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KEY POINTS

- Rice cultivation systems in Asia need transformational changes in crop establishment methods due to dwindling water resources, rising labor costs, and inadequate labor during the peak farming periods.
- Proven water-saving technologies for both irrigated and rainfed rice cultivations such as direct seeded rice and alternate wetting and drying are available, and their wide dissemination—combined with suitable improved rice varieties that best respond to local agroecology—has promising prospects in closing existing wide yield gaps and helping boost food security in Asia.
- For scaling the adoption of water-saving technologies and improved rice varieties, the modernization of agricultural practices—including precise land leveling, mechanized seeding, precise water management, efficient weed control, efficient nutrient management, and mechanized harvesting and threshing—needs to be introduced together to help farmers realize positive returns from the shift in rice cultivation systems.
- Governments can play an important role in scaling the adoption of advance technologies by supporting research and development, improving institutional outreach of extension services, investing in critical utilities and infrastructure that support water-saving technologies, and introducing regulatory reform to institute incentives for farmers.

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DEVELOPING AND DISSEMINATING WATER-SAVING RICE TECHNOLOGIES IN ASIA[1]

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FOOD AND NUTRITION SECURITY CHALLENGE IN ASIA AND THE PACIFIC

The Asia and Pacific region is one of the world's most dynamic regions, where rapid transformations necessitate rethinking about its strategy for food and nutrition security. Although the region has achieved the Millennium Development Goal of halving the hunger rate supported by economic growth, 490 million remain hungry today and high levels of malnutrition persist (FAO, IFAD, and WFP 2015).

Over the long term, pressures on food and nutrition security are likely to intensify due to changing demographic and consumption patterns. Roughly 65% of Asians are expected to live in cities while an additional 3 million more will join the middle class by 2030 (ADB 2011). The more affluent consumers in urban areas will consume more resource-intensive food items such as meat, dairy, and processed foods. Consequently, by 2050, it is estimated that the 9.2 billion global population will need 60%–70% more food (WRI 2013).

[1] This brief has been prepared for discussions at the Food Security Forum in ADB Headquarters on 22–24 June 2016 based on 17 technical papers prepared by the International Rice Research Institute, its partner research institutes and ADB under RETA 6276: Developing and disseminating water-saving rice technologies in South Asia. The technical papers are available at http://www.adb.org/projects/documents/dev-dissemination-climate-resilient-rice-varieties-for-water-short-areas-of-sa-sea-17-papers-tacr

To meet future food demand, crop yield must be increased at the annual growth rate of 2.4%, which is required to double food production by 2050 (Ray et al. 2013). However, the current crop yield growth has been much less than the required rate. Hence, closing the existing crop yield gaps and the genetic improvement of crop yields bear strategic significance for ensuring food and nutrition security at global, country, and household levels.

In Asia, a wide range of yield gaps between potential and actual productivity of 15% to 70% exist for rice, indicating ample opportunities for drastic productivity improvement through disseminating existing technologies such as improved suitable rice varieties, application of fertilizer and other inputs, and efficient crop management (Lobell et al. 2009). Rainfed rice in particular shows relatively large yield gaps and a declining trend in productivity due to water shortages resulting from the erratic nature of monsoon and climate change. Pradhan et al. (2015) estimates that closing such yield gaps can ensure food security in most countries in Asia through the application of inputs and sound farming management.

Closing the yield gaps in rainfed areas will not only impact on food and nutrition security but also on inclusive growth as rainfed agriculture is closely linked to poverty. Roughly 46% of the rice area in the world is rainfed and predominantly grown by small landholders. In Asia, at least 23 million hectares of rice area are rainfed that are prone to water deficit, causing rice yields to be highly unstable (Pandey and Bhandari 2008). Due to the uncertainty of water availability in rainfed agriculture, farmers typically grow rice with limited inputs, leading to a further reduction in yield. Thus, improvement of crop yield in rainfed areas should be a priority for public sector investments.

