Fourth Edition

Rice Almanac

CGIAR

Research Program on Rice

Global Rice Science Partnership

Fourth Edition

Rice Almanac

Source Book for One of the Most Important Economic Activities on Earth

2013

The Global Rice Science Partnership (GRiSP), which is the CGIAR Research Program on Rice, represents for the first time a single strategic and work plan for global rice research. GRiSP brings together hundreds of scientists to embark on the most comprehensive attempt ever to harness the power of science to solve the pressing development challenges of the 21st century. Cutting-edge science is deployed to develop new rice varieties with high yield potential and tolerance of a variety of stresses such as flooding, salinity, drought, soil problems, pests, weeds, and diseases. Improved natural resource management practices will allow farmers to fully realize the benefits of such new varieties on a sustainable basis while protecting the environment. Future rice production systems are designed to adapt to climate change and to mitigate the impacts of global warming. Policies conducive to the adoption of new varieties and cropping systems will be designed to facilitate the realization of development outcomes. GRiSP is training future rice scientists and strengthening the capacity of advisory systems to reach millions of farmers. For impact at scale, GRiSP scientists are collaborating with hundreds of development partners from the public and private sector across the globe.

GRiSP was launched in 2010 and is coordinated by three members of the CGIAR Consortium—the International Rice Research Institute (IRRI, the lead institute), Africa Rice Center (AfricaRice), and the International Center for Tropical Agriculture (CIAT)—and three other leading agricultural agencies with an international mandate and with a large portfolio on rice: Centre de cooperation internationale en recherche agronomique pour le développement (CIRAD), L'Institut de recherche pour le développement (IRD), and the Japan International Research Center for Agricultural Sciences (JIRCAS). Together, they align and bring to the table consortia, networks, platforms, programs, and collaborative projects with more than 900 partners from the government, nongovernment, public, private, and civil society sectors.

The responsibility for this publication rests solely with the Global Rice Science Partnership.

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Foreword

The Rice Almanac had its origins in 1993 as an answer to the long-felt need to bring together general information about rice—its origin, its growth and production, the ecosystems under which it is grown, and opportunities for increased yields. This first almanac was focused mainly on Asia.

A second edition was published in 1997, incorporating much updated material. Also included was information on: (1) rice production in West African countries coming from the West Africa Rice Development Association (WARDA), now Africa Rice Center; (2) the Latin American and Caribbean countries coming from the Centro Internacional de Agricultura Tropical (CIAT); and European rice production. IRRI, WARDA, and CIAT were copublishers of the second edition.

The second edition gave rise to an Internet site, initially called Riceweb, which contained all the almanac contents as well as a host of additional information about rice and access to rice literature and many other rice-related Web sites from around the world. Riceweb became a highly visited site, earning acclaim also from several Web site-rating and other organizations. Thus, we knew there was high demand for the almanac that formed its basic structure.

For the third edition in 2002, the number of countries with production-related information was doubled to 64, thanks to help from the Food and Agriculture Organization of the United Nations (FAO), which also became a copublisher.

This fourth edition breaks new ground in its coverage of issues related to rice production, both environmental—including climate change—and importance for food security and the global economy. For the first time, a Global Rice Science Partnership (GRiSP) is described. It will harness the resources of all the major rice-related research and development institutions to overcome the challenges of future rice production. In addition to IRRI, AfricaRice, and CIAT, other major partners in GRiSP include the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), L'Institut de recherche pour le développement (IRD, formerly known as ORSTOM), and the Japan International Research Center for Agricultural Sciences (JIRCAS).

This edition of the almanac further expands coverage up to 99.9% of the world's rice production, covering 81 of the 117 rice-producing countries, and includes summary information for most rice-producing regions.

Meanwhile, the online Riceweb has 'evolved' to become Ricepedia (www.ricepedia.org), which will be available in early 2014. Ricepedia includes, among other things, all the material in this almanac as well as issues not covered here, such as production constraints in the minor rice-producing countries and the countries not included that produce the other 0.1% of world rice production.

The production and other statistics used herein are derived primarily from FAO, which include official country data (FAOSTAT), surveys, reports, and personal communications; IRRI's RICESTAT database, which is based on primary data from requests and questionnaires and secondary data from statistical publications and international organizations including FAO, the International Labor Organization, the World Bank, etc.; and regional data from AfricaRice and CIAT. As in any printed publication, these statistics will soon be outdated. An important function of Ricepedia will be to have the latest data available on demand at all times.

We trust that the fourth edition of the Rice Almanac will continue to increase awareness of rice as the most important staple food in the world and of all that is involved in maintaining rice production.

Bas Bouman
Director, GRiSP

Acknowledgments

This fourth, enlarged edition of the Rice Almanac is a joint effort of several institutions associated with the Global Rice Science Partnership (GRiSP) and many people. The major institutions are the International Rice Research Institute (IRRI), AfricaRice, and Centro Internacional de Agricultura Tropical (CIAT); others are the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), L'Institut de recherche pour le développement (IRD, formerly known as ORSTOM), and Japan International Research Center for Agricultural Sciences (JIRCAS).

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Unless otherwise noted, most images in this Almanac come from the photo archives of IRRI, CIAT, and AfricaRice.

A note on the country rice maps

Considering that rice is economically, socially, and culturally important to so many people in so many countries, it is surprisingly difficult to find detailed information on where rice is grown. Few, if any, published maps accurately depict where rice is cultivated around the world. To fill this knowledge gap, IRRI, in collaboration with GRiSP partners, has brought together the best available information to estimate where rice is grown in each of the 81 countries covered in the Rice Almanac.

The maps are based on several sources of information. First of all, we collected rice area statistics for each country and, whenever possible, we collected rice area statistics for each subnational unit (i.e., state, province, region, district, county) within those countries. We call these "rice mapping units" and there are more than 9,000 of them across 112 countries.

The next challenge was to determine where rice is most likely to be cultivated *within* each rice mapping unit. Some units cover vast areas, but only a small proportion of the mapping unit area may be used for rice cultivation. We relied on a range of sources and methods to do this. For some countries, we were able to use published rice extent maps such as those developed by Gumma et al (2011) and Xiao et al (2006), the Commission of the European Communities, and the United States Geological Survey. These covered most of the rice-growing countries of Asia and Europe, and the United States. For other regions of the world, we relied on local expertise to identify rice-growing areas and, at the same time, we used other spatial information to exclude any area that was demarcated as a protected area or forest, water body, and urban or other land types that are unsuitable for crops. From all these sources, we developed a global rice area "mask" as the basis for our rice maps.

The "dot density" maps used in the almanac depict two things: the general geographic distribution where we believe rice is grown and the estimated harvested rice area. Each dot represents a number of hectares of rice; the denser the dot pattern, the greater the harvested area. We changed the number of hectares per dot from map to map to best display the distribution of rice within a country. The dots do not and cannot be used to map the exact location of where rice is cultivated within each country—they serve only to display our best estimate of the general distribution of the rice-growing area.

The IRRI GIS team is very thankful to colleagues and partners in GRiSP who assisted us in the generation of these maps. We are continuously updating our information on where rice is grown and will update the online maps whenever better data become available.

IRRI does not guarantee the accuracy of the data included in the maps. The boundaries, colors, denominations, and other information shown on any map do not imply any judgment on the part of IRRI concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

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The facts of rice

Production

Rice farming is the largest single use of land for producing food.
Rice is nearly all (90%) produced in Asia.
Rice production totaled 696 million tons in 2010.
Rice production is one of the most important economic activities on Earth.
Thousands of varieties of rice are farmed.
Only 7% of all rice production is exported from its country of origin.

Employment

Rice eaters and growers form the bulk of the world's poor.
Rice is the single most important source of employment and income for rural people.
Rice is grown on some 144 million farms, mostly smaller than 1 hectare.

Significance in human culture

Rice farming is about 10,000 years old.
Rice cultivation was once the basis of the social order and occupied a major place in Asia's religions and customs.
Rice is still sometimes used to pay debts, wages, and rent in some Asian rural areas.

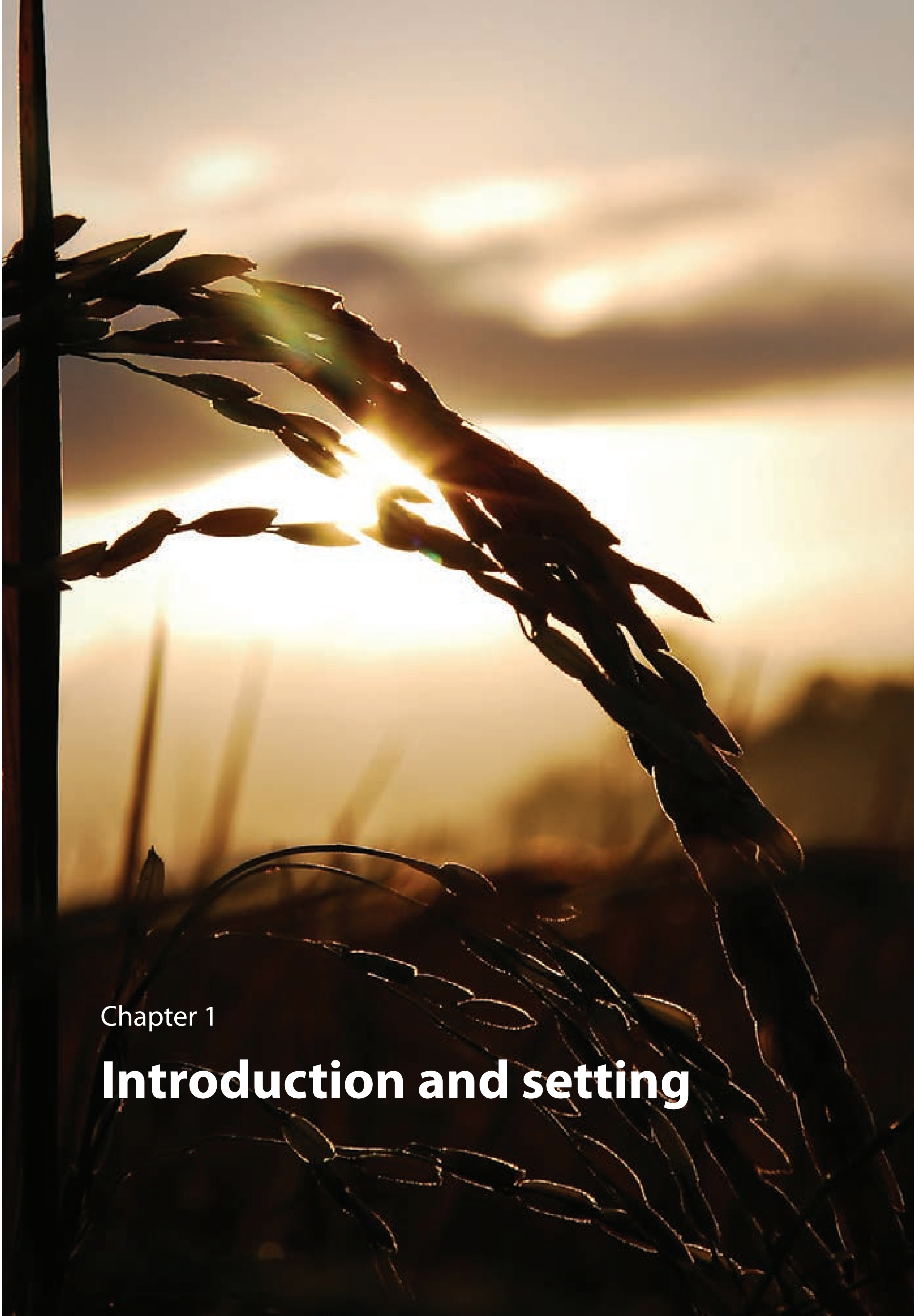
Significance as food

Rice is the staple food for the largest number of people on Earth.
Rice is eaten by nearly half the world's population.
Rice is the single largest food source for the poor.
Rice is the source of one quarter of global per capita energy.
Rice is synonymous with food throughout Asia.
Rice is the most important food grain in most of the tropical areas of Latin America and the Caribbean, where it supplies more calories in people's diets than wheat, maize, cassava, or potato.
Toyota means bountiful rice field.
Honda means the main rice field.

Benefits of rice research

Research has provided 75% of the rice varieties now grown.
Research has increased potential yields from 4 to more than 10 tons per hectare per crop.
Research has been a major factor in more than doubling world rice production from 260 to nearly 700 million tons over the past 50 years.
Research has provided rice plants that grow faster, enabling 2 or even 3 crops per year; plants that resist various pests and diseases, need less fertilizer, or thrive in saline water; and plants with enhanced levels of micronutrients.

Many more facts on rice production are contained in the Rice Facts on page 261.



Chapter 1

Introduction and setting

A brief history of rice farming

The origins of rice have long been debated. The plant is of such antiquity that the exact time and place of its first development will perhaps never be known. It is certain, however, that domestication of rice ranks as one of the most important developments in history. Rice has fed more people over a longer time than has any other crop.

Pottery shards bearing the imprint of both grains and husks of the cultivated rice species *Oryza sativa* were discovered at Non Nok Tha in the Korat area of Thailand. Plant remains from 10,000 B.C. were discovered in Spirit Cave on the Thailand-Myanmar border.

In China, extensive archeological evidence points to the middle Yangtze and upper Huai rivers as the two earliest places of *O. sativa* cultivation in the country. Rice and farming implements dating back at least 8,000 years have been found. Cultivation spread down these rivers over the following 2,000 years.

Transplanting rice in the Philippines.

Early spread of rice

From early, perhaps separate, beginnings in different parts of Asia, the process of diffusion has carried rice in all directions and today it is cultivated on every continent save Antarctica. In the early Neolithic era, rice was grown in forest clearings under a system of shifting cultivation. The crop was direct seeded, without standing water—conditions only slightly different from those to which wild rice was subject. A similar but independent pattern of the incorporation of wild rice into agricultural systems may well have taken place in one or more locations in Africa at approximately the same time.

Puddling the soil—turning it to mud—and transplanting seedlings were likely refined in China. Both operations became integral parts of rice farming and remain widely practiced to this day. Puddling breaks down the internal structure of soils, making them much less subject to water loss through percolation. In this respect, it can be thought of as a way to extend the utility of a limited water supply.

Transplanting is the planting of 1- to 6-week-old seedlings in puddled soil with standing water. Under these conditions, the rice plants have an important head start over a wide range of competing weeds, which leads to higher yields. Transplanting, like puddling, provides farmers with the ability to better accommodate the rice crop to a finite and fickle water supply by shortening the field duration (since seedlings are grown separately and at higher density) and adjusting the planting calendar.

With the development of puddling and transplanting, rice became truly domesticated. In China, the history of rice in river valleys and low-lying areas is longer than its history as a dryland crop. In Southeast Asia, however, rice originally was produced under dryland conditions in the uplands, and only recently came to occupy the vast river deltas.

Migrant people from southern China or perhaps northern Vietnam carried the traditions of wetland rice cultivation to the Philippines during the second millennium B.C., and Deutero-Malays carried the practice to Indonesia about 1500 B.C. From

China or the Korean peninsula, the crop was introduced to Japan no later than 100 B.C.

Movement to western India and south to Sri Lanka was also accomplished very early. Rice was a major crop in Sri Lanka as early as 1000 B.C. The crop may well have been introduced to Greece and the neighboring areas of the Mediterranean by returning members of Alexander the Great's expedition to India around 344-324 B.C. From a center in Greece and Sicily, rice spread gradually throughout southern Europe and to a few locations in northern Africa.

