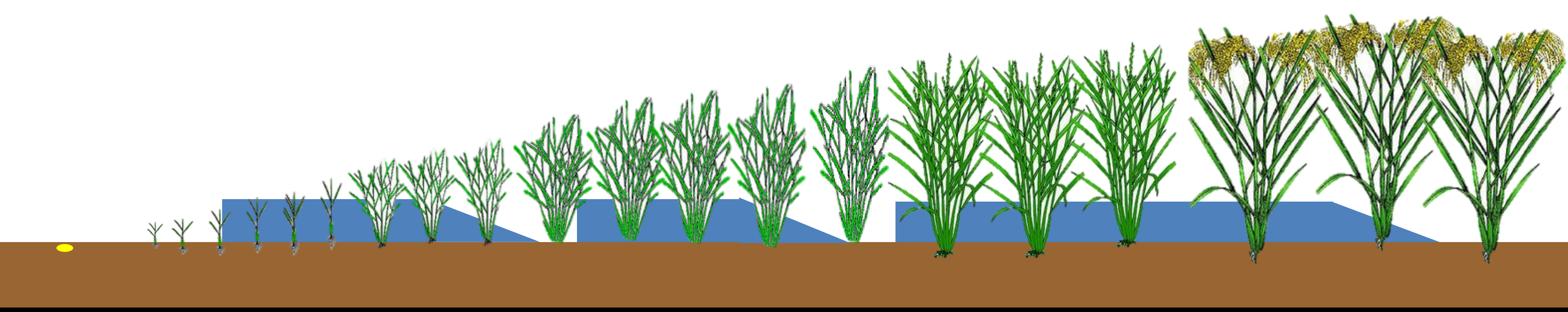
Greenhouse gas emissions on rice fields subjected to alternate wetting and drying

Bruce Linquist

Merle Anders, Arlene Adviento-Borbe,
Daniela Carrijo, Gabriel LaHue

July 13, 2016

Stuttgart, Arkansas



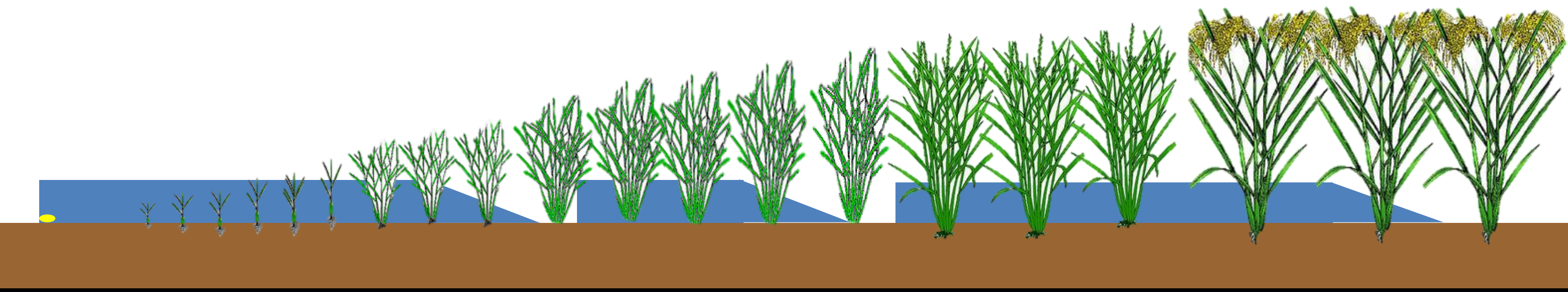
UC DAVIS
University of California

Outline

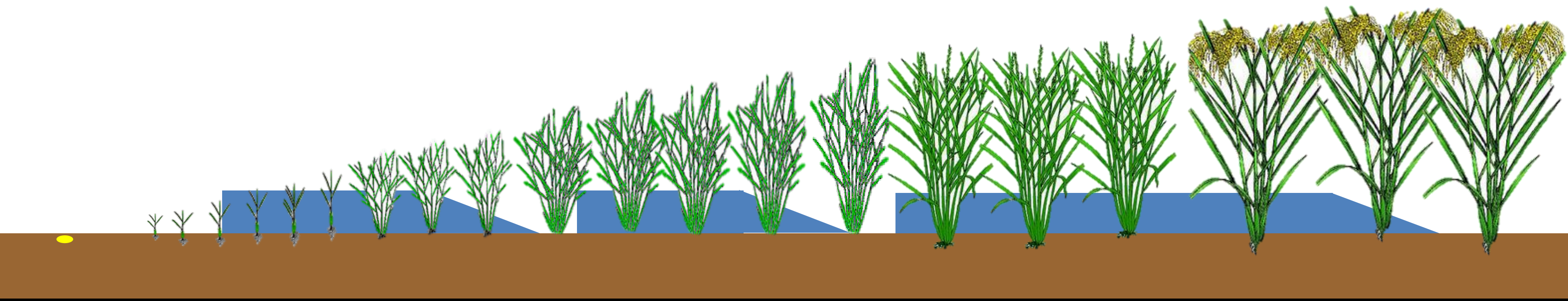
- What is it and why?
- Managing drain timing and duration to achieve desired outcomes
- Challenges

Alternate wetting and drying

Water seeded



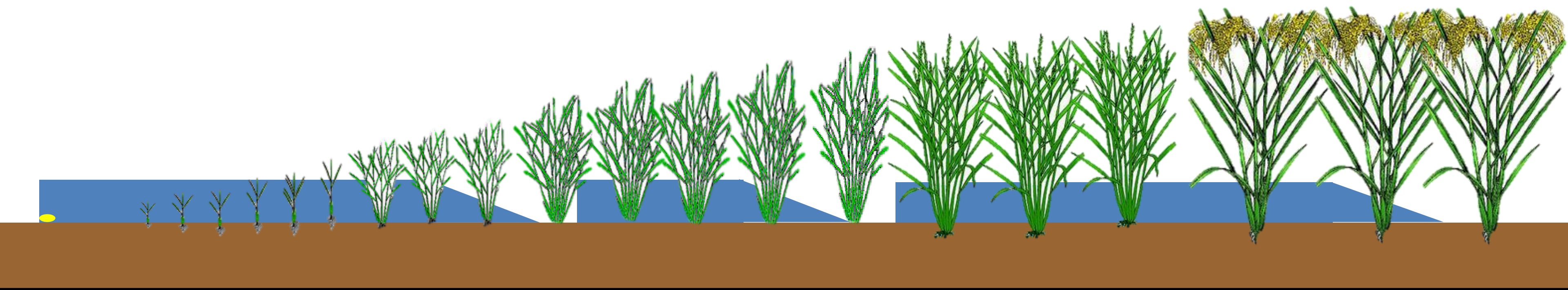
Drill seeded



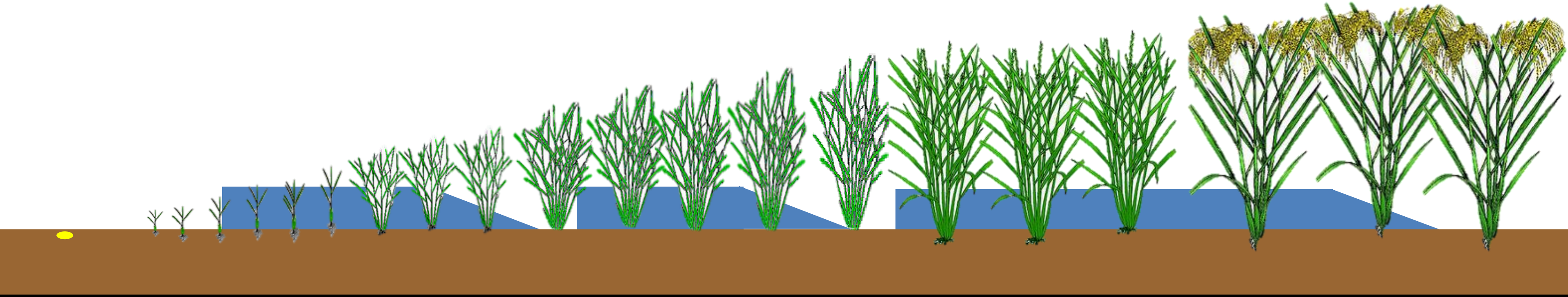
UC DAVIS
University of California

Why AWD?