PARADIGM SHIFT FOR GROWING RICE IN ASIA

Rice is the staple food crop for more than 50% of the world's population, and its sustainable production growth continues to be important for food security, particularly in Asia where consumption accounts for 90% of the global total. Although a declining trend is observed in per capita rice consumption in recent years, the International Rice Research Institute (IRRI 2013) estimates that global consumption of rice will increase by 114 million tons by 2035 due to population and economic growth in Asian and African countries. To meet growing demand, rice cultivation needs to be transformed into a sustainable intensification system supported by encouraging the adoption of advanced technologies and mechanization. Key binding factors, such as dwindling water resources, rising labor costs and inadequate labor during the peak farming periods, enforce the paradigm shift to alternate crop establishment methods in place of the traditional transplanted rice system.

Water Scarcity

Asian countries already suffer from either physical or economic water scarcity. In the northwest region of India, ground water, apart from surface water, has also been found to be seriously depleted due to excessive pumping to irrigate crop lands (Rodell et al. 2009). With increasing population, expanding residential requirements, increased water demand for industry and household use, and the looming water crisis due to climate change, it is clear that severe water shortages are going to intensify not only in rainfed areas but also in irrigated rice-growing areas.

Over the centuries, lowland rice has proven to be a remarkably sustainable system for rice production largely because of water availability. The looming water crisis, however, has threatened the sustainability of traditional lowland rice production, which necessitates a strategic development of water-saving rice production systems such as direct-seeded cultivation. Rice is the major user of freshwater resources in the world. It accounts for the withdrawal of 24%–30% of the total fresh water and the consumption of 34%–43% of the total irrigation water of the world. Majority of the farmers in both irrigated and rainfed rice ecosystems grow rice in puddled transplanted conditions regardless of the topography and availability of irrigation water. This conventional rice production ecosystem requires an average of 2,500 liters of water to produce 1 kilogram of rough rice (Bouman et al. 2007). To ensure sustainable growth in rice production, Asia needs alternative methods of rice cultivation to produce more rice with less water.

Shrinking Farm Workforce

Rice systems also need to adjust to increasing rural–urban migration. In Asia, as more rural labor force migrate to cities to supplement rural household incomes, the farming workforce is shrinking while the agricultural wage level has been increasing. Wiggins and Keats (2014) found that real rural average wages from 2000 to 2010 more than doubled in many provinces of the People's Republic of China and Viet Nam, and increased 36%–38% in India, 44%–53% in Bangladesh, and 60% in Nepal.

Consequently, traditional labor-intensive rice farming practices have become prohibitively expensive and capital intensive technologies need to replace wage labor in rural Asia. The choice of advance farming technologies, therefore, would need to be labor saving in nature or associated with mechanization of farming practices to widely disseminate technologies and improved rice varieties. In rural Asia today, this has become a key condition for successful yield gap closing through the adoption of advanced technologies.

WATER-SAVING TECHNOLOGIES

Technologies that can drastically improve water use efficiency in rice systems are now increasingly being adopted in Asia with the assistance of IRRI and its local partner research institutions. Rice can be grown by transplanting seedlings in puddled fields or by direct seeding in dry or puddled fields (Kumar and Ladha 2011). The practice of both puddling and nonpuddling operations was reported to be equally effective for crop growth, producing comparable rice yields (Bajpai and Tripathi 2000).

Although the intensive water and labor requirements in transplanting rice in puddled fields are well known, technologies such as dry and wet direct seeding and alternate wetting and drying (AWD) could be an option to produce rice in both irrigated and rainfed rice ecosystems. Direct seeding, in particular, is being extensively researched and tested in rice-growing areas to develop a suitable alternative to transplanted rice in irrigated as well as rainfed conditions. Aerobic rice cultivation under direct seeding, and AWD in transplanted rice with suitable drought-tolerant varieties, will not only save water but also bring more areas under cultivation and increase rice productivity. The research and farmers' field trials of IRRI and its partner organizations have so far found that dry direct-seeding is generally suitable for South Asia, wet direct-seeding (unpuddled transplanting) for Southeast Asia, and AWD for irrigated ecologies in other parts of Asia.

