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DEUTSCHE ZUSAMMENARBEIT

Published by:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

SEI Stockholm Environment Institute

In cooperation with:

ASEAN climate resilience network

Climate-Smart Land Use Insight Brief No. 2

Alternate wetting and drying for climate change adaptation, mitigation and livelihoods

Key Messages

- Southeast Asia grows as much as a quarter of the world's rice, a staple food across the region and a source of livelihoods for millions of mostly smallholder farmers. Rice production is highly vulnerable to climate change impacts, including shifts in precipitation patterns and reduced water availability.

- Rice production is also a major source of greenhouse gas emissions – in particular, methane, which is released by flooded fields. Moreover, crop irrigation in Asia consumes around 80% of available freshwater, and traditional rice production is one of the most water-intensive crops. In Southeast Asia, 45% of rice production is irrigated.

- Alternate wetting and drying (AWD), a rice production technique in which fields are flooded, drained and reflooded as needed to maintain optimal water levels, can reduce water use by 15–35% without significant yield losses when implemented correctly. It can also halve methane emissions and reduce runoff and erosion, improving soil structure and making rice paddies more suitable for crop rotation and mechanisation.

- AWD can reduce water, seed and fertiliser costs, making it particularly beneficial for low-income farmers. However, it does deviate from traditional practices and requires capacity-building and support for farmers, who may see weed growth and a shift in pests and diseases. AWD is not suitable for rainfed rice, and may not work well in rainy areas where fields may not dry well.

- Realising AWD's potential to build resilience and improve the lives of smallholders requires deliberate attention to equity and inclusion. With their food security at stake, AWD may be too risky for poor farmers unless they have support to avoid or make up for any yield reductions. It is also crucial to address structures that may exclude women and other marginalised groups.

- ASEAN and its Member States already recognise AWD as a promising climate change adaptation and mitigation strategy and have promoted it through national policies, ASEAN guidance and regional collaborations. Several international organisations are supporting AWD implementation as well, with pilot projects in multiple Southeast Asian nations. Still, AWD has yet to be scaled up across the region. Policy-makers, project implementers and researchers all have roles to play in strengthening incentives, helping farmers adopt AWD, and deepening the knowledge base.

Rice is a staple food for more than half of the global population and a major source of livelihoods, grown on more than 144 million farms (GRiSP 2013). The vast majority of the world's rice is grown in Asia – about 90% of annual production from 1980 to 2019, [1] one-fifth to a quarter of it in Southeast Asia, with Indonesia, Thailand and Vietnam as the top producers in the region.

In that period, the area harvested for rice in Southeast Asia grew by about a quarter, to about 44 million hectares, while yields more than doubled, to 189 million tonnes in 2019. In Thailand alone, rice is grown on 45% of the country's farmland; only India exports larger volumes (Sowcharoensuk 2019). The economic and political importance of rice production is evident in national and regional policy interventions to stabilise domestic rice production and pricing and stockpiling regional rice reserves (Caballero-Anthony et al. 2016).

Global demand for rice is projected to grow by 26% from 2010 to 2035 (GRiSP 2013), to 555 million tonnes, driven by population growth as well as increased consumption outside Asia. The Asian Development Bank has projected that rice production in ASEAN Member States will increase by 1.37% annually (Subhan 2018). Yet productivity improvements have slowed, and rice farmers in Southeast Asia face escalating environmental challenges.

Over the past 20 years, extreme weather events such as severe droughts and torrential rains have become more frequent in rice-producing countries in Southeast and South Asia, compared with the previous two decades (Hellin et al. 2020). Key climate change impacts expected in Southeast Asia include rising sea levels, with associated flood risks as well as saltwater intrusion; more extreme and variable precipitation; rising temperatures; and ecosystems degradation (Hijioka et al. 2014). Extreme weather events can also ruin crops and damage infrastructure, causing large economic losses (Howden et al. 2007).

Rice is very sensitive to climate change, and changing weather and precipitation patterns and increasingly frequent and intense extreme weather pose large challenges for rice farmers. At the same time, there has been growing recognition of agriculture – and rice production in particular – as a source of greenhouse gas (GHG) emissions (Hellin et al. 2020). Rice paddies release methane into the atmosphere, a short-lived climate pollutant about 30 times as potent as carbon dioxide over 100 years (Myhre et al. 2013). Rice is also the largest consumer of water in the agriculture sector (Thakur et al. 2011).

