$ | 20.6 $^{a}$ | 29.5 $^{d}$ | 28.7 $^{a}$ | 23.9 $^{a}$ | - | 0.45 $^{a}$ |
| 60 N | 108.4 $^{c}$ | 22.4 $^{b}$ | 28.8 $^{cd}$ | 78.8 $^{b}$ | 101.8 $^{b}$ | 425.9 | 0.56 $^{c}$ |
| 90 N | 107.3 $^{c}$ | 22.9 $^{b}$ | 27.8 $^{bc}$ | 93.1 $^{cd}$ | 101.1 $^{b}$ | 423.0 | 0.52 $^{bc}$ |
| 120 N | 106.5 $^{c}$ | 22.9 $^{b}$ | 26.6 $^{ab}$ | 96.9 $^{d}$ | 104.1 $^{b}$ | 435.6 | 0.52 $^{bc}$ |
| 150 N | 96.0 $^{b}$ | 23.7 $^{b}$ | 25.9 $^{a}$ | 85.9 $^{bc}$ | 98.4 $^{b}$ | 411.7 | 0.53 $^{bc}$ |
| L.S.D (p = 0.05) | 10.24 | 1.59 | 1.43 | 9.09 | 14.32 | - | 0.05 |
| SE | 3.53 | 0.54 | 0.5 | 3.08 | 4.85 | | 0.02 |
| **Interaction (W×N)** | | | | | | | |
| AWD × ABC | 26.6 $^{a}$ | 19.6 | 28.3 | 22.9 $^{a}$ | 23.1 | - | 0.5 |
| AWD ×0N | 26.5 $^{a}$ | 20.9 | 30.8 | 27.6 $^{a}$ | 22.9 | - | 0.4 |
| AWD ×60N | 111.0 $^{de}$ | 23.1 | 28.8 | 76.9 $^{b}$ | 103.1 | 450.2 | 0.6 |
| AWD ×90N | 112.5 $^{de}$ | 23.6 $^{d}$ | 28.2 | 91.5 $^{cd}$ | 103.5 | 452.0 | 0.5 |
| AWD ×120N | 118.2 $^{ef}$ | 24.5 | 27.2 | 100.2 $^{d}$ | 108.6 | 474.2 | 0.5 |
| AWD ×150N | 128.3 $^{f}$ | 23.8 | 27.2 | 102.2 $^{d}$ | 118.2 | 516.2 | 0.5 |
| CF× ABC | 24.1 $^{a}$ | 19.8 | 27.3 | 21.7 $^{a}$ | 20.6 | - | 0.5 |
| CF× 0N | 30.5 $^{a}$ | 20.3 | 28.3 | 29.8 $^{a}$ | 24.9 | - | 0.5 |
| CF× 60N | 105.8 $^{cde}$ | 21.8 | 28.7 | 80.6 $^{bc}$ | 100.5 | 403.6 | 0.6 |
| CF× 90N | 102.1 $^{cd}$ | 22.2 | 27.3 | 94.7 $^{d}$ | 98.7 | 396.4 | 0.5 |
| CF× 120N | 94.8 $^{c}$ | 21.2 | 26.0 | 93.6 $^{d}$ | 99.6 | 400.0 | 0.5 |
| CF× 150N | 63.6 $^{b}$ | 23.6 | 24.6 | 69.5 $^{b}$ | 78.5 | 315.3 | 0.5 |
| SE | 4.89 | 0.71 | 0.68 | 4.0 | 7.15 | | 0.03 |
| L.S.D (p = 0.05) | 14.48 | NS | NS | 11.75 | NS | - | NS |

NS: not significant; Different letters within the same column indicate a significant difference at $p < 0.05$.

# Results

- Water saving ranged from −2% to 34.3%, in which AWD × 150 recorded the highest water saving (34.3%), followed by AWD × 90 and AWD × 60 (11.2% and 10.2%, respectively). AWD has saved 10-50% reported in different part of the world.

- An equivalent amount of water used to produce 1 kg of rice ranged from 659.6 to 1810.7 L $kg^{-1}$, with the low amount being recorded under AWD × 60 and higher amount recorded under CF× ABC, indicating that AWD saved 87.1 L over CF.

- 800-600 liters is needed to produce one kg of rice if well managed ; farmers on average use 15,000 liters to produce 1 kg of paddy

- Water productivity ranged from 0.6 to 1.5 kg $cm^{-3}$ and was significantly affected by nitrogen levels ($p < 0.05$).

- AWD significantly improved yields ($p < 0.05$) by 13.3%, and the yield ranged from 21.8 to 118.2 g $pot^{-1}$.

- Nitrogen levels had significant effect ($p < 0.05$) on plant height, number of tillers, flag leaf area, chlorophyll content, total tillers, number of productive tillers, panicle weight, panicle length, 1000-grain weight, straw yield, grain yield, and grain harvest index

# Conclusion

The combination of AWD water management and 60 kg N $ha^{-1}$ nitrogen fertilization application was found to be the optimal management, however there was no significant difference between 60 and 90 kg N $ha^{-1}$, in which case 60 kg N $ha^{-1}$ is recommended because it lowers costs and raises net income.

The results showed that less water can be used to produce more rice under alternative wetting and drying irrigation practice

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## Evaluation of Growth, Yield, and Water Productivity of Paddy Rice with Water-Saving Irrigation and Optimization of Nitrogen Fertilization

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