Rice in the New World

As a result of Europe's great Age of Exploration, new lands to the west became available for exploitation. Rice cultivation was introduced to the New World by early European settlers. The Portuguese carried it to Brazil and the Spanish introduced its cultivation to several locations in Central and South America. The first record for North America dates from 1685, when the crop was produced on the coastal lowlands and islands of what is now South Carolina. The crop may well have been carried to that area by slaves brought from the African continent. Early in the 18th century, rice spread to what is now Louisiana, but not until the 20th century was it produced in California's Sacramento Valley. The introduction into California corresponded almost exactly with the timing of the first successful crop in Australia's New South Wales.

Present rice-growing areas

Rice is produced in a wide range of locations and under a variety of climatic conditions, from the wettest areas in the world to the driest deserts. It is produced along Myanmar's Arakan Coast, where the growing season records an average of more than 5,100 mm of rainfall, and at Al Hasa Oasis in Saudi Arabia, where annual rainfall is less than 100 mm. Temperatures, too, vary greatly. In the Upper Sind in Pakistan, the rice season averages 33 °C; in Otaru, Japan, the mean temperature for the growing season is 17 °C. The crop is produced at sea level on coastal plains and in delta regions throughout Asia, and to a height of 2,600 m on the slopes of Nepal's mountains. Rice is also grown under an extremely broad range of solar radiation, ranging from 25% of potential during the main rice season in portions of Myanmar, Thailand, and India's Assam State to approximately 95% of potential in southern Egypt and Sudan.

Rice occupies an extraordinarily high portion of the total planted area in

As long as there is enough water, Australia's highly efficient rice industry achieves some of the highest yields in the world.

South, Southeast, and East Asia. This area is subject to an alternating wet and dry seasonal cycle and also contains many of the world's major rivers, each with its own vast delta. Here, enormous areas of flat, low-lying agricultural land are flooded annually during and immediately following the rainy season. Only two major food crops, rice and taro, adapt readily to production under these conditions of saturated soil and high temperatures.

The highest rice yields have traditionally been obtained from plantings in high-latitude areas that have long daylength and where intensive farming techniques are practiced, or in low-latitude areas that have high solar radiation and cool nights. Southwestern Australia, northern California, southern Brazil, Uruguay, and the Nile Delta provide the best examples.

In some areas, such as South Asia, the crop is produced on miniscule plots using enormous amounts of human labor. At other locations, such as in Australia and the United States, it is raised on huge holdings with a maximum of technology and large expenditures of energy from fossil fuels. The contrasts in the geographic, economic, and social conditions under which rice is produced are truly remarkable.

The rice plant

Morphology

Cultivated rice is generally considered a semiaquatic annual grass, although in the tropics it can survive as a perennial, producing new tillers from nodes after harvest (ratooning). At maturity, the rice plant has a main stem and several tillers. Each productive tiller bears a terminal flowering head or panicle. Plant height varies by variety and environmental conditions, ranging from approximately 0.4 meter (m) to more than 5 m in some floating rice. The morphology of rice is divided into the vegetative phase (including germination, seedling, and tillering stages) and the reproductive phase (including panicle initiation and heading stages).

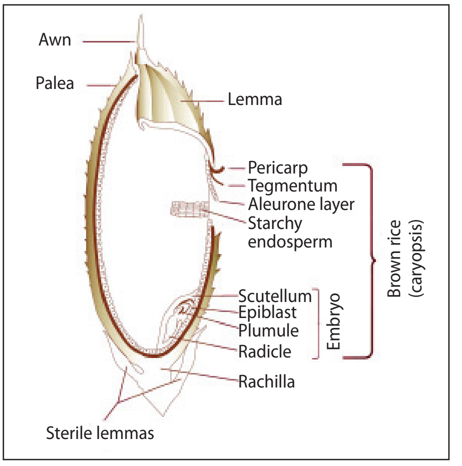


Fig. 1.1. Cross-section of the rice grain.

Seeds

The rice grain, commonly called a seed, consists of the true fruit or brown rice (caryopsis) and the hull, which encloses the brown rice. Brown rice consists mainly of the embryo and endosperm. The surface contains several thin layers of differentiated tissues that enclose the embryo and endosperm (Fig. 1.1).

The palea, lemmas, and rachilla constitute the hull of indica rice. In japonica rice, however, the hull usually includes rudimentary glumes and perhaps a portion of the pedicel. A single grain weighs 10–45 milligrams at 0% moisture content. Grain length, width, and thickness vary widely among varieties. Hull weight averages about 20% of total grain weight.

Seedlings

Germination and seedling development start when seed dormancy has been broken and the seed absorbs adequate water and is exposed to a temperature ranging from 10 to 40 °C. The physiological definition of germination is usually the time when the radicle or coleoptile (embryonic shoot) emerges from the ruptured seed coat. Under aerated conditions, the seminal root is the first to emerge through the coleorhizae from the embryo, and this is followed by the coleoptile. Under anaerobic conditions, however, the coleoptile is the first to emerge, with the roots developing when the coleoptile has reached the aerated regions of the environment.

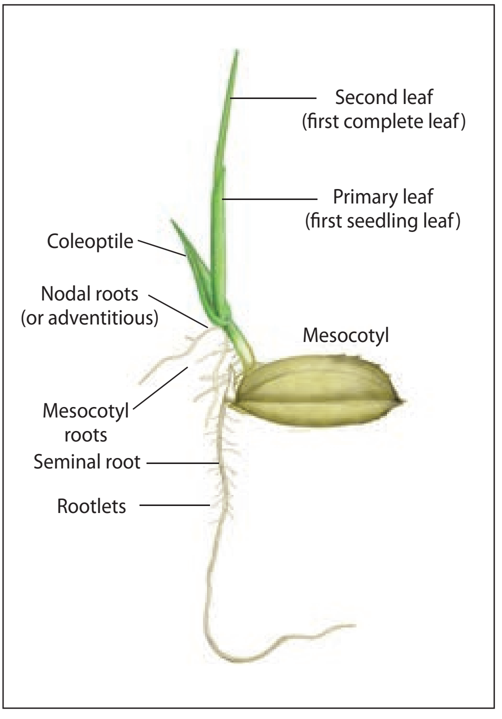


Fig. 1.2. Parts of a young seedling germinated in the dark.

If the seed develops in the dark as when seeds are sown beneath the soil surface, a short stem (mesocotyl) develops, which lifts the crown of the plant to just below the soil surface (Fig. 1.2). After the coleoptile emerges, it splits and the primary leaf develops.

Tillering plants

Each stem of rice is made up of a series of nodes and internodes (Fig. 1.3). The internodes vary in length depending on variety and environmental conditions, but generally increase from the lower to the upper part of the stem. Each upper node bears a leaf and a bud, which can grow into a tiller. The number of nodes varies from 13 to 16, with only the upper 4 or 5 separated by long internodes. Under rapid increases in water level, some deepwater rice varieties can also increase the lower internode lengths by more than 30 centimeters (cm) each.

The leaf blade is attached at the node by the leaf sheath, which encircles the stem. Where the leaf blade and the leaf sheath meet is a pair of clawlike appendages, called the auricles. Coarse hairs cover the surface of the auricles. Immediately above the auricles is a thin, upright membrane called the ligule.

The tillering stage starts as soon as the seedling is self-supporting and generally finishes at panicle initiation. Tillering usually begins with the emergence of the first tiller when seedlings have five leaves. This first tiller develops between the main stem and the second leaf from the base of the plant. Subsequently, when the sixth leaf emerges, the second tiller develops between the main stem and the third leaf from the base.

Tillers growing from the main stem are called primary tillers. These may generate secondary tillers, which may in turn generate tertiary tillers. These are produced in a synchronous manner. Although the tillers remain attached to the plant, at later stages they are independent because they produce their own roots. Varieties and races of rice differ in tillering ability. Numerous environmental factors also affect tillering such as spacing, light, nutrient supply, and cultural practices.

The rice root system consists of two major types: crown roots (including mat roots) and nodal roots (Fig. 1.3). In fact, both these roots develop from nodes, but crown roots develop from nodes below the soil surface. Roots that develop from nodes

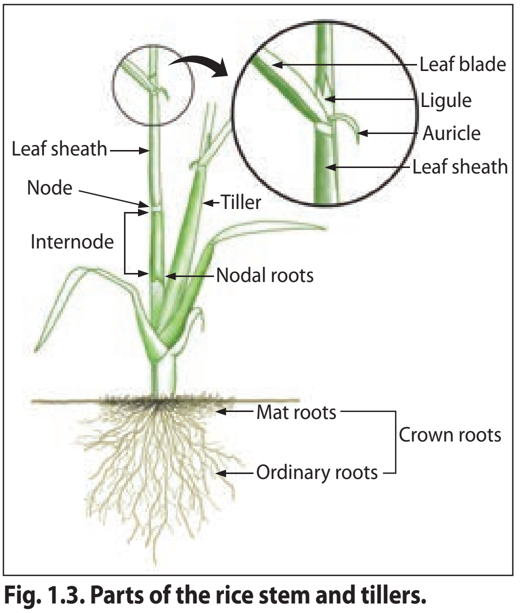


Fig. 1.3. Parts of the rice stem and tillers.

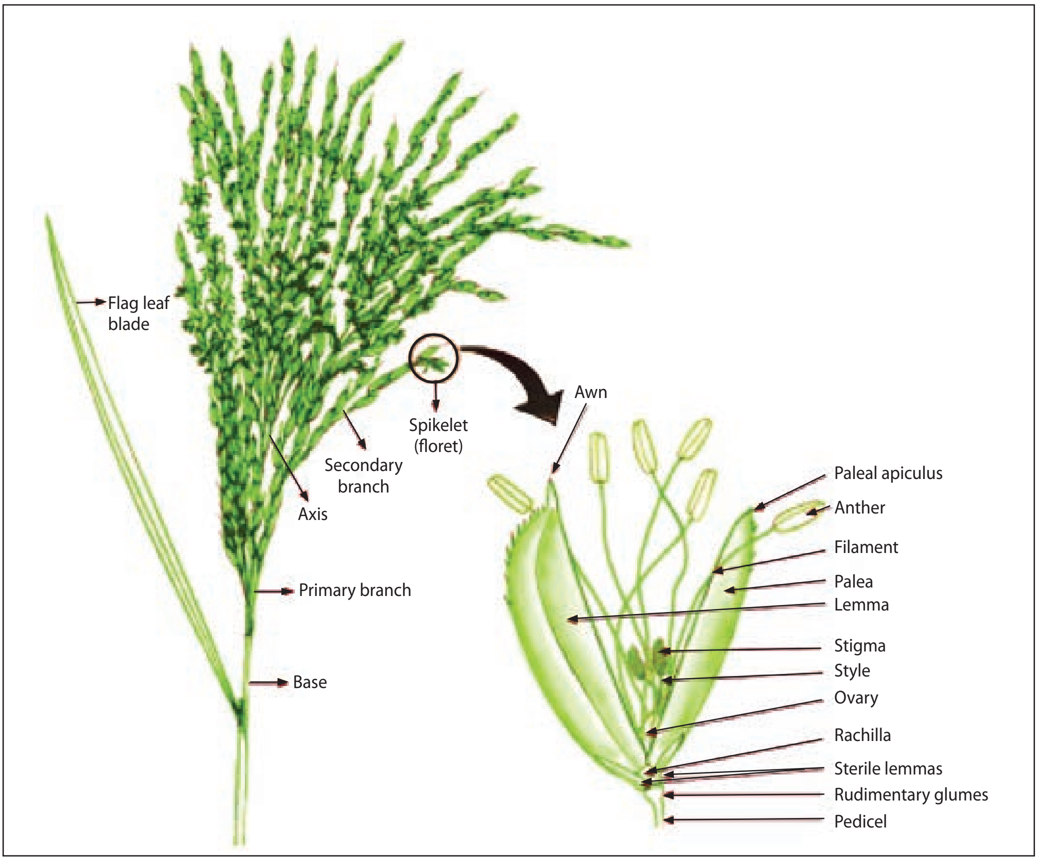


Fig. 1.4. Rice panicle and spikelets.

above the soil surface usually are referred to as nodal roots. Nodal roots are often found in rice cultivars growing at water depths above 80 cm. Most rice varieties reach a maximum depth of 1 m or more in soft upland soils. In flooded soils, however, rice roots seldom exceed a depth of 40 cm. That is largely a consequence of limited oxygen diffusion through the gas spaces of roots (aerenchyma) to supply the growing root tips.

Panicle and spikelets

The major structures of the panicle are the base, axis, primary and secondary branches, pedicel, rudimentary glumes, and spikelets. The panicle axis extends from the panicle base to the apex; it has 8–10 nodes at 2- to 4-cm intervals, from which primary branches develop. Secondary branches develop from the primary branches. Pedicels develop from the nodes of the primary and secondary branches; the spikelets are positioned above them (Fig. 1.4).

Since rice has only one fully developed floret (flower) per spikelet, these terms are often used interchangeably. The flower is enclosed in the lemma and palea, which may be either awned or awnless. The flower consists of the pistil and stamens, and the components of the pistil are the stigmas, styles, and ovary.

Growth

The growth duration of the rice plant is 3–6 months, depending on the variety and the environment under which it is grown. During this time, rice completes two distinct growth phases: vegetative and reproductive. The vegetative phase is subdivided into germination, early seedling growth, and tillering; the reproductive phase is subdivided into the time before and after heading, that is, panicle exsertion. The time after heading is better known as the ripening period (Fig. 1.5).

Potential grain yield is primarily determined before heading. Ultimate yield,

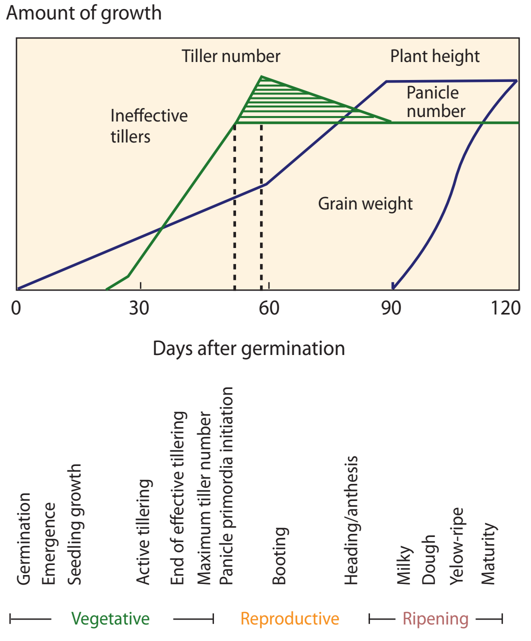


Fig. 1.5. Schematic growth of a 120-day rice variety in the tropics.

which is based on the amount of starch that fills the spikelets, is largely determined after heading. Hence, agronomically, it is convenient to regard the life history of rice in terms of three growth phases: vegetative, reproductive, and ripening. A 120-day variety, when planted in a tropical environment, spends about 60 days in the vegetative phase, 30 days in the reproductive phase, and 30 days in the ripening phase.

