Reduction of Greenhouse Gas Emissions in Rice Production

Walkyria Bueno Scivittaro
Embrapa Temperate Agriculture

Embrapa

XIII Conferencia Internacional de Arroz para América Latina y el Caribe

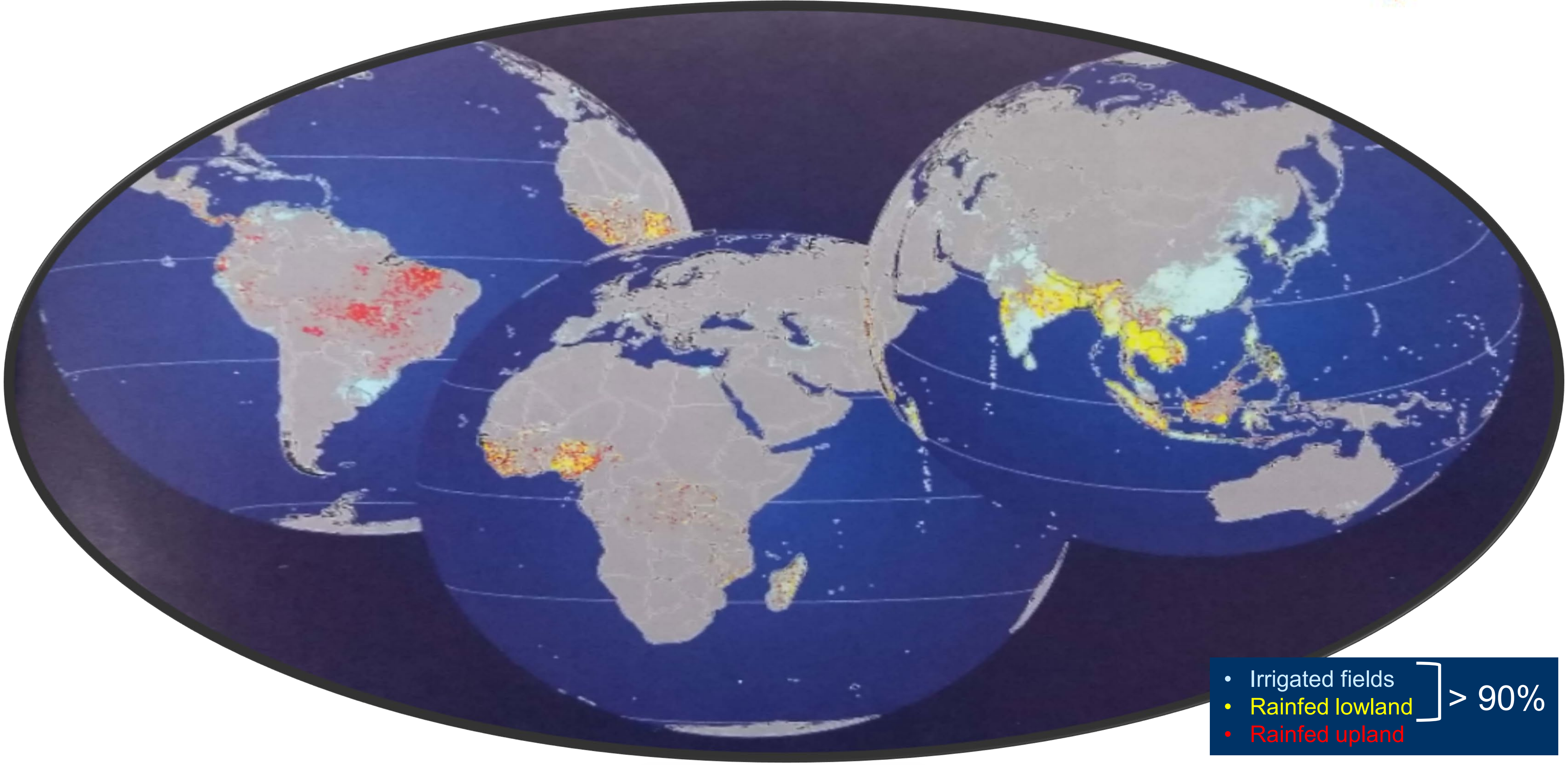
"Alianzas para la sostenibilidad de la producción arrocera"

Mayo 15 al 18, 2018 – Piura, Perú

Rice in the World

- Important cereal crops: half world’s population
- Rice fields area: 160 million ha (11% world’s arable lands)
- World demand: increase 24% next 20 years (productivity and area)
- GHG emissions