Water seeded

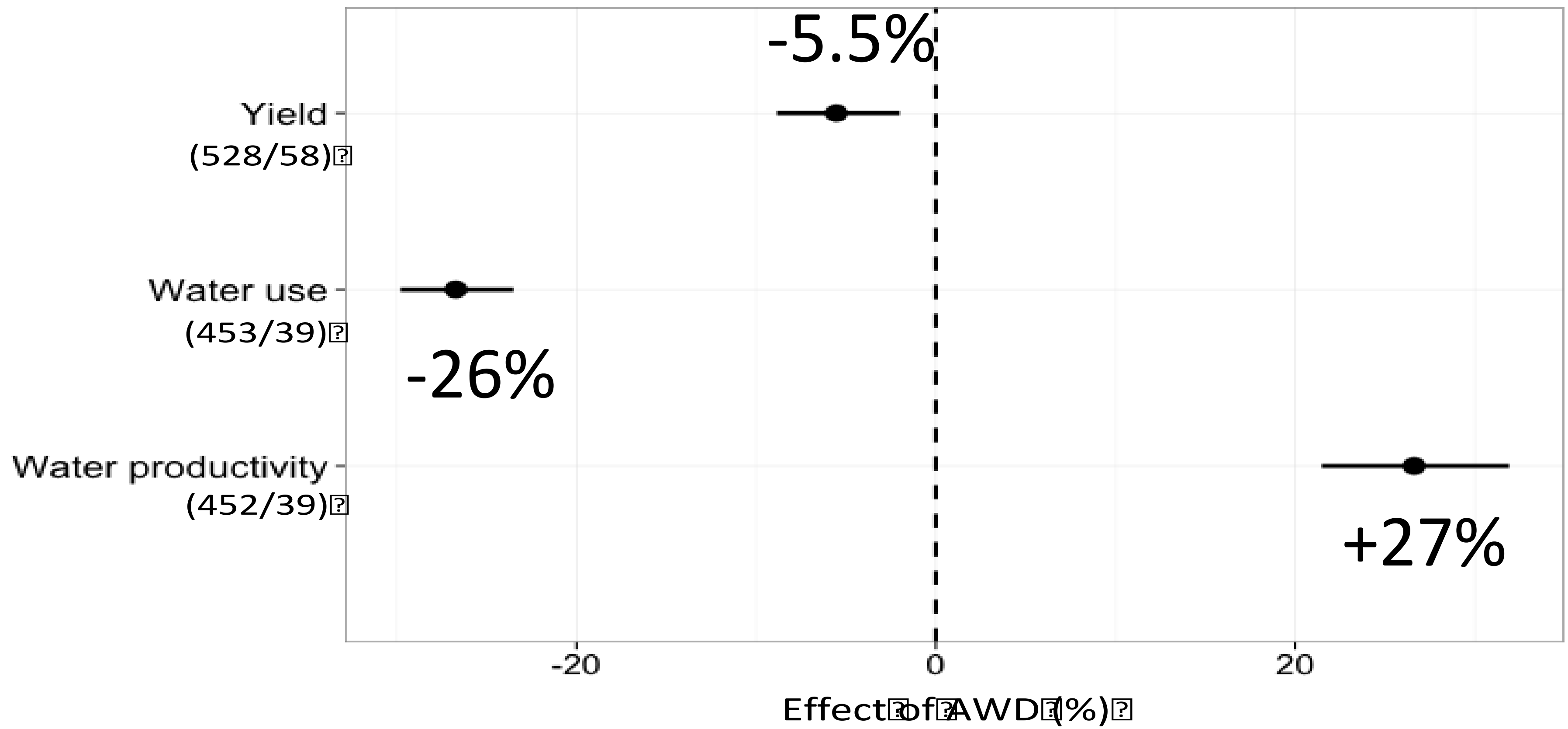


Drill seeded



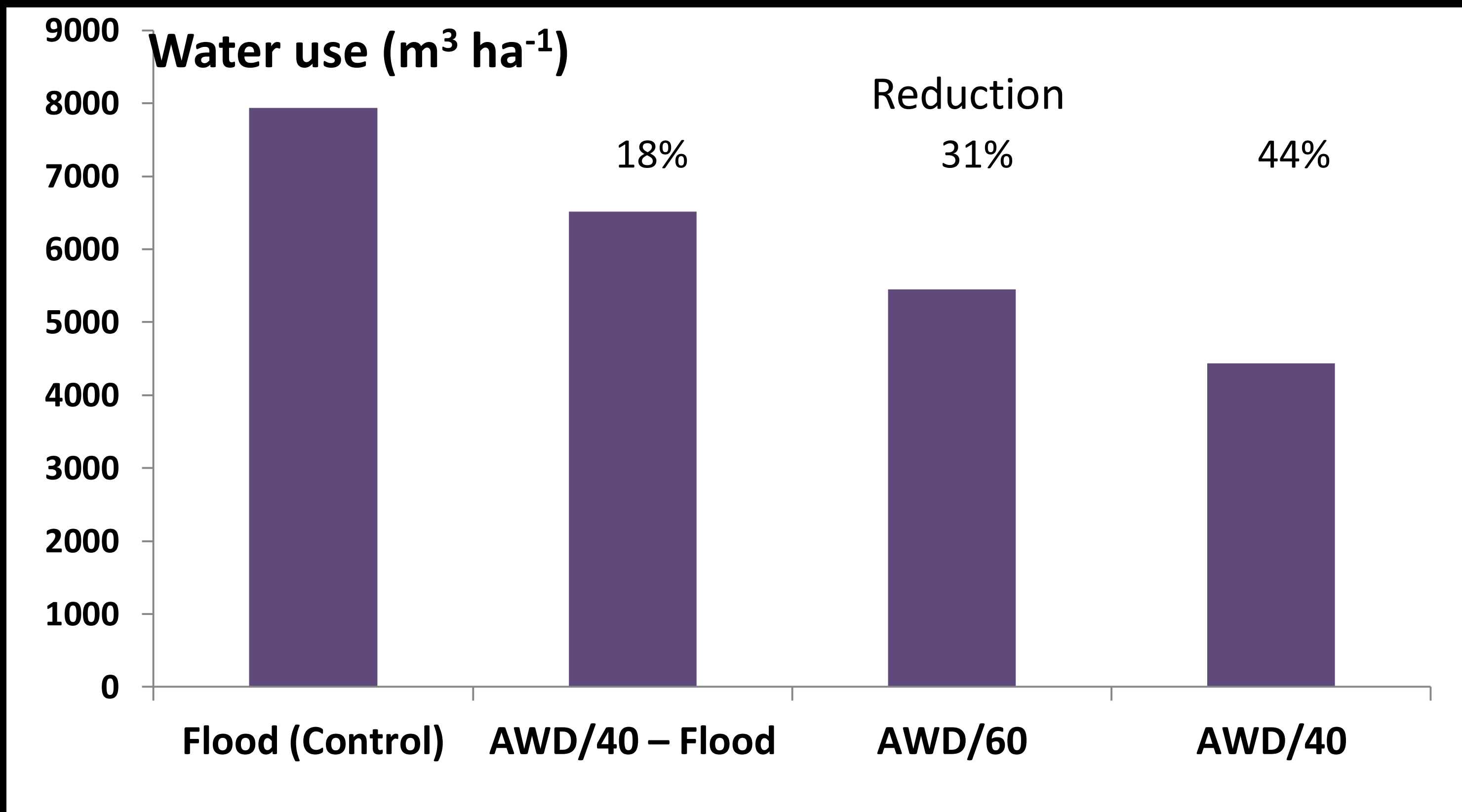
UC DAVIS
University of California

Water use: meta-analysis



UC DAVIS
University of California

Water use: Arkansas cross year averages



Linquist et al., 2015- Global Change Biology

UC DAVIS
University of California

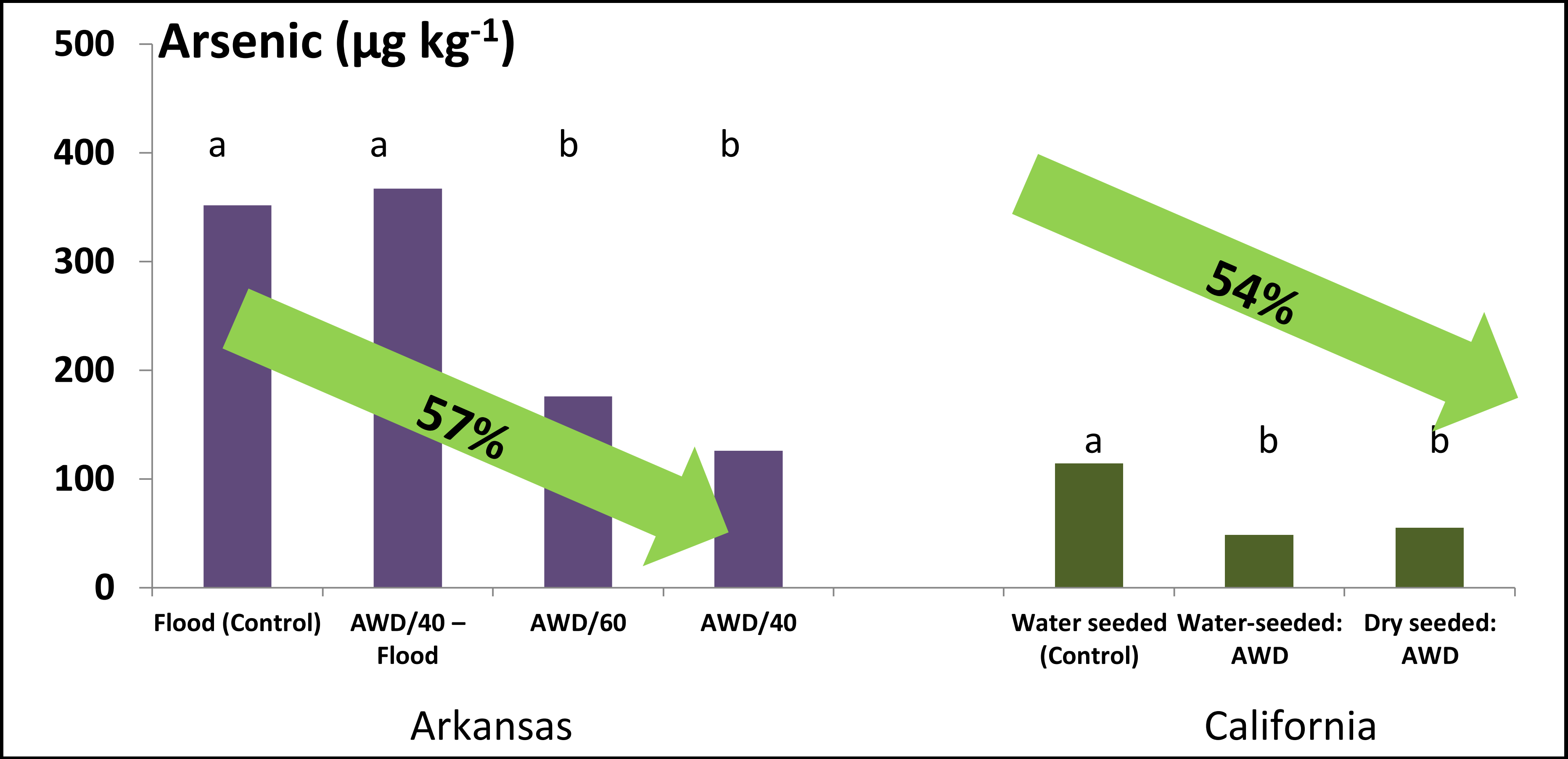
Heavy metals

- Arsenic (As)
  - Present in rice grain
  - Human health concern
  - Babies and populations with high rice intake

- Mercury (Hg)
  - Ecosystem concern
  - Flooding leads to methylation of Hg = methyl mercury (MeHg)
  - MeHg is toxic