This insight brief focuses on alternate wetting and drying (AWD), a climate-smart agriculture technique developed by the International Rice Research Institute that can significantly reduce water needs, making rice cultivation more resilient to water scarcity due to climate change and reducing methane emissions.

Water in traditional rice production

Rice is traditionally produced in flooded paddy fields. Many rice varieties have been bred to thrive in these wet conditions, and flooding the fields minimises weeds. In Southeast Asia, 55% of rice production is rainfed, and thus highly dependent on reliable precipitation (Redfern et al. 2012). The remainder is irrigated, which could also pose challenges as climate change reduces water availability. If climate change continues on current trends and there is no concerted effort to adapt rice production, crop yields are projected to decrease by up to 50% by 2100 (ADB 2017).

The heavy use of water is also why rice production is so GHG-intensive. Flooded paddy fields create an anaerobic environment that emits large amounts of methane. Methane from rice accounts for about 1.5% of global GHG emissions and could grow substantially (Searchinger and Waite 2014). With about 11% of global methane emissions, the rice sector has a carbon footprint comparable to that of international aviation (Global Environment Facility 2019). In rice-producing Asian countries, methane emissions from rice paddies are a substantial part of national GHG inventories (Minamikawa 2017).

Several solutions have been identified to adapt production practices to climate change as well as mitigate GHG emissions. One option is to switch to rice varieties that grow on non-puddled, aerobic, dry soil. Another, intermediate option is AWD.

Understanding alternate wetting and drying

AWD involves the alternate flooding and draining of rice fields throughout the production cycle (ASEAN Ministers of Agriculture and Food 2015). It is done in three stages: first, transplant rice seedlings into flooded fields. Then they dry out the field for about two weeks. During this time, the water will gradually decrease due to evapotranspiration, seepage and percolation. A perforated tube or pipe is used to monitor the water depth and measure water availability below the soil surface, and anytime the water level is less than 10–15 cm below the soil surface, the field is typically

[1] See FAOStat data on paddy rice (accessed 26 April 2021): http://www.fao.org/faostat/en/#data/QC.

reflooded to 3–5 cm above the surface to ensure the plants have enough water (Farnworth et al. 2017). This stage of reflooding, which also occurs constantly when the rice is flowering, helps ensure that rice yields remain high.

AWD is already being implemented in several ASEAN Member States, including Myanmar, the Philippines, Thailand and Vietnam, with plans to scale up across the region (ASEAN Ministers of Agriculture and Food 2015). Along with reducing water demand, AWD has been found to improve soil structure and reduce erosion and runoff, all of which makes rice paddies more suitable for crop rotation and mechanisation (Allen and Sander 2019). AWD can also enhance root depth and density, making rice paddies more drought- and disease-resistant; increase water and nutrient uptake; improve soil aeration, and reduce certain pests and diseases, though some others may become more prevalent.

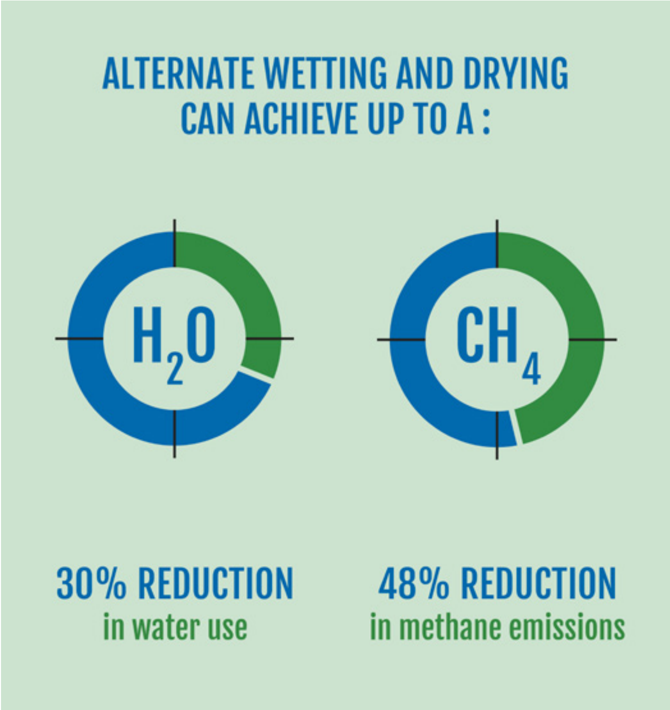
AWD has benefits to human health as well. It been found to improve the quality of the rice grains (Allen and Sander 2019), including their zinc content, and it can reduce arsenic accumulation in the grain by two-thirds (Linquist et al. 2015). With less standing water, mosquitoes and the diseases they transmit, such as malaria, can be reduced (Allen and Sander 2019).