Rice Environments: hydrological characteristcs classification



- Irrigated fields
- Rainfed lowland
- Rainfed upland

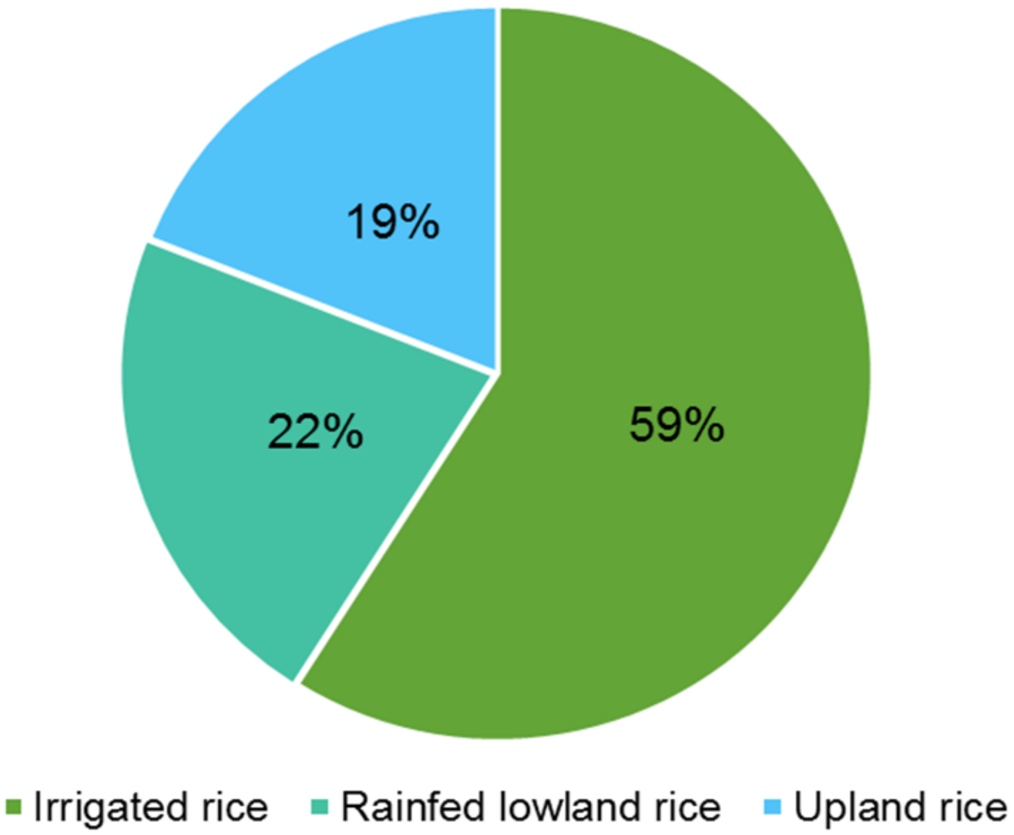
> 90%

CH_4: 30%

N_2O: 11%

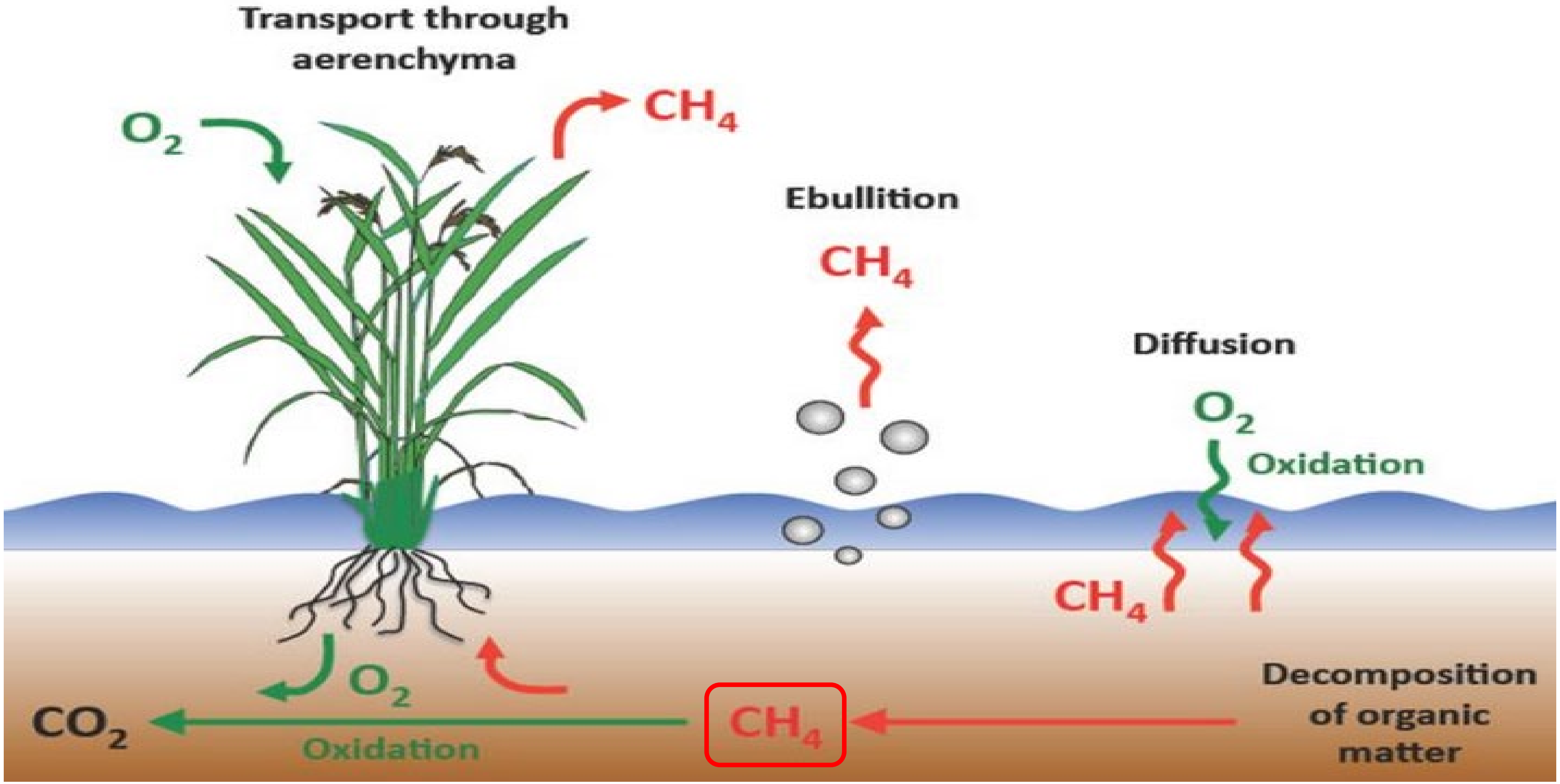
Source: GRiSP (2013)

Rice Production Systems LAC



Source: GRisP (2013)

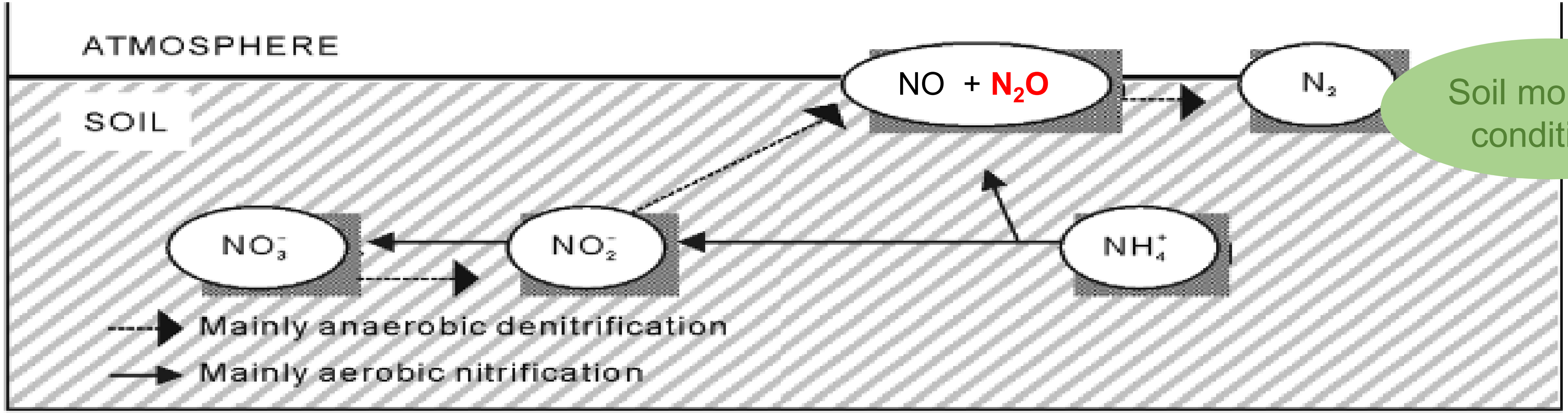
Methane emissions in wetland rice fields



Source: http://www.ibp.ethz.ch/research/environmentalmicrobiology/research/Wetlands

Main processes involved in N_2O release

Fertilizer management

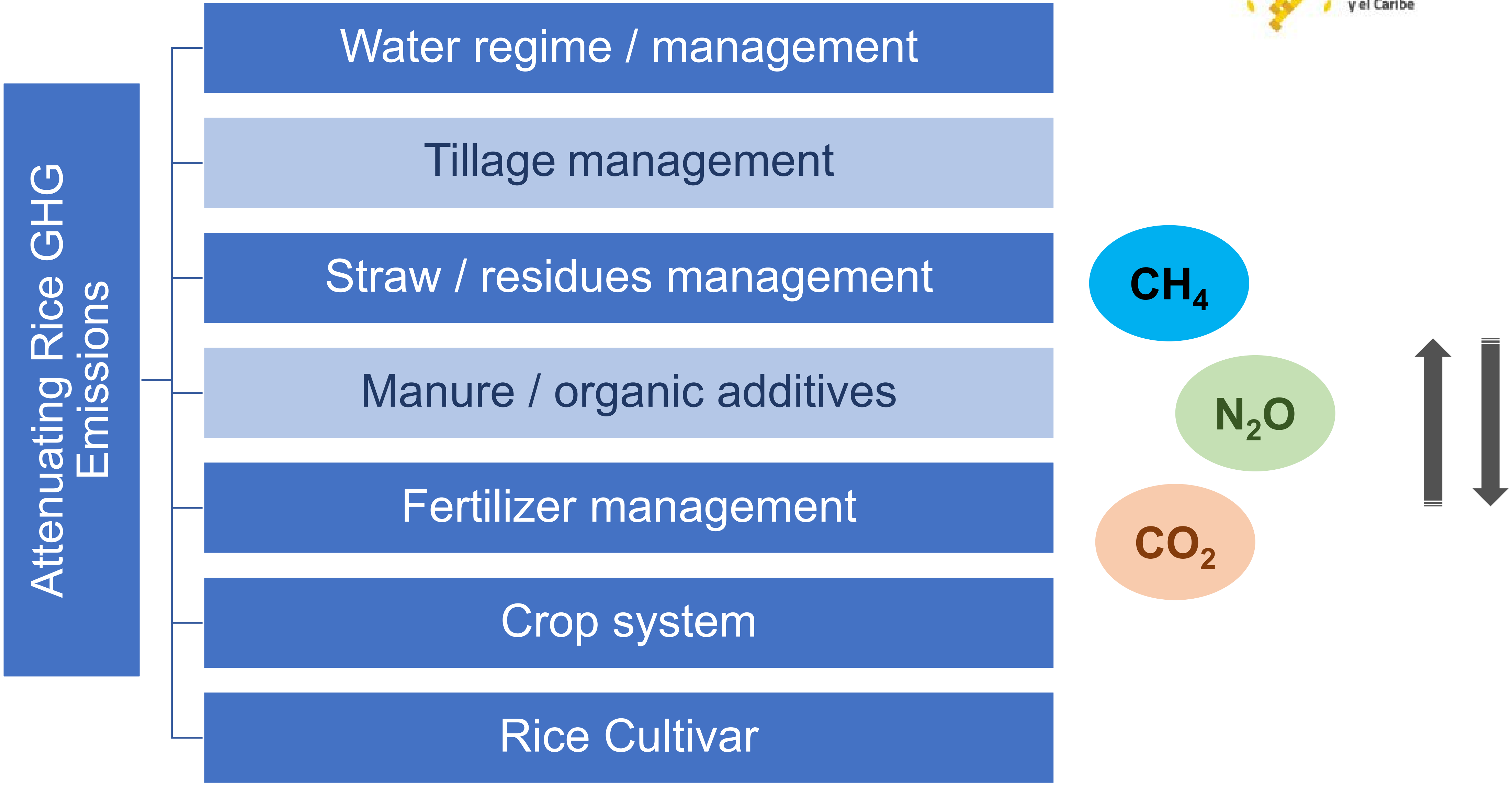


Soil moisture conditions

Adapted from Hénault et al. (2005).