Dry Direct Seeding for Aerobic Rice

Aerobic rice is an important water-saving technology for both irrigated and rainfed conditions, where water availability at the farm level is too low or too expensive for economic rice production. This minimizes the water losses associated with continuous flooding of the field.

Aerobic rice is grown in nonpuddled, nonflooded soil with the use of external inputs such as supplementary irrigation and fertilizer, with the aim to obtain high yield. In this system, rice can be established using different systems such as broadcasting, drilling, or dibbling in a well-prepared field, and direct seeding with zero tillage using a mechanical seed drill or raised beds (Kumar and Ladha 2011). Traditionally, this method has been practiced in rainfed upland and rainfed shallow lowland areas of Asia (Rao et al. 2007).

The water savings generated by dry direct seeding for aerobic rice, compared with conventional rice-growing practices, have made this method increasingly popular in irrigated areas where water is becoming scarce (Kumar and Ladha 2011). Other main enablers for the adoption of aerobic rice by farmers are reduced labor requirement and its relatively water deficit tolerance, which brings more stability to rice production in the rainfed production system. Castañeda et al. (2004) reported a savings of 73% in land preparation and 56% during crop growth. Aerobic rice yield depends on the effective use of herbicides and biocides (e.g., nematicides) as well as an adequate supply of plant nutrients.

Yields obtained with aerobic rice varieties vary from 4.5 to 6.5 tons per hectare, which are about double or triple than that obtained with traditional upland rainfed varieties, but 20% to 30% lower than that obtained with lowland varieties grown under flooded conditions (Farooq et al. 2009, Prasad 2011). In aerobic rice experiments at IRRI, the yield of aerobic rice gradually declined over time compared with that of a continuously flooded control (George et al. 2002, Peng et al. 2006). For the sustainability of the aerobic system, breeding efforts must be adopted for sustainable long-term yields through the development of varieties that do not show a yield decline under continuous aerobic rice cultivation or that follow appropriate crop rotation practices to allow soil to maintain its fertility and prevent soil-borne diseases, including the development of nematodes.

Dry Direct Seeding for Aerobic–Anaerobic Rice

Dry direct-seeded rice (DDSR) has received much attention over the past few years because of its low input use. The method involves sowing seeds into a well-prepared dry soil. The development of early maturing varieties, improved nutrient management techniques, and increased availability of chemical weed control methods have encouraged many farmers in India, the Philippines, and Thailand to switch to the DDSR method of rice cultivation. The shift from transplanting to the DDSR should substantially reduce crop water requirements, soil organic-matter turnover, nutrient relations, carbon sequestering, weed biota, greenhouse gas emissions, and, most importantly, the labor requirement. Currently, IRRI and other national research institutes have begun work on direct-seeded rice systems. In the next few years, it is expected that with the development of new varieties more suitable to DDSR, the technology will be accepted by farmers on a large scale.

Wet Direct Seeding

Wet direct seeding refers to the seeding of pregerminated rice seeds on the surface of a puddled rice field (aerobic wet direct seeding) or drilling into the puddled soil (anaerobic wet direct seeding) through broadcasting or line sowing, using a drum seeder or anaerobic seeder with a furrow opener and closer (Balasubramanian and Hill 2002, Kumar and Ladha 2011). This system has traditionally been followed in eastern India, where seeds are broadcast in puddled fields, coupled with beushening and thinning of seedlings to control weeds and ensure proper spacing between seedlings. The method can be highly useful in both rainfed and irrigated lowland conditions through the use of suitable varieties and cultivation practices. Wet seeding has been practiced on a large scale in Malaysia, Sri Lanka and Viet Nam. Wet direct-seeded fields can have fewer weed problems than dry direct-seeded fields because puddling and flooding kill a number of weeds. But wet direct seeding has lower water savings than dry direct seeding because of the amount of water required for flooding the field for puddling and the need for assured water supply in the beginning of the season for land preparation.

