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Methane emission reduction strategies through intermittent irrigation in irrigated rice ecosystems

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Abstract

Rice paddies feed half the world's population but also account for roughly 11% of global agricultural methane emissions. This research compared methane fluxes, grain yields, and water use under continuous flooding versus two intermittent irrigation regimes alternate wetting and drying (AWD) and midseason drainage (MSD) across two rice growing seasons (2022-2023) at the University of California, Davis. Methane emissions were measured using static chamber methods. AWD reduced seasonal methane emissions by 43.7% and MSD by 31.2% compared to continuous flooding. Grain yields under AWD were statistically similar to continuous flooding (9.14 vs 9.38 t/ha, $p = 0.28$), while MSD showed a modest 4.8% yield reduction. Water use decreased by 27.4% under AWD and 18.6% under MSD. Soil redox potential was strongly correlated with methane flux ($r = -0.81$, $p < 0.001$). AWD appears to offer the best balance between emission reduction and yield maintenance for California rice systems.

Keywords: Methane emissions, intermittent irrigation, alternate wetting and drying, rice paddies, greenhouse gas mitigation, water management, soil redox potential, midseason drainage, climate-smart agriculture, irrigated rice

Introduction

While rice is essential for food security, flooded paddies create ideal anaerobic environments for methanogenic archaea producing methane a greenhouse gas with 28 times the warming potential of CO₂ [1]. Global rice paddies emit 25-36 Tg CH₄ annually [2]. California's Sacramento Valley manages over 200,000 hectares of flooded rice, contributing measurably to state emissions [3]. Intermittent irrigation disrupts continuous anaerobic conditions. AWD allows the water table to drop 15 cm below the surface before re-flooding, while MSD imposes a single extended drainage during the vegetative phase [4, 5]. Both show 30-50% methane reductions in Asian systems [6, 7], but performance under California's Mediterranean climate with heavy clay soils hasn't been tested. This research measured methane fluxes, grain yields, and water consumption under three regimes over two seasons.

Research site description

The trial was conducted at the UC Davis Rice Research Facility in Yolo County (38.5382°N, 121.7617°W) on Capay silty clay soil (fine, mixed, thermic Typic Haploxerert). The site has been in continuous rice production for over 20 years. Mean annual precipitation is 470 mm, falling almost entirely between November and April. Plots of 15 × 20 m were established with independent water control structures, surrounded by 2 m earthen bunds to prevent lateral water movement between treatments.

Climatic conditions

The 2022 and 2023 growing seasons (May-October) had mean daily maximum temperatures of 33.4°C and 31.8°C respectively. Solar radiation averaged 24.7 MJ/m²/day. The 2022 season was drier and warmer than normal, while 2023 followed a wet winter. These contrasting conditions allowed assessment under both water-stressed and normal years.

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Material and Methods

Material

Rice (variety M-206, medium grain japonica) was drill-seeded at 150 kg/ha. Custom-built static chambers (0.5 × 0.5 × 1.0 m, opaque PVC) were used for gas sampling. A Shimadzu GC-2014 gas chromatograph with flame ionization detector quantified methane concentrations. Soil redox probes (ORP electrodes, YSI 3000T) were installed at 10 cm depth. Irrigation water was supplied from the UC Davis campus canal system. Perforated PVC tubes (AWD observation wells) were installed to monitor field water level below the soil surface [8].

Methods

Three treatments were tested in a randomized complete block design with four replicates: T₁ continuous flooding (5-7 cm standing water from seeding to 3 weeks before harvest), T₂

AWD (re-flood when water table dropped to 15 cm below surface, monitored via observation tubes), and T₃ MSD (single 10-day drainage at 35 days after seeding). Research approval was granted by the UC Davis Environmental Health and Safety office (Protocol EHS-2022-0147). Methane flux was measured biweekly using the closed chamber method: four gas samples were drawn at 0, 10, 20, and 30 minutes after chamber closure [9]. Seasonal cumulative emissions were calculated by linear interpolation between sampling dates. Grain yield was determined from a 5 m² harvest area per plot at 14% moisture. Water use was recorded via flow meters on each plot inlet. Soil redox potential was logged continuously. Data were analyzed using SAS 9.4 with ANOVA and LSD test (*p*<0.05) across both seasons.