  - MeHg bio-accumulates in food systems

UC DAVIS
University of California

Grain arsenic: Arkansas and California - cross year averages

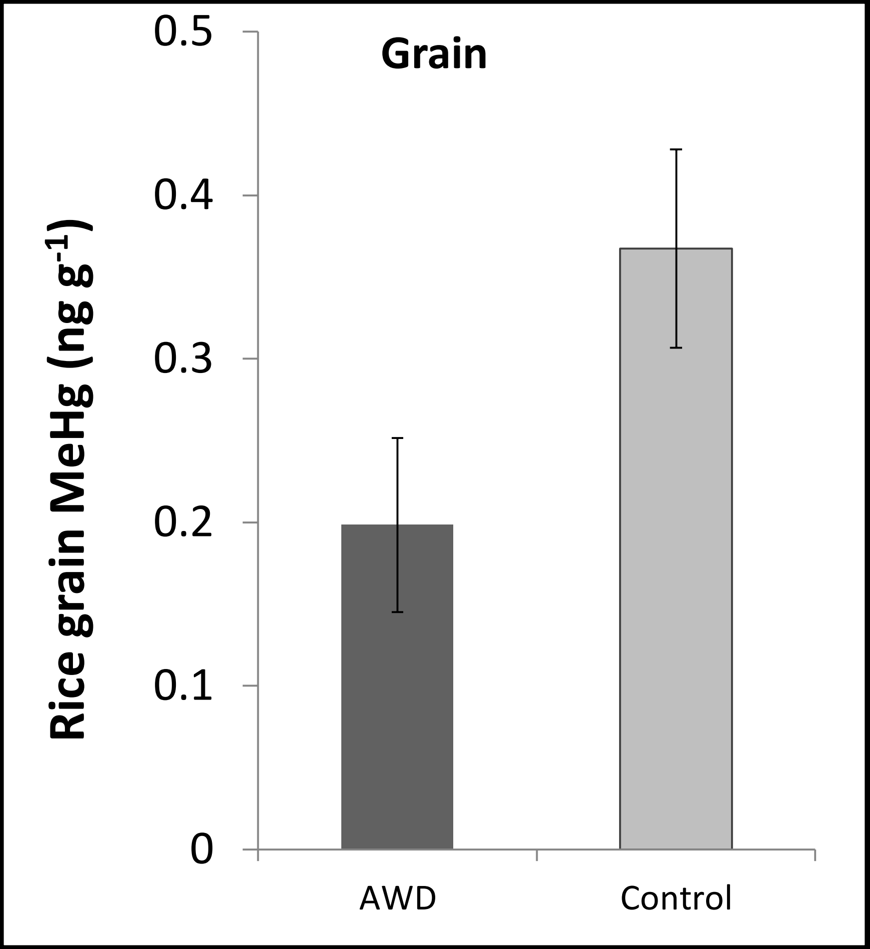


Arkansas data: Linquist et al., 2015- Global Change Biology
California data: LaHue et al., Submitted

UC DAVIS
University of California

Methyl mercury (MeHg)

- Rice grain MeHg levels not a health concern
- AWD reduced MeHg in grain by almost 50%
- Grain MeHg: good integrator of seasonal Hg dynamics
- Suggests that AWD may reduce overall MeHg production



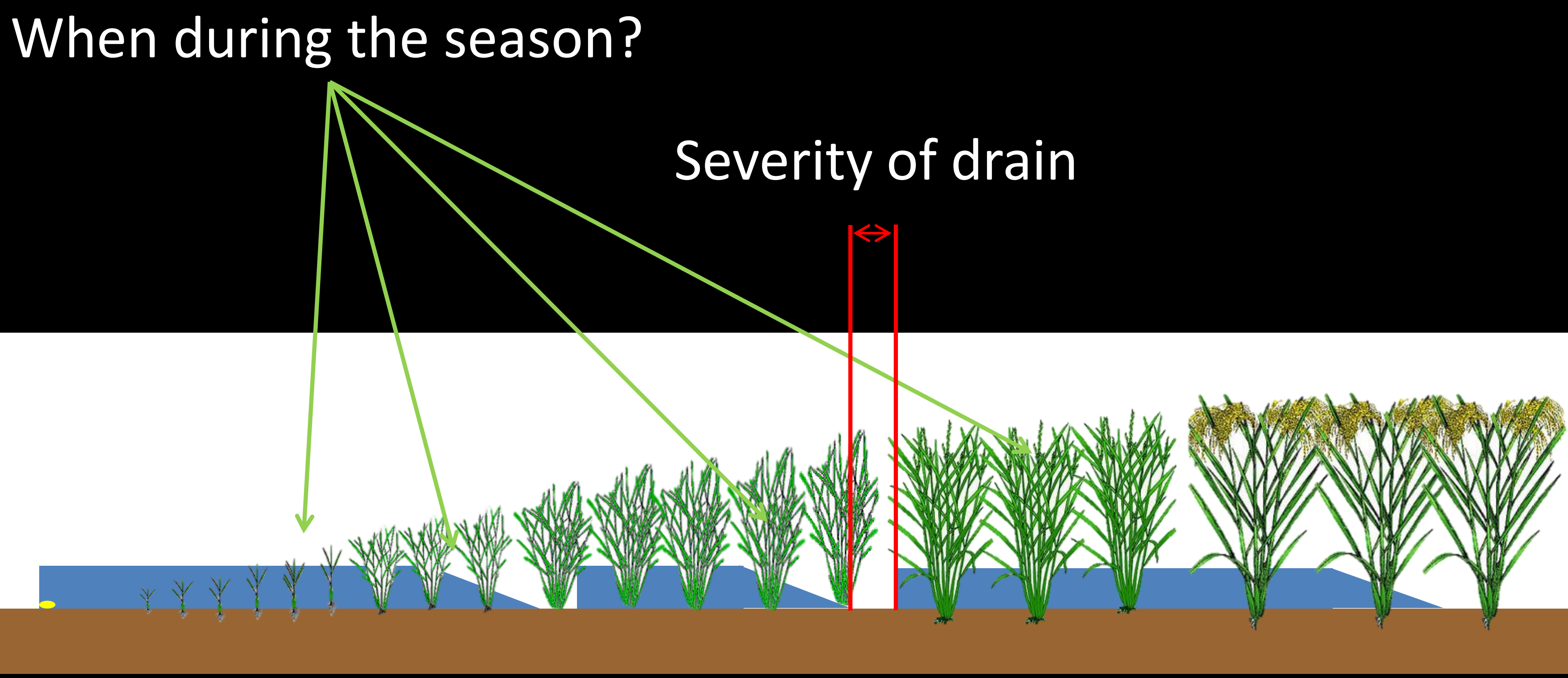
UC DAVIS
University of California

Drains: when and how long?