Vegetative phase

The vegetative phase is characterized by active tillering, a gradual increase in plant height, and leaf emergence at regular intervals. Tillers that do not bear panicles are called ineffective tillers. The number of ineffective tillers is a closely examined trait in plant breeding since it is undesirable in irrigated varieties, but is sometimes an advantage in rainfed lowland varieties in which productive tillers or panicles may be lost because of unfavorable conditions.

Reproductive phase

The reproductive growth phase is characterized by culm elongation (which increases plant height), a decline in tiller number, emergence of the flag leaf (the last leaf), booting, heading, and flowering of the spikelets. Panicle initiation is the stage about 25 days before heading when the panicle has grown to about 1 mm long and can be recognized visually or under magnification following stem dissection.

Spikelet anthesis (or flowering) begins with panicle exsertion (heading) or on the following day. Consequently, heading is considered a synonym for anthesis in rice. It takes 10–14 days for a rice crop to complete heading because there is variation in panicle exsertion among tillers of the same plant and among plants in the same field. Agronomically, heading is usually defined as the time when 50% of the panicles have exserted.

Anthesis normally occurs from 1000 h to 1300 h in tropical environments and fertilization is completed within 6 hours. Very few spikelets have anthesis in the afternoon, usually when the temperature is low. Within the same plant, it takes 7–10 days for all the panicles to complete anthesis; the spikelets themselves complete anthesis within 5 days.

Ripening phase

Ripening follows fertilization and can be subdivided into milky, dough, yellow-ripe, and maturity stages. These terms are primarily based on the texture and color of the growing grains. The length of ripening varies among varieties from about 15 to 40 days. Ripening is also affected by temperature, with a range from about 30 days in the tropics to 65 days in cool temperate regions, such as Hokkaido, Japan; and Yanco, Australia.

Genetic diversity

Two rice species are important cereals for human nutrition: *Oryza sativa*, grown worldwide, and *O. glaberrima*, grown in parts of West Africa. These two cultigens—species known only by cultivated plants—belong to a genus that includes about 25 other species, although the taxonomy is still a matter of research and debate.

Oryza is thought to have originated about 14 million years ago in Malesia.[1] Since then, it has evolved, diversified, and dispersed, and wild *Oryza* species are now distributed throughout the tropics. Their genomes can be classified into 11 groups labeled AA to LL, and most of the species can be grouped into four complexes of closely related species in two major sections of the genus (Table 1.1). Just two species, both diploids, have no close relatives and are placed in their own sections of the genus: *O. australiensis* and *O. brachyantha*.

Species of the *O. meyeriana* complex are genetically most different from the cultigens; they are diploid perennials found in dry hillside forests. Species of the *O. ridleyi* complex are tetraploids inhabiting lowland swamp forests. These two complexes, together with the tetraploid species *O. schlechteri* and *O. coarctata*, form the most primitive section of the genus, with a geographical distribution ranging from South Asia through Malesia to New Caledonia.

The *O. officinalis* complex consists of diploid and tetraploid species found throughout the tropics. All the species in this complex are perennials found in seasonal wetlands; some are rhizomatous and others form runners. They also differ in the habitats where they are found. Some occur in full sun in grasslands, others in partial to full shade in forests. Variation exists within these species as shown by the responses of different populations to pests and diseases.

The *O. sativa* complex consists of the wild and weedy relatives of the two rice cultigens as well as the cultigens themselves. All are diploids and are found throughout the tropics. The wild relatives of *O. glaberrima* in Africa consist of the perennial rhizomatous species *O. longistaminata*, which grows throughout sub-Saharan Africa and Madagascar, and the annual *O. barthii*, which extends from West Africa to East and southern Central Africa. The annual and weedy relatives of *O. glaberrima* are found primarily in West Africa.

[1]A biogeographic region encompassing the Philippines, New Guinea, Borneo, the Indonesian islands, and the Malay Peninsula and archipelago.

Among the wild relatives of *O. sativa*, the perennial *O. rufipogon* is widely distributed over South and Southeast Asia, southeastern China, and Oceania; the morphologically similar *O. glumaepatula* is found in South America, usually in deepwater swamps. A closely related annual wild form, *O. nivara*, is found in the Deccan Plateau and Indo-Gangetic Plains of India and in many parts of Southeast Asia. The habitats of *O. nivara* are ditches, water holes, and edges of ponds. Morphologically similar to (and sometimes indistinguishable from) *O. nivara* are the very widely distributed weedy forms of *O. sativa*, which represent numerous different hybrids between *O. sativa* and its two wild relatives. Throughout South and Southeast Asia, these spontaneous hybrids are found in canals and ponds adjacent to rice fields and in the rice fields themselves.

The primary center of diversity for *O. glaberrima* is in the swampy basin of the upper Niger River. Two secondary centers are to the southwest near the Guinean coast. *O. glaberrima* varieties can be divided into two ecotypes: deepwater and upland. In West Africa, *O. glaberrima* is a dominant crop grown in the flooded areas of the Niger and Sokoto River basins. It is broadcast on hoed fields. On shallowly flooded land, a rainfed wetland crop is directly sown by either broadcasting or dibbling, or transplanted. About 45% of the land planted to rice in Africa belongs to the upland (dryland) culture, largely under bush fallow or after the ground has been hoed. Some African farmers still use axes, hoes, and bush knives in land preparation. In hydromorphic soils, *O. glaberrima* behaves like a self-perpetuating weed. In wetland fields planted to *O. sativa, O. glaberrima* has become a weed.

Ecological diversification in *O. sativa,* which involved hybridization-differentiation-selection cycles, was enhanced when ancestral forms of the cultigen were carried by farmers and traders to higher latitudes, higher elevations, dryland sites, seasonal deepwater areas, and tidal swamps. Within broad geographic regions, two major ecogeographic races or variety groups were differentiated as a

Table 1.1. Classification and distribution of species in the genus Oryza.

Taxa	Genome	Distribution	Comments/alternative classification
		Section *Oryza*	
Series *Oryza*: *sativa* species complex			
O. sativa	AA	Worldwide	
O. glaberrima	AA	West Africa	
O. nivara	AA	Tropical Asia	Annual ecotype of *O. rufipogon*
O. rufipogon	AA	Tropical Asia to northern Australia	
O. meridionalis	AA	Northern Australia	
O. barthii	AA	Africa	
O. longistaminata	AA	Africa	
O. glumaepatula	AA	South America	South American *O. rufipogon; O. glumaepatula*
Series *Latifoliae: officinalis* species complex			
O. minuta	BBCC	Philippines, Papua New Guinea	
O. officinalis	CC	Tropical Asia to Papua New Guinea	
O. rhizomatis	CC	Sri Lanka	
O. malampuzhaensis	CCDD	India	Tetraploid race of *O. officinalis*
O. punctata	BB	Africa	
O. schweinfurthiana	BBCC	Africa	Tetraploid race of *O. punctata*
O. eichingeri	CC	West, Central, and East Africa, Sri Lanka	The only species found in both Africa and Asia
O. alta	CCDD	Central and South America	
O. grandiglumis	CCDD	South America	
O. latifolia	CCDD	Central and South America	
		Section *Australiensis*	
O. australiensis	EE	Australia	Member of *officinalis* complex
		Section *Brachyantha*	
O. brachyantha	FF	Africa	
		Section *Padia*	Basal or primitive section of *Oryza*
O. schlechteri	HHKK	Indonesia and Papua New Guinea	
O. coarctata	KKLL	South Asia to Myanmar	
Series *Ridleyanae*: *ridleyi* species complex			
O. longiglumis	HHJJ	Indonesia and Papua New Guinea	
O. ridleyi	HHJJ	Southeast Asia to Papua New Guinea	
Series *Meyerianae*: *meyeriana* species complex			*granulata* species complex
O. granulata	GG	South and Southeast Asia	Variety of *O. meyeriana*
O. meyeriana	GG	South and Southeast Asia	
O. neocaledonica	GG	New Caledonia	

result of isolation and selection: (1) indica, adapted to the tropics; and (2) japonica, adapted to the temperate regions and tropical uplands. Recent DNA studies have identified five subgroups within these two major groups. Indica is divided into indica proper, and aus, a group of diverse varieties from northeastern India and Bangladesh, named for the aus growing season, and which have been found to contain a number of stress tolerance genes that are absent from other variety groups. The Basmati or aromatic group of varieties, mainly from northwestern India and Pakistan, is an offshoot of the japonica variety group, which is further subdivided into temperate and tropical japonica.

The combined forces of natural and human selection; diverse climates, seasons, and soils; and varied cultural practices (dryland preparation and direct seeding vs puddling of the soil and transplanting) led to the tremendous ecological diversity now found in Asian cultivars. Selections made to suit cultural preferences and socioreligious traditions added diversity to morphological features, especially grain size, shape, color, and endosperm properties. The complex groups of cultivars now known are categorized on the basis of hydrologic-edaphic-cultural-seasonal regimes as well as genetic differentiation. Within the last 2,000 years, dispersal and cultivation of the cultivars in new habitats have further accelerated the diversification process. Today, thousands of rice varieties are grown in more than 100 countries. The full spectrum of germplasm in the genus *Oryza* consists of the following:

- Wild *Oryza* species, which occur throughout the tropics, and related genera, which occur worldwide in both temperate and tropical regions.
- Natural hybrids between the cultigen and wild relatives, and primitive cultivars of the cultigen in areas of rice diversity.
- Commercial types, obsolete varieties, minor varieties, and special-purpose types in the centers of cultivation.
- Pure-line or inbred selections of farmers' varieties, elite varieties of hybrid origin, F_1 hybrids, breeding materials, mutants, polyploids, aneuploids, intergeneric and interspecific hybrids, composites, and cytoplasmic sources from breeding programs.

The diversity of Asian, African, and wild rices has given breeders a wealth of genetic material to draw on for breeding improved cultivars.

In the Philippines, a large plate of rice dominates the dinner table.

Rice as human food

Rice, wheat, and maize are the three leading food crops in the world; together they directly supply more than 42% of all calories consumed by the entire human population. Wheat is the leader in area harvested each year with 225 million hectares (ha) in 2009, followed by maize and rice, both with 159 million ha. Human consumption in 2009 accounted for 78% of total production for rice, compared with 64% for wheat and 14% for maize.

Although rice farming is important to particular regions in some developed

In southwestern Bangladesh, rice is part of a balanced diet with fish, vegetables, and fruit.

countries, it is of greatest importance in low- and lower-middle-income countries, where it accounts for 19% of total crop area harvested. In upper-middle- and high-income countries, it accounts for just 2% of total crop area harvested. There are now some 144 million rice farms in the world, the vast majority in developing countries. The numbers of households farming the other two most widely grown crops in the world, wheat and maize, are likely to be much lower because a large proportion of the wheat and maize area is in upper-middle-income and developed countries, where farm sizes are larger. In 2008, 94% of total rice area was in low- and lower-middle-income countries compared with just 52% for maize and 41% for wheat.

Of the three major crops, rice is by far the most important in terms of human consumption in low- and lower-middle-income countries. Maize has always been primarily a feed crop for animals—feed use has historically accounted for about two-thirds of total consumption. This proportion has declined slightly in recent years to about 60%, but this is due to increased biofuel demand, not increased human consumption. For wheat, about one-fifth of production is typically used as animal feed. Of the remaining four-fifths, a large share is consumed in developed countries. In the case of rice, very little is used for feed, and rice consumption is relatively low in Europe and the United States.

Even though rice is the dominant food crop for low- and lower-middle-income countries, Table 1.2 still understates its importance to the poor because much of the wheat consumption in low- and lower-middle-income countries is restricted to the upper parts of the income distribution. Table 1.3 shows the proportions of rice and wheat consumption by the poorest and richest 20% of the population in a few large low-income countries. These data show that, although rice consumption is spread across income classes relatively equally, the poorest people actually consume relatively little wheat—most of the wheat consumption is by people in the upper part of the income distribution (who are not below the poverty line). The

Table 1.2. World food picture, 2009.

					Per capita/day		Share in nutritional intake (%/day)	
Human population (million)	6,815.8							
Land use, 2009 (million ha)								
Total land area	13,003.5							
Arable land	1,381.2							
Permanent crops	152.1							
Permanent meadows and pastures	3,355.7							
Forest area	4,038.7							
Other land	4,088.0							
Food production								
Crop	Area (million ha)	Production (million t)	Food (million t)		Calories (kcal)	Protein (g)	Calories (kcal)	Protein (g)
Rice (rough)	158.5	684.6	531.9	65% milling rate	536	10.1	18.9	12.7
Maize	158.8	819.2	114.0	80% for feed	141	3.4	5.0	4.3
Wheat	224.6	686.6	439.4	70% milling rate	532	16.2	18.8	20.4
Millet and sorghum	74.2	83.0	47.2	30% milling rate	59	1.7	2.1	2.1
Barley and rye	60.8	169.9	12.0	70% milling rate	13	0.4	0.5	0.5
Oats	10.2	23.2	3.6	65% milling rate	3	0.1	0.1	0.1
Potatoes	18.7	332.1	217.3	60% for feed	61	1.4	2.2	1.8
Sweet potatoes and yams	13.0	150.9	81.0	50% for feed	33	0.4	1.2	0.5
				Subtotal	1,378	33.7	48.7	42.5
				All foods	2,831	79.3	2,831	79.3

Source: Compiled by IRRI from FAO database.

Table 1.3. Percentage of national rice and wheat consumption by the poorest and richest quintiles of the population.[a]

Country (survey year)	Rice		Wheat	
	Poorest	Richest	Poorest	Richest
Bangladesh (2005)	18	21	9	45
Indonesia (1999)	17	19	6	43
Philippines (1999-2000)	18	22	15	27

[a]Percentages are calculated on the basis of consumption quantities (kg), not value. Sources of data: BBS (2007) for Bangladesh, BPS (2000) for Indonesia, and BAS (2001) for the Philippines.

reverse does not appear to be true in areas where wheat is the staple food, for example, Pakistan and the wheat-eating provinces in China. Thus, rice is clearly the world's most important food crop for the poor. The geographic pattern of rice production and consumption is further described in Chapter 3.

Rice provided 19% of global human per capita energy and 13% of per capita protein in 2009. Although rice protein ranks high in nutritional quality among cereals, protein content is modest. Unmilled (brown) rice of 17,587 cultivars in the IRRI germplasm collection averages 9.5% protein content, ranging from 4.3% to 18.2%.

Environmental factors (soil fertility, wet or dry season, solar radiation, and temperature during grain development) and crop management (added N fertilizer, plant spacing) affect rice protein content. Breeding efforts to increase protein have been largely unsuccessful because of the considerable effects of environment and because of complex inheritance properties in the triploid endosperm tissue.

Rice also provides minerals, vitamins, and fiber, although all constituents except carbohydrates are reduced by milling. Milling removes roughly 80% of the thiamine from brown rice. A precook rinse or a boiling of milled rice results in additional loss of vitamins, especially B1.

Where rice is the main item of the diet, it is frequently the basic ingredient of every meal and is normally prepared by boiling or steaming. In Asia, bean curd, fish, vegetables, meat, and spices are added depending on local availability and economic situation. A small proportion of rice is consumed in the form of noodles, which serve as a bed for various, often highly spiced, specialties or as the bulk ingredient in soups.

Most rice is consumed in its polished state. When such rice constitutes a high proportion of food, dietary deficiencies may result. Despite the dramatic losses in food value resulting from milling, brown rice is unpopular because (1) it requires more fuel for cooking, (2) it may cause digestive disturbances, and (3) oil in the bran layer tends to turn rancid during storage even at moderate temperatures.

