

Info Note

Alternate wetting and drying in irrigated rice

*Implementation guidance for
policymakers and investors*

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Key messages

- Alternate wetting and drying (AWD) is a rice management practice that reduces water use by up to 30% and can save farmers money on irrigation and pumping costs.
- AWD reduces methane emissions by 48% without reducing yield.
- Efficient nitrogen use and application of organic inputs to dry soil can further reduce emissions.
- Incentives for adoption of AWD are higher when farmers pay for pump irrigation.

Overview of alternate wetting and drying

Alternate wetting and drying (AWD) is a management practice in irrigated lowland rice that saves water and reduces greenhouse gas (GHG) emissions while maintaining yields. The practice of AWD is defined by the periodic drying and re-flooding of the rice field.

While AWD requires a specific water regime (see *The practice of AWD on the farm*, below), the practice of allowing the water table to drop below the soil surface at one or multiple points during cultivation is not new. AWD and other single- or multiple- drying practices have been used for several decades as water-saving practices. About 40% of rice farmers in China practice some form of water management and short intervals of non-flooded conditions are common among rice farmers in northwestern India and in Japan (more than 80%). AWD-like practices have continued to spread.

A large potential exists for GHG reductions from rice paddies through the use of systematically introduced AWD, optimized for GHG mitigation. At present, AWD is widely accepted as the **most promising practice for reducing GHG emissions from irrigated rice** for its large methane reductions and multiple benefits.

Benefits of AWD

Reduced water use. By reducing the number of irrigation events required, AWD can reduce water use by up to 30%. It can help farmers cope with water scarcity and increase reliability of downstream irrigation water supply.



Figure 1. Field water tube used for observation of water levels by farmers. The ability to observe the level of the water table below the soil helps build confidence in AWD. (Photo: IRRI)

Greenhouse gas mitigation potential. In the 2006 IPCC methodology, AWD is assumed to reduce methane (CH₄) emissions by an average of 48% compared to continuous flooding. Combining AWD with nitrogen-use efficiency and management of organic inputs can further reduce greenhouse gas emissions. This suite of practices can be referred to as AWD+.

Increased net return for farmers. “Safe” AWD (see *The practice of AWD on the farm*) does not reduce yields

compared to continuous flooding, and may in fact increase yields by promoting more effective tillering and stronger root growth of rice plants. Farmers who use pump irrigation can save money on irrigation costs and see a higher net return from using AWD. AWD may reduce labor costs by improving field conditions (soil stability) at harvest, allowing for mechanical harvesting.

Where can AWD be practiced?

In general, lowland rice-growing areas where soils can be drained in 5-day intervals are suitable for AWD. High rainfall may impede AWD. If rainfall exceeds water lost to evapotranspiration and seepage, the field will be unable to dry during the rice-growing period.

Farmers must have control over irrigation of their fields and know that they will have access to water once fields have drained. AWD in rainfed rice is not recommended due to uncertain water availability when fields have to be re-flooded.

Mitigation potential of AWD

Flooded rice systems (comprising irrigated, rainfed, and deepwater rice) emit significant amounts of CH₄. Although estimates vary and have high uncertainty, recent work suggests that flooded rice contributes about 10–12% of anthropogenic emissions from the agriculture sector globally.

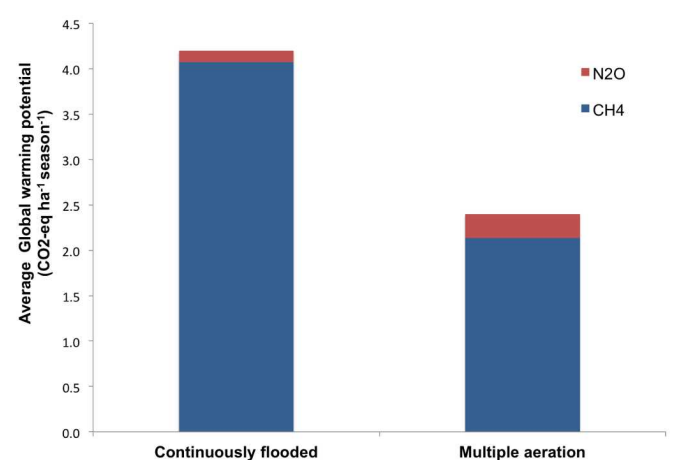


Figure 2. Research in Asia has found a reduction in Global Warming Potential of 43% associated with AWD. (Data from a meta-analysis by Sanchis et al. 2012.)