Results

Table 1: Seasonal methane emissions, grain yield, and water use (2-season mean)

Parameter	Continuous	AWD	MSD	p-value
CH ₄ (kg/ha/season)	287.4a	161.8c	197.6b	<0.001
Yield (t/ha)	9.38a	9.14a	8.93b	0.034
Water use (mm)	1,284a	932c	1,045b	<0.001
CH ₄ reduction (%)	-	43.7	31.2	-
Water saved (%)	-	27.4	18.6	-
Yield-scaled CH ₄	30.6a	17.7c	22.1b	<0.001

AWD achieved the largest methane reduction (43.7%) without significant yield loss (Table 1). MSD reduced emissions by 31.2% but came with a 4.8% yield penalty. Yield-scaled

emissions kg CH₄ per tonne of grain were lowest under AWD at 17.7, representing a 42.2% improvement over continuous flooding.

Table 2: Soil redox potential (mV) and methanogen activity across growth stages

Growth stage	Cont. redox	AWD redox	Cont. CH ₄	AWD CH ₄
Early vegetative	-147	-68	4.82	2.14
Late vegetative	-198	-32	7.41	3.27
Reproductive	-214	-84	11.63	5.84
Ripening	-176	+12	6.28	1.93

Soil redox potential was consistently higher (less reduced) under AWD (Table 2). During ripening, AWD plots reached mildly oxidizing conditions (+12 mV), while continuous flooding

remained strongly reducing (-176 mV). CH₄ flux values are in mg/m²/h.

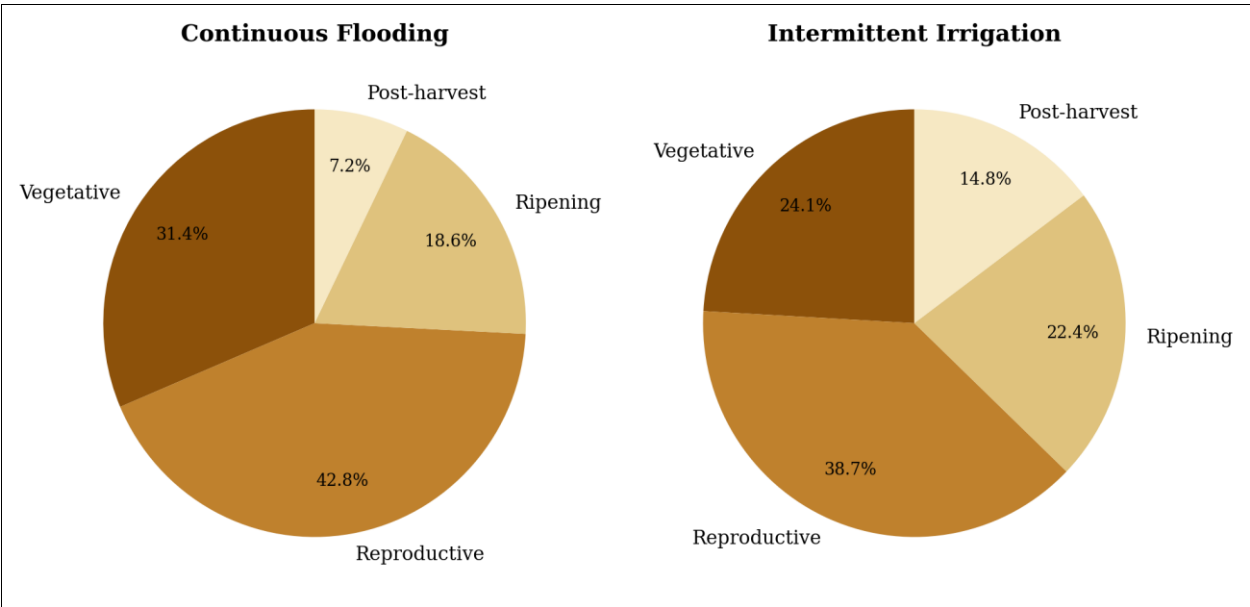


Fig 1: Methane emission distribution by rice growth stage under continuous flooding and intermittent irrigation