N_2O production
nitrification/denitrification

N_2O emission
Aerobic > Anaerobic



Attenuating Rice GHG Emissions

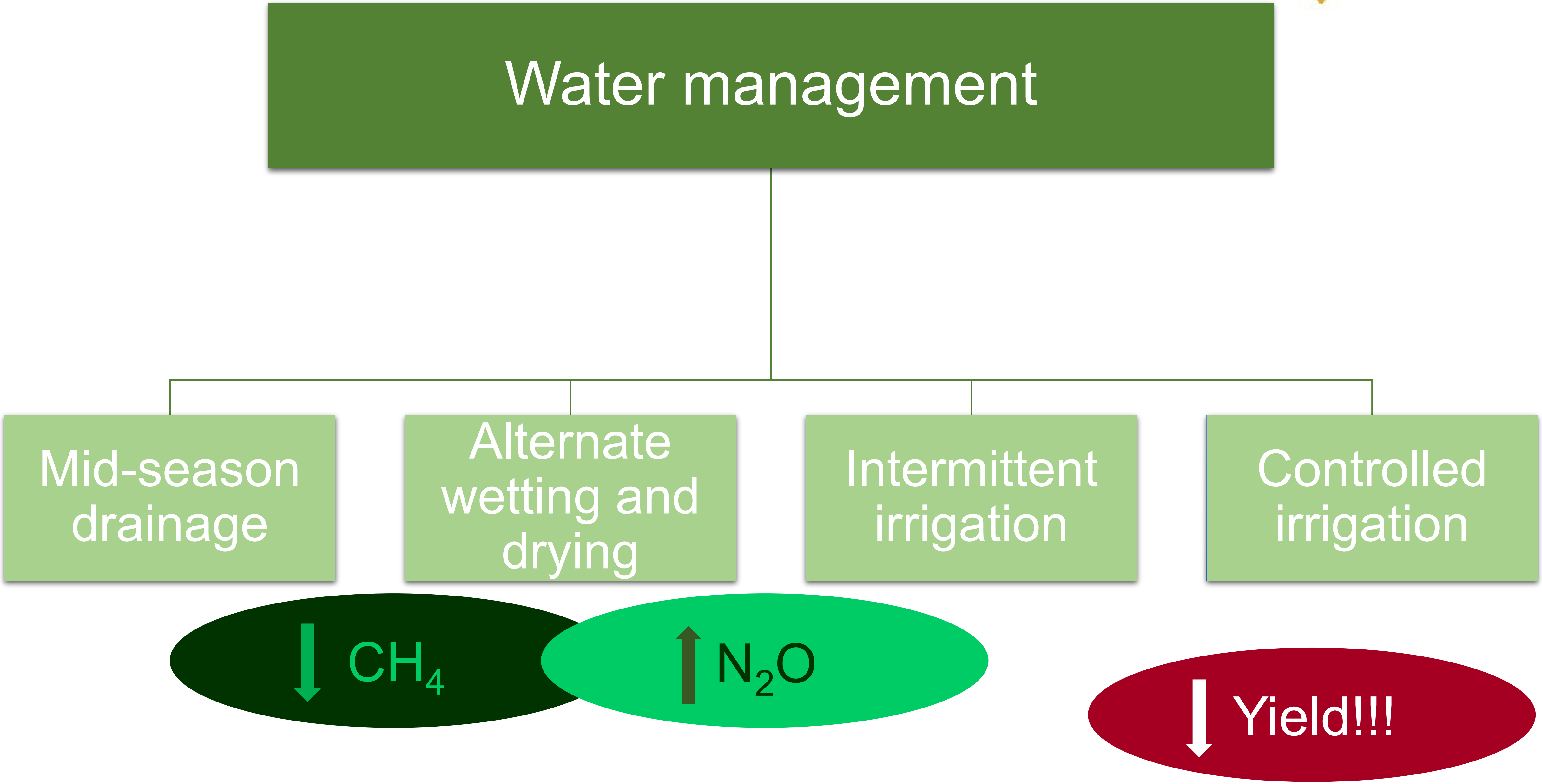
- Water regime / management
- Tillage management
- Straw / residues management
- Manure / organic additives
- Fertilizer management
- Crop system
- Rice Cultivar

CH_4

N_2O

CO_2

Adaptaded from Hussain et al. (2015)



Water management

- Mid-season drainage
- Alternate wetting and drying
- Intermittent irrigation
- Controlled irrigation

↓ CH_4

↑ N_2O

↓ Yield!!!

Water Management Options

- Mid-season drainage: envolve a distinct period of interrupted irrigation during the crop growth phase (usually a short-term drainage 5-20 days – vegetative phase).

- Alternate wetting and drying: is the periodic drying and reflooding of the rice field. Time intervals between dry and wet contions appear to be too short to facilitate the shift from aerobic to anaerobic soil conditions.

- Intermittent drainage/irrigation: involves a repetition of free drainage and irrigation.

- Controlled irrigation: comprises different water-saving managements, as reduction in the period of irrigation (delay flooding and early supression of irrigation), and reduction of water depth (lower water depth, saturation soil) with potential to reduce water use by rice and GHG emissions.