- **Windows**
  - When and for how long
  - Greatest benefits
  - Least affect on yield

UC **DAVIS**
University of California

Drain windows



UC DAVIS
University of California

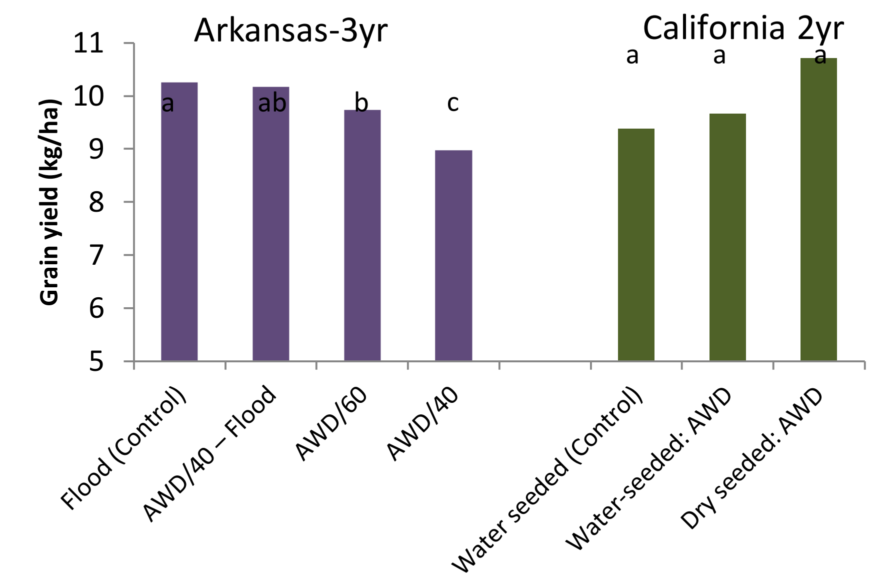
Focus studies: variation in drain severity

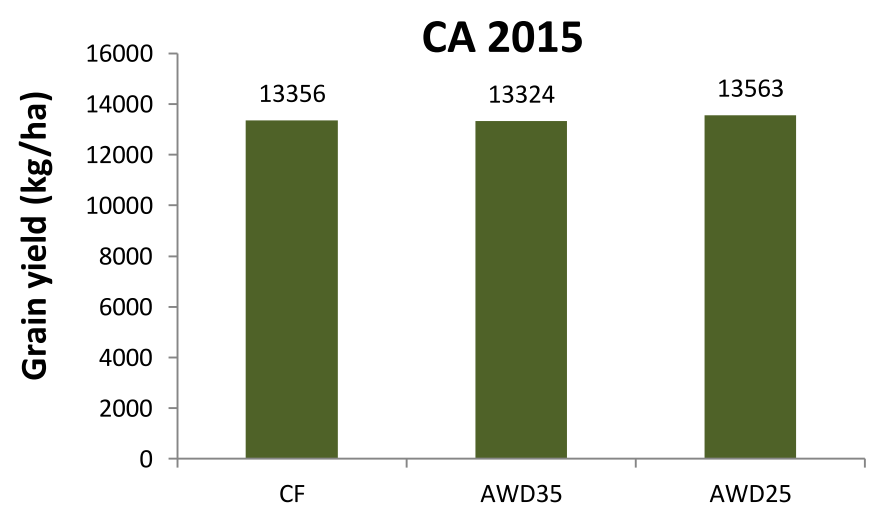
- Arkansas (Drill seeded - Linquist et al., 2015 Global Change Biology)
  - 3 years - Treatments
    - Continuous flood
    - One early drain
    - Two drains (60% saturation)
    - Two drains (40% saturation)
- California (Water seeded – LaHue et al., In Press)
  - 2 years - Treatments (all drains to 35 % VWC)
    - Water seeded continuous flood
    - Water seeded 2 drains
    - Drill seeded 2 drains
- California (Water seeded)
  - 2015 - Treatments
    - Water seeded continuous flood
    - Water seeded (35% VWC)
    - Water seeded (25% VWC)

UC DAVIS
University of California

Yields: Arkansas and California Cross year averages

- CA: no yield reduction with AWD or increased soil drying
- AR: decline with increased soil drying
- Different methodology to estimate soil moisture
  - AR-AWD 60 is drier than CA-AWD 35





AR data: Linquist et al., 2015- Global Change Biology
CA data: LaHue et al., 2016 – Agriculture ,Ecosystems and Environr

Factors affecting yield: Meta-analysis

- Primary factor affecting yields
  - water management
- Secondary factors that can reduce yields are
  - High pH soil
  - Low carbon soils
  - High clay soils

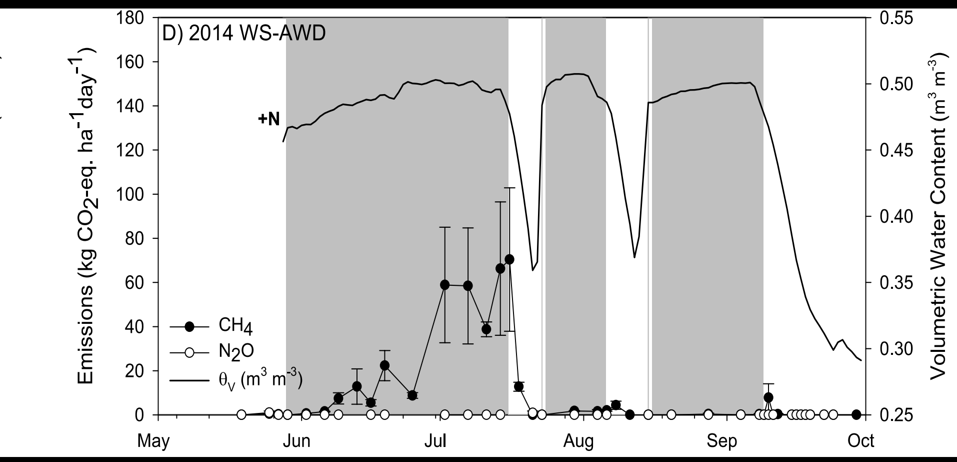
Carrijo et al., In Prep)

UC DAVIS
University of California

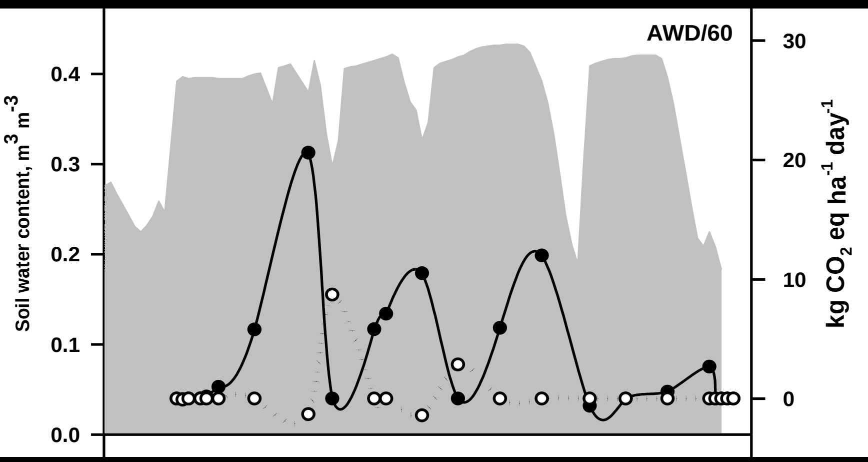
Greenhouse gas emissions

- CH4 emissions increase until first drain then drop.
  - In CA, very little CH4 after first drain
- In AR, N2O emissions increased during drain events. Not seen in CA