AWD can be part of the system of rice intensification (SRI), which aims to increase yields while minimising the use of water, seed, and chemical fertiliser and pesticides. SRI changes plant management by planting seedlings farther apart and not continuously flooding the fields (Uphoff 2008). Other elements of SRI include improving soil conditions and irrigation to optimise root and plant development. SRI is described as a "triple win" solution for agriculture, climate security and food security, as it increases crop productivity, facilitates climate change adaptation and promotes mitigation (SRI-Rice 2014). Additionally, plants cultivated using SRI methods are shown to improve resistance to drought, floods, storms, pests and diseases.

AWD is particularly suited to dry-season rice cultivation, when soils can be drained in five-day intervals. It requires reliable access to controlled irrigation and is most effective in lowland rice-growing areas with soils that hold moisture.

AWD is not always a good fit, however. The technique is not recommended for rainfed rice, because water may not be available at the intervals needed to reflood the fields. In regions with regular rainfall, AWD can sometimes reduce yields, if the fields are unable to dry properly. Productivity may also be reduced when the method is incorrectly implemented. To implement AWD, local farmers must be willing to deviate from traditional practices and have access to support from local government and water management officials. Farmers using AWD may also see an increase in weed growth; it is recommended that AWD be undertaken together with improved nutrient and pest management (Richards and Sander 2014).

Figure 1: Benefits of alternate wetting and drying.



Source: Adapted from CCAFS (2014).

Photo : IRRI/Amelia Henry

Climate change mitigation and adaptation potential

Given its multiple benefits, AWD is seen as a viable climate change mitigation and adaptation strategy for rice-producing countries in Southeast Asia (ASEAN Ministers of Agriculture and Food 2015). AWD is also valued for its potential to sustain or improve rice yields in areas where water is increasingly scarce and where mechanisation and crop rotation are needed to intensify land productivity. By reducing seed and fertiliser application rates, it could reduce costs to farmers (Farnworth et al. 2017) and it boost farmers' incomes, making them more resilient to climate change impacts (Celeridad 2019).

AWD reduces methane emissions by an average of 49% compared with traditional practices (Chidthaisong et al. 2017). When the soil dries, it releases less methane, though other factors also influence methane release, including soil type, climate, tillage management, crop residue, and the use of fertilisers and other inputs (IRRI 2016). Emission reductions could be quantified to obtain or sell carbon credits on the voluntary carbon market.

Combining AWD with fertiliser and pesticide management can further reduce GHG emissions. IRRI refers to this suite of practices as AWD+. Depending on the context, there is a variation of AWD known as site-specific AWD (AWDS), a more flexible method that aims to find the optimal water regime for GHG emission reduction (Setyanto et al. 2018).

A three-year experiment in Central Java, Indonesia, for example, measured the productivity, GHG emissions and water use (during wet and dry seasons) in three test sites. The first used continuous flooding. The second used standard AWD, with fields reflooded when the water level reached 15 cm below the soil surface. The third used AWDS, with site-specific water use responding to local conditions. Rice growth was normal in all three sites, but AWD and AWDS were found to significantly reduce water use and methane emissions, producing 35–38% less methane than continuous flooding (Setyanto et al. 2018).