20 - 90%

AWD - multiple drainage

Three year e … ırs of rice) /

pasture (3-4

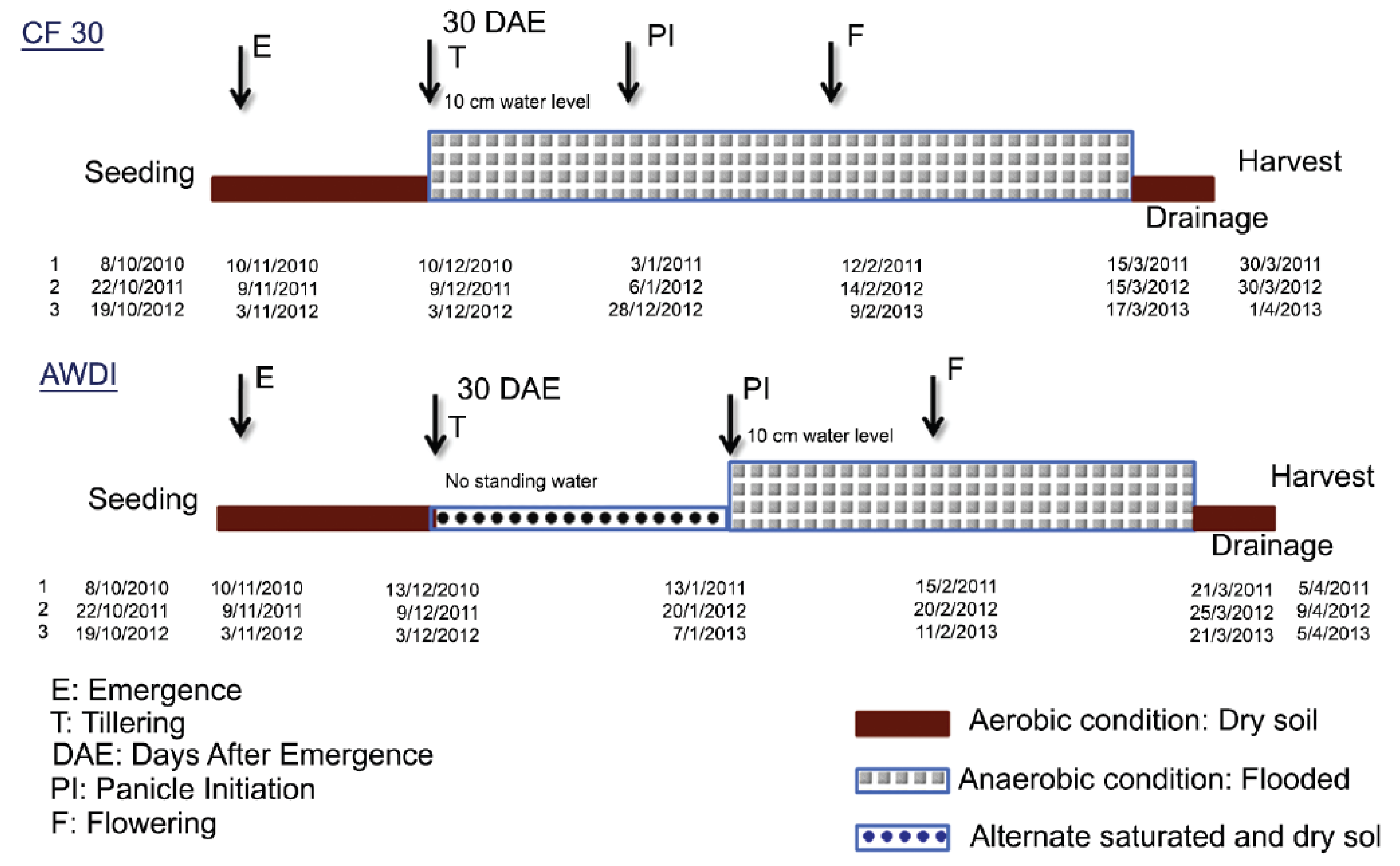
Irrigation trea

- Conventio
- Alternative … in number

  of days aft … This

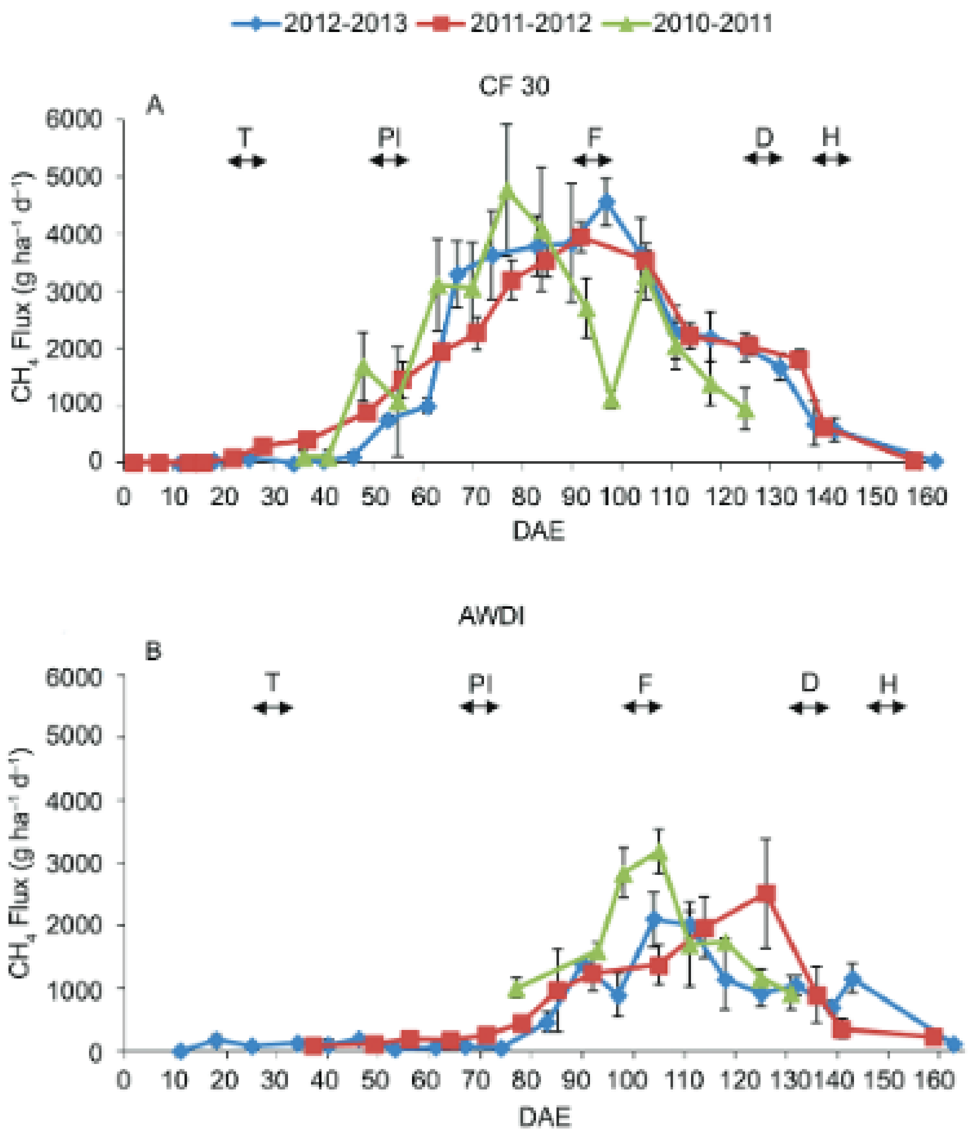
  treatment … 70 DAE),

  when the p … eatment.



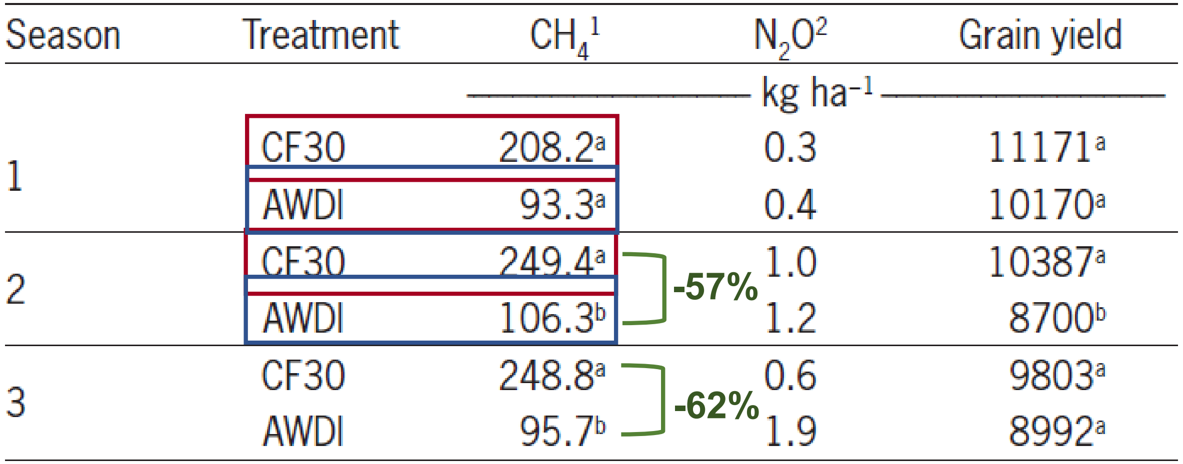
Source: Tarlera et al. (2016).

AWD - multiple drainage



Seasonal CH_4 emissions

Seasonal CH_4 and N_2O emissions and rice grain yield for two irrigation systems and three seasons. Treinta y Tres, Uruguay.