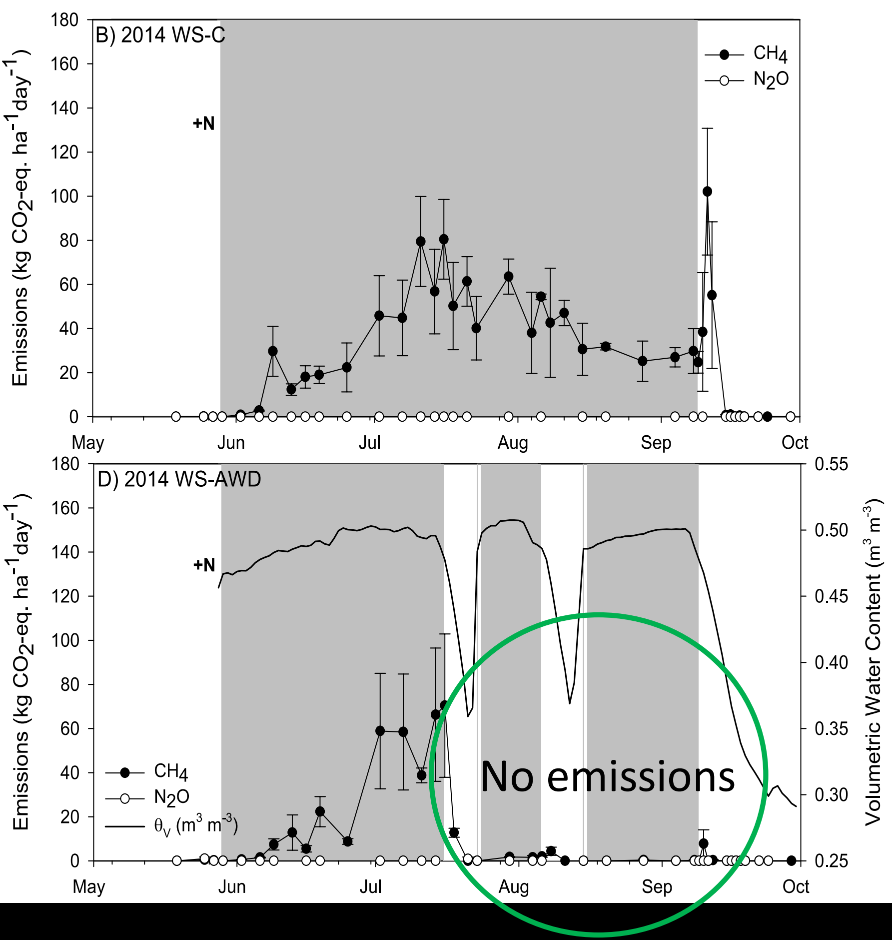
California Water-seeded

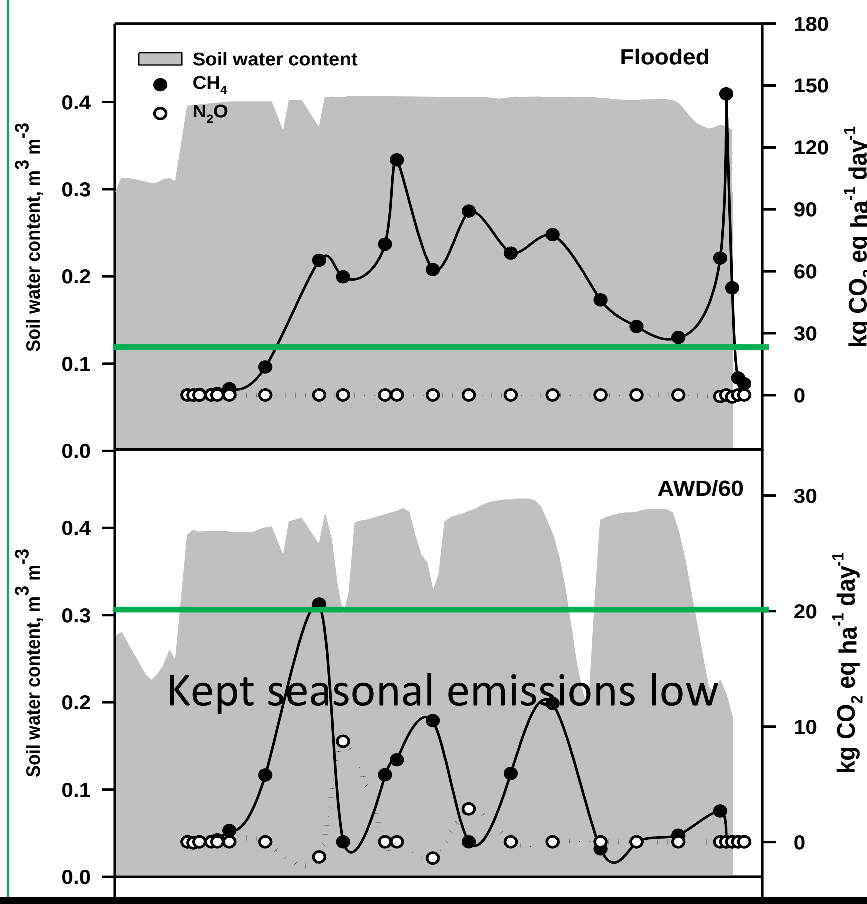


Arkansas Drill-seeded



Greenhouse gas emissions





GWP
(CH_4 + N_2O)

- CH4 reduced by 60-90% with two drains
- N_2O - low
- GWP reductions of 60 – 90% were achieved.
  - Discuss later

Treatment	CH_4 (kg CH_4-C ha^{-1})	N_2O (kg N_2O-N ha^{-1})	GWP (kg CO_2-eq ha^{-1})	GWP % Reduction
CA 2013-2014				
Flood	133 a	-0.02a	6035a	-
WS AWD	52 b	-0.03a	2361b	**61**
DS AWD	18 b	0.21a	903c	**85**
CA 2015				
Flood	338 a	-57 a	11262 a	-
AWD-35	92 b	-111 a	3003 b	**73**
AWD-25	111 b	-32 a	3681 b	**67**
AR 2012-2013				
Flood	105 a	0.03 b	3520 a	-
AWD/40–flood	55 b	0.17 ab	1922 b	**45**
AWD/60	7 c	0.28 ab	359 c	**90**
AWD/40	8 c	0.51 a	494 c	**86**

Yield-scaled GWP

- Yield-scaled GWP
  - kg CO_2 Mg^{-1} grain
- Yield-scaled GWP decrease similar to GWP
  - GWP decreased while yields changed little

TRT	Yield (Mg ha^{-1})	GWP (kg CO_2-eq ha^{-1})	GWP-Y (kg CO_2-eq Mg^{-1} grain)	GWP-Y %Reduction
CA 2013-2014				
Flood	9.38	6035a	**667a**	-
WS AWD	9.66	2361b	**251 b**	**62**
DS AWD	10.71	903c	**84 b**	**87**
CA 2015				
Flood	13.36	11,262 a	**947 a**	-
AWD-35	13.32	3,003 b	**253 b**	**73**
AWD-25	13.56	3,681 b	**305 b**	**68**
AR 2012-2013				
Flood	10.26	3520 a	**347 a**	-
AWD/40–flood	10.17	1922 b	**190 b**	**45**
AWD/60	9.73	359 c	**37 c**	**89**
AWD/40	8.97	494 c	**55 c**	**84**

Is there a GHG benefit to extended dry times?

- Allowing fields to dry longer did not reduce GHG emissions

California

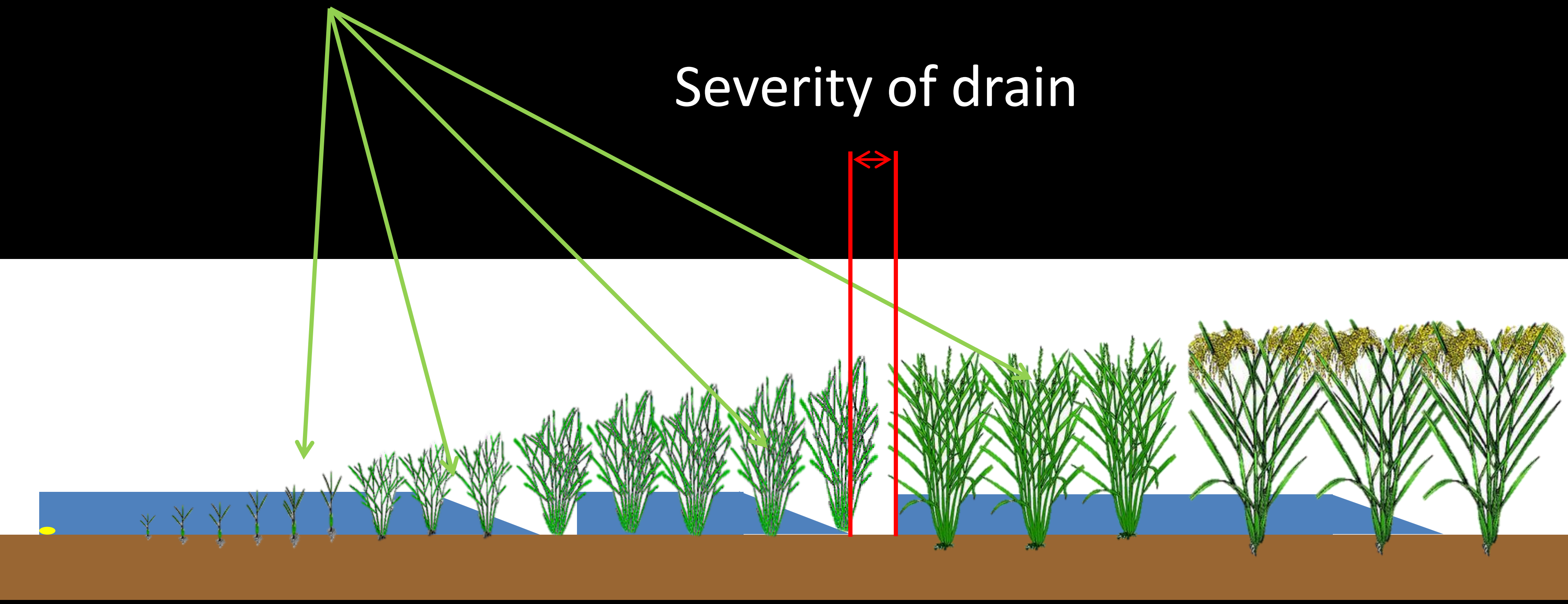
TRT	CH_4 kg CH_4-C ha^{-1}	N_2O kg N_2O-N ha^{-1}
~~Flood~~	~~338 a~~	~~-57 a~~
AWD-35	**92 b**	**-111 a**
AWD-25	**111 b**	**-32 a**

