Water: More crop per drop

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More crop per drop

by Sarah Carriger and Domitille Vallée

Rice cultivation in the 21st century will need to feed more people while reducing poverty and protecting the environment. Success depends on how the rice industry uses one of its most precious resources: water.

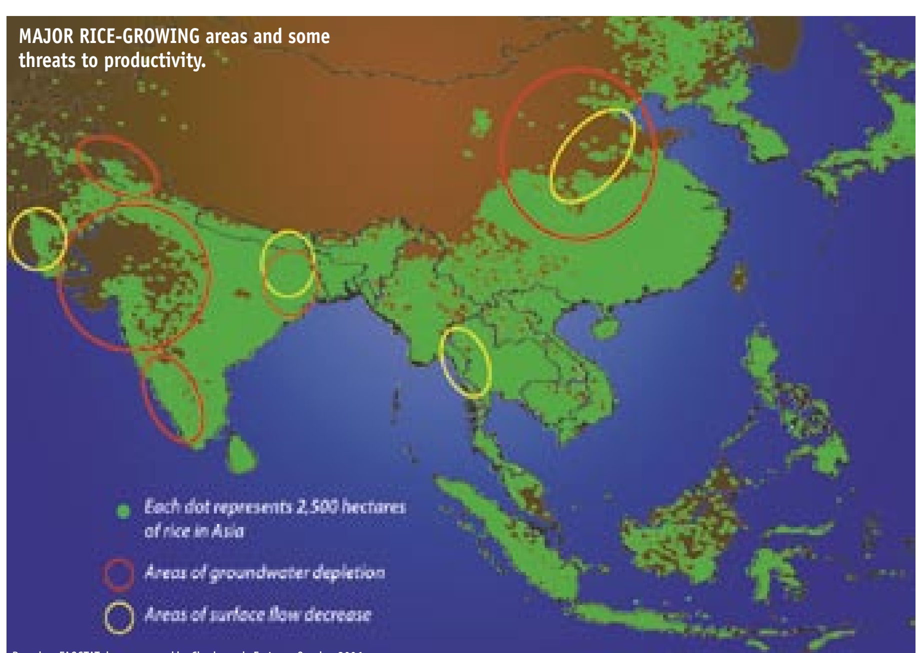
The challenge for rice cultivation in the next 50 years is to feed more people while keeping prices low to benefit poor rice consumers and reducing production costs to benefit poor growers. At the same time, water scarcity, drought, flooding, and salinity increasingly threaten the productivity of rice-based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

How can we meet this challenge? Some solutions exist; others require more investment in research. No single solution will fit all situations. Solutions need to be evaluated based on impacts on the poor, on the environment, and on the often unrecognized ecosystem services that rice landscapes provide (see *At your service*, opposite).

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

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

MAJOR RICE-GROWING areas and some threats to productivity.



Based on FAOSTAT data; prepared by Charlotte de Fraiture, October 2006.

So, where will the rice come from to feed these additional rice consumers? To avoid destruction of natural ecosystems, increasing yields on existing crop lands are 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 yield. In these countries, water and crop management technologies hold the most immediate promise. In other countries—namely, China, Japan, and Korea—the yield gap is already closing, and further yield increases are likely to 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 yield by 5–15%.

Many poor people spend 20–40% of their income on rice alone. The reduction in the price of rice—from US$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.

What to do about water and rice?

Key findings for rice production from the comprehensive assessment of water management in agriculture include the following:

- Keeping rice prices low, while reducing production costs, is crucial for poverty reduction in rice-growing and -consuming areas.
- Rice systems provide both food and 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 socioeconomic 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.

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 sizes varying by country from 0.5 to 4 hectares. And, in many areas, rice farming is the main source of employment. Increasing yields and reducing production costs are the first steps 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 affect men and women differently because 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 a source of employment for women, depending on whether or not they are paid for their labor.

Purely technical approaches will not work. Any solutions need to take into account that, in many

At your service

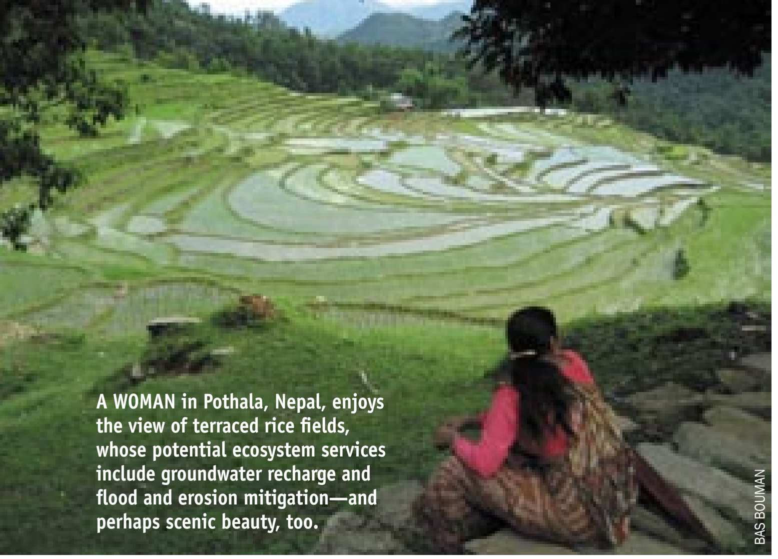
Depending on the method of cultivation and the physical characteristics of the landscape, ecosystem services provided by rice fields can include

- 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 and 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- or arsenic-contaminated groundwater, and releasing greenhouse gases (such as methane and nitrous oxide) into the atmosphere.

Decisions increasing production and/or decreasing water requirements need to weigh both ecosystem services and negative environmental impacts.

FOR AN ESTIMATED 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.