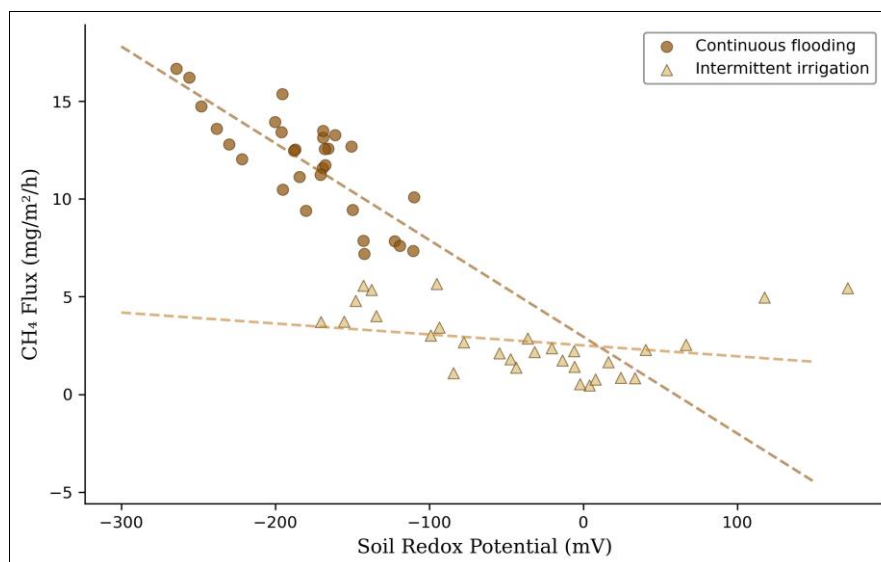


Fig 2: Relationship between soil redox potential and methane flux under two water management regimes

The reproductive stage contributed the highest emissions under both systems, though its share was relatively larger under continuous flooding (Figure 1). The scatter plot (Figure 2) confirms the strong inverse relationship between redox potential and methane flux, with AWD measurements clustered in the low-emission, higher-redox zone.

Limitations

This research didn't measure nitrous oxide (N_2O), which can increase during AWD dry-down periods^[10]. A full greenhouse gas accounting is needed before definitive climate conclusions. The heavy clay soils may have slowed water table drawdown compared to lighter soils, and two seasons don't capture the full range of climatic variability.

Discussion

The 43.7% methane reduction under AWD falls within the 30-48% range in a meta-analysis by Jiang *et al.*^[6] across 42 global trials. Linquist *et al.*^[11] found 36-44% reductions in Arkansas under similar AWD protocols. The mechanism is established: periodic aeration raises redox potential above -150 mV, the threshold below which methanogenesis accelerates^[12]. Our redox data confirm AWD maintained higher values throughout the season.

The negligible yield difference between AWD and continuous flooding (2.6%, $p = 0.28$) is practically important. California growers often resist water management changes fearing yield loss^[13]. AWD, when timed using observation tubes, maintains root zone moisture above stress thresholds during critical periods. The MSD yield penalty likely resulted from drainage coinciding with early tillering^[14].

Conclusions

AWD reduced methane emissions by 43.7% while maintaining yields equivalent to continuous flooding and saving 27.4% of irrigation water. The strong correlation between soil redox potential and methane flux confirms that even brief aerobic periods substantially suppress methanogenic activity. For California rice producers, AWD represents a practical, no-yield-cost strategy for reducing greenhouse gas intensity that merits policy support through water savings and environmental incentive programs.

