Greenhouse gas emissions in US-Mid South rice production under different crop rotation, residue, and irrigation management

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JUSTIFICATION OF THE STUDY

- **Rice** crop contributes to global warming potential (GWP) due to both methane (CH_4) and nitrous oxide (N_2O) emissions.
- **Crop rotation** and management practices such as **residue** or **irrigation management** play a key role on GHG emissions from rice fields (Linquist et al., 2018).
- **Alternate wetting and drying** (AWD) irrigation has been proven to reduce CH_4 emissions (Leavitt et al., 2023), but it can also increase N_2O emissions due to excess fertilizer N inputs (Lagomarsino et al., 2016).
- **Organic amendments** can increase CH_4 emissions due to the addition of a carbon source, however this effect is greatly affected by the type of the organic material added (Penido et al., 2016). Here, we show results from a rice husk amendment experiment that aimed to reduce grain metalloid concentrations and provide stress resilience (Runkle et al. 2021).
- The **goal** of this study was to evaluate the effect on Greenhouse gas (GHG) emissions of:
  - **Crop rotation history**
  - **Irrigation management:** AWD vs. Continuous flooded (CF)
  - **Residue management:** Rice straw incorporation vs. straw burning
  - **Rice husk addition** as an amendment

EXPERIMENTAL DESIGN AND DATA ANALYSIS

Year 2019
2 PAIRED FIELDS (ARKANSAS) SILTY CLAY- CL XL745 cultivar (RR15B fields) and Gemini 214 CL cultivar (RR40I fields)

FIELDS

RR15B-1	RR15B-2	RR40I-1	RR40I-1
Rice-rice +15 yr	Rice-rice +15 yr	Rice-rice +40 yr	Rice-rice +40 yr
Previous residue **burnt**	Previous residue **burnt**	Previous residue **incorp.**	Previous residue **incorp.**
AWD	**AWD**	**AWD**	**CF**
6 plots per field	6 plots per field	6 plots per field	6 plots per field

Year 2022
2 PAIRED FIELDS (ARKANSAS) SILTY CLAY- RTv 7321 MA cultivar

FIELDS

RR15B-1	RR15B-2	RR3B-1	RR3B-2
Rice-rice +15 yr	Rice-rice +15 yr	Rice-rice 3 yr	Rice-rice 3 yr
Previous residue **burnt**	Previous residue **burnt**	Previous residue **burnt**	Previous residue **burnt**
		Husk addition (3 rates)	**Husk addition** (3 rates)
AWD	**AWD**	**AWD**	**CF**
6 plots per field	6 plots per field	2 plots per treat.	2 plots per treat.

- Two paired farmers' fields (side by side, Fig 1.a) in each year were studied in Arkansas.
- GHG fluxes were measured with the closed chamber methodology (Fig1 b-c).
- Fluxes were calculated with linear or nonlinear regression when needed and interpolated to calculate the cumulative emissions for the entire growing season. Emissions were converted to CO_2 eq using IPCC factors and GWP was calculated as the sum from CH_4 and CO_2.
- T-test was used to compared differences between groups at P level= 0.05.