Alternate Wetting and Drying

The AWD system of rice cultivation is a water-saving technology in which irrigation water is applied 3 to 5 days after the disappearance of water in the field. Even without ponded water, rice roots can access the water in the subsurface soil, which remains saturated. The total water use in a rice crop is 20%–25% less than in continuous flooding.

Using this method, fields were sometimes exposed to mild drought stress, resulting in a yield reduction in AWD as compared to transplanted rice. Safe AWD is now recommended, which includes irrigating the field when water reaches 15-centimeter depth, and keeping the field flooded for 10 days after transplanting or 20 days after direct seeding, as well as 1 week before flowering to 1 week after flowering. Safe AWD has reported yields similar to transplanted rice, reducing water input by 15%–30% (Bouman et al. 2007, Tuong 2009).

Since most of the varieties developed for irrigated conditions do not perform well under AWD, IRRI has been developing varieties with better adaptation to AWD conditions.

DRIVERS FOR SCALING TECHNOLOGY ADOPTION

Water, Labor, Energy, and Seed Cost Saving

Direct seeding, unlike transplanting, can reduce the labor requirement by up to 50% (Santhi et al. 1998). However, farmers may end up using most of the labor saved from transplanting for weed management operations. As a result, even though the total labor requirement shows no substantial reduction, the demand for labor spreads over a longer period of time than with transplanting. This enables farmers to make full use of labor, thus efficiently avoiding bottlenecks in overall cultural practices (Pandey and Velasco 1999). In recent years, the use of pre-emergence and post-emergence weedicides have been demonstrated to be equally effective as manual weed control methods, which have been practiced for several decades.

Water-saving rice technologies also allow the mechanization of labor-intensive farming practices and help realize positive returns for adopting the technologies, with substantial cost savings from less irrigation, water, energy, and seed without compromising yields. This should work as effective incentives for many farmers in Asia and help scale technology adoption.

Mechanized seeding through tractor-driven seed drills has not only facilitated sowing at optimum soil depth of 2 to 3 centimeters but has also reduced the seed rate from 80–200 kilograms per hectare to 20–25 kilograms per hectare. The lower seed rate has also helped overcome spikelet sterility and lodging problems (Kumar and Ladha 2011). Savings of 12% to 35% in irrigation water and up to 60% savings in labor under direct-seeded rice (DSR) as compared with transplanted rice have been observed. The yield under DSR with rice varieties suited to transplanted conditions has been reported to be similar to that of transplanted rice except for an 8% to 28.5% decline reported in India and Pakistan (Kumar and Ladha 2011). DSR compared with transplanted rice has been reported to have a lower cost of production by $22 to $80 per hectare, which resulted in higher economic returns of $30-$50 per hectare compared with transplanted rice (Kumar and Ladha 2011). Under DSR, a yield decline takes place under conditions of unavailability of assured water for irrigation that leads to exposure of the crop to mild or moderate water-deficient conditions.

Potential GHG Emission Reduction

Apart from labor and water savings, nonflooded rice cultivation may bring other advantages such as reducing methane emissions, maintaining soil structure beneficial to nonrice crops in the rotation, and promptly switching over to a subsequent crop season by reducing the turnaround time for land preparation.

Globally, rice cultivation is estimated to emit greenhouse gases of 500 million tons per year or 10% of total emissions in agriculture (WRI 2014). One of the most promising interventions in reducing greenhouse gas emissions (GHG) from rice cultivation is to reduce the periods of flooding rice fields. Rice plants under anaerobic conditions release methane into the atmosphere through roots and stems. In theory, water-saving managements can reduce emissions by up to 90% compared to conventional full flooding practice, while maintaining or increasing rice yield.

