Comprehensive
assessment
of water management in agriculture

water for food, water for life issuebrief#5

Rice cultivation in the 21st century:

How to feed more people, reduce poverty, and protect ecosystem services

The challenge for rice cultivation in the next 50 years is to feed more people, while keeping prices low to benefit poor rice consumers and reducing production costs to benefit poor growers. At the same time, water scarcity, drought, flooding and salinity increasingly threaten the productivity of rice-based systems (see Fig. 1).

How to meet this challenge? Some solutions exist; others require more investment in research. No single solution will fit all situations. They need to be evaluated based on impacts on the poor, on the environment and on the often unrecognized ecosystem services rice landscapes provide (see Box 2).

Rice systems are also social systems—in many cases, based on hundreds, even thousands of years of tradition. Unless solutions are designed and implemented with the active participation and support of communities, they will not be successful.

Box 1: Key findings

Keeping rice prices low, while reducing production costs, is crucial for poverty reduction in rice growing and consuming areas.

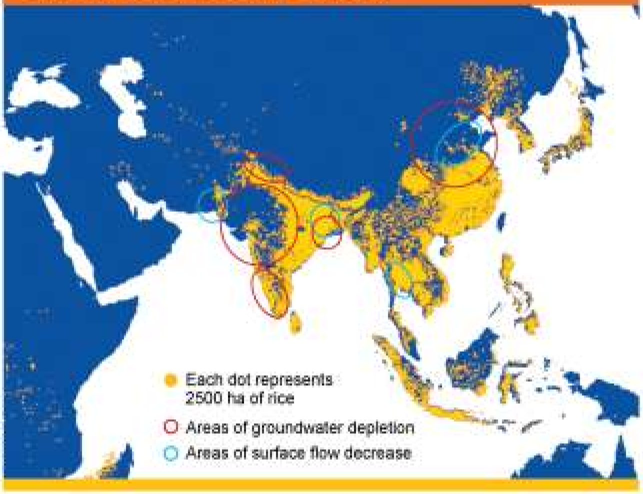
Rice systems not only provide food, but also ecosystem services—such as flood mitigation; groundwater recharge; erosion control; and habitats for birds, fish, and other animals—which need to be recognized and protected.

To keep up with the food needs of the world's increasing population, rice cultivation will have to adapt to water scarcity, drought, flooding, salinity, and climate change. Greater investment in research and extension is needed to meet these challenges.

Solutions need to be tailored to the specific physical and socio-economic context and evaluated in terms of impacts on the environment and on the health, income, and food security of poor rice growers—both men and women.

Because of the hydrological connectedness of rice fields and because of the unique role rice cultivation plays in many cultures, solutions need to be developed with communities.

Fig. 1. Major rice-growing areas in Asia and some water-related threats



IRRI, 2006

Keeping up with demand

Rice is currently the staple food of some 3 billion people, and demand is expected to continue to grow as population increases—by 1% annually until 2025 in Asia and by 0.6 to 0.9 % worldwide until 2050. While the bulk of the world's rice is grown and consumed in Asia, changing dietary preferences are also impacting rice consumption in other parts of the world. Rice demand is increasing the most rapidly in West and Central Africa—by 6% each year.

So where will the rice come from to feed these additional rice consumers? To avoid destruction of natural ecosystems, increasing yields on existing croplands is the best option. This includes both irrigated and rainfed land, although most of the additional production will come from irrigated lowlands, which already supply 75% of the world's rice.

In some major rice-producing countries, such as Bangladesh, the Philippines and Thailand, there is still a large gap between actual and potential yields. In these countries, water and crop management technologies hold the most immediate promise. In other countries—namely China, Japan, and Republic of Korea—the yield gap is already closing, and further yield increases can only come from genetic improvement. This means more research and investment in breeding programs. In irrigated lowlands with ample water supply, the development of hybrid rice has the potential to increase yields by 5% to 15%.

Rice as a crucial factor in reducing poverty

Many poor people spend 20% – 40% of their income on rice alone. The reduction in the price of rice—from $1,000 per metric ton in 1960 to an average of around $250 over the past 5 years—may have done more to benefit Asia's poor than any other single factor. Keeping rice prices low remains in the best interests of poverty reduction in areas where rice is the staple food.

On the other hand, low prices can hurt poor rice growers. Most of the world's rice farming takes place on small, family-owned farms—with average farm sizes varying by country from 0.5 ha to 4 ha. And in many areas rice farming is the main source of employment. Here increasing yields and reducing production costs is the first step for many families to escape poverty. Rice-related policies, breeding programs, and water and land management technologies and practices, need to take into account possible impacts—positive and negative—on the poor who depend on rice as a source of food and income.

Interventions impact men and women differently—as the division of labor in rice cultivation is, in most countries, along gender lines. This means, for example, that in areas where women do most of the transplanting, changing to direct seeding, can mean either an additional burden or source of employment for women—depending on whether they are unpaid or paid labor. Purely technical solutions will not work—they need to take into account that in many communities, rice cultivation is at the heart of social and religious life.