In contrast, parboiling rough rice before milling, as is common in India and Bangladesh, allows a portion of the vitamins and minerals in the bran to permeate the endosperm and be retained in the polished rice. This treatment also lowers protein loss during milling and increases whole-grain recovery.

Even though rice diets are often marginally deficient in protein, vitamins, and minerals, clinical manifestations of deficiency are not common among people whose diets are otherwise adequate in calories. The exception is when people do heavy labor and their higher calorie demand is met by an increase in rice without a corresponding increase in other foods such as legumes or fish. Under these conditions, there is danger of beriberi, which is related to a deficiency of thiamine or vitamin B1.

Research is under way to fortify rice with micronutrients in areas where these are inadequate in the diet. Vitamin A is an

Rice husks can be used for fuel, bedding, and incubation material.

important one—a severe lack causes irreversible blindness—and has now been incorporated in experimental lines known as Golden Rice. Other new varieties are rich in iron and zinc, micronutrients often deficient in people consuming mainly rice. These fortified rice varieties are being tested in nutrition trials before farmers grow them commercially.

Specialty uses of rice

Glutinous rice plays an important role in some cultures. In Laos and northeastern Thailand, for example, glutinous rice is the staple food. In other cultures, it is prepared in a sweetened form for snacks, desserts, or special foods for religious or ceremonial occasions. In a few areas, glutinous rice is pounded and roasted to be eaten as a breakfast cereal.

Alcoholic beverages made from rice are found throughout the rice-producing world. The most common is a rice beer produced by boiling husked rice, inoculating the mix with a bit of yeast cake, and allowing the mixture to ferment for a short period.

The mash left at the bottom of the container is often prized. Among the Ifugao of the Philippines, the mash is frequently reserved for the village priest. Among the Kachins of Myanmar, it is the first food offered to a recently captured and hungry wild elephant. Kachins believe that the elephant will be loyal forever to the person who first provides such a meal.

Sake is widely consumed in Japan, as is wang-tsiu in China. These rice-based wine-like beverages are served warm and featured at ceremonial feasts.

In some parts of the world, especially in North America and Europe, rice is developing a new market niche as a staple and as a gourmet food. This trend appears to be related to the arrival of large numbers of immigrants from Southeast Asia, who introduced aromatic rice to markets where it was previously unknown. It has been adopted by a food quality-conscious public over the past several years.

In much of Tanzania, rice is used for making bread; in the south, it is also used in ceremonies. In West Africa, rice bread, rice cake, and rice porridge are used for ceremonies such as funerals and weddings. Some “old” varieties (most likely *O. glaberrima*) are used in traditional religious rituals in West Africa, while certain parts of some varieties are used as medicines in the traditional treatment of illnesses.

Rice contains many compounds in the grains that promote shiny hair and good skin. Several countries are now making face washes, liquid shower soaps, and hair products from rice, including Japan, Republic of Korea, the Philippines, and Thailand. Also, in Thailand and the US, milk is made from rice for lactose-intolerant people.

An extensive list of other ways of using rice is given by the Food and Agriculture Organization of the United Nations (FAO):

- Milled rice is marketed precooked, canned, dried, and puffed for breakfast cereals as rice flour; extrusion-cooked foods; puddings and breads; cakes and crackers; noodles and rice paper; fermented foods and vinegars; rice starch; and syrups.
- Rice bran, which forms 5% to 8% of the grain weight, is used as livestock feed, a pickling medium, a medium for growing mushrooms, and as a growing medium for some enzymes, as well as for flours, concentrates, oils, and dietary fiber.
- Hulls and husks, about 20% of the grain weight, are used for fuel, bedding, and incubation material, and as a seedbed medium, as well as being sometimes incorporated in livestock feeds, concrete blocks, tiles, fiberboard, ceramics, cement, filters, charcoal briquettes, and cooking gas production.
- Rice straw, more or less equivalent in production weight to grain, is used as fuel for cooking, roofing material, livestock feed, fertilizer, and a medium for growing mushrooms.

Chapter 2

Rice and the environment

Rice fields near the Oyunahara Shrine, Hongu Wakayama Prefecture in Japan.

Rice grows in a wide range of environments. More than 90% of global rice production is harvested from irrigated or rainfed lowland rice fields. Awareness is growing that lowland rice environments provide a rich variety of ecosystem services. Rice production also has environmental impacts, largely by releasing or sequestering gases and compounds to/from the atmosphere and troposphere and by changing the chemical composition of the water flowing through the rice fields.

Rice environments and cropping systems

Rice grows in a wide range of environments and is productive in many situations where other crops would fail. Most classifications of rice environments are based on hydrological characteristics. Irrigated lowland rice is grown in bunded fields with ensured irrigation for one or more crops a year. Farmers generally try to maintain 5–10 cm of water ("floodwater") on the field. Rainfed lowland rice is grown in bunded fields that are flooded with rainwater for at least part of the cropping season to water depths that exceed 100 cm for no more than 10 days.

In both irrigated and rainfed lowlands, fields are predominantly puddled, and plants are transplanted. Direct seeding on wet or dry soil is also widely practiced and has largely replaced transplanted irrigated rice in Southeast Asia. Deepwater rice and floating rice are found in flood-prone environments, where the fields suffer periodically from excess water and uncontrolled, deep flooding. Upland rice is grown under dryland conditions (no ponded water) without irrigation and without puddling (harrowing or rototilling under shallow submerged conditions), usually in nonbunded fields. Figure 2.1 shows the major growing areas of the three basic systems.

Irrigated environments

Worldwide, about 93 million ha of irrigated lowland rice provide 75% of the world's rice production. Some 56% of the world's irrigated area of all crops is in Asia, where rice accounts for 40–46% of the irrigated area of all crops. Rice occupies 64–83% of the irrigated area in Southeast Asia, 46–52% in East Asia, and 30–35% in South Asia. At the field level, rice receives up to 2–3 times more water per hectare than other irrigated crops, but an unknown portion of the water losses is reused by other fields downstream. Assuming a reuse rate of 25%, we estimate that irrigated rice receives 34–43% of the

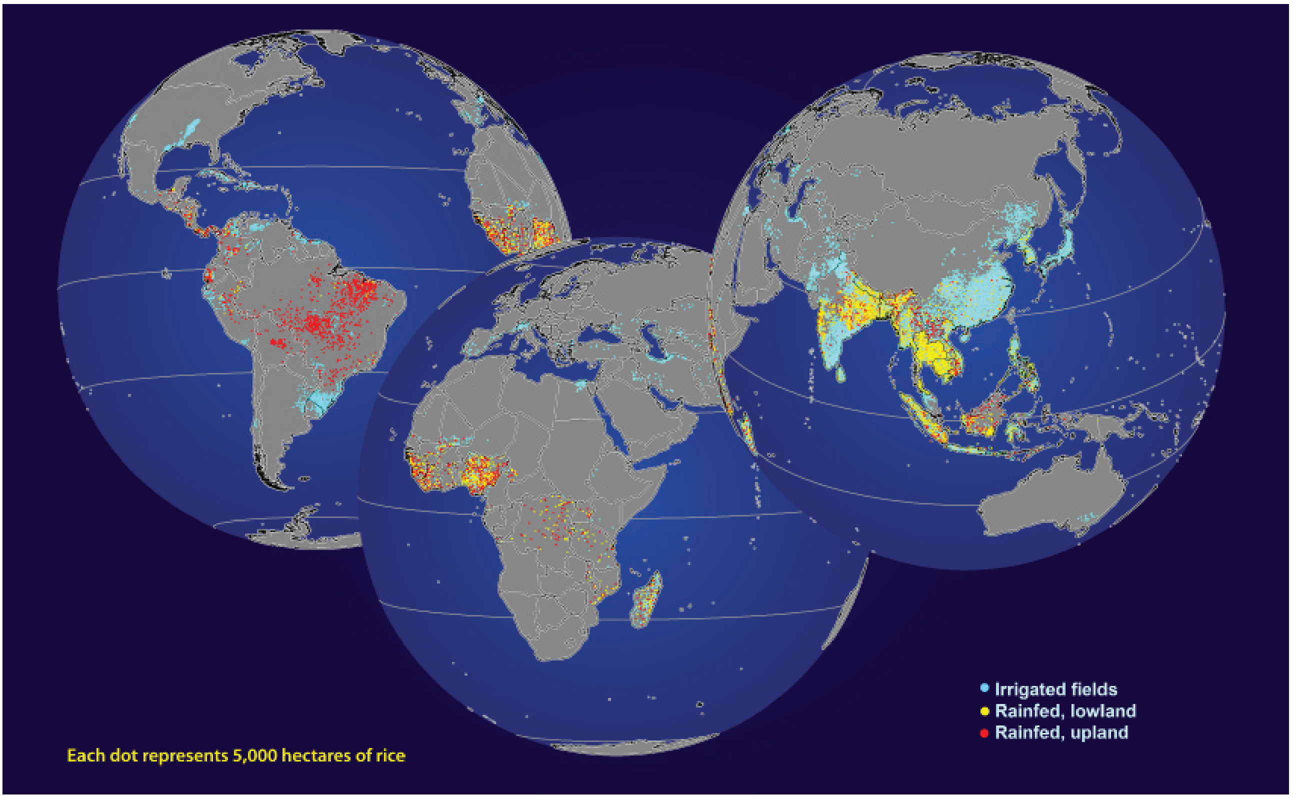


Fig. 2.1. Major global rice-growing areas and ecosystems.

world's irrigation water and 24–30% of the world's developed freshwater resources.

Irrigated rice is grown mostly with supplementary irrigation in the wet season and is reliant entirely on irrigation in the dry season. The proportion of the Asian rice area that is irrigated (excluding China, where essentially all rice is irrigated) increased substantially from the late 1970s (35%) to 2010 (55%) because of an increase in the irrigated area coupled with a large decline in upland and deepwater rice cultivation. In many irrigated areas, rice is grown as a monoculture with two crops a year. However, significant areas of rice are also grown in rotation with a range of other crops, including 15–20 million ha of rice-wheat systems. At the turn of the millennium, country average irrigated rice yields in Asia ranged from 3 to 9 tons (t)/ha, with an overall average of about 5 t/ha, which increased to 5.3–5.4 t/ha by 2012.

Rainfed environments

Worldwide, about 52 million ha of rainfed lowlands supply about 19% of the world's rice production, and 15 million ha of rainfed uplands contribute about 4% of the world's total rice production. Rainfed rice environments experience multiple abiotic stresses and high uncertainty in the timing, duration, and intensity of rainfall. Some 27 million ha of rainfed rice are frequently affected by drought, the largest, most frequently, and most severely affected areas being eastern India (about 20 million ha) and northeastern Thailand and Lao PDR (7 million ha). Drought is also widespread in Central and West Africa. Further constraints arise from the widespread incidence of problem soils with poor physical and chemical properties. Country average rice yields are only some 2.3 t/ha in the lowlands and 1 t/ha in the uplands.

In rainfed lowlands, small to moderate topographic differences can have important consequences for water availability, soil fertility, and flooding risk. The unpredictability of rainfall often results in field conditions that are too dry or too wet. Besides imposing water-related stresses on crop growth, these conditions prevent timely and effective management operations such as land preparation, transplanting, weed control, and fertilizer application. If such operations are delayed or skipped, yield losses can be large, even though the plants have not suffered physiological water stress.

Rainfed uplands are highly heterogeneous, with climates ranging from humid to subhumid, soils from relatively fertile to highly infertile, and topography from flat to steeply sloping. With low population density and limited market access, shifting cultivation with long (more than 15 years) fallow periods was historically the dominant land-use system. Increasing population and improved market access have put pressure on these systems, but shifting cultivation with 3–5-year fallow periods still accounts for 14% of the Asian upland rice area, mainly in northeastern India, Lao PDR, and Vietnam. However, some 70% of Asia's upland rice areas have made the transition to permanent systems in which rice is grown every year and is closely integrated with other crops and livestock. In Central and West Africa, the rice belt of Africa, upland areas represent about 35% of the area under rice cultivation and employ about 70% of the region's rice farmers. As market access remains limited, most of the world's upland rice farmers tend to be self-sufficient by producing a range of agricultural outputs.

Upland rice in Lao PDR.

Research efforts to increase yields and yield stability in rainfed environments, limited in the past, have been intensified in the past 10–15 years, especially in the lowlands. Together with socioeconomic developments, this has considerably improved the potential of rainfed systems through better access to information and markets for inputs and outputs, more opportunities for off-farm income, improved varieties, and (partial) mechanization.

Flood-prone environments

Flood-prone environments include deepwater areas submerged under more than 100 cm of water from 10 days to a few months, areas that are affected by flash floods of longer than 10 days, extensive low-lying coastal areas where plants are subject to daily tidal submergence, and areas with problem soils (acid-sulfate and sodicity) where the problem is often excess water but not necessarily prolonged submergence. Altogether, 11 million ha of flood-prone rice areas have average yields of more than 1.5 t/ha.

Salinity-prone environments

Salinity is widespread in coastal areas, and salinity, alkalinity, or sodicity is widespread in inland areas of arid regions. These problems occur in both irrigated and rainfed environments. In coastal areas, rice can suffer from salinity because of seawater ingress during high tides. In inland areas, salinity arises from salt deposits present in the soil or bedrock or from the use of salty irrigation water. In the mid-1980s, an estimated 1.3 million ha of rice-growing areas were affected by salinity or alkalinity. The extent of affected land has since increased greatly, with some 3.8 million ha affected in India alone.

Soils

Most lowland rice soils are wetland soils that are grown to rice. Wetlands are defined as having free water at or near the surface for at least the major part of the growing season of arable crops, or for at least 2 months of the growing season of perennial crops, grasslands, forests, or other vegetation. The floodwater is sufficiently shallow to allow the growth of a crop or of natural vegetation rooted in the soil. Free surface water may occur naturally, or rainfall, runoff, or irrigation water may be retained by field bunds, puddled plow layers, or traffic pans.

Wetlands have at least one wet growing season, but may be dry, moist, or without surface water in other seasons. Wetland soils may therefore alternately support wetland and upland crops when cultivated.

The transition from wetlands to uplands is often gradual. It may fluctuate from year to year, depending on variations in precipitation, runoff, or irrigation. If water (both drainage and irrigation) can be fully controlled, farmers can choose to establish wetlands or uplands. But, in most wetlands, drainage capacities are insufficient to prevent soil submergence during the rainy season, particularly in the lowlands of the humid tropics.

The presence of "aquic" soil conditions is indicated by redoximorphic features such as zones of accumulation and depletion of iron and manganese. Plowing and puddling often result in the development of a dense layer below the cultivated topsoil.

Three types of water saturation occur in rice soils: (1) endosaturation, in which the entire soil is saturated with water; (2) episaturation, in which upper soil layers are saturated but underlain by unsaturated subsoil layers; and (3) anthric saturation, a variant of episaturation with controlled flooding and puddled surface soil.

The properties of a typical soil profile of a flooded rice soil during the middle of a growing season are shown in Table 2.1.

Water use and water productivity

More than 90% of the world's rice production is harvested from irrigated or rainfed lowland rice fields. Traditionally, lowland rice is raised in a seedbed and then transplanted into a main field that is kept under continuous or intermittent ponded water conditions to help control weeds and pests. Land preparation consists of soaking, plowing, and puddling. Puddling is also done to control weeds, to reduce soil permeability and percolation losses, and to ease field leveling and transplanting. The

Rice field irrigation using a water pump.