AWD is of particular interest for Asia because irrigated agriculture consumes around 80% of available freshwater (Tuong and Bouman 2003), and traditional rice production is one of the most water-intensive crops. AWD has been found to reduce irrigation water use by 15–35% without

Harvesting rice on a field in Laguna, Philippines. Photo: International Rice Research Institute (IRRI).

significant yield loss (Lampayan et al. 2015; Siopongco et al. 2013). Efficient use of irrigation can help farmers adapt to reduced and more variable precipitation due to climate change. As droughts are projected to increase in many areas of Southeast Asia as a result of climate change (ICEM 2013), the ability to grow rice using less water enhances the resilience of rice farmers in this region while also contributing to food security for a growing population.

AWD and social inclusion

Small-scale farmers in the tropics are particularly vulnerable to the adverse impacts of climate change, as they often farm on marginal land and have limited resources and adaptive capacity (Hellin et al. 2020). Given that AWD is both low-cost and relatively easy to implement, it can be particularly beneficial for low-income smallholders (Allen and Sander 2019). However, realising AWD's potential for poverty reduction and resilience-building requires deliberate attention to social equity.

Agricultural development projects often fail to consider key social factors, including gender roles, which may reduce their effectiveness, as they miss key barriers to success and do not incorporate the knowledge, livelihood practices and innovation potential of women and other marginalised groups (Farnworth et al. 2017). Effective AWD implementation requires understanding who makes production decisions and who has the necessary resources and technical capacity and then correcting for inequities, such as when women do a large share of the work but are excluded from decision-making.

AWD is particularly suitable for farmers with limited water supplies (Celeridad 2019), and in river basins where upstream and downstream communities compete for water, reducing overall irrigation water consumption can also reduce conflicts (Allen and Sander 2019). However, when water is provided at a fixed rate, there is little incentive to limit its use, and some farmers may actually use more water to control weeds and mitigate the potential risk of pump failure (Pandey et al. 2020). This can exacerbate water scarcity downstream.

Some irrigation authorities have mandated AWD to manage limited water supplies. For example, the National Irrigation Administration in Bohol, Philippines, allows farmers to irrigate for three days, followed by 10–12 days without irrigation, to allow for more equitable resource-sharing between upstream and downstream users (Richards and Sander 2014).

It is important to note that simply raising water fees to incentivise lower use will disproportionately harm the poor. Instead, allocation schemes and fee schedules need to provide appropriate amounts of water, at affordable rates, when needed, with escalating costs for use beyond those levels (Simmons 2014). Training, extension support and financial assistance may also be needed. While AWD can reduce water, fertiliser and pesticide costs, if done incorrectly, it can significantly increase weeds (Pandey et al. 2020) and reduce yields, imperilling low-income households' food security.

Many poor farmers have little or no access to irrigation water, proper infrastructure or credit (Thangjam and Jha 2020). Programmes supporting the adoption of AWD and other new technologies need to be tailored to low-income farmers' needs, or else they risk reinforcing existing inequalities. Too often, it is more well-off farmers who adopt and benefit more from the adoption of climate-smart practices, because they are less risk-averse and are often targeted for extension services (Resurreccion et al. 2008).

Structural gender inequalities can also limit the benefits of adaptation and mitigation initiatives such as AWD (Gallina and Farnworth 2016). Given that women are heavily involved in rice production, there is a clear need for equity in providing training and support for women as well as men, recognising the different knowledge, perspectives and innovation capacities they bring to the table (Farnworth et al. 2017).

More research is needed to fully understand how AWD implementation impacts gendered labour roles and equitable participation in decision-making. However, looking broadly at low-emissions development strategy implementation, Edmunds et al. (2013) proposed conducting a political ecology analysis, explicitly assessing women's contributions and supporting local innovations to ensure that the strategies provide material, personal and social benefits to poor women.

AWD within ASEAN countries and partnerships

Southeast Asian nations have adopted policies to produce food self-sufficiency, boost production, stabilise prices and ensure a stable food supply (Bello 2005). Given the increasing attention on the adaptation and mitigation potential of AWD, a number of countries have also included this method in their national planning (Hellin et al. 2020).