CH₄ emissions from rice fields have been intensively studied, with more than 300 peer-reviewed scientific journal articles since the 1990s documenting the factors that affect CH₄ and nitrous oxide (N₂O) emissions. The vast majority of this work has taken place in China, Japan, and the US and, to a lesser extent, in India and Southeast Asia. Water

regime and organic inputs are the primary determinants of CH₄ emissions in rice systems but soil type, weather/ climate, tillage management, residue, fertilizers, and rice cultivars also play a role.

Research has consistently found that noncontinuous water regimes such as AWD produce significantly lower CH₄ emissions than continuous flooding. According to empirical models, 15–20% of the benefit gained by decreasing CH₄ emission is offset by the increase in N₂O emissions. However, net GWP is still significantly lower under AWD than in continuously flooded fields (Figure 2).

The mitigation potential of AWD depends strongly on its proper execution. Incomplete drainage (not allowing the water table to drop to 15 cm below soil surface) can result in negligible reductions in GHG emissions.

By the numbers: GHG reduction by AWD

- Flooded rice produces approximately 20–40 Mt of CH₄ per year, or about 10–12% of anthropogenic emissions from the agriculture sector globally.
- In a review of on-station experiments in Asia, the CH₄ emission reduction associated with multiple drying ranged from 14 to 80%, with a mean of 43%.
- On-farm experiments with AWD have shown reductions in CH₄ emissions by 20–70%.
- IPCC 2006 Guidelines for National Greenhouse Gas Inventories estimate a 48% reduction in methane emissions from AWD.
- Using IPCC 2006 guidelines, it has been estimated that if all continuously flooded rice fields were drained at least once during the growing season, global CH₄ emissions would be reduced by 4.1 Mt per year.
- Emissions models estimate that application of rice straw in the fallow period—instead of soil incorporation directly during puddling—would further significantly reduce CH₄ emissions.

How does AWD reduce GHG emissions?

CH₄ in wet or “paddy” rice soil is produced by the anaerobic decomposition of organic material after the flooding of rice fields. Allowing the field to drain removes the anaerobic condition for a time and halts the production of CH₄, thus reducing the total quantity of CH₄ released during the growing season.

The production of N₂O is also regulated by the presence of oxygen. In contrast to CH₄ however, the recurring shift between aerobic and anaerobic conditions favors bacterial conversion of other nitrogen compounds to N₂O and its

release from the soil. The production of N_2O is also strongly influenced by the availability of nitrogen in the soil. Thus, N_2O emissions increase with the amount of nitrogen fertilizer applied to rice paddies.

Research advances in AWD

Building incentives for AWD

Proper design of irrigation schemes and coordination among farmers, irrigation authorities, and local governments can enable large-scale benefits from AWD. In the Philippines, water for irrigation is a limited and dwindling resource due to competition with residential and industrial uses, increasing frequency of drought, and pollution of surface waters. Since the early 2000s, the International Rice Research Institute (IRRI) has collaborated with the Philippine Rice Research Institute (PhilRice) and the National Irrigation Administration (NIA) of the Philippines to disseminate AWD as a water-saving technology. These efforts became more urgent in 2009, when decreasing irrigation water supply during the dry season led the Department of Agriculture to issue an administrative order for the adoption of water-saving technologies in irrigated rice production. This created an opportunity for large-scale implementation of AWD, with benefits not only for water savings but for coping with climate change as well.



Figure 3. Pump irrigation in the Philippines. (Photo: IRRI)

Among the lessons learned in the Philippines' experience with AWD is that the incentive for farmers to adopt AWD varies greatly with the irrigation scheme. In areas served by gravity-driven canal irrigation, there is little private incentive for AWD adoption, as farmers pay a flat irrigation fee (per ha and season) regardless of the volume of water used. In rice areas outside of irrigation schemes, or at the 'tail end' area of gravity irrigation systems where canal water may

become scarce, farmers often use pumps. Some of these are operated by cooperative irrigators' associations, under which farmers must individually buy the fuel to operate the pump. Application of AWD by these farmers allows them to save money by irrigating less frequently or for a shorter period.