Box 2: Ecosystem services provided by rice landscapes

Rice fields provide unique, but often unrecognized, ecosystem services. Depending on the method of cultivation and the physical characteristics of the landscape, these can include:

- providing a habitat for birds, fish and other animals (thus conserving biodiversity and supplying additional food sources)
- recharging groundwater
- mitigating floods
- controlling erosion
- flushing salts from the soil
- providing water filtration
- sequestering carbon
- regulating temperature/climate

But rice cultivation can also have negative impacts on the environment—polluting groundwater and surface water with agro-chemicals, raising water tables in areas with saline/arsenic-contaminated groundwater, and releasing greenhouse gases (especially methane) into the atmosphere. Decisions about interventions to increase production and/or decrease water requirements, need to weigh both ecosystem services and negative environmental impacts.

See CA Water for Food, Water for Life Brief #1 on agro-ecosystems for more information on maximizing ecosystem services while reducing negative environmental impacts.

Photo: 6 - Hotel/IRRI

For 2,000 years the rice terraces of the Philippine Cordilleras have provided communities with food and cultural and ecosystem services, but now they are under threat. In 2001, they were added to the UNESCO's list of World Heritage sites in danger.

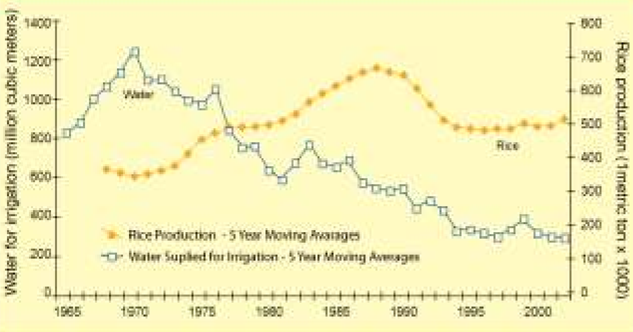
Adapting to threats to rice productivity

Water scarcity and competition for water with cities and industries: In the next 25 years,15-20 million ha of irrigated rice are projected to suffer some degree of water scarcity—particularly wet-season irrigated rice in parts of China, India and Pakistan. Even in water abundant areas, "hot spots" of water scarcity exist. Economic water scarcity—where lack of financing prevents harnessing water resources for productive use—limits cultivation of the 22 million ha of dry-season irrigated rice in South and Southeast Asia.

Between a quarter and a third of the world's tapped freshwater resources are already used to irrigate rice. Pressure to reallocate water from irrigated agriculture to cities and industries is already impacting rice cultivation in many parts of the world. This type of transfer can be accomplished without a drop in rice productivity (see Fig. 2), but it requires a combination of supportive policies and the introduction of improved practices and technologies.

Increasing water scarcity may also force a shift in rice production to more water-abundant delta areas. And in water short areas, aerobic rice production—that is growing rice without a standing water layer—and alternate wet and dry regimes may come to predominate alongside a shift to non-rice dryland crops such as maize.

Fig. 2. Decreasing irrigation water supplied while increasing production in Zanghe Irrigation System (ZIS), China



Over the past 30 years, ZIS farmers have been able to produce more rice with less water thanks to the introduction of an integrated package of technological, institutional, and policy measures.

Source: Paddy and Water Environment 2004.

Droughts, flooding and salinity: These are all current threats to productivity, particularly in rainfed areas, and may increase in severity under climate change.

Frequent droughts afflict approximately 25 million ha of rainfed rice—primarily in eastern India, northeastern Thailand, Lao PDR and Central and West Africa.

Salinity affects another 9-12 million ha—mostly in India, but also Bangladesh, Thailand, Vietnam, Indonesia and Myanmar. Salinity is a threat in deltas where sea water intrudes inland and in some island rice production systems.

Some 11 million ha of both irrigated and rainfed rice are prone to flooding. Even though rice is adapted to water-logging, most varieties can survive complete submergence only 3 to 4 days.

In areas prone to drought, salinity and floods the combination of improved varieties and specific management packages has the potential to increase on-farm yields by 50 – 100% in the coming 10 years—provided that investment in research and extension is intensified.

Groundwater mining: Groundwater development—most of it private and largely unregulated—has enabled small rice growers in many areas to prosper, but unsustainable pumping threatens the viability of these production systems. For example, in the North China Plain water tables are dropping by 1 to 3 meters per year and in the northwest Indo-Gangetic Plain they are dropping by 0.5 to 0.7 meters per year.

Declining water tables due to over pumping threaten not only agricultural productivity, but also human health, since many communities are dependant on groundwater for their drinking water supply. In Bangladesh and parts of India, falling water tables have been linked to contamination of groundwater with naturally occurring arsenic and fluoride.

Climate change: Climate change may impact rice productivity in several ways. It is expected to increase the frequency of droughts and flooding and to increase temperatures, which will have a negative impact on yields. Simulations find that for every 1°C rise in mean temperature, there is a corresponding 7% decline in rice yield. Developing rice varieties that are less sensitive to higher temperatures is the only way to cope with this eventuality.