CHALLENGES TO ADOPTING WATER-SAVING TECHNOLOGIES

Weeds in Dry-seeded Rice Systems

DSR is a water- and labor-saving technology but weeds are the major constraint to the successful production of a DSR crop. Herbicides are being used to manage weeds in DSR, but they do not provide complete and season-long weed control. A single strategy may not provide effective control of weeds, and there is a need to integrate different weed control strategies, including the use of clean seed and equipment, the stale seedbed practice, thorough land preparation, weed-competitive varieties, narrow row spacing, crop residue as mulches, pre- and post-emergence herbicides, and intercultural operations to achieve effective and sustainable weed control in DSR.

The Rice Root-Knot Nematode

In South and Southeast Asia, the rice root-knot nematode *Meloidogyne graminicola* is considered one of the most important pathogens of rice, especially in a range of rice production systems. Recently, this nematode species has also been identified as a major causal agent of yield decline and even yield failure in tropical aerobic rice. Identification of tolerant/resistant donors and genes, and the use of identified donors and genes in breeding water-saving varieties, will help develop rice varieties with stable yield under water-saving conditions.

Soil Sickness in Tropical Aerobic Rice

Soil sickness is not unique to continuous aerobic rice monocropping, and it has been observed in various crops that have been grown on the same land for several consecutive seasons. In aerobic systems, improved adapted rice varieties are grown in nonpuddled aerobic soil without standing water. Successive cultivations of this crop lead to symptoms of soil sickness. Although breeding is continuous for increased yield potential of aerobic rice, yield decline caused by soil sickness due to successive aerobic rice monocropping needs to be immediately addressed to ensure sustainability of the system. The factors involved in soil sickness due to continuous aerobic rice monocropping include nutrient deficiencies, soil alkalinity, and buildup of root-infecting nematodes and fungi.

Studies point to the importance of site-specific soil nutrient management, as well as ensuring the supply of good-quality irrigation water. Cultural management involving crop rotations and fallow periods has also been helpful in diminishing the harmful effects of continuous cultivation. Control of soil-borne root diseases through host-plant resistance, nonhost crop rotations, and organic matter amendment also plays a role in alleviating soil sickness.

In addition to host-plant resistance, alternative practices that increase soil fertility and biodiversity and increase plant vigor, such as crop rotations with legumes, fallowing, cover crops (green manure) and application of organic amendments, may help overcome problems of soil sickness due to nutrient deficiencies, pathogen buildup, reduced plant immunity as well as auto-toxicity to allelochemicals. These ecologically based agronomic practices help retain the capacity of soil to function as a vital living system to sustain biological productivity, and promote environmental quality and plant health (Doran and Zeiss 2000).

THE WAY FORWARD

Dynamic agroecological and socioeconomic changes in Asia call not only for the dissemination of water-saving varieties but also for adopting technologies that achieve the optimum use of natural resources. In Malaysia, Sri Lanka, and the United Sates, the supporting technologies for disseminating suitable varieties, including precise land leveling, mechanized seeding, precise water management, efficient weed control, efficient nutrient management, and mechanized harvesting and threshing, enabled the successful expansion of direct seeding practices.

For wider dissemination of rice technologies, it is important to avail of the right combinations of water-saving technologies and suitable rice varieties that allow farmers to realize positive economic returns from rice cultivation with less use of water, labor, nitrogen, and fossil fuel energy per unit of rice produced. This incentive is the key to scaling adoption of water-saving technologies, thereby enabling rapid food grain production growth through sustainable intensification to meet future food demand. Under the past technical assistance projects of the Asian Development Bank, IRRI and its partner research institutions have been developing packages of improved rice varieties suitable for water-saving rice technologies to support their wide dissemination in Bangladesh, India, Nepal, Pakistan, and the Philippines.

The highly diverse microclimate, climatic variation, and season-specific availability of water in Asian countries require extensive research for a clear demarcation of specific challenges within each ecosystem as well as the development and dissemination of water-saving technologies suited to these ecosystems. A site-specific package of production technologies will need to be developed for different rice production systems. Breeding and distributing high-yielding rice varieties suitable to local conditions are important to realize potential savings of natural resources as well as to narrow existing crop yield gaps.