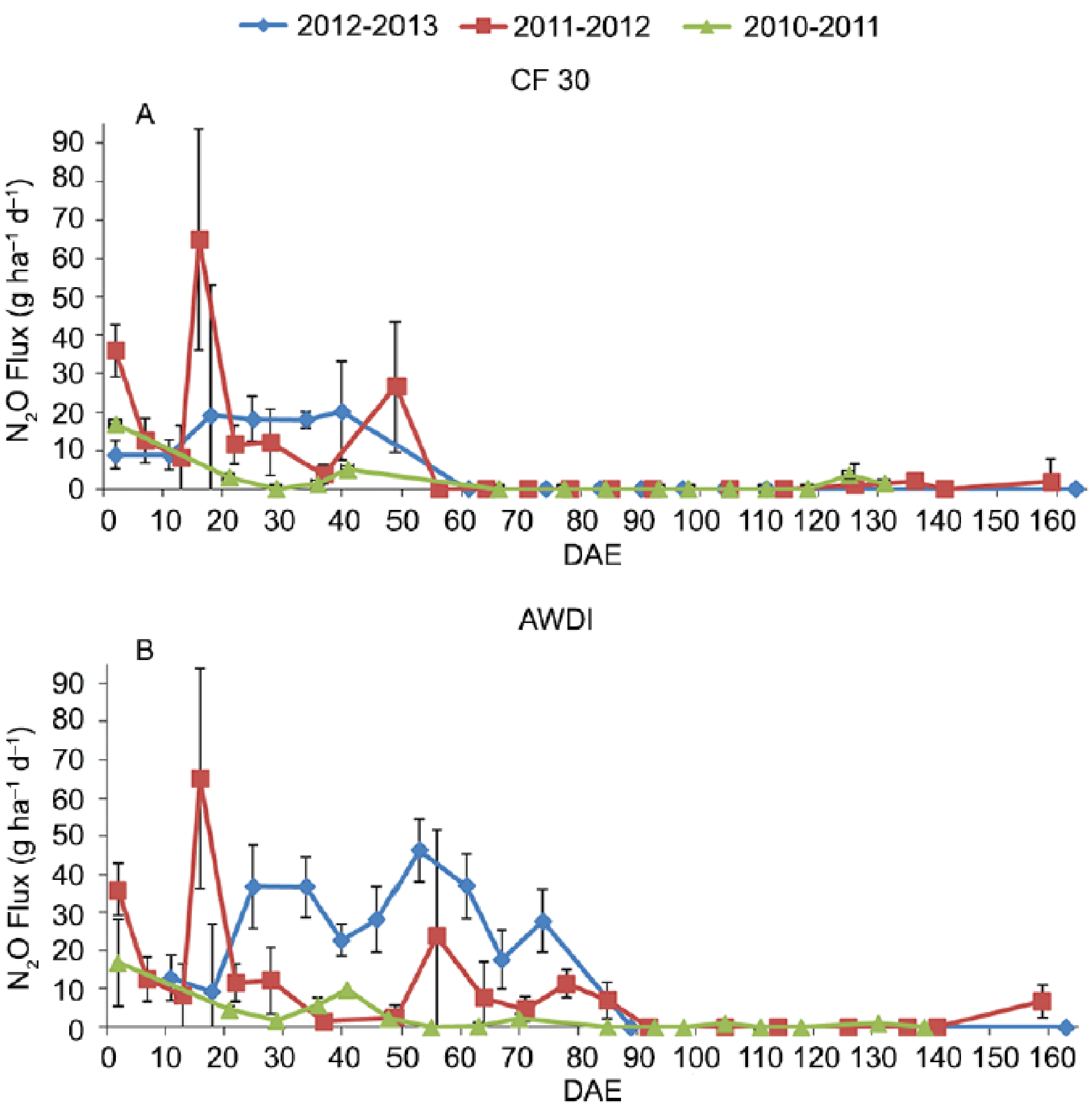


Season	Treatment	$CH_4{}^1$		N_2O^2	Grain yield
		kg ha⁻¹			
1	CF30	208.2^a		0.3	11171^a
	AWDI	93.3^a		0.4	10170^a
2	CF30	249.4^a	-57%	1.0	10387^a
	AWDI	106.3^b		1.2	8700^b
3	CF30	248.8^a	-62%	0.6	9803^a
	AWDI	95.7^b		1.9	8992^a

Different letters indicate diferences between treatments ($p < 0.05$)

Source: Tarlera et al. (2016).

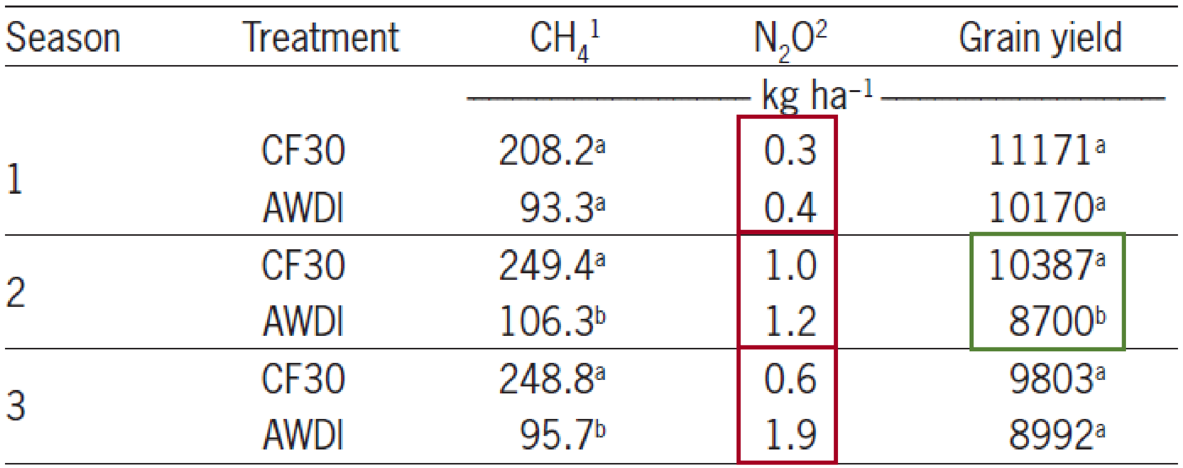
AWD - multiple drainage



Source: Tarlera et al. (2016).

Seasonal N_2O emissions / Rice yields

Seasonal CH_4 and N_2O emissions and rice grain yield for two irrigation systems and three seasons. Treinta y Tres, Uruguay.

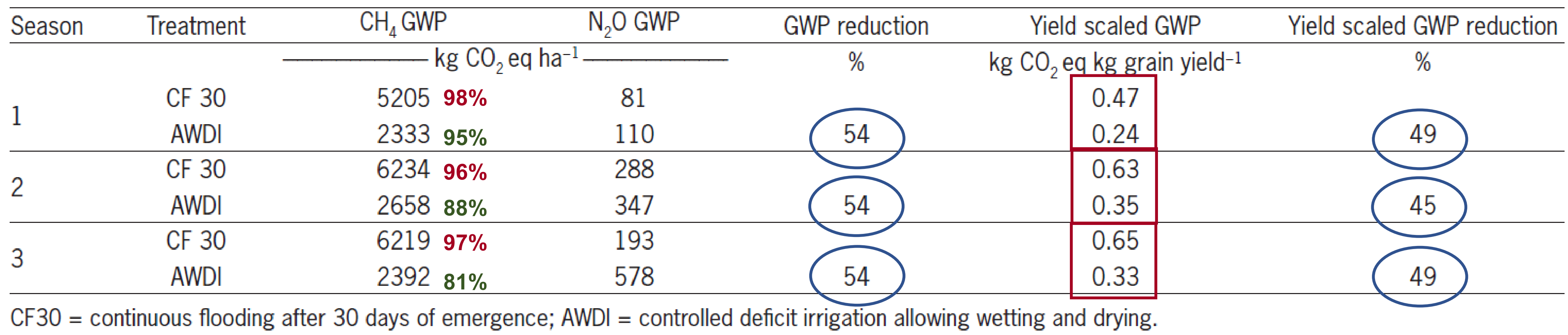


Season	Treatment	CH_4[1]	N_2O[2]	Grain yield
		kg ha^{-1}		
1	CF30	208.2[a]	0.3	11171[a]
	AWDI	93.3[a]	0.4	10170[a]
2	CF30	249.4[a]	1.0	10387[a]
	AWDI	106.3[b]	1.2	8700[b]
3	CF30	248.8[a]	0.6	9803[a]
	AWDI	95.7[b]	1.9	8992[a]

Different letters indicate diferences between treatments ($p < 0.05$)

AWD - multiple drainage / Global warming potential

Global warming potential (GWp) and Yield scaled GWP for three rice seasons.



Season	Treatment	CH_4 GWP	N_2O GWP	GWP reduction	Yield scaled GWP	Yield scaled GWP reduction
		kg CO_2 eq ha^{-1}		%	kg CO_2 eq kg grain yield^{-1}	%
1	CF 30	5205 **98%**	81		0.47	
	AWDI	2333 **95%**	110	54	0.24	49
2	CF 30	6234 **96%**	288		0.63	
	AWDI	2658 **88%**	347	54	0.35	45
3	CF 30	6219 **97%**	193		0.65	
	AWDI	2392 **81%**	578	54	0.33	49

CF30 = continuous flooding after 30 days of emergence; AWDI = controlled deficit irrigation allowing wetting and drying.