Box 3: How much water does rice really use?

Perhaps not as much as you might think. At field level, rice receives up to 2-3 times more water per hectare than any other crop, but not all of this water is "consumed"–evaporated from the field or taken up by the plants and transpired as water vapor.

Under flooded conditions, water productivity for rice is almost the same as that of wheat, when measured by the amount of water actually consumed through evapotranspiration per unit of grain.

Nonproductive outflows of water by runoff, seepage and percolation are about 25 – 50% of all water applied in heavy soils with shallow water tables and 50 – 80% in coarse soils with deep water tables. Though runoff, seepage, percolation are losses at field level, they are often captured and reused downstream and do not necessarily lead to true water depletion at the irrigated area or basin scales.

Growing more rice with less water

Of the potential threats explored in this brief, water scarcity and increasing competition for water in irrigated rice systems are perhaps the most pressing—in terms of potential impact on overall production levels. There are various response options for reducing the amount of water needed to grow rice, but all of these options have different impacts in terms of environmental sustainability and ecosystem services (see Table 1).

Table 1: Example of tradeoffs associated with one response option to water scarcity

Option:

Moderate alternate wetting & drying regimes

Benefits:

- Reduced field water application (by 15 – 20% without affecting yield)
- Reduction in disease causing vectors
- Less ammonia volatilization & methane emissions

Drawbacks:

- Fewer options for informal reuse downstream
- More weed growth & pests (need for more herbicides and insecticides &/or labor)
- Reduction in soil fertility over time (greater need for fertilizer)
- Higher nitrous oxide emissions & nitrate leaching
- Loss of habitats for some species

Breeding to improve water productivity: The overall scope to increase the transpiration efficiency of rice is small compared with scope to increase water productivity by lessening necessary total water inputs per unit of production—especially by reducing seepage and percolation losses. Currently most breeding programs focus on rice breeding under ponded water conditions, but to address water scarcity and increasing competition for water, breeders need to start looking at high-yielding varieties under aerobic growing conditions and alternate wetting and drying regimes.

Water saving technologies and management practices: The biggest water savings at the field level comes from reducing seepage, percolation, and surface drainage flows, but these may not result in savings at irrigation system or basin-scale. Water-saving measures at field-level include land-leveling, farm channels, and good puddling and bund maintenance. Minimizing turnaround time between wet land preparation and transplanting can also save water by reducing the time when no crop is present and outflows of water from field don't contribute to production.

Water management techniques such as moderate alternate wetting and drying regimes (without subjecting crops to water stress), can also reduce field water application 15 – 20% without affecting yield. But this may reduce options for informal reuse downstream. In irrigated systems, integrated approaches that take into account the options for reuse of water and for conjunctive use of surface water and groundwater offer the best way forward to improve total water use efficiency at the system scale.

Photo: Maria Bellio

Weerawila Rice Field, South Sri Lanka. Flooded rice fields serve as a habitat for many species. The Ramsar Convention on Wetlands recognizes flooded rice fields as human-made wetlands. If such fields are converted to dryland crops or aerobic rice cultivation due to water scarcity, the impact be on wetland biodiversity needs to be considered.

Box 4. Need for better knowledge

Meeting the challenges rice cultivation faces will require filling various knowledge gaps:

- The ecosystem and cultural services provided by rice systems and how to value them.
- The sustainability and impacts of various response options on the environment and ecosystem services.
- The social as well as technical aspects of crafting effective solutions in communities where rice cultivation is an integral part of the culture.
- Technologies for increasing rice productivity in rainfed and unfavorable environments (drought-prone, flood-prone, and salinity-affected).

For more information. Email: comp.assessment@cgiar.org **Visit: www.iwmi.cgiar.org/assessment**

The Comprehensive Assessment of Water Management in Agriculture (CA) is a five-year initiative to analyze the benefits, costs, and impacts of the past 50 years of water development and management in agriculture, to identify present and future challenges, and to evaluate possible solutions. The main Assessment report Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture is published by Earthscan (forthcoming). More on the CA donors, co-sponsors (CBD, CGIAR , FAO, Ramsar), process and publications can be found at: http://www.iwmi.cgiar.org/assessment.

The International Rice Research Institute (IRRI) is the world's leading rice research and training center. Based in the Philippines, it is an autonomous, nonprofit institution and is one of 15 centers funded through the Consultative Group on International Agricultural Research (CGIAR).

The Challenge Program on Water and Food (CPWF) is an international research and capacity-building initiative of the CGIAR to find ways of growing more food with less water—while improving rural livelihoods and protecting the environment. The CPWF supports IRRI research and CA work.

This Brief is based on the book *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture,* 2007.
Chapter 15: 'Rice: Feeding the Billions' by B. A. M. Bouman, R. Barker, E. Humphreys, T. P. Tuong and others.

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