Major challenges to the large-scale adoption of water-saving technologies include farmers' lack of knowledge about available water-saving technologies, traditional habits of cultivating rice, poor linkages among stakeholders, and inadequate government support. Continued support of research and extension agencies is hence imperative to ensure the effective scaling up of water-saving technologies among farmers in Asian countries.

Considering that rice water-saving technologies are knowledge intensive, realizing their full potential can be limited by the lack of well-trained extension staff. Further spread of these useful technologies would thus depend on actions that need to be taken at the government level to improve and institutionalize their dissemination and adoption in Asian countries.

Public infrastructure investments and regulatory reform can also support farmers in adopting the technologies to realize rice yield increase and production cost savings (irrigation and energy costs). For instance, frequent power shortage need to be addressed to enable farmers to practice in-time irrigation. In addition, to generate economic incentives to save water in rice cultivation, irrigation payment schemes can be decided based on volume of water used, not on fixed-rate arrangements that have already been decided prior to the start of the season.

Development of Water-Saving Technologies and Improved Rice Varieties in Asia

	Technologies	New Varieties	Water Savings	Yield	Labor	Weed Management	Risk and Return
BANGLADESH							
All seasons (aus, aman and boro) Suitable for Water-short and drought-prone northwest region	Direct Seeded (Aerobic)	IR74963-262-4-1-3-3, BRRI dhan 56	29% savings compared to continuous flooded conditions without significant yield decline Water productivity of 0.79 kg m^{-3} (conventional 055 kg m^{-3}	2.0–5.0 t/ha	Labor-saving opportunities with mechanization	The use of herbicide (Refit 25 EC) and two hand weeding effective	Cost effective
Transplanted aus, transplanted aman and boro, pump irrigation	AWD	IR83142-B-71-B-B, PSBRc 82, BRRI dhan 66, BRRI dhan 71	20%–25% less irrigation water use than continuous flooding	1.0 t/ha more than the popular variety cultivated in different regions	Labor-saving opportunities with mechanized transplanting		Cost effective
Pump irrigation areas	AWD	BRRI dhan 49	15%–30% water savings Reduction in the number of irrigations by 28%	Increase in yield by 0.4–0.5 t/ha	Labor-saving opportunities with mechanized transplanting		Drop in energy costs (fuel/ electricity) in irrigation by 20%
INDIA							
Irrigated and rainfed	Direct Seeded (Aerobic)	CR dhan 200, CR dhan 201, CR dhan 202, CR dhan 203, CR dhan 205, Anagha	Highest yield per unit of water used among all water-saving rice technologies	3.5–6.1 t/ha (double the yield of upland varieties; 25%–30% lower than irrigated lowland varieties under flooded conditions)	Labor-saving input is the key driver in adopting the technology	Proper land preparation, clean seed, pre/ post emergence herbicides, cultural operation	Small sowing window, high rainfall just after sowing reduces germination, establishment, higher return in case of scattered initial rain
Rainfed: Water-limited uplands and shallow low lands in Eastern region (Jharkhand and Odisha)	Direct Seeded (Aerobic)	Input-responsive rice in non-flooded, direct-seeded conditions Sahbhagi Dhan	Limited opportunity for water savings	2.0–4.5 t/ha depending upon ecosystem and water availability; 1.0 t/ha higher yield over currently grown varieties under water shortage	Labor saving, better opportunities for mechanized seeding and crop management	Proper land preparation, clean seed, pre/ post emergence herbicides, cultural operation	Reduced risk of crop establishment if monsoon is delayed Possible early harvest allows a sequence crop with residual moisture
Rainfed: Drought-prone eastern region (Odisha, Karnataka)	Direct Seeded (Aerobic)	Apo, Sahbhagi dhan, CR dhan 203, CR dhan 205 and Sharada (Direct seeding, fertilizer-responsive high-yielding varieties with supplementary irrigation)	Limited opportunity for water savings	2.0–4.5 t/ha depending upon ecosystem and water availability; 1.0 t/ha higher yield over currently grown varieties under water shortage	Labor saving, better opportunities for mechanized seeding and crop management	Proper land preparation, clean seed, pre/ post emergence herbicides, cultural operation	Small sowing window, high rainfall just after sowing reduces germination, establishment, higher return in case of scattered initial rain