Table 2.1. Typical profile of a flooded rice soil.

Horizon	Description
Ofw	A layer of standing water that becomes the habitat of bacteria, phytoplankton, macrophytes (submerged and floating weeds), zooplankton, and aquatic invertebrates and vertebrates. The chemical status of the floodwater depends on the water source, soil, nature and biomass of aquatic fauna and flora, cultural practices, and rice growth. The pH of the standing water is determined by the alkalinity of the water source, soil pH, algal activity, and fertilization. Because of the growth of algae and aquatic weeds, the pH and O_2 content undergo marked diurnal fluctuations. During daytime, the pH may increase to 11 and the standing water becomes oversaturated with O_2 because of photosynthesis of the aquatic biomass. Standing water stabilizes the soilwater regime, moderates the soil temperature regime, prevents soil erosion, and enhances C and N supply.
Apox	The floodwater-soil interface that receives sufficient O_2 from the floodwater to maintain a pE + pH value above the range below which NH_4^+ is the most stable form of N. The thickness of the layer may range from several millimeters to several centimeters, depending on perturbation by soil fauna and the percolation rate of water.
Apg	The reduced puddled layer is characterized by the absence of free O_2 in the soil solution and a pE + pH value below the range at which Fe(III) is reduced.
Apx	A layer that has increased bulk density, high mechanical strength, and low permeability. It is frequently referred to as a plow or traffic pan.
B	The characteristics of the B horizon depend highly on water regime. In epiaquic moisture regimes, the horizon generally remains oxidized, and mottling occurs along cracks and in wide pores. In aquic moisture regimes, the whole horizon, or at least the interior of soil peds, remains reduced during most years.

water balance of lowland rice, because of its flooded nature, is different from that of other cereals such as wheat.

Dry or wet direct seeding in irrigated rice offers the advantages of more efficient water use and higher tolerance of water deficit, as well as faster and easier planting, reduced labor, earlier crop maturity by 7–10 days, and lower methane emission, and it also eliminates operations related to nursery preparation for transplanting. Wet direct seeding involves sowing pre-germinated seed, either broadcast or drilled, onto puddled wet soil. In dry seeding, rice is broadcast or drilled into dry soil and the seed is then covered.

Total seasonal water input to rice fields (rainfall plus irrigation, but excluding capillary rise, which is rarely quantified) is up to 2–3 times more than that for other cereals. It varies from as little as 400 millimeters (mm) per field in heavy clay soils with shallow groundwater tables that supply water for crop transpiration by capillary rise to more than 2,000 mm in coarse-textured (sandy or loamy) soils with deep groundwater tables. About 1,300 mm seems to be a typical average value for irrigated rice in Asia. Nonproductive outflows of water by runoff, seepage, and percolation are 25–50% of all water input in heavy soils with shallow water tables of 20–50-cm depth and 50–85% in coarse-textured soils with deep water tables of 1.5-m depth or more (see Box 2.1). 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 irrigation area or basin scale. However, the proportion and magnitude of reuse of these flows are not generally known.

Modern rice varieties, when grown under flooded conditions, are similar in transpiration efficiency to other C_3 cereals, such as wheat, at about 2 kilograms (kg) grain per cubic meter of water transpired. What few data are available indicate that water productivity of rice as measured by evapotranspiration is also similar to that of wheat, ranging from 0.6 to 1.6 kg grain per cubic meter of evapotranspired water, with

Plowing and puddling often result in the development of a dense layer beneath the cultivated topsoil.

Box 2.1. Water flows from a rice field

For lowland rice, water is needed to prepare the land and to match the outflows of seepage, percolation, and evapotranspiration during crop growth. The amount of water used for wetland preparation can be as low as 100–150 mm when the time lag between soaking and transplanting is only a few days or when the crop is directly wet seeded. But, it can be as high as 940 mm in large-scale irrigation systems with poor water control, where the time lag between soaking and transplanting is as long as 2 months.

After the crop is established, the soil is usually kept ponded until shortly before harvest. Seepage is the lateral subsurface flow of water, and percolation is the flow of water down below the root zone. Typical combined values for seepage and percolation vary from 1–5 mm/day in heavy clay soils to 25–30 mm/day in sandy and sandy loam soils. Evaporation is water lost into the air as vapor from the ponded water layer or from the surface of the soil, and transpiration is water released into the air as vapor through the plants. Typical combined evapotranspiration rates of rice fields are 4–5 mm/day in the wet season and 6–7 mm/day in the dry season, but can be as high as 10–11 mm/day in subtropical regions before the onset of the monsoon. Over-bund flow or surface runoff is the spillover when water depths rise above the bunds of the fields. Seepage, percolation, evaporation, and over-bund flow are all nonproductive flows of water and are considered losses at the field level.

a mean of 1.1 kg grain per cubic meter. The higher evaporation rates from the water layer in rice than from the underlying soil in wheat are apparently compensated for by the higher yields of rice. Maize, as a C_4 crop, has a higher evapotranspiration efficiency (ranging from 1.1 kg to 2.7 kg grain per cubic meter of water, with a mean of 1.8). The water productivity of rice for total water input (irrigation plus rainfall) ranges from 0.2 kg to 1.2 kg grain per cubic meter of water, with an average of 0.4, less than half that of wheat.

Ecosystem services

Though only a few studies have been conducted so far, awareness is growing that lowland rice environments provide an unusually rich variety of ecosystem services. Studies on the value of rice ecosystems beyond crop production have recently received a boost by the threat to rice price supports and trade restrictions in many countries presented by multilateral trade negotiations under the World Trade Organization.

Provisioning functions

The most important provisioning function of the rice environment is the production of rice. Irrigated rice culture has been sustained for thousands of years in various parts of Asia. Recent findings of 30 long-term continuous cropping experiments at 24 sites in Asia confirm that, with an assured water supply, lowland rice fields are extremely sustainable and able to produce continuously high yields. Flooding has beneficial effects on soil acidity; phosphorus, iron, and zinc availability; and biological nitrogen fixation. Other provisioning services are the raising of fish and ducks in rice fields, ponds, or canals. Frogs and snails are collected for consumption in some countries.

Regulating services

Bunded rice fields may increase the water storage capacity of catchments and river basins, lower the peak flow of rivers, and increase groundwater flow. The many irrigation canals and reservoirs associated with the lowland rice landscape have a similar buffering function.

Other regulatory services of bunded rice fields and terraces include trapping of sediments and nutrients and the prevention or mitigation of land subsidence, soil erosion, and landslides. Percolation from rice fields, canals, and storage reservoirs recharges groundwater systems. Such recharge may also provide a means of sharing water equitably among farmers, who can pump from shallow aquifers at relatively low cost rather than suffer from inequitably shared or poorly managed surface irrigation systems. The moderation of air temperature by rice fields has been recognized as a regulating service in peri-urban areas where paddy and urban land are intermingled. This function is attributed to relatively high evapotranspiration rates that lower the ambient temperature of the surrounding area in the summer and result in lateral heat emission from the water body in winter. Rice can be used as a desalinization crop because of its ability to grow well under flooded conditions where continuously percolating water leaches salts from the topsoil.

Supporting services

As a supporting service, flooded rice fields and irrigation channels form a comprehensive water network, which together with their contiguous dry land provides a complex mosaic of landscapes. The Ramsar Convention on wetlands classified irrigated rice land as a human-made wetland. Surveys show that such landscapes sustain a rich biodiversity, including unique and threatened species, and enhance biodiversity in urban and peri-urban areas. In parts of the United States such as California, rice fields are ponded in winter and used to provide habitat for ducks and other water birds.

The cultural services of rice environments are especially valued in Asian countries, where rice has been the main staple food and the single most important source of employment and income for rural people for centuries if not millennia. Many old kingdoms as well as small communities have been founded on the construction of irrigation facilities to stabilize rice production. The collective approach needed to invest in rice systems (construction of terraces, tank systems for irrigation) and operation and maintenance (terraces, but also cropping calendar) requires strong community efforts. Rice affects daily life in many ways, and the social concept of rice culture gives meaning to rice beyond its role as an item of production and consumption. Many traditional festivals and religious practices are associated with rice cultivation, and rice fields are valued for their scenic beauty. Rice is also an integral part of the history and culture of Africa, where it has been grown for more than 3,000 years.

Managing pests in the rice ecosystem

Rice fields harbor a tremendous diversity of animals, plants, and microorganisms, some of which are harmful to the rice crop and many of which are beneficial. The goal of many scientists at IRRI and other institutions is to manage rice pests in ways that are safe, sustainable, and economical. Emphasis is placed on breeding rice varieties with resistance to insect pests and diseases and on minimizing the use of pesticides to promote natural biological control by beneficial insects, spiders, and microorganisms. The importance of biological control in rice was dramatically demonstrated in the 1970s, when the indiscriminate use of broad-spectrum insecticides devastated populations of beneficial insects and spiders and led to huge outbreaks of the brown planthopper, which had previously been a minor pest.

A rice pest is any organism that causes economic loss in rice production, including arthropods (insects and mites), pathogens (bacteria, fungi, and viruses), weeds, mollusks (snails), and vertebrates (rodents and birds). Some common pests are shown in Table 2.2. The damage they do ranges

Yellow stem borer is a serious pest of rice.

from severing stems or killing tissue to competing with the crop for nutrients and sunlight.

Weeds are an almost universal companion of rice in the tropics. In many situations, weed growth is prolific and weeds are a major constraint to crop yield. Weeding is a major production cost, with estimates of 50–150 person-days per hectare required for manual weeding, depending on the number of weedings and type of rice culture. For many farmers, weeding requires the greatest labor input during the agricultural cycle, and labor is often not available when weeds are most damaging to the crop. Upland rice more than any other crop shows the ravages of a lack of proper weeding. Sometimes, when the land is too weedy, the crop is abandoned.

The demands of transplanting and manual weeding and increasing shortages of labor have encouraged the move to direct-seeding in irrigated and rainfed lowlands. Weeds become a major problem in direct-seeding systems because rice and weeds emerge at the same time, and weed control by flooding is difficult in seeded rice.

With weeding a major cost in both transplanted and direct-seeding systems, herbicide use to control weeds is increasing rapidly. As a result, herbicide-resistant weeds and pollution are emerging problems in rice production.

Insects attack all parts of the rice plant. Hundreds of species feed on rice, but only

Table 2.2. Examples of organisms that may harm or compete with the rice crop.

Insect pests	
Stem borers	
African rice gall midge	*Orseolia oryzivora* (Harris & Gagne)
Yellow stem borer	*Scirpophaga incertulas* (Walker)
White stem borer	*S. innotata* (Walker)
Striped stem borer	*Chilo suppressalis* (Walker)
Dark-headed rice borer	*C. polychrysus* (Meyrick)
Defoliators	
Rice leaffolders	*Cnaphalocrocis medinalis* (Guenée) and others
Rice caseworm	*Nymphula depunctalis* (Guenée)
Leafhoppers	
Green leafhopper	*Nephotettix virescens* (Distant) *N. nigropictus* (Stål) *N. parvus* Ishihara et Kawase *N. cincticeps* (Uhler)
Planthoppers	
Brown planthopper	*Nilaparvata lugens* (Stål)
Whitebacked planthopper	*Sogatella furcifera* Horvath
Rice bugs	
Malayan black rice bug	*Scotinophara coarctata* (Fabricius)
Rice grain bug	*Leptocorisa oratorius* (Fabricius)
Rodents	
Rice field rats	*Rattus argentiventer* (Rob. & Kloss) *R. tanezumi* (Temminck)
Diseases	
Viral diseases and their vectors	
Rice tungro	*Nephotettix virescens* (Distant) *N. nigropictus* (Stål)
Ragged stunt	*Nilaparvata lugens* (Stål)
Rice yellow mottle	*Chaetocnema pulla* *ChapiusTrichispa sericia* (Guérin)
Bacterial diseases and their causal agents	
Bacterial blight	*Xanthomonas oryzae* pv. *oryzae* (Uyeda ex Ishiyama 1922) Swings et al 1990
Fungal diseases and their causal agents	
Blast	*Pyricularia oryzae* Cav.
Sheath blight	*Rhizoctonia solani* *(Thanatephorus cucumeris* [Frank] Donk)
Weeds	
Ageratum conyzoides L.	
Cyperus difformis L.	
C. iria L.	
Echinochloa colona (L.) Link	
E. crus-galli (L.) P. Beauv.	
Fimbristylis miliacea (L.) Vahl	
Monochoria vaginalis (Burm. f.) Presl	

a few cause yield loss. The most important and widely distributed pest species are stem borers, leaffolders, planthoppers, and gall midge. Stem borers are chronic pests, found in every field in every season, but generally at low numbers. Planthoppers and gall midge usually create localized outbreaks, causing high yield losses in relatively small areas. Biological control by natural enemies plays a critical role in the management of all insect pests. Resistant rice varieties are of importance in the control of planthoppers and gall midge. No strong sources of resistance to stem borers have been found in rice germplasm, although modern semidwarf rice varieties generally have less stem borer damage than the traditional varieties they replaced. Insecticides are used extensively against planthoppers in temperate areas of Asia, where mass immigration of planthoppers from tropical areas is a frequent problem.

Disease. Bacterial blight, blast, and sheath blight are the most important diseases of rice and they have a worldwide distribution. Three insect-vectored viral diseases are also of importance: tungro in Asia, hoja blanca in South America, and rice yellow mottle in Africa. Bacterial blight and blast have been successfully controlled by resistant varieties for many years. However, the evolution of resistance-breaking strains of these pathogens has necessitated the continuing release of new resistant varieties. Strong sources of resistance for sheath blight have not been identified in rice germplasm. Sheath blight is a particularly important disease in intensive rice-growing conditions where high amounts of nitrogen fertilizer are applied.

Environmental impacts

Rice production mainly affects the environment by releasing or sequestering gases or compounds that are active in the atmosphere or troposphere and by changing the chemical composition of the water flowing through rice fields. Rice is in turn affected by environmental changes, such as global climate change.

Ammonia volatilization

Ammonia volatilization is the major pathway of nitrogen loss from applied nitrogen fertilizer in rice systems. Across irrigated environments in Asia, nitrogen fertilizer input averages 120 ± 40 kg/ha, with the highest amounts in southern China, at up to 250 kg/ha. In tropical transplanted

Farmers hand weed their rice field in the uplands of Lao PDR.

rice, nitrogen losses from ammonia volatilization can be 50% or higher, while in direct-seeded rice in temperate regions, losses are generally negligible because most of the fertilizer is incorporated into the soil before flooding. Ammonia-nitrogen volatilizations from lowland rice fields are estimated at 3.6 teragrams (Tg) a year (compared with 9 Tg a year emitted from all agricultural fields worldwide), which is 5–8% of the estimated 45–75 Tg of globally emitted ammonia-nitrogen each year. The magnitude of ammonia volatilization depends largely on climatic conditions, field water management, and method of nitrogen fertilizer application. Volatilized ammonium can be deposited on the earth by rain. This can be a beneficial source of (free) nitrogen fertilizer in agricultural lands, but it can also lead to soil acidification and unintended nitrogen inputs into natural ecosystems.