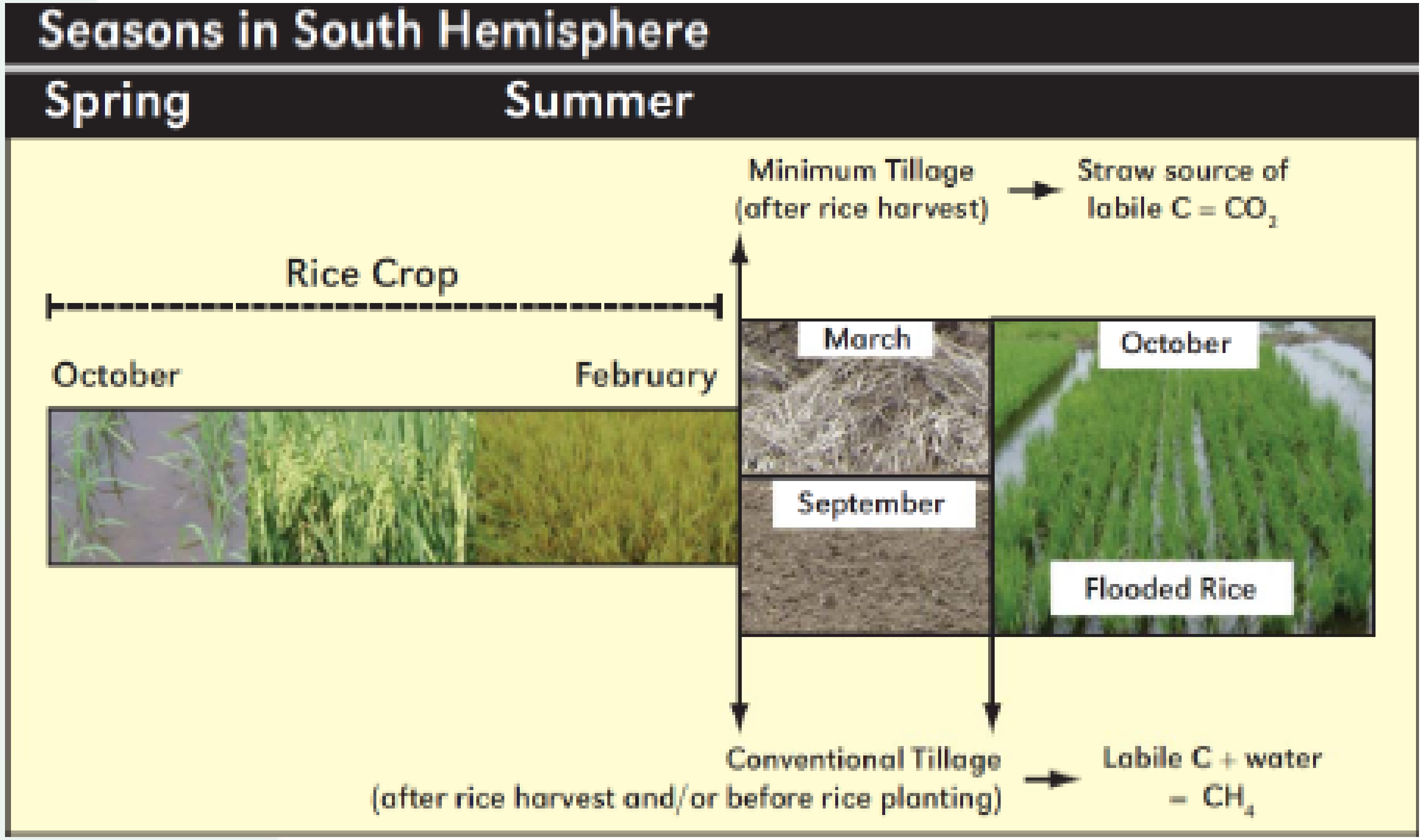
Soil tillage practices
(straw, residues management)

- Conventional tillage
- No-tillage
- Reduced tillage
  (frequency, intensity)
- Fall tillage /
  “antecipated”

↓ CH_4

↓↑ N_2O

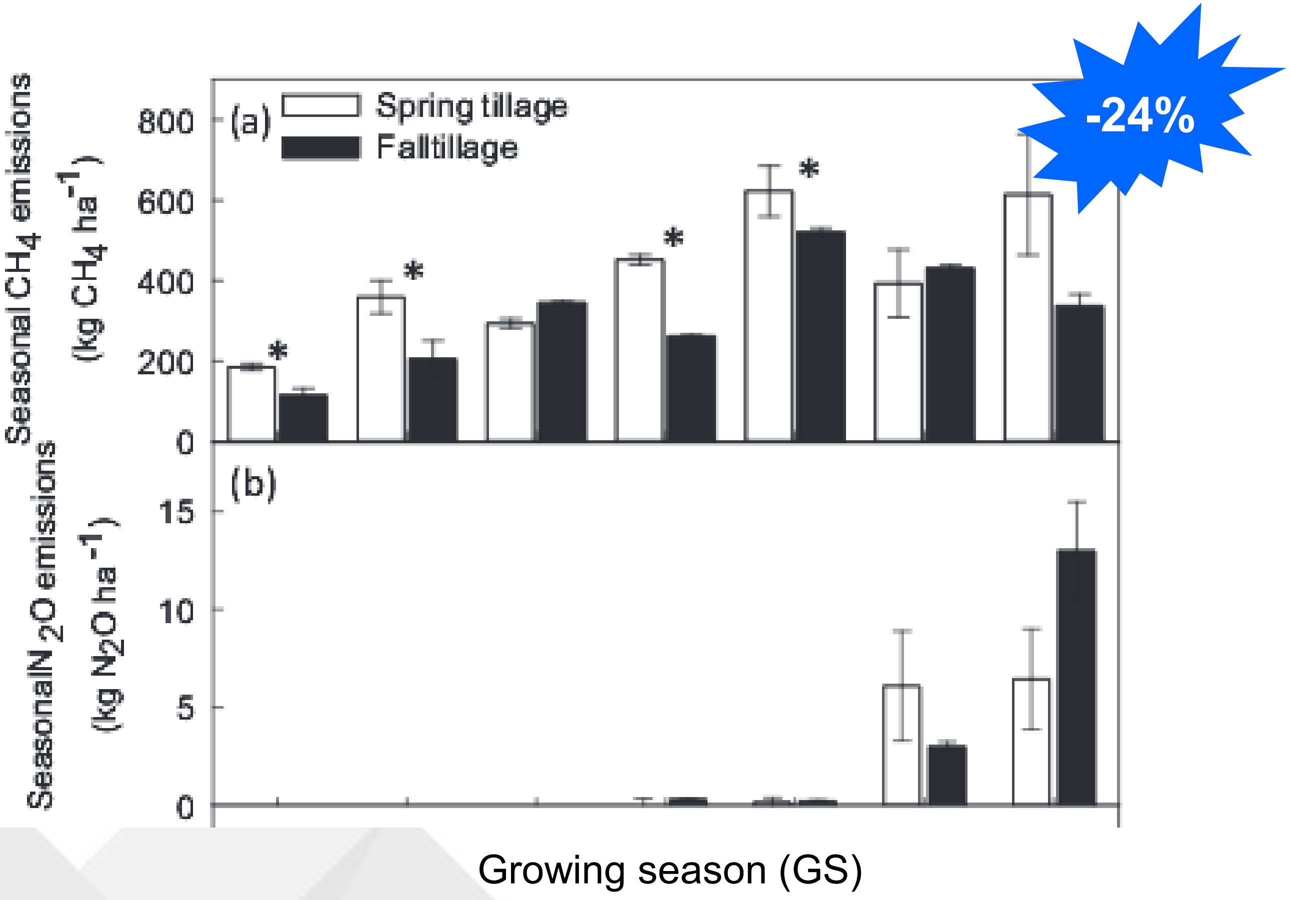
Mitigation Strategies: conventional tillage X minimum tillage technologies



CT: rice straw and winter crop residues are incorporated into soil in spring, acting as a source of labile C for CH_4 production.

MT: rice straw is incorporated into soil in fall/winter (non-flooded conditions). Part of the labile carbon is converted into CO_2, decreasing CH_4 emission potential once the area is flooded again to next rice crop. The area is ready before, allowing be sown in the ideal time.