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Continuation

	Technologies	New Varieties	Water Savings	Yield	Labor	Weed Management	Risk and Return
Irrigated, Odisha	Direct Seeded (Aerobic) and AWD	MTU1010, DRR dhan 42, DRR dhan 44	(Aerobic) 25% irrigation water savings, water use efficiency of 3.84kg/ha/mm (3.37 kg grain/ha/mm for conventional system) (AWD) 33% irrigation water saving and water use efficiency of 3.43 kg grain/ha/mm (2.64 kg grain/ha/mm for conventional system)	Aerobic: 2.4–4.2 t/ha (25%–30% lower than conventional) AWD: 4.82–5.0 t/ha (12%–14% lower than conventional)	Labor-saving opportunities with mechanized DSR planting/transplanting	Preemergence herbicide followed by one manual weeding at 3 WAS increase yield Ground nut or mung bean sequentially can enhance yield (4.3 to 4.6 t/ha)	Small sowing window for direct seeded rice
NEPAL							
Hilly upland and shallow rainfed lowland irrigated and rainfed area	Direct Seeded (Aerobic)	Sukha dhan 1, Sukha dhan 2, Sukha dhan 3	Limited opportunities for water savings in rainfed areas	3.0–4.3 t/ha, 1.0 t/ha more yield over cultivated popular varieties under water shortage	Labor-saving opportunities in rainfed and irrigated areas with mechanized seeding	Weed management by butachlor at 1.5 kg a.a./ha sprayed 2 WAS and hand weeding 4 WAS most effective	Short window for direct seeding, higher return
Irrigated and rainfed transplant areas	AWD	IR05N-449 and IR78937-B-B-B-B-1 Tarahara 1, and Hardinath	8%–13% irrigation water savings without any yield decline	4.1–4.3 t/ha	Labor saving opportunities with mechanized transplanting		Higher return compared to conventional flooded irrigation
PAKISTAN							
Punjab and Sindh	Direct Seeded (Aerobic) and AWD	IR79597-56-1-2-1, IR80416-B-32-3	At least 25% savings for aerobic, 20% savings for AWD compared to conventional	5.0–5.8 t/ha, an increase by 14% over currently popular varieties	Labor-saving opportunities with mechanized seeding/transplanting	Weed management successfully addressed with herbicides (ethoxysufuron and sodium2, 6bis-benzoate) and increased yield	Aerobic: Incremental return of $402/ha
Irrigated areas	AWD	IR82082-B-B-96-1, IR70210-39-CPA-7-1, KSK 133, DR 92, Basmati 2000	20% or more of water savings than conventional	5.5–6.1 t/ha	Labor-saving opportunities with mechanized transplanting		Higher return and profit compared to conventional flooded irrigation
PHILIPPINES							
Tarlac Nueva Ecija Bulacan	Direct Seeded (Aerobic)	Apo, Sahod Utan 1, Sahod Ulan 12		Apo: 4.0–5.5t/ha, 2.0 t/ha in Bulacan Sadod Ulan 1: 5.26 t/ha in Bulacan	Labor-saving opportunities with mechanized seeding		Return as good as irrigated lowland rice. A good alternative for rainfed and water-short areas
Irrigated areas	AWD	PSBRc82, NSICRc 222	16%–24% savings of irrigation water	4.5–5.5 t/ha	Labor-saving opportunities with mechanized transplanting		Higher return and increased net profit

AWD = alternate wetting and drying, h = hectare, t = ton, WAS = week after seeding
Source: RETA 6276: Developing and disseminating water-saving rice technologies in South Asia, 17 technical papers, http://www.adb.org/projects/documents/dev-dissemination-climate-resilient-rice-varieties-for-water-short-areas-of-sa-sea-17-papers-tacr

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