Greenhouse gases

Of the three main greenhouse gases, rice production sequesters carbon from carbon dioxide and likely increases emissions of nitrous oxide and methane, though by how much is not reliably known.

Carbon sequestration. Rice soils that are flooded for long periods of the year tend to sequester carbon, even with the complete removal of aboveground plant biomass. Significant carbon accumulation results from biological activity in the soil-floodwater system. Average soil organic carbon content in irrigated double and triple rice systems in Asia is 14–15 g/kg in the upper 20–25 cm of soil. Assuming an average bulk density of about 1.25 t per cubic meter of soil and a physical land area of about 24 million ha, these monoculture systems alone store about 45 t/ha of carbon or a total of 1.1 petagrams of carbon (10^9 t) in the topsoil. Additional carbon is stored in other irrigated rice systems (such as single rice and rice-maize), although typically in smaller amounts than in monoculture systems. However, reliable information on soil carbon stocks is not available for rice systems in most countries, and it is not known how soil organic carbon amounts will change in response to changing climate or management practices.

Nitrous oxide. In irrigated rice systems with good water control, nitrous oxide emissions are small except when nitrogen fertilizer rates are excessively high. In irrigated rice fields, the bulk of nitrous oxide emissions occur during fallow periods and immediately after flooding of the soil at the end of the fallow period. In rainfed systems, however, nitrate accumulation in aerobic phases might contribute to considerable emission of nitrous oxide.

Methane. In the early 1980s, it was estimated that lowland rice fields emitted 50–100 Tg of methane per year, or 10–20% of the then-estimated global methane emissions. Recent measurements show that many rice fields emit substantially less methane, especially in northern India and China, both because methane emissions have decreased with changes in rice production systems and because techniques for measuring greenhouse gas emissions have improved with the use of simulation models coupled with geographic information systems (GIS) data based on soil and land use (Fig. 2.2).

There is more uncertainty about the amount of methane emissions from rice fields than from most other sources in the global methane budget. Current estimates of annual methane emissions from rice fields are in the range of 20–60 Tg, or 3–10% of global emissions of about 600 Tg. Estimates of annual methane emissions from the principal rice producers China and India are 10–30 Tg. The magnitude and pattern of methane emissions from rice fields are determined mainly by the water regime and organic inputs and to a lesser extent by soil type, weather, tillage practices, residue management, fertilizer use, and rice cultivar. The use of organic manure generally increases methane emissions. Flooding of the soil is a prerequisite for sustained emissions of methane. Mid-season drainage, a common irrigation practice in the major rice-growing regions of China and Japan, greatly reduces methane emissions. Similarly, rice environments with an uneven supply of water, such as rainfed environments, have a lower emission potential than environments where rice is continuously flooded.

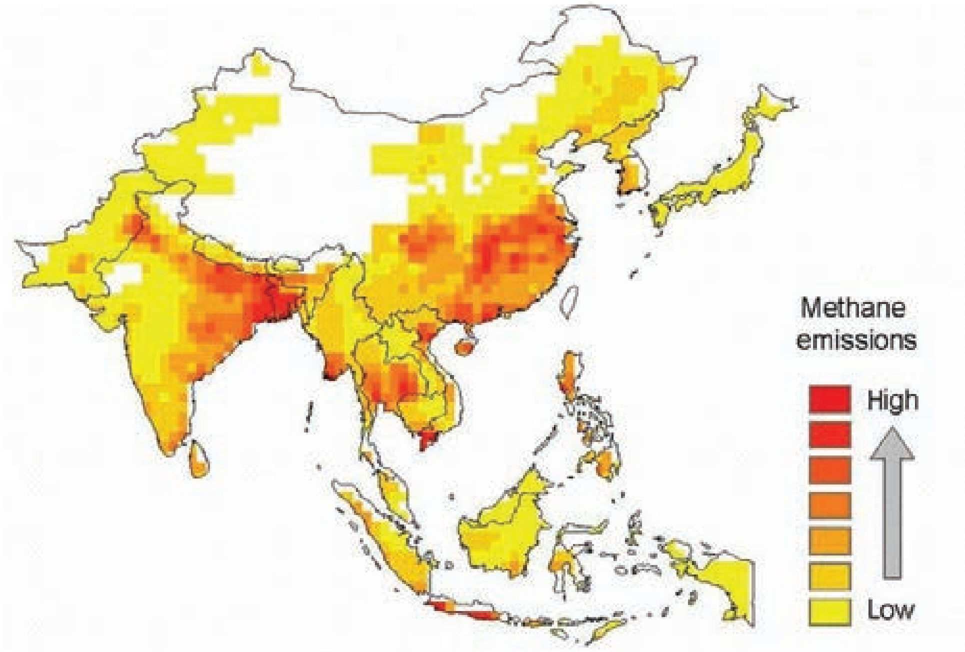


Fig. 2.2. Methane emissions from rice production in Asia. Map drawn by K. Sumfleth.

Water pollution

The changes in water quality associated with rice production can be positive or negative, depending on the quality of the incoming water and on management practices relating to fertilizer and biocide use, among others. The quality of the water leaving rice fields may be improved by the capacity of the wetland ecosystem to remove nitrogen and phosphorus. On the other side of the ledger, nitrogen transfers from flooded rice fields by direct flows of dissolved nitrogen in floodwater through runoff or drainage warrant more attention. The pollution of groundwater is covered below in the discussion of human health.

Salinization

Percolating water from lowland rice fields usually raises the water table. Where the groundwater is saline, this can salinize the root zone of nonrice crops in the area and cause waterlogging and salinity in lower areas in the landscape, such as in parts of Australia and the northwest Indo-Gangetic Plain. Where irrigation water is relatively fresh, flooded rice can be used in combination with adequate drainage to leach salts that had previously accumulated under nonrice crops out of the root zone, as in parts of northern China, and to reclaim sodic soils when used in combination with gypsum, as in parts of the northwest Indo-Gangetic Plain.

Rice and health—pollution and nutrition

Many of the rural poor in Asia obtain water for drinking and household use from shallow aquifers under agricultural land. Among the agrochemicals that pose the greatest threats to domestic use of groundwater are nitrate and biocide residues. In addition, contamination of groundwater with arsenic has recently emerged as a major health issue in Asia. Other health aspects concern malnutrition and vector-borne diseases related to rice production.

Nitrates

Nitrate leaching from flooded rice fields is normally negligible because of rapid denitrification under anaerobic conditions. In the Philippines, for example, nitrate pollution of groundwater under rice-based cropping systems exceeded the 10 mg/liter (mg/L) limit for safe drinking water only when highly fertilized vegetables were included in the cropping system. In the Indian Punjab, however, an increase in nitrate of almost 2 mg/L was recorded between 1982 and 1988, with a simultaneous increase in nitrogen fertilizer use from 56 kg/ha to 188 kg/ha, most of it on combined rice-wheat cultivation. The relative contribution to this increase from rice, however, is not clear.

Biocides

Mean biocide use in irrigated rice systems varies from 0.4 kg/ha of active ingredients in Tamil Nadu, India, to 3.8 kg/ha in Zhejiang Province, China. In the warm and humid conditions of the tropics, volatilization is the major process of biocide loss, especially when biocides are applied on the water surface or on wet soil. Relatively high temperatures favor rapid transformation of the remaining biocides by photochemical and microbial degradation, but little is known about the toxicity of the residual components. In case studies in the Philippines, mean biocide concentrations in groundwater under irrigated rice-based cropping systems were one to two orders of magnitude below the single (0.1 microgram [μg]/L) and multiple (0.5 μg/L) biocide limits for safe drinking water, although temporary peak concentrations of 1.14–4.17 μg/L were measured.

Biocides and their residues may be directly transferred to open water bodies through drainage water flowing overland from rice fields. The potential for water pollution by biocides is greatly affected by field water management. Different water regimes result in different pest and weed populations and densities, which farmers may combat with different amounts and types of biocides. In traditional rice systems, relatively few herbicides are used because puddling, transplanting, and ponding water are effective weed control measures.

Arsenic

Arsenic in groundwater has been reported in several countries in Asia. Severe problems of arsenicosis occur in rural areas in Bangladesh and in West Bengal in India. In the past two decades, the number of shallow tubewells for irrigation in these areas has increased dramatically, and dry-season rice production (boro rice) depends heavily on groundwater. It is unclear whether groundwater extraction for irrigation influences arsenic behavior in the shallow aquifers, but irrigation from arsenic-contaminated aquifers may pose several risks. Arsenic accumulates in the topsoil as a result of irrigation water input. Because rice fields receive higher inputs of irrigation water than other crops, they accumulate more arsenic than other fields. Moreover, arsenic is potentially more bioavailable under flooded than nonflooded conditions.

It is not yet possible to predict arsenic uptake by plants from the soil, and significant correlations are not often found between total arsenic in the soil and in plants. Arsenic that is taken up by rice is

Few herbicides are needed for weed control in systems using puddling and transplanting.

found mostly in roots and shoot tissue, and very little in the grains. In Bangladesh, no milled rice samples have been found to contain more arsenic than the government threshold of 1 part per million for safe consumption, although straw samples have, raising concerns about arsenic toxicity in animal feed.

Arsenic in the soil may also affect crop production, but this aspect has not received much attention yet, and understanding of the long-term aspects of arsenic in agriculture is too limited to assess the risks. Water-saving irrigation techniques for rice (such as alternate wetting and drying irrigation and aerobic rice) reduce the irrigation inputs and arsenic contamination risk of the topsoil. As the soil becomes more aerobic, the solubility and uptake of arsenic also decline.

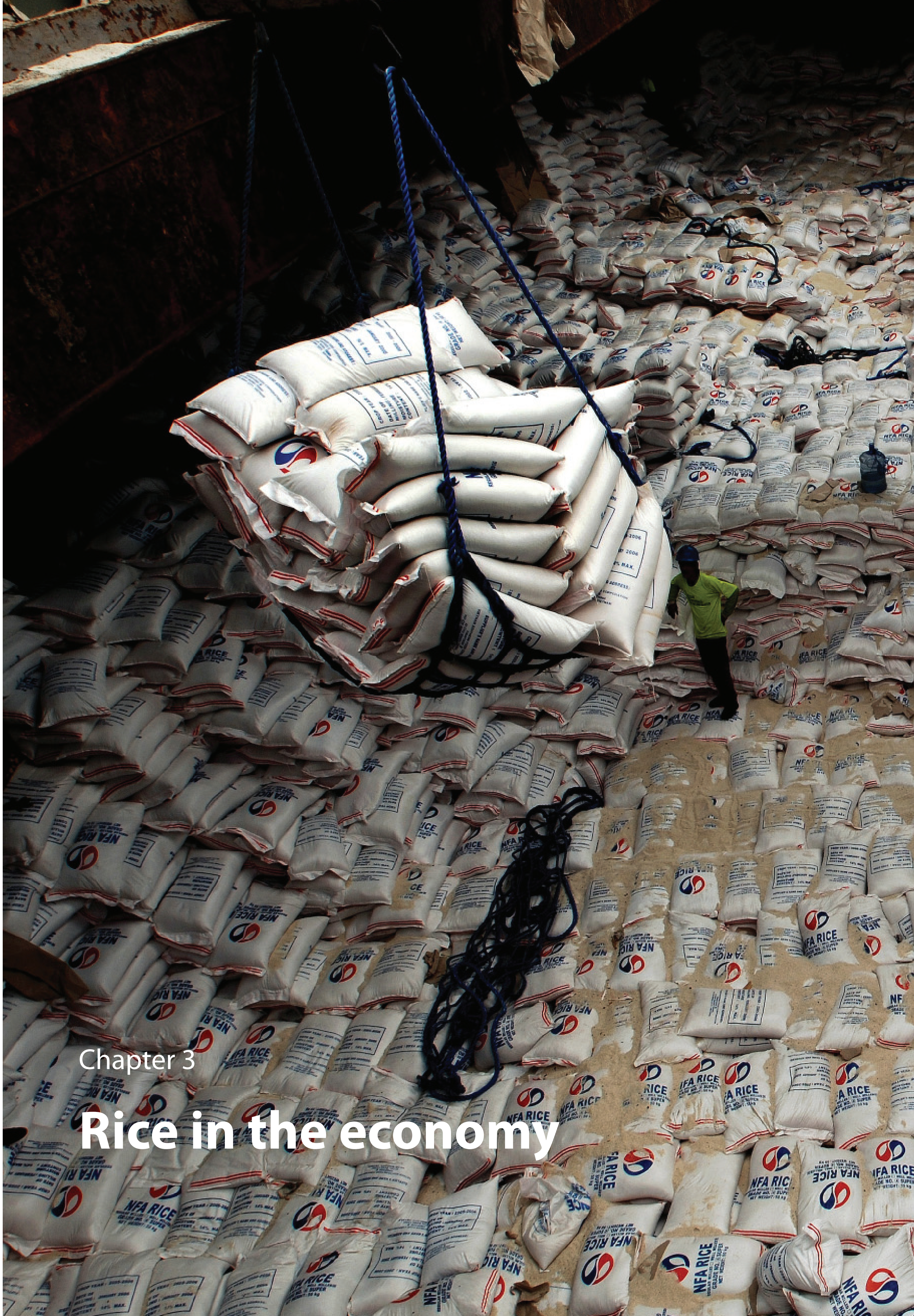
Nutrition

Human micronutrient deficiencies are relatively severe in areas where rice is the major staple. Increasing the density of provitamin A carotenoid, iron, and zinc in rice can alleviate these deficiencies, especially among the urban and rural poor who have little access to alternatives such as enriched foods and diversified diets. Promising examples are the development of Golden Rice to combat vitamin A deficiency and of iron-rich rice to combat iron deficiency, although it is still debated whether such increases in the endosperm are sufficient to significantly affect human nutrition. To drive the adoption of micronutrient-rich varieties, however, the improved traits will need to be combined with other traits that are attractive to farmers, such as tolerance of drought, salinity, or submergence.

Vector-borne diseases

Irrigated rice fields can serve as breeding sites for mosquitoes and snails, intermediate hosts capable of transmitting human parasites. In particular, before transplanting and after harvest, puddles in rice fields are attractive breeding grounds for the mosquito *Anopheles gambiae*, Africa's most efficient malaria vector. Factors that determine whether the introduction of irrigated rice increases or reduces the incidence of malaria are known, and technical options exist to mitigate this impact, including alternate wetting and drying irrigation. Moreover, countries such as Sri Lanka have made great strides in controlling epidemics through broad-based public health campaigns. Japanese B-encephalitis is highly correlated with rice irrigation in Asia, especially where pigs are also reared, as in China and Vietnam. Again, alternate wetting and drying can help reduce the breeding of vectors.

Golden Rice grains with other beta carotene-rich (vitamin A) foods.



Chapter 3

Rice in the economy

Global rice production and consumption

Rice is grown on more than 144 million farms worldwide, most certainly more than for any other crop, on a harvested area of about 162 million ha (2010). Most of the rice is grown and consumed in Asia, from Pakistan in the west to Japan in the east. "Rice-producing Asia" as thus defined (excluding Mongolia and the countries of Central Asia) accounted for 91% of world rice production, on average, in 2006-10, unchanged since the early 1960s. Because rice-producing Asia is a net exporter of rice to the rest of the world, its current share in global rice consumption is slightly less, at about 87%.