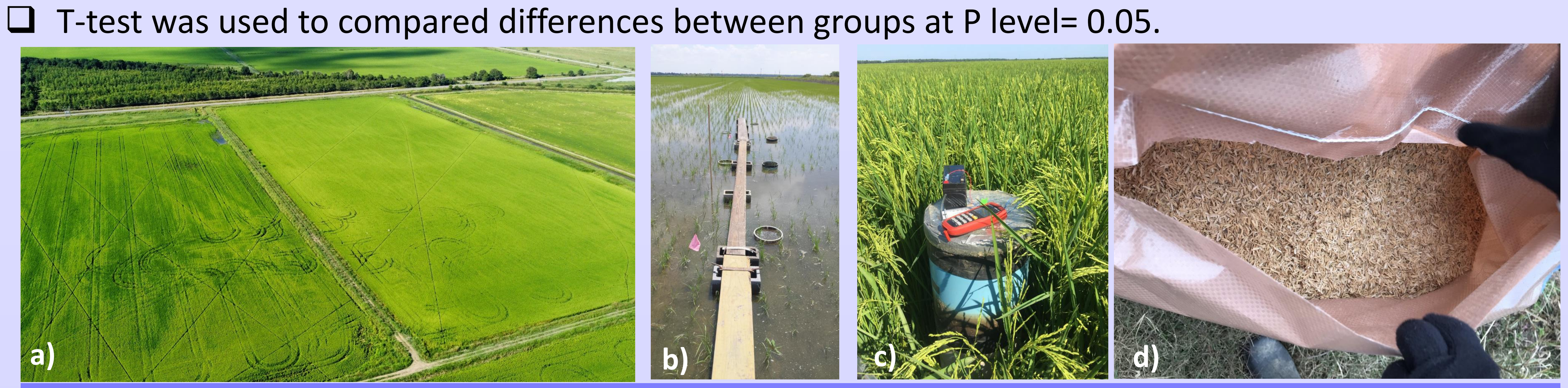

Fig 1. a) Aerial view of study fields in 2022 (RR3B, taken by Harrison Jones), b) experimental plots with PVC collars inserted in the soil, c) closed chamber during gas sampling and d) rice husk used to amend plots.

References:

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- Linquist et al., 2018. Greenhouse Gas Emissions and Management Practices that Affect Emissions in US Rice Systems. J. Env. Quality.
- Penido et al., 2016. Biogeochemical impacts of Si-rich rice residue incorp. into flooded soils: implications for rice nutrition and cycling of As. Plant Soil.
- Runkle et al., 2021. Socio-Technical Changes for Sustainable Rice Production: Rice Husk Amendment, Conservation Irrigation, and System Changes. Front. Agron.

RESULTS

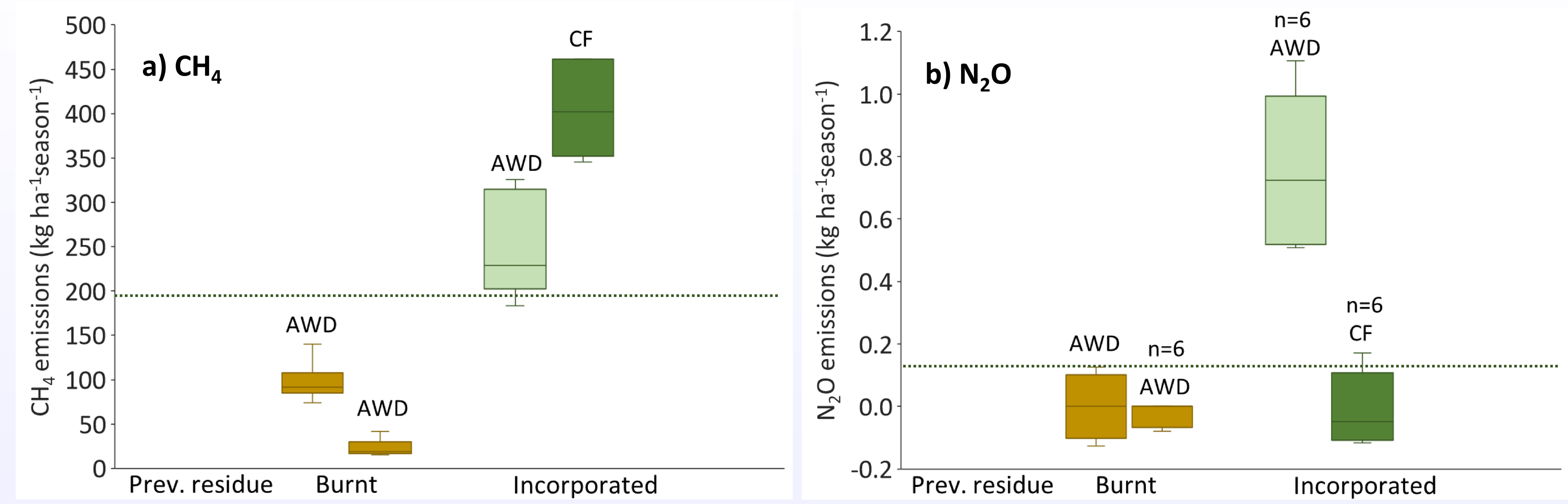

Fig 2. Cumulative CH_4 (a) and N_2O (b) emissions (kg ha^{-1}) over the growing season depending on residue and irrigation management (for the paired fields in 2019). Dashed lines represent the baseline for a flooded field in the US Mid-South (Linquist et al., 2018)

Table 1. GWP (kg CO_2 eq ha^{-1}) for the fields in 2019

Field	Rotation	Residue mgmt.	Water mgmt.	GWP kg CO_2 eq ha^{-1}
RR15B-1	R-R +15 yr	Burnt fall	AWD	619
RR15B-2	R-R +15 yr	Burnt fall	AWD	2,647
RR40I-1	R-R +40 yr	Incorp. Spring	CF	10,998
RR40I-2	R-R +40 yr	Incorp. Spring	AWD	6,946

- ***Significantly higher CH_4 emissions*** were found in fields where ***residue was incorporated*** with a ***decrease*** for the ***AWD*** treatment (Fig 2.a)
- ***N_2O emissions were significantly higher in the AWD*** treatment for the field with residue incorporation (Fig 2. b), however ***it was outweighed by the decrease in CH_4 emissions***, resulting in a ***lower GWP*** than the CF field (Table 1).