Arkansas

TRT	CH_4 kg CH_4-C/ha	N_2O kg N_2O-N/ha
~~Flood~~	~~105 a~~	~~0.03 b~~
AWD/60	**7 c**	**0.28 ab**
AWD/40	**8 c**	**0.51 a**

Drain windows and nitrogen mgmt to keep N_2O low

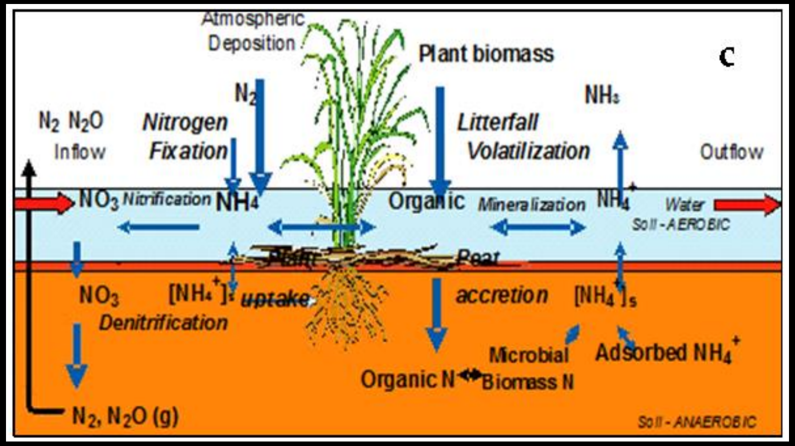
When during the season?



UC DAVIS
University of California

Nitrogen management

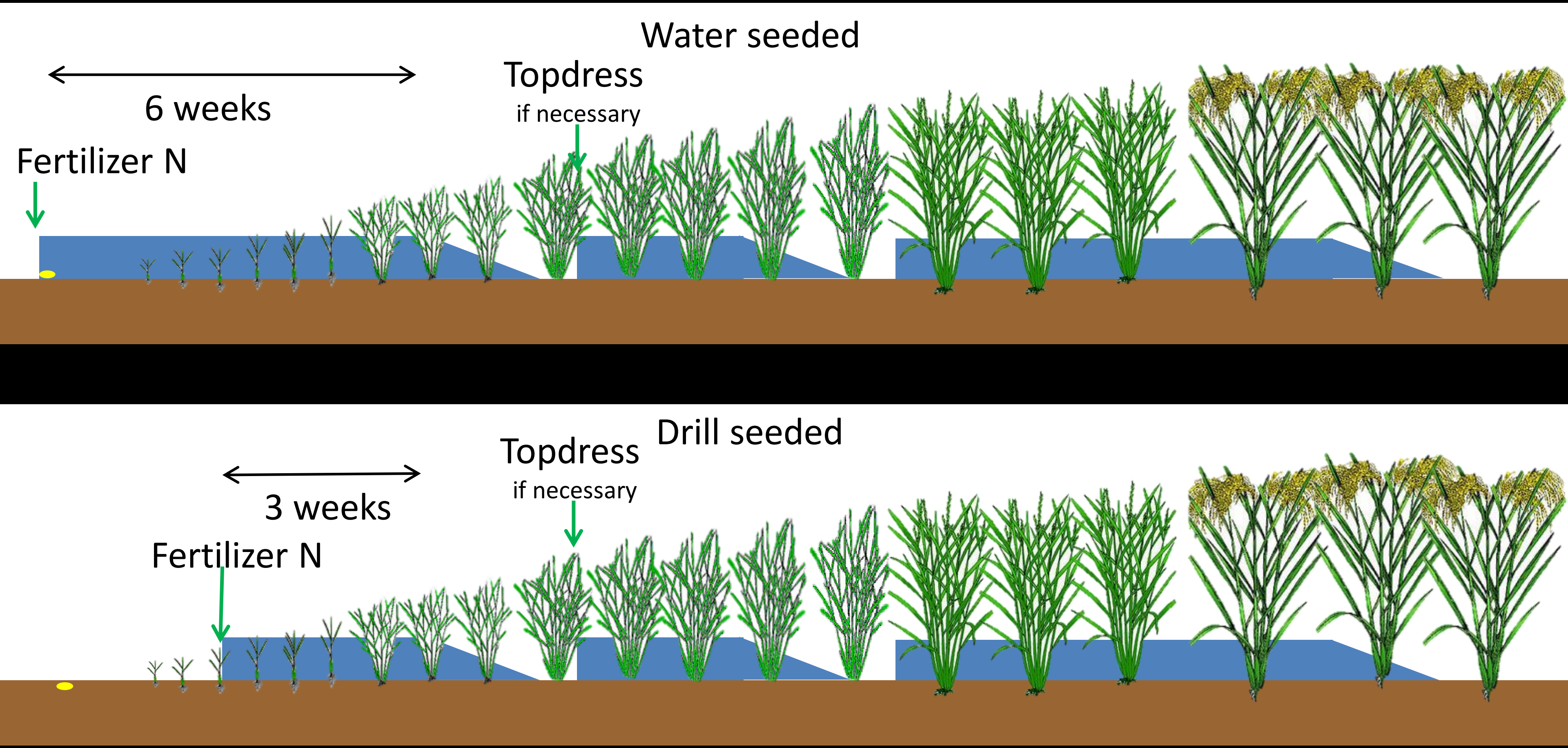
- Keeping GWP low requires optimal N and water management to minimize N_2O losses
- Introducing aerobic periods into system increases opportunities for losses via denitrification



2008, USEPA

UC DAVIS
University of California

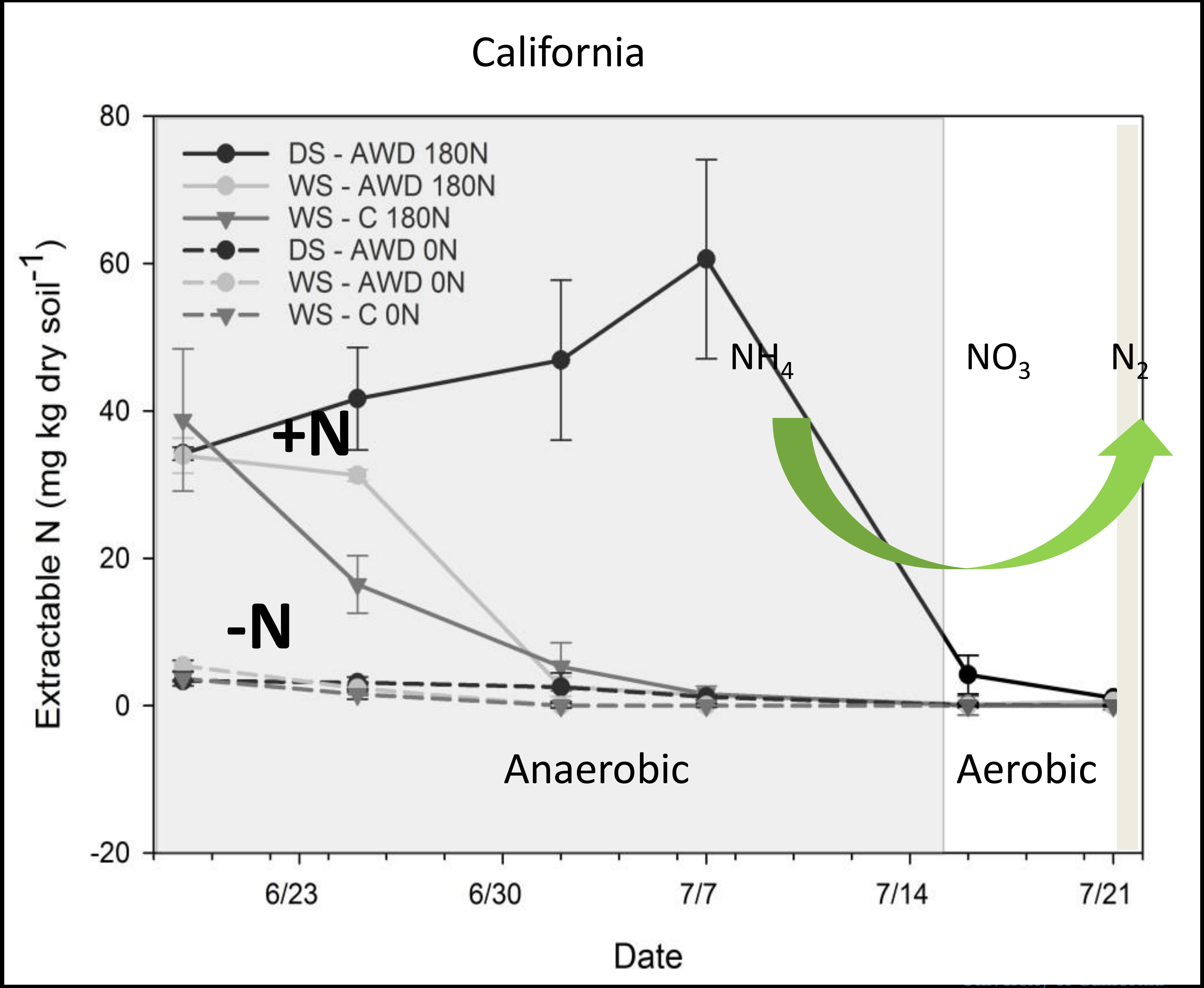
AWD: N management to reduce N_2O emissions and N losses