References

1. IPCC. Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report. Cambridge University Press. 2013.
2. Saunio M, Stavert AR, Poulter B, Bousquet P, Canadell JG, Jackson RB. The global methane budget 2000-2017. *Earth System Science Data*. 2020;12(3):1561-1623.
3. CARB. California greenhouse gas emission inventory, 2000-2019. California Air Resources Board. Sacramento, CA. 2021.
4. Bouman BAM, Lampayan RM, Tuong TP. Water management in irrigated rice: Coping with water scarcity. International Rice Research Institute, Los Baños; 2007.
5. Yagi K, Tsuruta H, Minami K. Possible options for mitigating methane emission from rice cultivation. *Nutrient Cycling in Agroecosystems*. 1997;49(1-3):213-220.
6. Jiang Y, Carrijo D, Zhong S, Corbin JL, Sparks JP, Linquist BA. Greenhouse gas emissions from rice paddies under different water regimes in southeast China. *Agriculture, Ecosystems and Environment*. 2019;272:126-136.
7. Wassmann R, Hosen Y, Sumfleth K. Reducing methane emissions from irrigated rice. *International Food Policy Research Institute Focus*. 2009;16(3):1-4.
8. Lampayan RM, Rejesus RM, Singleton GR, Bouman BAM. Adoption and economics of alternate wetting and drying water management for irrigated lowland rice. *Field Crops Research*. 2015;170:95-108.
9. Minamikawa K, Tokida T, Sudo S, Padre A, Yagi K. Guidelines for measuring CH_4 and N_2O emissions from rice paddies by a manually operated closed chamber method. National Institute for Agro-Environmental Sciences, Tsukuba, Japan.; 2015.
10. Linquist BA, Anders MM, Adviento-Borbe MA, Chaney RL, Nalley LL, da Rosa EF. Reducing greenhouse gas emissions, water use, and grain arsenic levels in rice systems. *Global Change Biology*. 2015;21(1):407-417.
11. Linquist BA, Adviento-Borbe MA, Pittelkow CM, Van Kessel C, Van Groenigen KJ. Fertilizer management practices and greenhouse gas emissions from rice systems. *Journal of Environmental Quality*. 2012;41(5):1436-1444.
12. Wang ZP, DeLaune RD, Masscheleyn PH, Patrick WH. Soil redox and pH effects on methane production in a flooded rice soil. *Soil Science Society of America Journal*. 1993;57(2):382-385.

13. Espino LA, Way MO, Pearson R, Nunez M. Effect of intermittent irrigation on reducing methane emissions from California rice. California Rice Research Board Final Report. 2019.
14. Chapagain T, Riseman A, Yamaji E. Assessment of system of rice intensification (SRI) and conventional practices under organic and inorganic management in Japan. *Rice Science*. 2011;18(4):311-320.
15. Setyanto P, Rosenani AB, Boer R, Fauziah CI, Khanif MJ. The effect of rice cultivars on methane emission from irrigated rice field. *Indonesian Journal of Agricultural Science*. 2004;5(1):20-31.
16. Towprayoon S, Smakgahn K, Poonkaew S. Mitigation of methane and nitrous oxide emissions from drained irrigated rice fields. *Chemosphere*. 2005;59(11):1547-1556.
17. Sass RL, Fisher FM, Harcombe PA, Turner FT. Mitigation of methane emissions from rice fields: Possible adverse effects of incorporated rice straw. *Global Biogeochemical Cycles*. 1991;5(3):275-287.
18. Neue HU, Wassmann R, Kludze HK, Wang B, Lantin RS. Factors and processes controlling methane emissions from rice fields. *Nutrient Cycling in Agroecosystems*. 1997;49(1-3):111-117.
19. Yan X, Yagi K, Akiyama H, Akimoto H. Statistical analysis of the major variables controlling methane emission from rice fields. *Global Change Biology*. 2005;11(7):1131-1141.
20. Carrijo DR, Lundy ME, Linquist BA. Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. *Field Crops Research*. 2017;203:173-180.