For example, Vietnam has included AWD as a technique to reduce GHG emissions, noting that increasing the areas with mid-season water drainage and applying AWD on 45,000 hectares of rice was estimated to reduce GHG emissions by 160 tonnes CO2e (The Socialist Government of Viet Nam 2020). A report on adaptation and mitigation in rice cultivation in the Philippines, meanwhile, highlights AWD as having the greatest potential for GHG mitigation (Arnaoudov et al. 2015). The Thai Rice Nationally Appropriate Mitigation Action also highlights AWD as a technique central to lowering emissions in the rice sector (NAMA Facility 2018).

Another way in which AWD is being implemented in Southeast Asia is as a component of "climate-smart villages" in the region. International organisations, including the International Rice Research Institute, the International Water Management Institute (IWMI) and WorldFish, have launched projects in more than 30 communities across Southeast Asia to apply locally appropriate climate-smart agriculture concepts, including AWD. [2] Part of this work is to help communities adapt to and help mitigate climate change impacts in rice-based systems.

In addition, RICE, the second phase of the Global Rice Science Partnership (GRiSP), is helping advance AWD in ASEAN countries. [3] The network, which includes more than 900 research and development partners engaged in rice research, development and implementation, aims to "reduce poverty and hunger, improve human health and nutrition, reduce the environmental footprint and enhance ecosystem resilience of rice production systems through high-quality international rice research, partnership, and leadership" (IRRI et al. 2010, p.24).

AWD in key ASEAN documents and policy processes

ASEAN and its Member States have long recognised rice production as key to the region's food security. Already in 1979, the Agreement on the ASEAN Food Security Reserve (ASEAN 1979) acknowledged the need to maintain food stocks to help alleviate poverty and eradicate malnourishment. Member States committed themselves to maintaining Emergency Rice Reserves without disrupting the market.

ASEAN has also developed policies to promote exports and advance the region's global competitiveness. The ASEAN Integrated Food Security (AIFS) Framework and Strategic Plan of Action on Food Security in the ASEAN Region 2021–2025 (ASEAN 2020), for instance, highlights rice as a key agricultural commodity. It includes activities to replenish and better manage rice reserves as well as provisions on rice trade and cooperation to improve rice production. The plan builds on a 2009 ASEAN strategy that tasked the International Rice Research Institute with drafting a Rice Action Plan for the region, beginning a close collaboration that continues today (ASEAN and IRRI 2016; IRRI 2020). Since then, the Rice Action Plan has been folded into GRiSP/ RICE, which ASEAN ministers have supported implementing across Southeast Asia. IRRI provides technical and policy support to the ASEAN Member States in developing their rice sectors, and it has disseminated high-yielding and resilient rice varieties, advanced cultivation techniques, and educational programmes and tools to extension systems across ASEAN. It is also helping build capacity within ASEAN countries, including by training rice scientists.

ASEAN has directly promoted AWD implementation among its members. The ASEAN Regional Guidelines for Promoting Climate Smart Agriculture (CSA) Practices, for example, present AWD as a climate change adaptation technology with mitigation co-benefits (ASEAN Ministers of Agriculture and Food 2015). They address key challenges and enablers, regional cooperation, and the importance of a regional experience-sharing platform to facilitate mutual learning among ASEAN Member States. AWD is also mentioned in the 2017 ASEAN Guidelines on Soil and Nutrient Management as a critical irrigation technique in SRI (ASEAN Sectoral Working Group on Crops 2017).

ASEAN Member States have also highlighted the mitigation potential of AWD at the international level. In 2015, the ASEAN Negotiators Group on Agriculture developed the region's first joint statement on agriculture to deliver at the international climate negotiations, outlining a number of priorities for action (ASEAN 2015). The group's submission to the 44th session of the UNFCCC Subsidiary Body for Scientific and Technological Advice includes AWD on a list of practices proven to sustainably enhance food security, resilience and productivity. It also highlights the need for greater investments in capacity-building and research to effectively scale up the application of the method.

An agenda for action

In Southeast Asia, rice plays a key role in the economy, livelihoods and food security. Yet rice production is both highly vulnerable to climate change impacts, and a significant source of GHG emissions. AWD has shown great promise as a way to make rice production both more sustainable and more resilient. Scaling up AWD implementation in the region requires coordinated action by a variety of stakeholders through innovations in policy, research and implementation.