Rice also dominates overall crop production (as measured by the share of crop area harvested of rice) and overall food consumption (as measured by the share of rice in total caloric intake) to a much greater extent in rice-producing Asia than elsewhere in the world. On the consumption side, the only countries outside Asia where rice contributes more than 30% of caloric intake are Madagascar, Sierra Leone, Guinea, Guinea-Bissau, and Senegal (countries with population less than 1 million are excluded) (Fig. 3.1). On the production side (Fig. 3.2), the only countries outside Asia where rice accounts for more than 30% of total crop area harvested are Madagascar, Sierra Leone, and Liberia in West Africa, plus Suriname, Guyana, French Guiana, and Panama in Latin America.

The world's largest rice producers by far are China and India. Although its area harvested is lower than India's, China's rice production is greater due to higher yields because nearly all of China's rice area is irrigated, whereas less than half of India's rice area is irrigated. After China and India, the next largest rice producers are Indonesia, Bangladesh, Vietnam, Thailand, and Myanmar (Fig. 3.3). These seven countries all had average production in 2006-10 of more than 30 million t of paddy. The next highest country on the list, the Philippines, produced only a little more than half that. Collectively, the top seven countries account for more than 80% of world production. Production, yield, and trade data for all rice-producing countries are given in Rice Facts (page 261).

Despite Asia's dominance in rice production and consumption, rice is also very important in other parts of the world. In Africa, for example, rice has been the

In Ifugao Province, Philippines, an experienced farmer selects choice seeds for the next season's planting.

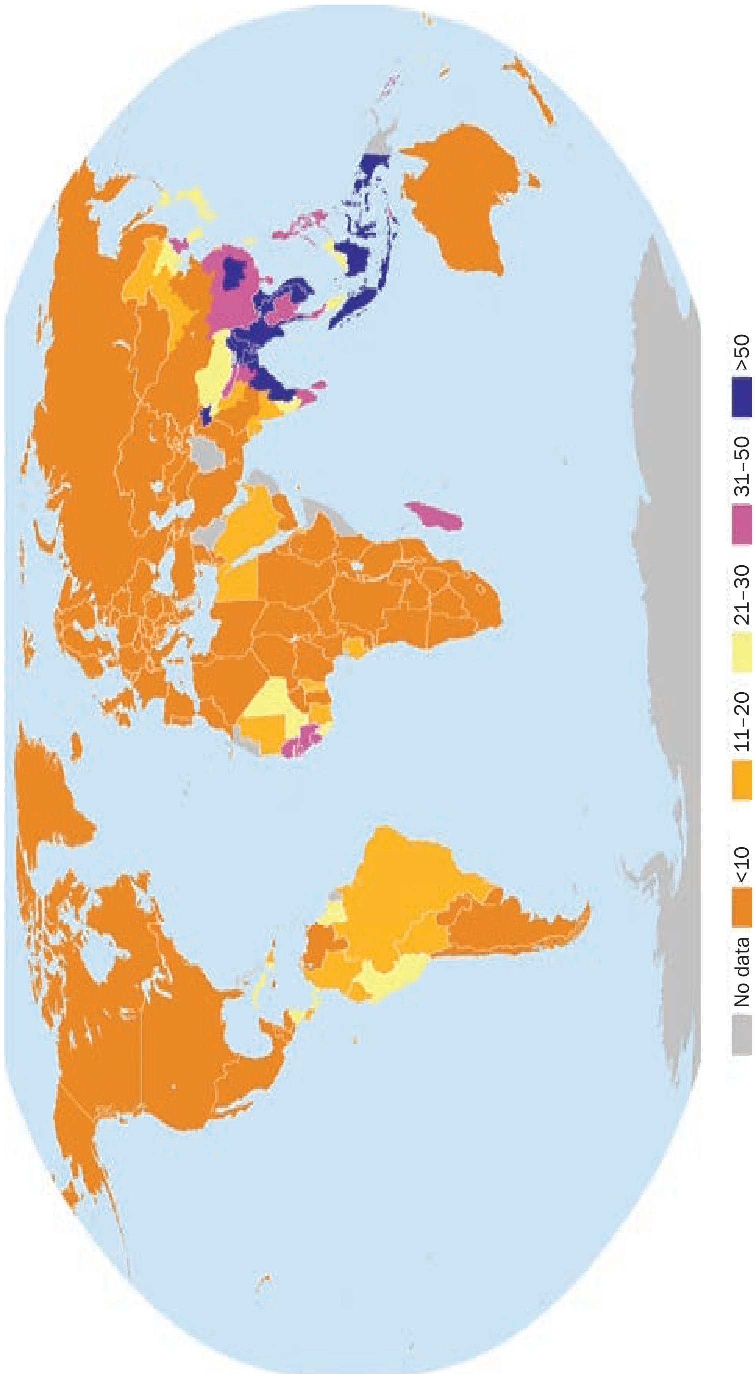


Fig. 3.1. Percentage of calories coming from rice.

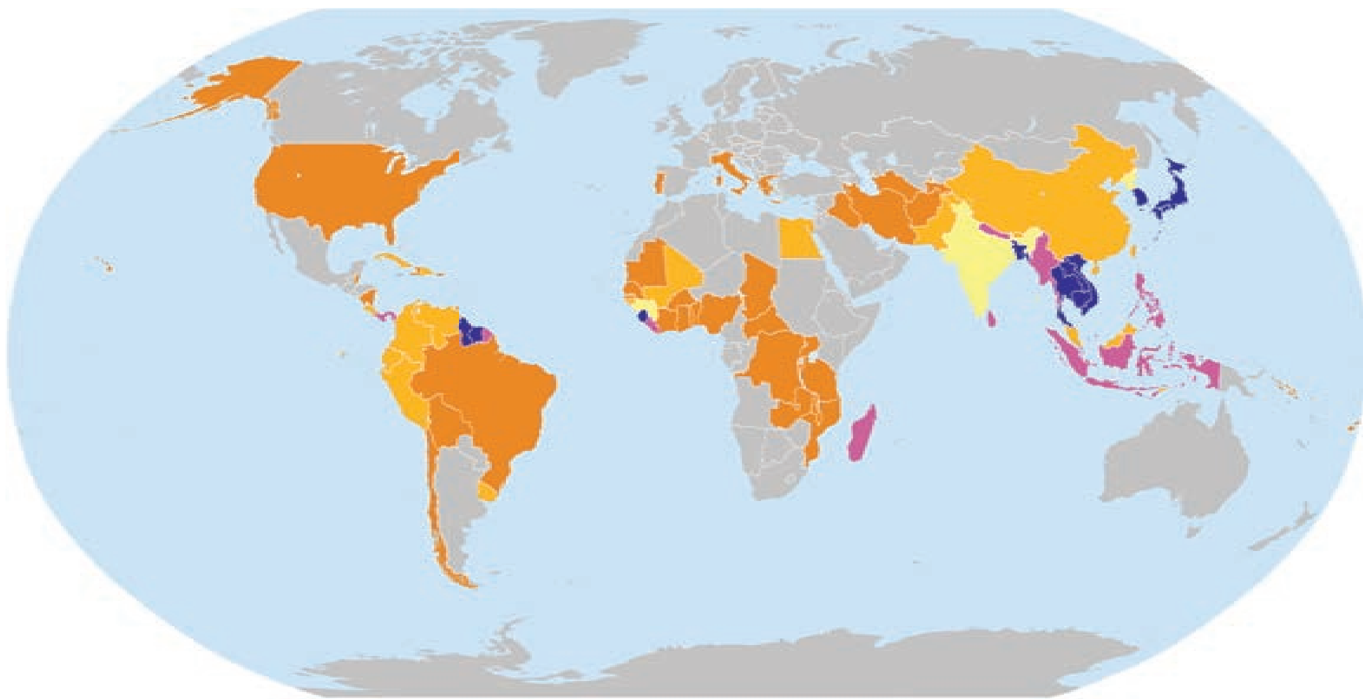


Fig. 3.2. Percentage of total crop area harvested that comes from rice.

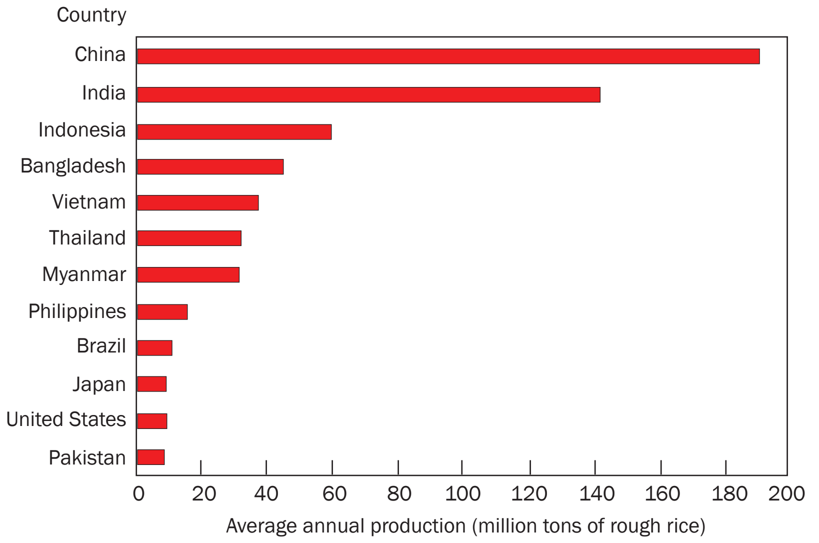


Fig. 3.3. Leading rice producers in the world, 2006-2010.

Source of raw data: FAOSTAT database online.

main staple food (defined as the food, among the three main crops, that supplies the largest amount of calories) for at least 50 years in parts of western Africa (Guinea, Guinea-Bissau, Liberia, Sierra Leone) and for some countries in the Indian Ocean (Comoros and Madagascar). In these countries, the share of calories from rice has generally not increased substantially over time. In other African countries, however, rice has displaced other staple foods because of the availability of affordable imports from Asia and rice's easier preparation, which is especially important in urban areas. In Côte d'Ivoire, for instance, the share of calories from rice increased from 12% in 1961 to 22% in 2007. In Senegal, the share increased from 20% to 31% during the same time, whereas, in Nigeria, the most populous country on the continent, it increased from 1% to 8%. On balance, in Africa, production has grown rapidly, but rice consumption has grown even faster, with the balance being met by increasing quantities of imports. Western Africa is the main producing subregion, accounting for more than 40% of African production in 2006-10. In terms of individual countries, the leading producers of paddy (2006-10) are Egypt (6.1 million t), Madagascar (4.1 million t), and Nigeria (3.9 million t).

In Latin America and the Caribbean, rice was a preferred pioneer crop in the first half of the 20th century in the savannas of Brazil, Bolivia, Colombia, Uruguay, and Venezuela, and in forest margins throughout the region. Today, rice is the most important source of calories in many Latin American countries, including Costa Rica, Ecuador, Guyana, Panama, Peru, and Suriname, and the Caribbean nations of Cuba, Dominican Republic, and Haiti. It is less dominant in consumption than in Asia, however, because of the importance of wheat, maize, and beans in regional diets. Brazil is by far the largest producer, and it accounts for nearly half (45% in 2006-10) of paddy production in the region. After Brazil (11.7 million t), the largest producers are Peru (2.6 million t), Colombia (2.4 million t), and Ecuador (1.6 million t) in 2006-10.

Elsewhere, the most important production centers are in the United States (California and the southern states near the Mississippi River), which produced 9.6 million t of paddy on average in 2006-10. The leading European producers are Italy, Spain, and Russia. Australia used to be an important producer, but its output has declined substantially in recent years because of recurring drought.

Rice consumption in the Pacific islands has increased rapidly over the past two decades. Rice, which is all imported apart from a small amount grown in Fiji and Papua New Guinea, is displacing traditional starchy root crops as a major staple due to changing tastes, ease of storage and preparation, and sometimes cost. The annual national consumption of imported rice in the Solomon Islands doubled from 34 kg to 71 kg per capita during 2002-07 and tripled in Samoa (from 6 kg to 19 kg) and the Cook Islands (5 kg to 15 kg) in the same period.

The ongoing revolution

The Green Revolution was the rapid acceleration during 1965-90 of a continuing process of change in cereal farming technology and policy that began in Japan in the latter part of the 19th century and spread to Taiwan and Republic of Korea during the late 1920s and 1930s. For rice, the revolution began with the release by IRRI of the high-yielding semidwarf variety IR8 in 1966. Rice farming yields began to rise dramatically and even better high-yielding varieties (HYVs) became available over subsequent years. The world average rice yield in 1960, the product of thousands of years of experience, was about 2.0 t/ha. Astonishingly, in only 40 more years, as the Green Revolution spread, it doubled, reaching 4.0 t/ha in 2000. The rice varieties and technologies developed during the Green Revolution have increased yields in some areas to between 6.0 and 10.0 t/ha.

The need for rapid increases in cereal production, principally wheat and rice, had become very evident by the mid-1960s: "Hunger and malnutrition were widespread, especially in Asia, which increasingly depended on food aid from rich countries. Back-to-back droughts in India during the mid-1960s made the already precarious situation worse, and a 1967 report of the U.S. President's Science Advisory Committee concluded that the scale, severity and duration of the world food problem are so great that a massive, long-range, innovative effort unprecedented in human history will be required to master it."

The crisis led directly to the establishment of IRRI in 1960 and later its sister institutions in the then Consultative Group on International Agricultural Research (CGIAR) system.

A technology and policy package

Basically, the Green Revolution was a technology revolution, comprising a package of modern inputs—irrigation, fertilizers, improved seeds, and pesticides—and

Release of rice variety IR8 began the Asian Green Revolution in 1966.

small-scale mechanization that together dramatically increased yields of many cereal crops. But its implementation also depended on strong public support for developing the technologies; building up the required infrastructure; ensuring that markets, finance, and input systems worked; and ensuring that farmers had adequate knowledge and economic incentive to adopt. Public interventions were especially crucial in Asia for ensuring that small farmers were not left behind, and without which the Green Revolution would have been much less pro-poor.

Asia was already investing heavily in irrigation prior to the Green Revolution and, by 1970, around 25% of the agricultural land was already irrigated. Significant additional investments were made across Asia during the Green Revolution era, and the irrigated area grew from 25% to 33% of the agricultural area between 1970 and 1995.

Like irrigation, fertilizer use across Asia was also growing prior to the Green Revolution. In 1970, 24 kg/ha of plant nutrients were applied on agricultural land and average use grew rapidly to reach 102 kg/ha by 1995, and was about 200 kg/ha for rice in the Philippines and Vietnam.

Irrigation and fertilizer helped raise cereal yields, but their full impact was realized only after the development of the HYVs. Building on rice breeding work undertaken in China, Japan, and Taiwan, IRRI scientists developed semidwarf rice varieties that were more responsive to plant nutrients, and had shorter and stiffer straw that would not fall over under the weight of heavier heads of grain. They also wanted tropical rice varieties that could mature more quickly and were insensitive to daylight length, thereby permitting more crops to be grown each year on the same land.

The first of these HYVs, named IR8, was released in 1966. Adoption of HYVs occurred quickly and about 40% of the total cereal area in Asia was planted to modern varieties by 1980. This increased to about 80% of the cropped area by 2000.

HYVs were not developed overnight but were the product of a long and sustained research effort in Asia. Also, although many of the initial rice varieties released were successful in dramatically raising yield potential, they proved susceptible to a number of important pests and diseases and had cooking traits that were less appealing to consumers. Continuing investments in agricultural research led to the eventual development of second- and third-generation varieties that successfully combined high yield potential with good pest and disease resistance and preferred consumption traits.