A WOMAN in Pothala, Nepal, enjoys the view of terraced rice fields, whose potential ecosystem services include groundwater recharge and flood and erosion mitigation—and perhaps scenic beauty, too.

BAS BOUMAN

communities, rice cultivation is at the heart of social and religious life.

Over the coming decades, farmers, policymakers, and researchers alike will need to adapt to several threats to rice productivity.

In the next 25 years, 15–20 million hectares of irrigated rice are projected to suffer from some degree of water scarcity—particularly wet-season irrigated rice in parts of China, India, and Pakistan. Even in areas where water is abundant, hotspots of water scarcity exist. Economic water scarcity, where lack of financing prevents harnessing water resources for productive use, limits cultivation of the 22 million hectares 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 affecting rice cultivation in many parts of the world. This type of transfer can be accomplished without a drop in rice productivity (see figure, *below*), 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—growing rice without a standing water layer—and irrigation regimes of alternate wetting and drying may come to predominate alongside a shift to nonrice dryland crops such as maize.

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

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

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

Some 11 million hectares of both irrigated and rainfed rice are prone to flooding. Even though rice is adapted to waterlogging, most varieties can survive complete submergence for only 3 to 4 days. The recent development by researchers at the International Rice Research Institute of submergence-tolerant rice, which can withstand 10–14 days of submergence with up to three times the yield of nontolerant varieties, offers hope to farmers in flood-prone areas (see *From genes to farmers' fields* on pages 28-31 of *Rice Today* Vol. 5, No. 4).

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 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 1–3 meters per year and in the northwest Indo-Gangetic Plain they are dropping by 0.5–0.7 meter per year.

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

Climate change may affect 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 rising temperatures.

Of the potential threats, 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 strategies 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. Take alternate wetting and drying, for example. Moderate regimes can reduce field water application by 15–20% without affecting yield, can reduce disease-causing vectors, and produce less ammonia volatilization and fewer methane emissions. But drawbacks include fewer options for informal reuse downstream; more weed growth and pests and a consequent need for more chemical applications and/or labor; reduction in soil fertility over time and, eventually, greater need for fertilizer; higher nitrous oxide emissions and nitrate leaching; and habitat loss for some species.

There is good 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.

The biggest water savings at the field level come from reducing seepage, percolation, and surface drainage flows, but these may not result in savings at the irrigation system or basin scales. Water-saving measures at the 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, therefore minimizing water loss.

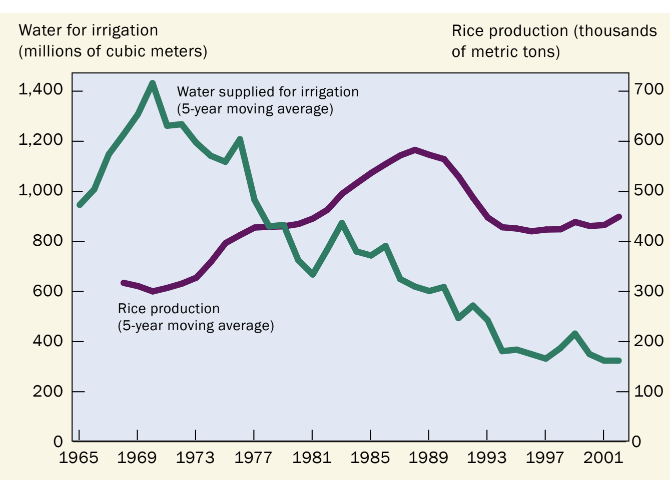
In irrigated systems, integrated approaches that take into account the options for reuse of water and for conjunctive use of surface water and groundwater offer the best way forward to improve total water-use efficiency at the system scale.

How thirsty is rice, really?

Perhaps not as thirsty as you might think. At the 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, and percolation are losses at the field level, they are often captured and reused downstream and do not necessarily lead to true water depletion at the irrigated area or basin scale.



Source: Paddy and Water Environment 2004.

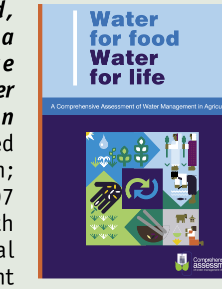
DECREASING IRRIGATION water supplied while increasing production in Zanghe Irrigation System, China.

IN WATER-SHORT AREAS, aerobic rice production—growing rice without a standing water layer—may come to predominate.

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 on wetland biodiversity needs to be considered.

ARIEL JAVELLANA (2)

Water, food, and life



Water for food, water for life: a comprehensive assessment of water management in agriculture (edited by David Molden; published in 2007 by Earthscan with the International Water Management Institute; 688 pages).

How do we manage finite water resources to feed two billion extra people, eliminate poverty, and reverse ecosystem degradation? This book brings together the work of over 700 researchers in the most comprehensive and authoritative assessment of water resources ever written. Critically evaluating current thinking on water and its interplay with agriculture, the book charts the way forward with concrete actions from management to policy across all countries and territories. After framing the main issues and providing a comprehensive examination of trends and scenarios in world water management, the book critically examines the issues of water in poverty reduction, reforming institutions for sustainable water management, avoiding or mitigating ecosystem impacts, and improving water productivity. Thematic chapters follow, covering such key issues in water management as irrigation, groundwater use, inland fisheries, rice cultivation, land conservation, and river basin management and development.

The *Comprehensive assessment of water management in agriculture* is a 5-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.

For purchasing information, visit http://tinyurl.com/2qk2hl.

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This article is based on *Rice: Feeding the Billions* (authors BAM. Bouman, R Barker, E Humphreys, and TP Tuong), which is Chapter 15 of the book *Water for food, water for life: a comprehensive assessment of water management in agriculture*. For more information, visit www.iwmi.cgiar.org/assessment.