The development community, national policy-makers, project implementers and researchers all have roles to play:

[2] See https://www.cgiar.org/annual-report/performance-report-2019/climate-smart-villages-in-southeast-asia/.

[3] See http://grisp.net.

Recommendations for policy-makers and project implementers

- Provide incentives for farmers to adopt AWD and reduce water usage. Farmers who pay a flat fee for water usage, for example, have fewer incentives to implement water-saving techniques. Private pump owners and local water management systems could also play a role in enabling these incentives and motivating farmers to switch to AWD.

- Explore how AWD could be a tool for mitigation and adaptation in projects proposed under the Nationally Appropriate Mitigation Actions, the Green Climate Fund, or the Clean Development Mechanism.

- Consider how AWD and other water-saving rice production technologies can be incorporated in sustainable and climate adaptive water governance.

- Provide extension support and capacity-building to farmers to help them determine whether AWD is appropriate for their land and to make sure they are able to implement AWD correctly and minimise yield reductions. This could include integrated crop management.

- Ensure that farmers who would like to implement AWD have access to well-functioning and efficient irrigation systems. This includes coordinating among farmers and local authorities to design irrigation schemes suitable to limited water resources for rice production.

- Further explore the added benefits of AWDS and AWD+ and develop simple guidance for how farmers can choose the best method for their land and implement it.

- Support a strong integration of gender and social equity principles in the implementation of AWD and other low-emissions technologies, drawing on insights from initiatives such as the Climate Change, Agriculture and Food Security Research Program (CCAFS) of the Consultative Group for International Agricultural Resources (CGIAR).

Priorities for further research

- Explore how to optimise the benefits of AWD through nitrogen use efficiency and management of organic inputs as well as optimal water use.

- Assess how AWD impacts susceptibility to pests and diseases to inform farmers and provide further incentives to implement AWD.

- Systematically review the impacts of widespread AWD implementation in ASEAN, especially in relation to groundwater recharge, downstream water availability and ecosystem services.

- Continue to study the gendered implications of implementing alternative rice production methods.

- Given that women do not usually control irrigation systems and may only have indirect roles in AWD implementation, explore how women can most effectively contribute to AWD implementation and take part in irrigation-related decision-making.

- Research the benefits and challenges associated with selling carbon credits from AWD emission reductions in the voluntary carbon market. This could lead to designing a carbon verification standard and identifying a carbon verifier.

- Assess women's contributions to AWD implementation in existing projects and the resulting benefits to them and to their communities, to gauge how their involvement (or exclusion) has affected GHG emissions and impacts on livelihoods and food security, and what practices are most effective in promoting gender equity.

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About the Insight Brief series

This Insight Brief is part of a series prepared by the Stockholm Environment Institute on behalf of the Climate-Smart Land Use (CSLU) in ASEAN project, which receives funding from the German Federal Ministry for Economic Cooperation and Development (BMZ) and is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in close cooperation with the ASEAN Secretariat. The Insight Briefs aim to raise awareness on the mitigation and adaptation potential of selected climate-smart land use practices and approaches in order to contribute to their application in Southeast Asia as well as to enhance the technical knowledge exchange among ASEAN Member States (AMS).

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The CSLU project builds on the successes of the Forestry and Climate Change Project (FOR-CC) under the Former ASEAN-German Program on Response to Climate Change (GAP-CC), which supported ASEAN in improving selected Framework conditions for sustainable agriculture and Forestry in AMS. CSLU aims to strengthen the coordination role of ASEAN in contributing to international and national climate policy processes for climate-smart land use in agriculture and forestry.

The authors would like to thank Ella Nanda for her research support, and Paul Teng, Hanna Reuter and Takeshi Takama for their helpful comments on earlier drafts. Thanks also to Moch Taufiqul Mujib for providing support in the publication of this brief.

Recommended citation

Anschell, N., and Salamanca, A. (2021) *Alternate wetting and drying for climate change adaptation, mitigation and livelihoods*. ASEAN Climate-Smart Land Use Insight Brief 2. Jakarta: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Published by
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices Bonn and Eschborn, Germany

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As at
June 2021

Design
Jippy Rinaldi, Jakarta

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