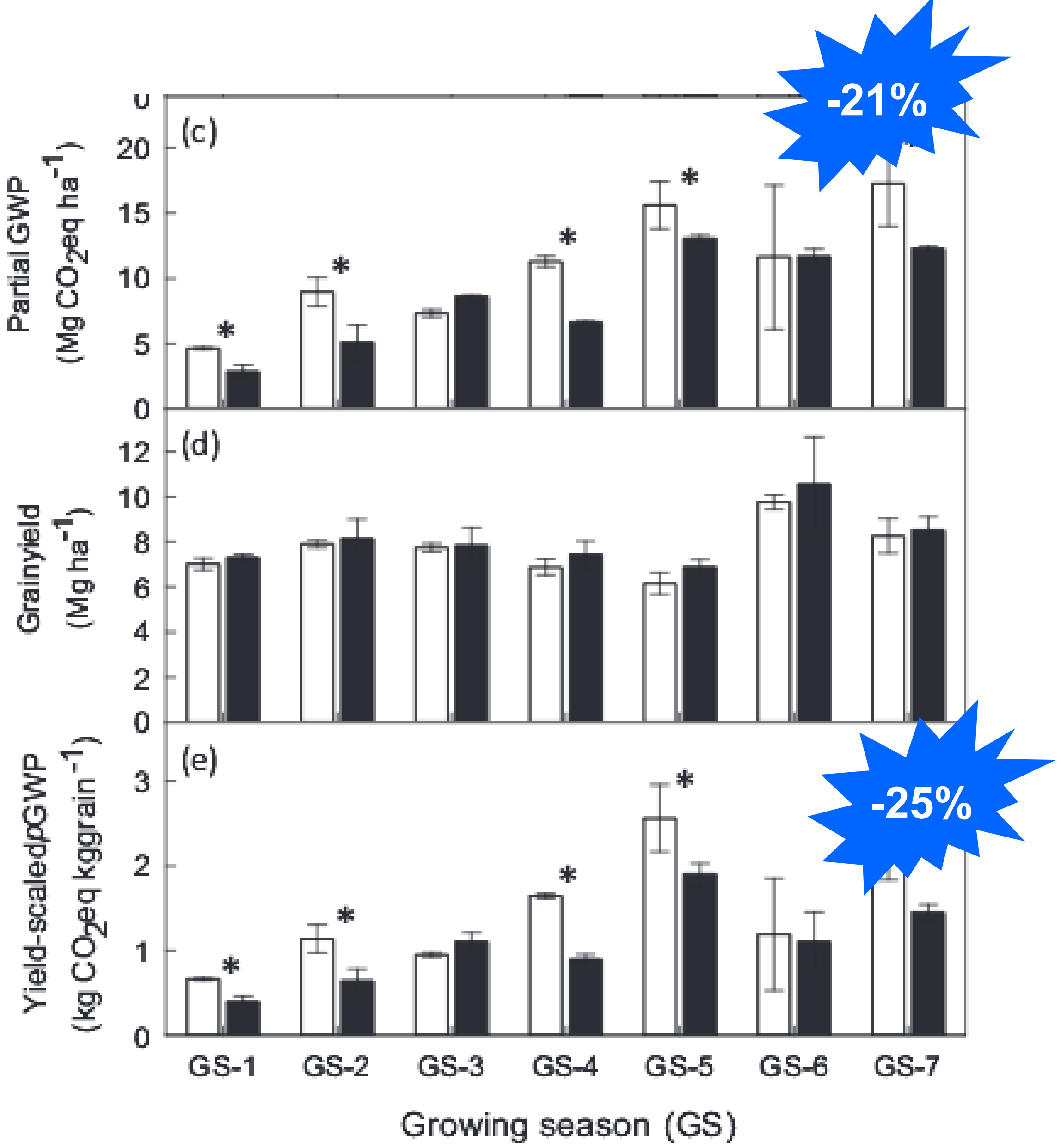
Bayer et al. (2014)



-24%

Seasonal CH_4 (a) and N_2O (b) emission by growing season and tillage management.

Source: Bayer et al. (2015).

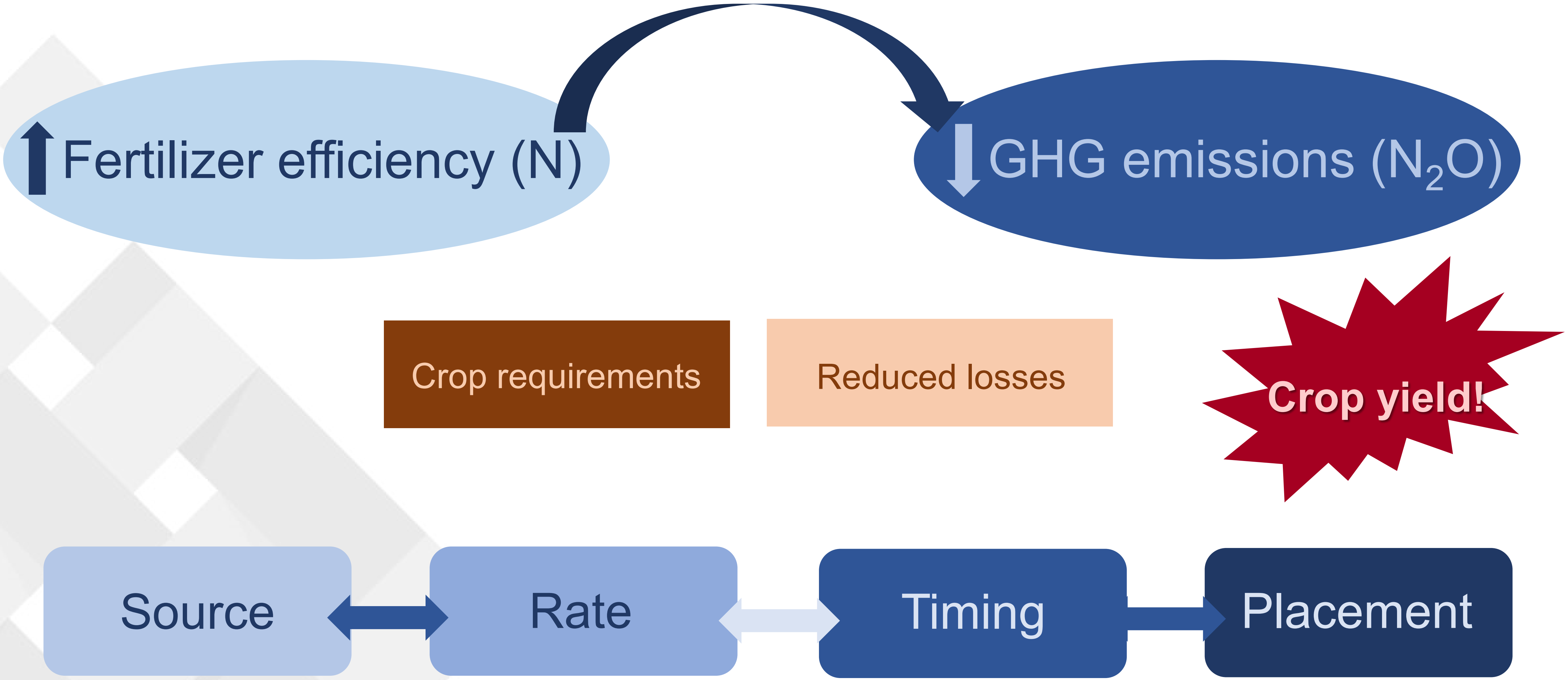


-21%

-25%

Partial global warming potential (pGWP) (c), rice grain yield, and yield-scaled pGWP by growing season and tillage management.

Fertilizer Management / Environmental Impact



↑ Fertilizer efficiency (N)

↓ GHG emissions (N_2O)

Crop requirements

Reduced losses

Crop yield!

Source

Rate

Timing

Placement

Nitrogen sources: effect on N_2O and CH_4 emissions (Ghosh et al., 2014)

Total seasonal CH_4 and N_2O emission in an upland irrigated rice field of North India.

Treatment	Total CH_4 emission (kg ha^{-1})	Total N_2O emission (g ha^{-1})
No nitrogen	24.5 ± 3.7a	37.8 ± 7.1a
Urea	37.3 ± 5.1e	167.9 ± 7.9d
Ammoniun sulphate	33.0 ± 2.1d	151.4 ± 7.9c
Potassium nitrate	28.1 ± 1.0c	186.7 ± 20.1e
Urea + DCD	29.0 ± 2.7c	79.5 ± 10.8b
Ammonium sulphate + DCD	28.7 ± 3.4c	81.9 ± 6.7b
Potassium nitrate + DCD	26.4 ± 1.0b	167.5 ± 10.7d

Values followed by same letter are not significantly different from each other at 5% level of significance according to DMRT.