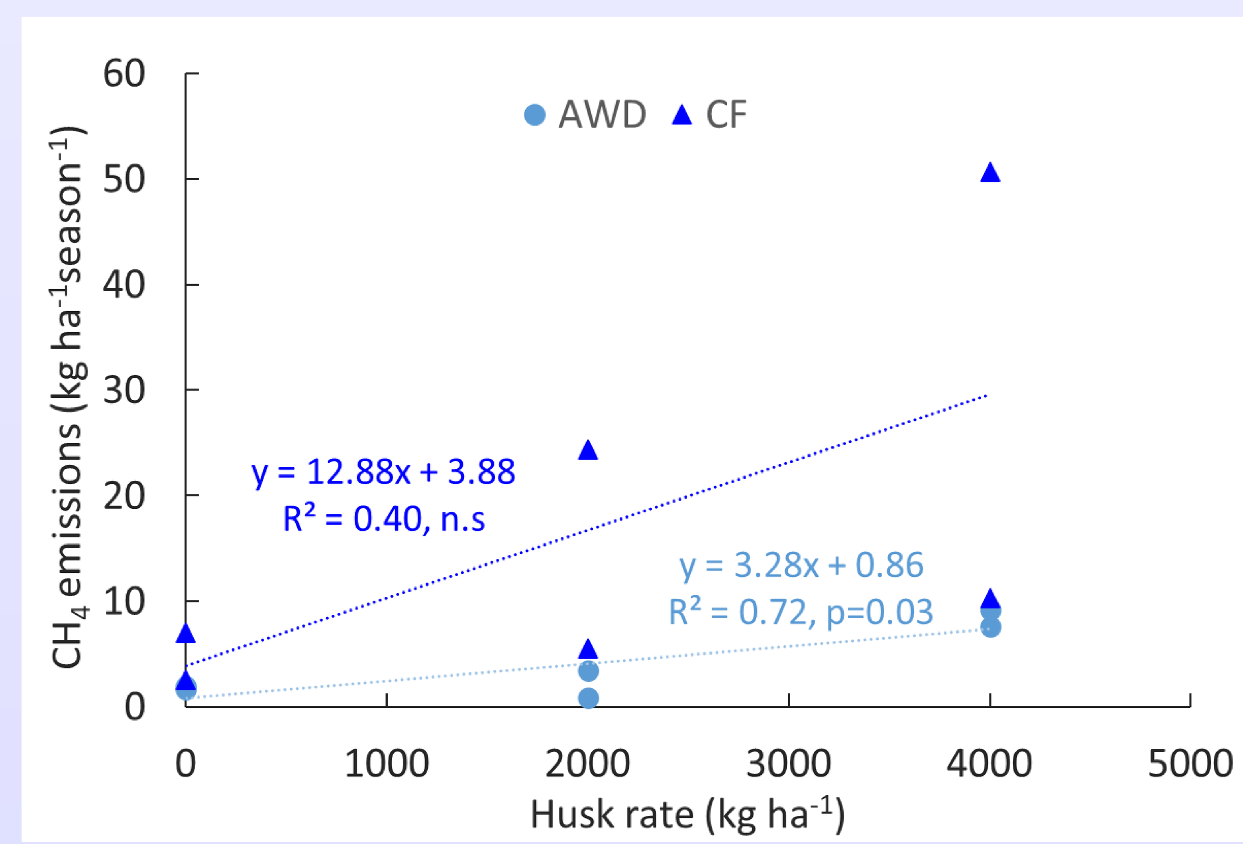

Fig 3. Relationship between cumulative CH_4 emissions and husk rate application for the study in RR3B fields in 2022. There were 2 replicates per each husk rate.