UC DAVIS
University of California

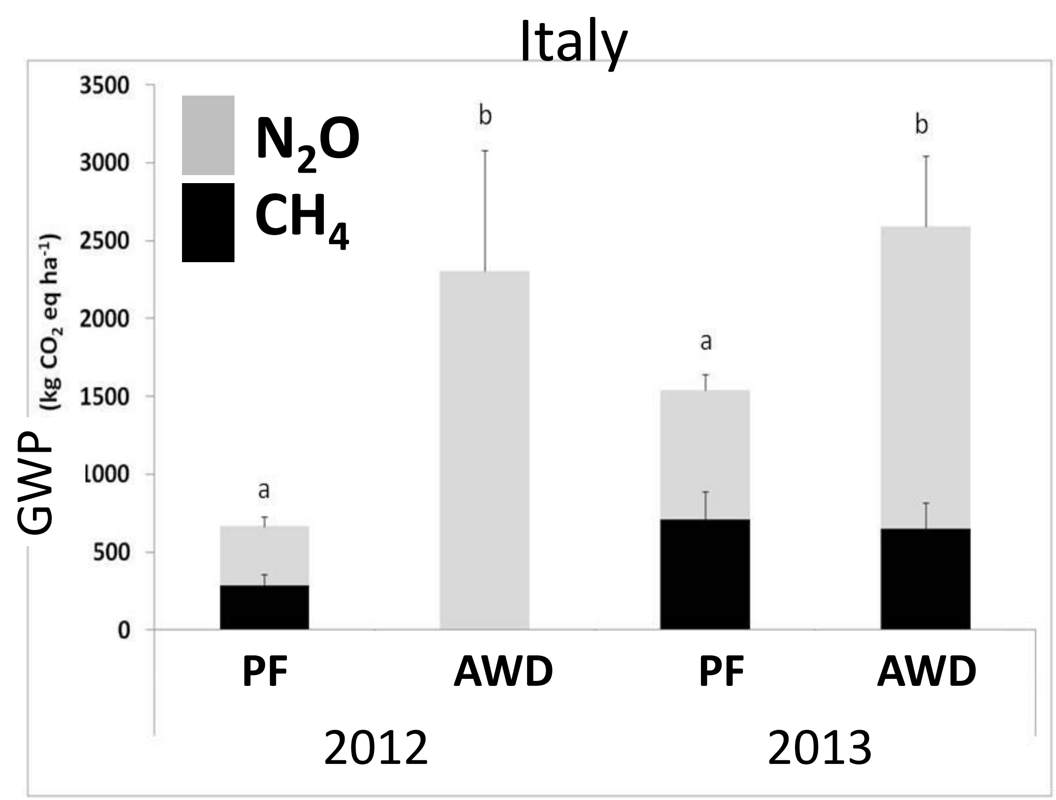
Managing N fertilizer and water

- Eliminated or reduced N_2O emissions
- Little to no N additional losses
  - Same N rate to achieve optimum yield



Managing N fertilizer and water

- Italian study
- Permanent flood vs AWD
- Used nitrification inhibitor
- Drained randomly
- CH_4
- N_2O



PF=Permanent flood

Lagomarsino et al., (2016) Pedosphere

UC DAVIS
University of California

Drain windows: timing

- Water seeded
  - First drain 45-50 days after planting
    - Fertilizer N has been taken up
    - Canopy cover has been achieved (reduced weed issues)
- Drill seeded
  - First drain 3 weeks after permanent flood
    - Fertilizer N has been taken up
    - Canopy cover has been achieved

UC DAVIS
University of California

Drain windows: duration

- Drain times: 7-10 days from soil saturation
- Longer drain times lead to:
  - Increased risk of yield loss
  - Increased water savings
  - Lower As???
- Longer drain times do not:
  - Reduce GWP

UC DAVIS
University of California

2016 studies: Duration

- Drain duration:
  - Critical for developing strategies for large fields
  - Reflood up to 5 days
- Studies
  - Water seeded continuous flood
  - Safe AWD (reflood when water reaches 15 cm below soil surface)
  - Water seeded (35% VWC)
  - Water seeded (25% VWC)
- Duration range: 2-10 days
- Examining 1 vs 2 drains

UC DAVIS
University of California

In Summary

- AWD presents a real win-win-win opportunity
  - Farm: save water/pumping costs, no yield reduction
  - Health: reduce grain As
  - Environment: water resources, GHG, MeHg

UC DAVIS
University of California

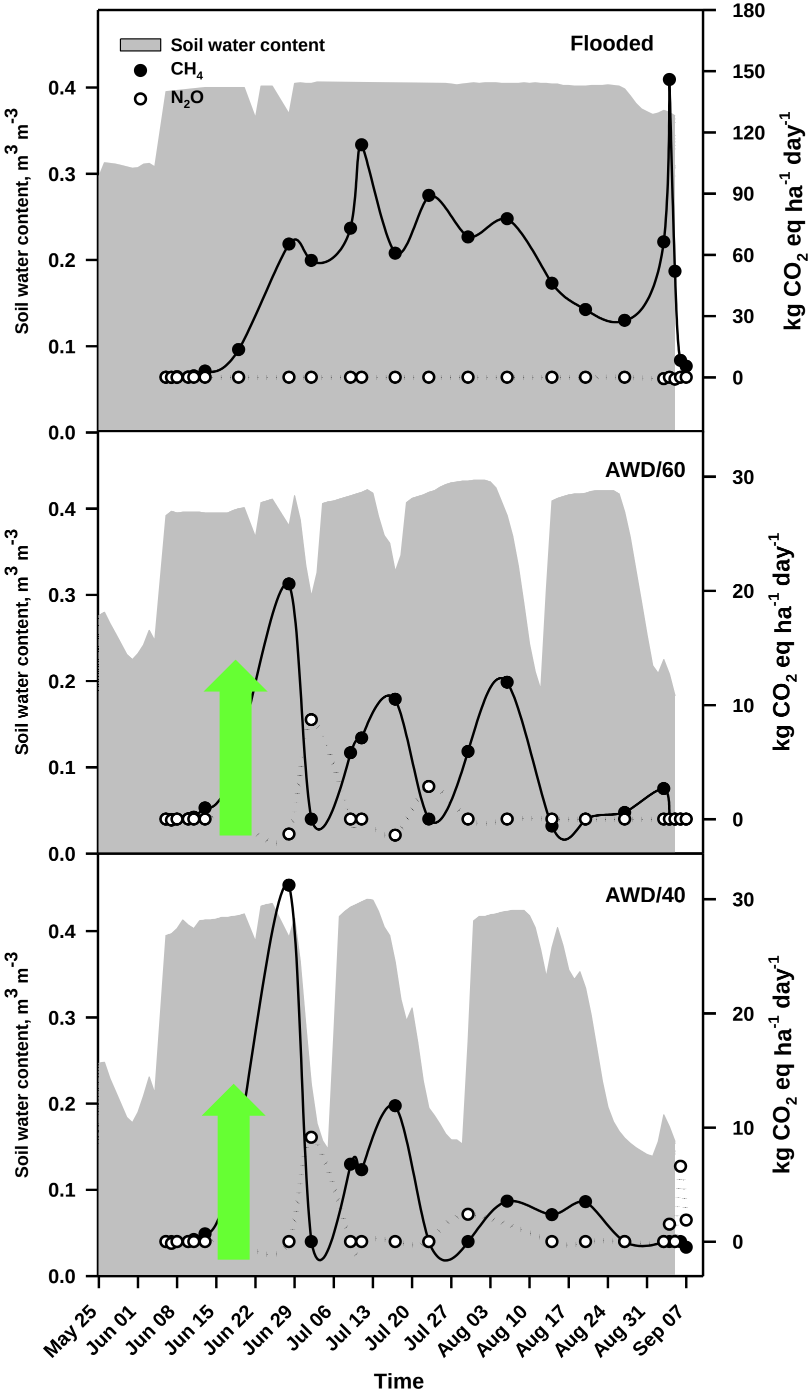
Challenges and opportunities

- Field scale
  - Variability
    - soils/moisture/rate of drying
  - Rapid/timely application of water
    - Wells and poly-pipe are big advantage
  - Grower comfort
    - Programs that allow testing with minimal risk
- Future research
  - Identify dry-down windows where desired benefits are achieved without yield risk
    - Time during season and length
  - Develop technologies to monitor soil moisture conditions