On-farm experiments with AWD in the Central Luzon region of the Philippines underpinned the differing incentives for AWD adoption. Canal-irrigated farms had little reduction in CH_4 emissions. Because they paid a flat fee for their water, there was little incentive to reduce irrigation, and the farmers rarely allowed their fields to drain completely. In contrast, CH_4 emissions on pump-irrigated farms decreased by nearly 70% under AWD. Once farmers were confident that the practice would not reduce yields, they used it as an opportunity to reduce money spent on fuel for pumping.

In places with flat-fee gravity irrigation, the irrigation authorities play a key role in tailoring the water supply of a given rice area to the actual demand following the AWD scheme. This 'imposed' AWD is practiced on Bohol Island in central Philippines.

To optimize the use of irrigation water from one of Bohol's dams, NIA introduced an imposed AWD irrigation schedule in 2006. Each farmer has irrigation water for 3 days, then none for the next 10–12 days. The rotation of water is divided between upstream and downstream users. Downstream irrigators' associations have benefited from a more reliable water supply, which is critical to the practice of AWD and allows a larger area to be cultivated. Optimum use of irrigation water has allowed a shift from a single rice crop to a double rice crop in some areas of the island. Imposed AWD requires good control of water flow as found in newly built or rehabilitated irrigation infrastructure.

Funding mechanisms for AWD

Implementation of AWD requires not only well-functioning irrigation systems, but also funds for proper technology transfer and education. Co-ownership is critical; in the Bohol case, contributions from NIA, local governments, and irrigators' associations ensured wide buy-in for the project. Additional support for large-scale implementation could come from funding mechanisms such as Nationally Appropriate Mitigation Actions (NAMAs) and the Clean Development Mechanism (CDM).

IRRI's feasibility study for an AWD CDM in Central Luzon (see *Further Reading*) can provide guidance for policymakers interested in such mechanisms. IRRI is also collaborating with the government of Japan and the Global Research Alliance on Agricultural Greenhouse Gases to develop

guidelines for monitoring, reporting, and verifying (MRV) emissions reductions in rice.

Increasing the benefits of AWD with AWD+

Proper management of rice straw and fertilizers can further reduce CH₄. Efficient nitrogen use can help mitigate the increase in N₂O emissions with AWD while increasing yields and saving farmers money.

A decade of research at IRRI has developed the approach of site-specific nutrient management. This approach allows farmers to tailor nutrient management to the specific conditions of their field. IRRI has developed a computer- and mobile phone-based application called *Rice Crop Manager* that provides farmers with site- and season-specific recommendations for fertilization. The tool allows farmers to adjust nutrient application to crop needs in a given location and season.



Figure 4. *Rice Crop Manager* is an open-access web application that allows extension agents to enter basic location and management information in the field and give farmers immediate fertilizer recommendations. (Source: <http://webapps.irri.org/ph/rcm>)

See the *Rice Crop Manager* site for more information: <http://webapps.irri.org/ph/rcm>. A version that calculates greenhouse gas emissions from various practices is under development.

Soil amendments such as phosphogypsum, silicate fertilizer, ammonium sulfate, and calcium carbide can further mitigate GHG emissions in intermittently irrigated rice. In combination with nitrogen fertilizer, silicate fertilization and phosphogypsum have been shown to

improve rice yields and can also decrease CH₄ emissions under intermittent irrigation by more than 30%. Calcium carbide acts as a nitrification inhibitor, decreasing N₂O emissions by approximately one-third under AWD. Where they are available, these amendments could increase the mitigation benefits of AWD.

Organic inputs such as rice straw, manure, and compost are best applied to dry soil in the off-season to avoid increased CH₄ emissions. The feasibility of this practice depends on the cropping calendar, as in some areas fields are also irrigated during the dry season, leaving little time for aerobic decomposition of organic inputs. Straw and manure, which can also be composted, emit less CH₄ than fresh organic material once applied to rice soils. Ideally, management of organic residue includes biogas technology. Biogas (CH₄) produced from rice straw reduces fossil fuel consumption. The remaining biogas slurry represents a good form of fertilizer with low CH₄ emission potential, compared with soil application of fresh organic material.

