Alternate wetting-and-drying for the California rice system

Background

In agricultural fields nitrous oxide (N_2O) and methane (CH_4) are the major greenhouse gases (GHG). Flooded rice fields are a source of greenhouse gas emissions – especially CH_4. Methane is produced by bacteria that decompose organic matter (such as rice straw and roots) under anaerobic conditions (anoxic or low oxygen). Flooding rice fields create these conditions. The CH_4 produced in the soil gets into the atmosphere mostly through the plant or bubbling up through the flood water. In flooded rice systems, N_2O (a more potent GHG) is usually low. However, if fields are drained when there is a lot of nitrogen in the soil, N_2O emissions can be high.

Alternate wetting-and-drying

Since CH_4 is produced under anaerobic conditions, removing the flood water creates aerobic conditions and reduces CH_4 emissions. The practice of alternate wetting-and-drying (AWD) has been widely studied and has been shown to reduce CH_4 emissions by 30 to 80% (average about 50%). AWD is the practice of flooding and then letting the soil dry to a certain level and then reflooding again. In some cases this is done multiple times during the season. However, in California it is not practical or feasible to flood and dry multiple times. During the first month after planting, due to high nitrogen levels in the soil and weed control practices, drying the soil is not a good idea. Later in the season, during booting, it is recommended to keep water levels high to protect the panicle from cool overnight temperatures which can cause blanking. During flowering and grain fill, it is risky to drain due to potential effects on grain filling and grain quality.

Figure 1. When to practice a mid-season drain and appropriate times for N application. DAP=days after planting.

There is a window of opportunity between 35 and 50 days when a field can be dried for a mid-season drain (a form of AWD) (Fig 1). A number of trials were conducted to test a mid-season dry down (a form of AWD) during this period. Results show that a mid-season drain results in CH_4 reductions of 40-60% (similar to multiple dry down periods). To achieve these reductions, the field needs to be dried for 7 to 10 days before reflooding (starts when the soil is no longer flooded but is fully saturated). Before reflooding, the soil will usually beginning to crack (Fig. 3). Drying the soil more than this (25% gravimetric water content) does not result in more CH_4 reductions (Fig. 2). Also, soil N levels are low at this time, so N_2O emissions will be low.

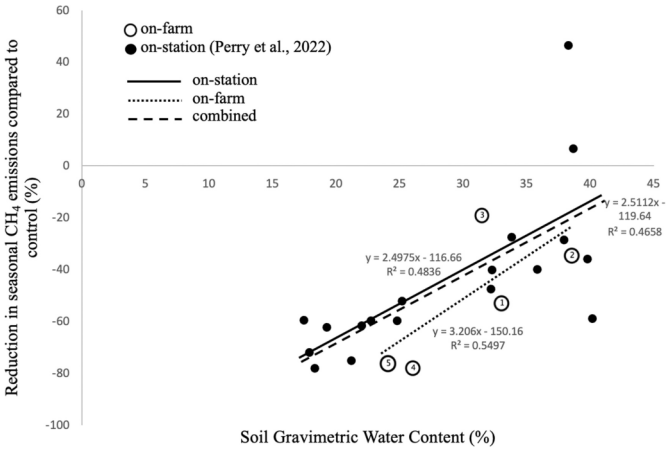

Figure 2. Relationship between soil dryness and the reduction in CH_4 emissions. Open circles are on-farm locations.

Considerations for success

Field set up and topography: Ideally a field should be leveled and have a slight slope for uniform drainage and drying. Use of in-field ditches and multiple outlets facilitate a uniform drainage and dry down. A slope, ditches and multiple inlets also help reflood the field rapidly and uniformly.

Timing: As mentioned earlier, the drain should be done between 35 and 50 days after planting. This coincides with the final clean-up herbicide applications for many growers. These herbicides are usually contact herbicides, meaning that the flood water has to be lowered to expose weeds. While growers usually reflood after this, it is possible to extend this drain period (after the herbicide is applied) to achieve the 7 to 10 day dry down.

While some growers may choose to drain a field by removing outlet boards, it is possible to simply let the flood water subside through evapotranspiration.

Top-dress nitrogen: Many growers apply a top-dress nitrogen application during this period. If practicing a mid-season drain, apply the top-dress nitrogen application just before reflooding for maximum efficiency and to keep N_2O emissions low.

Use of steel-wheeled tractors: Tractors with these wheels are often necessary to apply herbicides. However, they rut up the field. These ruts can make uniform drainage (and soil drying) across a field and rapid reflood more challenging.

Figure 3. Soil conditions and rice just before reflooding in a field with a mid-season drain.

Water savings: In California, with the heavy clay soils and low percolation, AWD saves little water. However, in coarser textured soils with more percolation, water savings could be significant.

Potential pest problems: This practice exposes the soil to air, but we have not seen an increase in weeds. This is because the drain occurs when the canopy is closed, which limits light to small germinated weeds. There may be a potential for increased blast incidence (we have not seen it). Using a blast resistant variety or fungicide is advised.

Yields: We have not seen a reduction in yield due to this practice in any of the trials we have conducted. Some drying periods have been 12 to 14 days long. In China and Japan, a similar type of drain is done to promote higher yields. That said, on coarse textured soils which may dry out faster, one may need to reflood a bit sooner.

For more on this topic:

- ✓ Perry et al. (2022) Single midseason drainage events decrease global warming potential without sacrificing grain yield in flooded rice systems. *Field Crops Research* doi.org/10.1016/j.fcr.2021.108312.
- ✓ Perry et al. (2024) Mid-season drain severity impacts on rice yields, greenhouse gas emissions and heavy metal uptake in grain: evidence from on-farm studies. *Field Crops Research* doi.org/10.1016/j.fcr.2024.109248

Agronomy Research and Information Center

http://agric.ucdavis.edu/

UC CE University of California Cooperative Extension

Author: Bruce Linquist and Henry Perry

2025