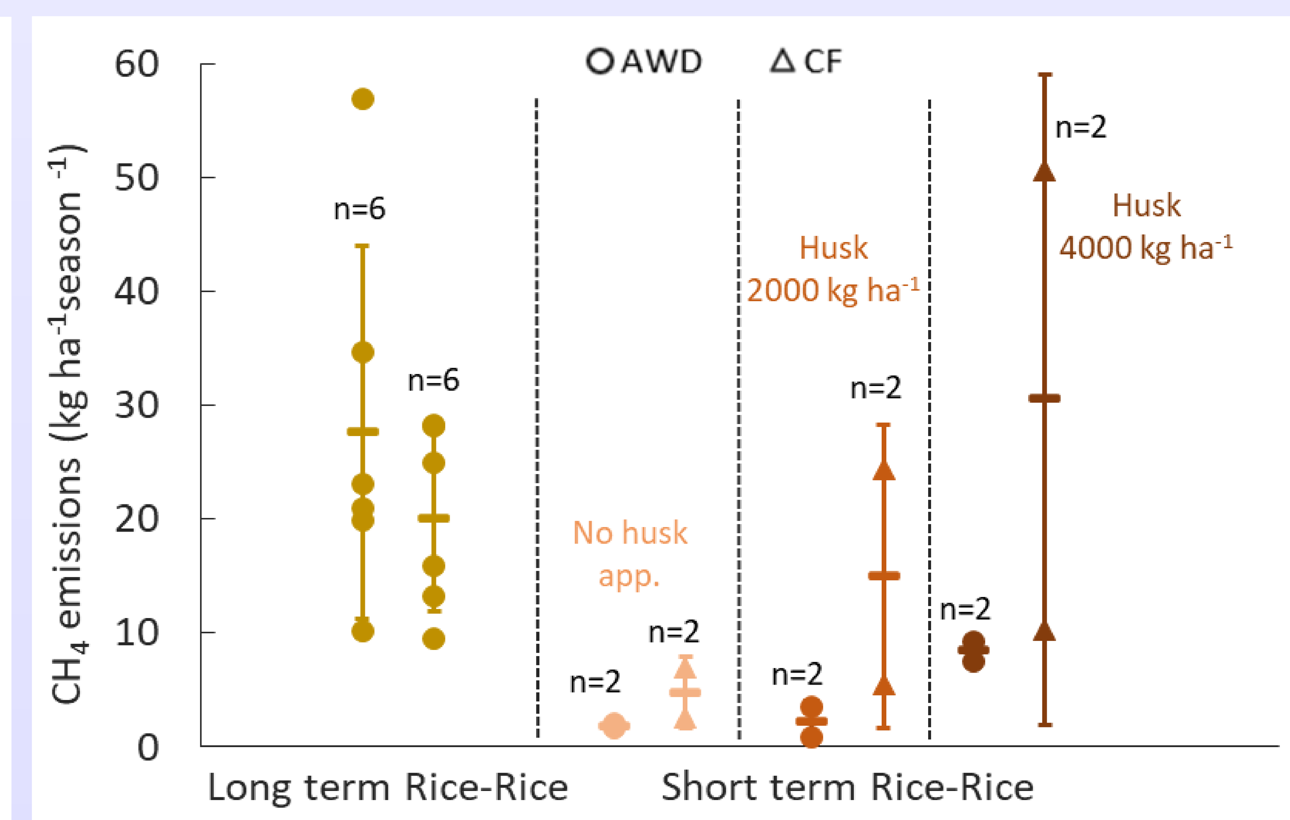

Fig 4. Cumulative CH_4 emissions (kg ha^{-1}) over the growing season depending on the rotation, irrigation mgmt. and husk application (for the paired fields in 2022). The central line represents the mean value, and the error bars show standard deviation.

- There was a ***positive relationship between CH_4 emissions and husk rate***, for both AWD and CF treatments (Fig. 3).
- ***Fields recently converted to R-R rotation*** (without husk amendment) showed significantly ***lower CH_4 emissions*** than fields under long term R-R rotation (Fig. 4).
- Even though husk application increased CH_4 emissions for fields under short-term R-R rotation, the magnitudes were lower than for the fields under long-term R-R rotation for the same water treatment (AWD) (Fig. 4).

CONCLUSIONS AND FUTURE WORK

- Methane emissions were higher when straw was incorporated. Practicing AWD increased the N_2O emissions for the field under straw incorporation, however the decrease in CH_4 emissions allowed to decrease GWP, suggesting that ***AWD is an effective strategy to decrease GWP when organic residues are incorporated to the soil***.
- Fields under ***long-term R-R rotation*** showed ***higher CH_4 emissions*** than fields recently converted to R-R rotation.
- ***Rice husk app. increased CH_4 emissions*** in fields under short-term R-R rotation, but those were still lower than for the long-term R-R rotation. Thus, the application of husk should be tested in experimental fields under long-term R-R rotation.

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