The practice of AWD on the farm

- At about two weeks after transplanting, the field is left to dry out until the water level is at 15 cm below the soil surface. Then, the field is flooded again to a water depth of approximately 3–5 cm before draining again. This irrigation scheme is repeated except during flowering time, when the field is maintained at a flooded water depth of 3–5 cm. The number of drainages and the number of days that the field is non-flooded will vary.
- A drainage level of 15 cm is called “safe AWD” because this level will not cause a yield decline (see *Further Reading*). Farmers monitor the water level in the field using a field water tube—a 30-cm length of 15-cm diameter plastic pipe or bamboo, with drilled holes, which is sunk into the rice field until 10 cm of it protrudes above soil level. This has been effective in assuring farmers that the rice plant is accessing water even when there is no standing water in the field. Once AWD has become established, the tube is often dispensed with and farmers base the decision to irrigate on soil monitoring.
- Proper leveling of rice fields is necessary to ensure that no areas are excessively dry or wet, which could adversely affect yields. Laser land-leveling may be appropriate in some farming systems.
- Weed management is important, as periods of drying can encourage weed growth. Maintaining flooded conditions until around 2 weeks after transplanting discourages the growth of weeds while the rice plant becomes established.

- Farmers in the Philippines noted an increase in rats under AWD due to decreased flooding time. Some studies, however, have found reduced susceptibility to other pests under AWD. Periodic soil drying may also reduce incidence of fungal diseases.
- AWD leads to firmer soil conditions at harvest, which is beneficial to operating machines in the field (such as a combine harvester).
- In many contexts, women do not control irrigation water and thus do not have direct roles in AWD implementation. Influences on gender relations should be considered.
- AWD should not be seen as isolated management practice but as an integral part of crop management. For example, PhilRice has integrated AWD into their *PalayCheck System*, a package of recommended rice management practices (see *Further Reading*) that also includes guidelines for land preparation and nutrient and pest management.

Further reading

- Ali MA, Hoque MA, Kim, PJ. 2013. Mitigating global warming potentials of methane and nitrous oxide gases from rice paddies under different irrigation regimes. *Ambio* 42: 357–68. (Available from: <http://dx.doi.org/10.1007/s13280-012-0349-3>)
- IRRI. 2013. Nutrient Manager for Rice. Los Baños, Philippines: International Rice Research Institute (IRRI). (Available from: <http://webapps.irri.org/ph/rcm>)
- IRRI. 2013. Tackling climate change and addressing water scarcity through AWD. Los Baños, Philippines: International Rice Research Institute (IRRI). (Available from: <http://irri.org/our-impact/tackling-climate-change/addressing-water-scarcity-through-awd>)
- IRRI. 2009. Saving water: alternate wetting and drying (AWD). IRRI Rice Fact Sheet. Los Baños, Philippines: International Rice Research Institute (IRRI). (Available from: http://www.knowledgebank.irri.org/factsheetsPDFs/watermanagement_FSAWD3.pdf)
- PhilRice. PalayCheck System for the Philippine Irrigated Lowland Rice. Science City of Munoz, Nueva Ecija, Philippines: Philippine Rice Research Institute (PhilRice). (Available from: <http://www.pinoyrkb.com/main/>)
- Sanchis E, Ferrer M, Torres AG, Cambra-López M, Calvet S. 2012. Effect of Water and Straw Management Practices on Methane Emissions from Rice Fields: A Review through a Meta-Analysis. *Environmental*

Engineering Science 29: 1053–1062. (Available from: <http://dx.doi.org/10.1089/ees.2012.0006>)

- Siopongco JDLC, Wassmann R, Sander BO. 2013. Alternate wetting and drying in Philippine rice production: feasibility study for a Clean Development Mechanism. IRRI Technical Bulletin No. 17. Los Baños, Philippines: International Rice Research Institute (IRRI). (Available from: http://books.irri.org/TechnicalBulletin17_content.pdf)
- Wassmann R, Pathak H. 2007. Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: II. Cost–benefit assessment for different technologies, regions and scales. *Agricultural Systems*, 94(3): 826–840. (Available from: <http://dx.doi.org/10.1016/j.agsy.2006.11.009>)
- Yan X, Akiyama H, Yagi K, Akimoto, H. 2009. Global estimations of the inventory and mitigation potential of methane emissions from rice cultivation conducted using the 2006 Intergovernmental Panel on Climate Change Guidelines. *Global Biogeochemical Cycles* 23. (Available from: <http://dx.doi.org/10.1029/2008GB003299>)

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