↑ NH_4^+: ↑ methanotrophic, CH_4 oxidation; ↓ CH_4 emission

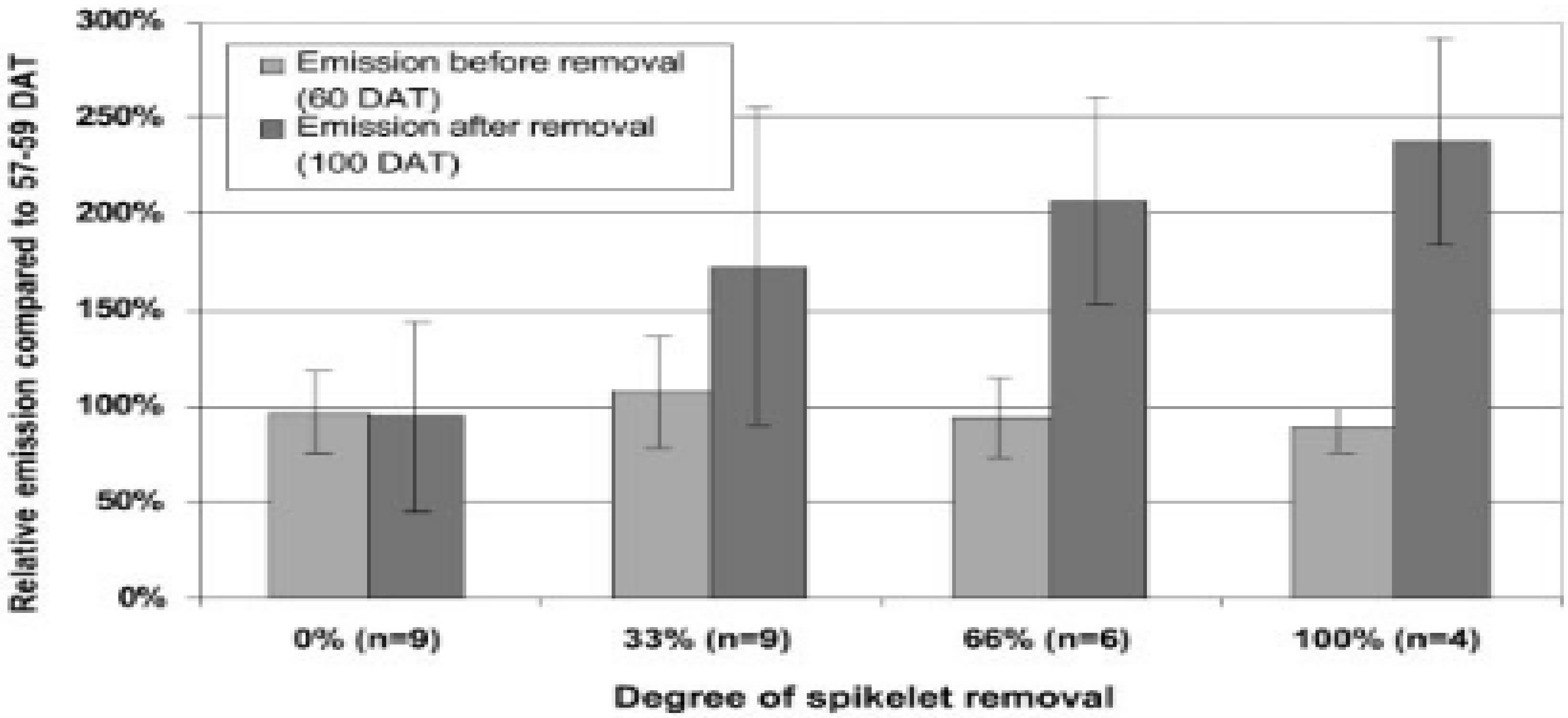
↑ SO_4^{2}-: ↑ sulfate reducing bacteria and methanogens; ↓ CH_4 production

Selection of Rice Cultivar

CH_4

- Inter-varietal differences in CH_4 emissions from rice fields (production, oxidation, and transport capacities)
- Varietal diferences in CH_4 emissions are regulated by the amount of root exudates and degrading roots (substrate availability); tillers number; leaf area and quantity; duration in the field; aerenchyma structure, etc.
- Varietal-specific differences in CH_4 emissions: masked by crop management practices; vary among seasons

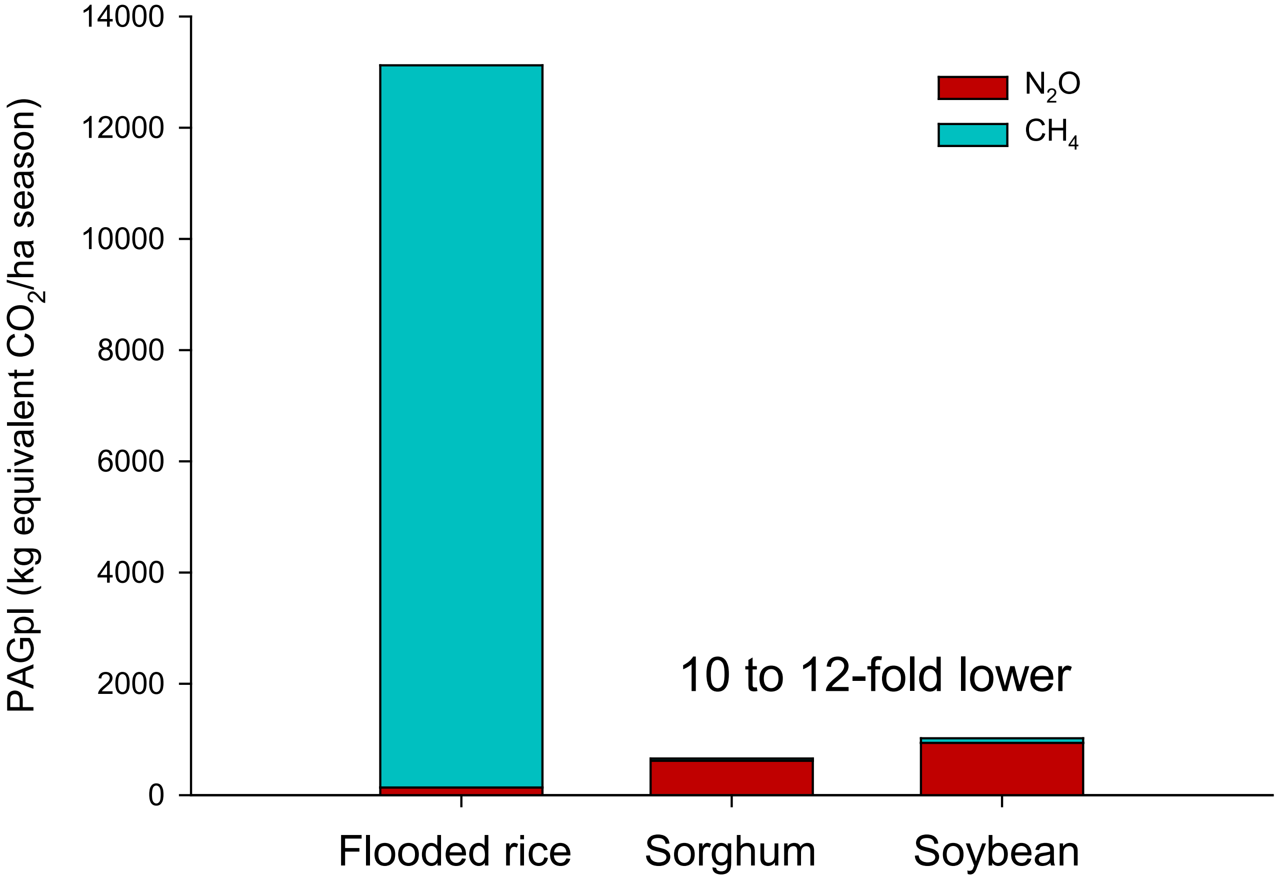
Denier van der Gon et al. (2002)



Methane emission before and after spikelet removal expressed relative to the emission at 58 days after transplanting.

High yield and low emitting varieties: sustainable approach GHG emissions reductions!

Crop diversification



Partial global warming potential (CH_4 + N_2O in CO_2 equivalent) in lowland fields cultivated with soybean, sorghum and flooded rice under conventional tillage in Southern Brazil.

Source: Scivittaro et al. (2017)

Considerations:

- Environmental-friendly agricultural production system with low C footprint is a crucial strategy that will drive international agricultural markets in the near future
- Crop management practices influence GHG emissions in rice fields, and modifications in traditional crop management practices possess a huge potential to overcome GHG emissions
- Several options to mitigate GHG emissions from paddy rice fields:
    - Water management
    - Tillage permutations
    - Managing organic and fertilizer inputs
    - Selection of rice cultivar
    - Crop diversification / crop rotation
- Changes of the management practices influence CH_4, N_2O e CO_2 (different mechanisms, antagonistic effects)
- Estimation of GWP of different approaches: suitable option

Regional Research

Thank you!

walkyria.scivittaro@embrapa.br