Thank you
UC DAVIS
University of California

AWD - GHG

TRT	CH_4	N_2O
	kg CH_4-C/ha	kg N_2O-N/ha
Flood	105 a	0.03 b
AWD/40–flood	55 b	0.17 ab
AWD/60	7 c	0.28 ab
AWD/40	8 c	0.51 a



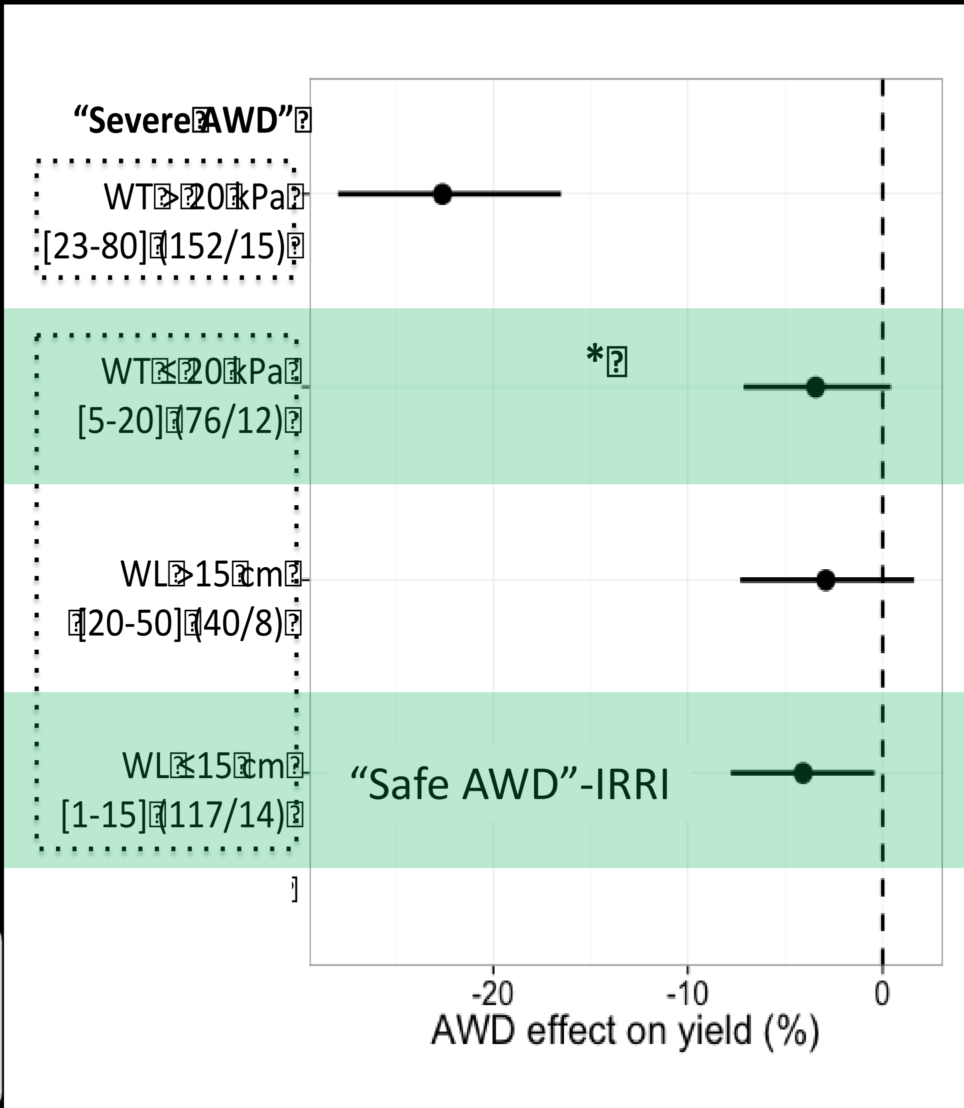
Linquist et al., 2015 Global Change Biology

Managing water

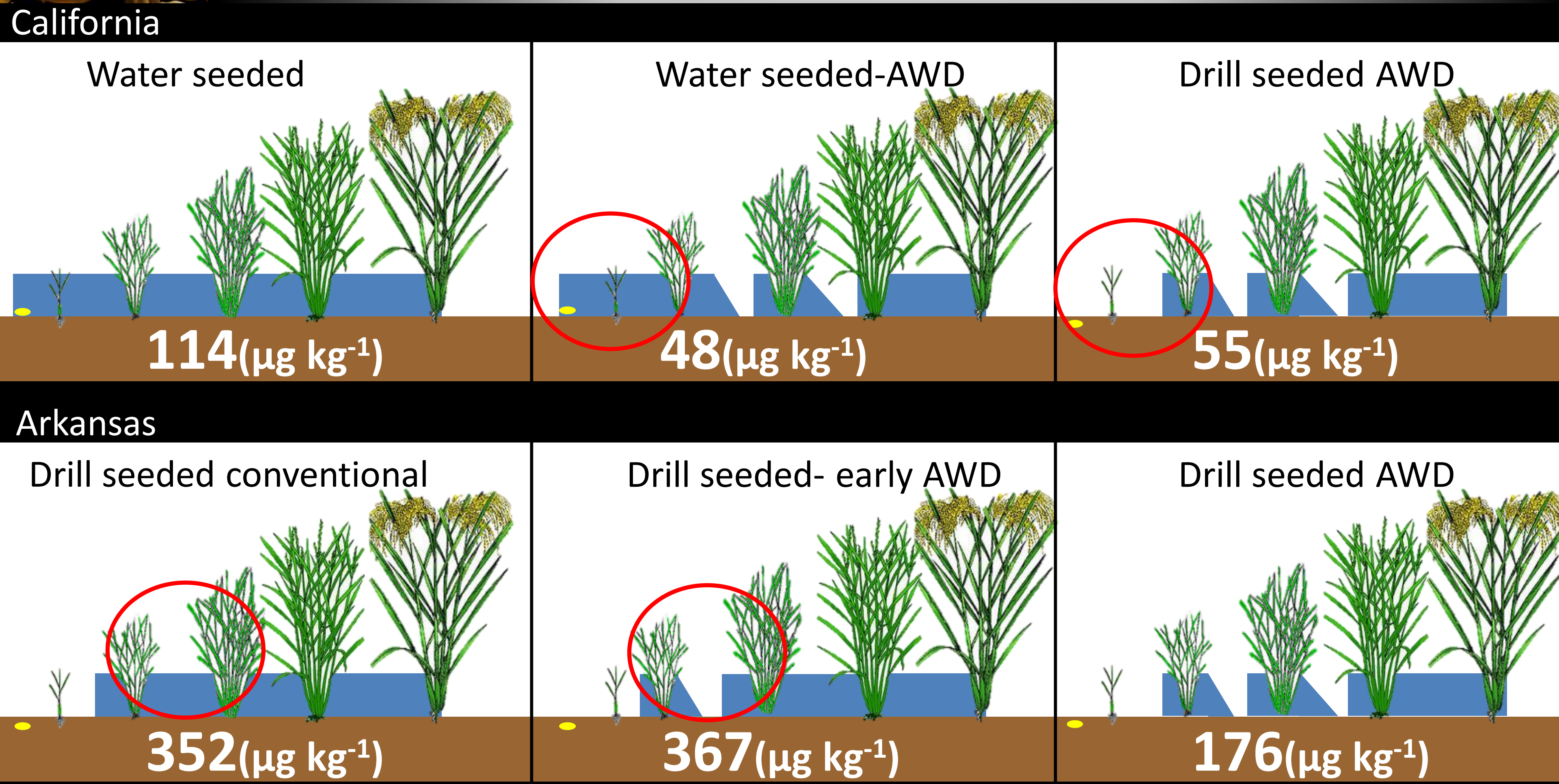
UC DAVIS
University of California

Meta-analysis: Soil moisture and yields

- > 20kPa resulted in 23% yield loss
- <20 kPa or “Safe AWD” resulted in 2-4% yield loss.
- Safe AWD
  - measured water table below soil surface <15cm
  - Conservative measure
    - No difference between < or >15cm
  - CA occurred 2 days after soil saturation.
  - AWD treatments were reflooded 5 to 10 days after soil saturation.
  - Useful?



AWD drain timing and grain As



Early season aerobic periods had little impact on grain As concentrations

UC DAVIS
University of California

Length of drain time and grain As

- Possibly a small effect of longer drain times on rice grain As.
- On average a 12% further reduction in grain As with increased drain times.
- In no individual study was this significant.

State	Treatment	Polished rice total As (ug/g)	% reduction
Arkansas-RS	Flood	343	-
	AWD/60	165	52
	AWD/40	114	67
Arkansas-RR	Flood	370	-
	AWD/60	199	46
	AWD/40	149	60
California	Flood	111	-
	35%	44	60
	25%	36	68

UC DAVIS
University of California