The Green Revolution was more than a technology fix. It also required a supporting economic and policy environment in order to educate farmers about the new technology, rapidly expand input delivery and credit systems, and increase processing, storage, trade, and marketing capacities to handle the surge in production. Asian countries invested heavily to launch their Green Revolution and continued to invest in agriculture to sustain the gains that were achieved. On average, Asian countries were spending 15.4% of their total government spending on agriculture by 1972 and they doubled the real value of their agricultural expenditure by 1985.

Governments also shored up farm credit systems, subsidized key inputs—especially fertilizer, power, small machines, and water—and intervened in markets to ensure that farmers received adequate prices each year to make the technologies profitable. Many governments used their interventions to ensure that small farms did not get left behind. Substantial empirical evidence at the time showed that small farms were the more efficient producers in Asia and land reform and small farm development programs were implemented to create and support large numbers of small farms. Small farm-led agricultural growth proved to be not only more efficient but also more pro-poor, a win-win proposition for growth and poverty reduction.

Impact of the Green Revolution

*Impact on cereal yields and production***.** Average rice yields grew by 2.5% per year from 1965 to 1982. The average paddy rice yield rose from 2.03 t/ha in 1965 to 3.04

t/ha in 1982, and reached 4.2 t/ha by 2007. Asian paddy rice production increased from 232.2 million t in 1965 to 383.4 million t in 1982 and to 598.9 million t in 2007. Although the population increased by 60%, the increase in food production meant that, instead of widespread famine, cereal and calorie availability of rice (and wheat) per person increased by nearly 30%, and these cereals became cheaper. All the gains were achieved with negligible growth per year in the total area planted to cereals.

Impact on factor productivity and food prices. The Green Revolution not only increased yields, it also reduced the production costs per kg of cereal harvested. This enabled a win-win outcome in which cereal prices could decline to the benefit of consumers even while farmers and agricultural workers increased their earnings. This was possible because the HYVs shifted the yield function upward, giving higher returns to each unit of modern input—fertilizer, pesticides, and water—than earlier varieties, leading to higher returns to land and labor. For Asia as a whole, average land and labor productivity in agriculture grew by 3.03% and 1.53% per year, respectively, during 1967-82, and increased to 3.55% and 2.98% per year, respectively, during 1982-95.

There were also substantial increases in agricultural productivity in many other parts of the world. It is difficult to attribute the amount of the price decline to Asia's Green Revolution. A global food model simulation of what would have happened to world cereal prices after 1965 if only the developed countries had experienced crop genetic improvements while the crop varieties in the developing world remained unchanged showed that, by 2000, the rice price would have been 80–124% higher than the actual.

And, of course, in poor areas of Asia, widespread famine would have resulted.

The powerful economy-wide benefits emanating from the Green Revolution were amply demonstrated in India. The fact that India's national employment share in agriculture did not change for over a century until the full force of the Green Revolution was under way in the 1970s provided strong circumstantial evidence of the importance of agricultural growth as a motor for the Indian economy. Modeling studies using computable general equilibrium (CGE) models of other Asian country economies have also demonstrated the powerful growth impacts following productivity-enhancing investments in agriculture.

Impact on poverty. Reliable poverty data are not available for the early Green Revolution period. The rate of poverty in Asia fell from nearly 60% in 1975 to less than 33% by 1995. The absolute number of poor declined by 28%, from 1.15 billion in 1975 to 825 million in 1995. These reductions in poverty would have been even more impressive if the total population had not grown by 60% over the same period. Since the vast majority of the poor who were lifted out of poverty were rural and obtained important shares of their livelihood from agriculture and allied activities, the Green Revolution was undoubtedly one of the forces accounting for that shift. The Green Revolution was very successful in increasing the per capita supply of food and reducing the prices of food staples in Asia. Making food staples more available and less costly has proved to be an important way through which poor people benefited.

Given the complex causes underlying poverty and the diversity of livelihoods found among poor people, the relationship between the Green Revolution and poverty alleviation is necessarily complex and this has led to a large and contentious debate in the literature. Village and household studies conducted soon after the release of Green Revolution technologies raised concern that large farms were the main beneficiaries of the technologies and that poor farmers were either unaffected or made worse off. Later evidence showed mixed outcomes. Many small farmers also benefited from greater employment opportunities and higher wages in the agricultural and nonfarm sectors. In some cases, small farmers and landless laborers actually ended up gaining proportionally more income than larger farmers, resulting in a net improvement in the distribution of village income.

A meta-analysis of studies up to the mid-1990s found that 40% of the studies reviewed reported that income became more concentrated within adopting regions, 12% reported that it remained unchanged or improved, and 48% offered no conclusion. Among the studies, Asian authors gave more favorable outcomes than non-Asian authors; micro-based case studies reported the most favorable outcomes, while macro-based essays reported the worst outcomes. However, later repeat studies undertaken at the same sites over a longer period of time all found favorable longer-term impacts on inequality.

In Asia, each 1% increase in crop productivity has resulted in a reduction in numbers of the poor by around 0.4%. This relationship is probably diminishing over time, however, because the rural poor are becoming less dependent on agriculture.

Production, area, and yield trends over time

Global rice production more than tripled between 1961 and 2010, with a compound growth rate of 2.24% per year (2.21% in rice-producing Asia). This increase was slightly greater than that for wheat (2.02% per year), but substantially less than that for maize, which grew at 2.71% per year. Most of the increase in rice production was due to higher yields, which increased at an annual average rate of 1.74%, compared with an annual average growth rate of 0.49% for area harvested. In absolute terms, paddy yields increased at an annual average rate of 51.1 kg/ha per year, although this rate of increase has declined in both percentage and absolute terms (see below).

Since most rice is produced and consumed in rice-producing Asia, it makes sense to compare these growth rates with population growth in that part of the world. Population growth in this region was 1.77% per year from 1961 to 2010, nearly identical to the rate of yield growth. Coupled with the expansion in area harvested, this yield growth led to a cumulative 30% increase in per capita production during the period.

The trend in rice yield has been positive in all parts of the world although the rates of growth and yield vary by region (Fig. 3.4). Yields are much higher in East Asia and the United States than in most of the rest of the world. After an initial rapid growth in yield in East Asia, yield growth rate decreased considerably and was almost zero in recent years. Yield has continued to grow in the United States despite some fluctuations. The average yields in recent years were almost 20% higher than in East Asia.

The yield trends for South and Southeast Asia are similar to that of East Asia, but are lower. These regions have substantial area under rainfed conditions, in contrast with East Asia, where rice is mainly irrigated. Growth in yield has fallen

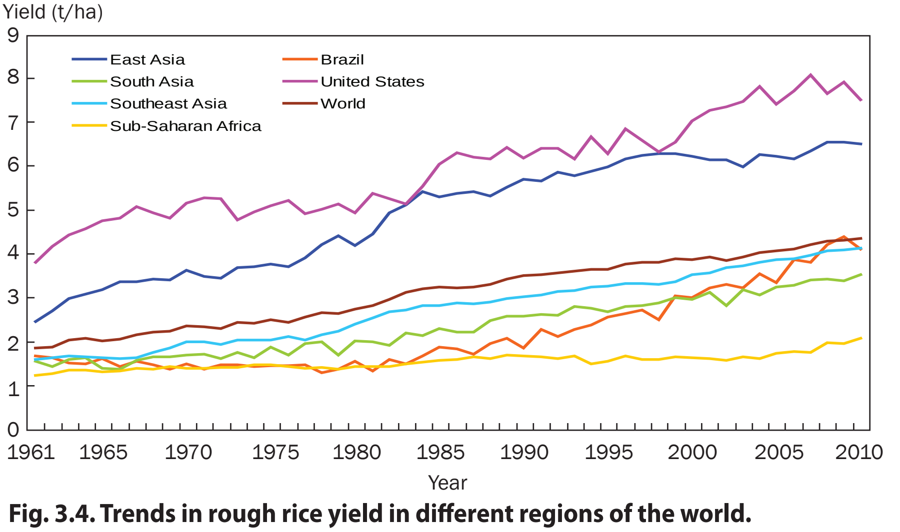


Fig. 3.4. Trends in rough rice yield in different regions of the world.
Source: FAOSTAT, accessed 6 September 2012.

over time in both South and Southeast Asia, especially after the mid-1990s. Africa has the lowest average yield and the historical growth rate in yield there has also been lower, with some indication of an increase in growth rate during more recent years.

Changes in rice area harvested

National and global production statistics typically report area harvested, not physical area. If a farmer plants two crops of rice, each of 4 months' duration, on 1 ha of land in a given year, then the physical rice area would be 1 ha, but rice area harvested would be 2 ha. Growth in area harvested can thus come from either expansion of the physical area given to rice or an increased cropping intensity, for example, growing two crops of rice per year on 1 ha of land when only one crop was grown before.

Data on the relative magnitude of increases in physical area and rice-cropping intensity are not available in most countries. Some countries, however, have data available on rice area harvested by season. In Bangladesh and Vietnam, two countries with high population densities, there has been a small contraction in the physical area planted to rice, but increased cropping intensity has more than compensated for that loss. In India, the Philippines, and Sri Lanka, there has been a net increase over time in both physical area and cropping intensity, with the increase in cropping intensity being equal to or larger than the increase in physical area. Finally, in Thailand and Laos, two countries with relatively low population densities by regional standards, the increase in physical area has surpassed the increase in cropping intensity by a fair margin.

Yield growth due to area shifts

Just as the growth in area harvested can be broken down into changes in physical area and cropping intensity, growth in yield also has two components: growth in yield within a specific ecosystem (e.g., irrigated or rainfed) or season, and growth in yield due to area shifts from one ecosystem or season to another. In all countries, within-ecosystem yield growth (weighted average yield growth across ecosystems/seasons, with initial period allocations as weights) has been the dominant source of yield growth, with yield growth due to shifts in area across ecosystems being generally low. Among the few countries with relevant data, Bangladesh has experienced the most yield growth due to area shifts. This has come from an increased dominance of irrigated boro-season rice (the area quadrupled between the early 1970s and the last few years of the 2000s) at the expense of upland rice grown in the aus season, in which area harvested declined by 69%. But, even in Bangladesh, most of the yield growth was due to growth within ecosystems/seasons, not area shifts across ecosystems.

Shifting comparative advantage

Within Asia, the comparative regional advantage in rice production is shifting. Before World War II, the delta regions in Bangladesh, Cambodia, eastern India, Myanmar, Thailand, and Vietnam held the comparative advantage in rice production and were the main sources of rice exports. The early beneficiaries of the Green Revolution technologies of the 1960s and 1970s were areas where it was possible to irrigate two crops of rice with the construction of reservoir storage. Also benefiting was the northwestern Indo-Gangetic Plain, where private investment in groundwater pumping and public investment in irrigation systems and other government policies (subsidies for inputs and minimum price support schemes for grain) favored rice production.

For political reasons and because of the inability to manage floods, the deltas initially were unable to take advantage of the new rice technologies. Over the past 15–20 years, however, with the availability of low-cost pump technology and new cropping systems based on short-duration rice varieties that can avoid the floods, the delta areas have regained their comparative advantage and shown the most rapid growth in rice production and exports. With the improved water control provided by pumps, the delta regions have been able to shift out of low-yielding deepwater and floating rice by planting one crop before and one after the floods. In short, rice production

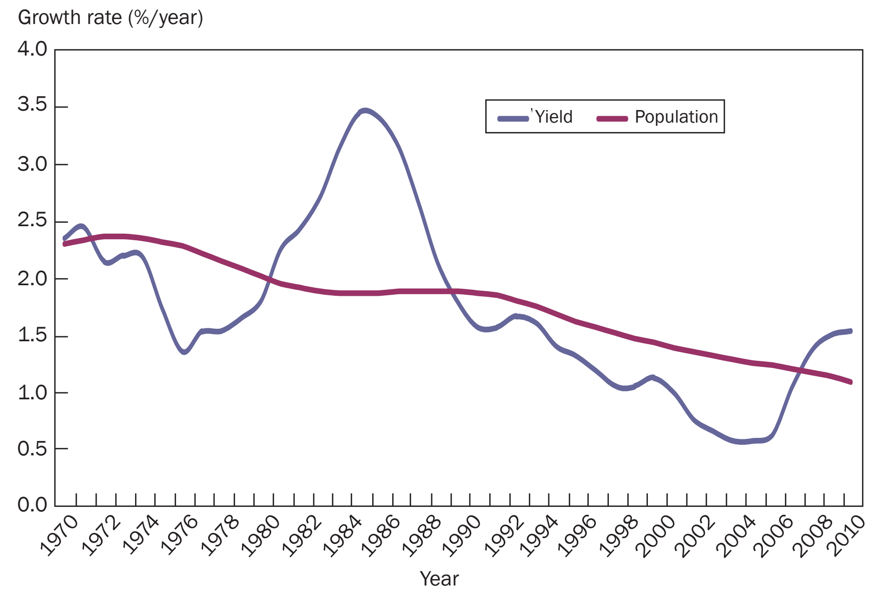


Fig. 3.5. Annual average percentage increase in rice yields and population between successive rolling 5-year periods in rice-producing Asia. The figure shows the annual average percentage change in yields and population. For example, the data for 1970 are the percentage change between 1966-70 and 1961-65. Source of raw data: FAOSTAT, accessed 6 September 2012.

is gaining in regions with plentiful water supply and cheap labor relative to areas of water scarcity, and this trend is expected to continue. In the northwestern Indo-Gangetic Plain, there are now grave concerns about the sustainability of irrigated rice production because of rapidly falling groundwater tables and the government's need to reduce the large fiscal costs associated with policies that promote rice production.

Declining yield growth and environmental problems

Cereal yields have continued to rise on average across Asia since the Green Revolution era, but annual growth rates slowed down over a 20-year period ending in 2005 (Fig. 3.5). Since then, yield growth has been improving, and the area under rice has also greatly expanded in recent years. Population growth in rice-producing Asia has been steadily declining since the 1970s. Since population growth has been the main source of rice demand growth, this trend helped to keep rice prices in check for a time. But, from the mid-1990s until the mid-2000s, the gap grew steadily larger, creating a significant imbalance between supply and demand. This trend was evident for Asia as a whole, but also separately for East Asia, Southeast Asia, and South Asia. Stagnation in area harvested further contributed to the problem, and prices eventually began to rise. Indeed, world market rice prices rose steadily by a cumulative 67% between April 2001 and September 2007, even before the world price crisis.

There are several possible reasons for the slowdown in rice yield growth and production: displacement of cereals on better lands by more profitable crops such as groundnuts, diminishing returns to modern varieties when irrigation and fertilizer use were already high, and the fact that cereal prices fell relative to input costs, making additional intensification less profitable. There is also concern that breeders have largely exploited the yield potential of major Green Revolution crops.

Environmental problems that have arisen in a few areas include excessive use of fertilizers and pesticides that pollute waterways and kill beneficial insects and other wildlife, irrigation practices that lead to salt buildup and eventual abandonment of some farming lands, increasing water scarcities in major river basins, and retreating groundwater levels in areas where more water is being pumped for irrigation than can be replenished.

Some of these outcomes were inevitable as millions of largely illiterate farmers began to use modern inputs for the first time, but the problem was exacerbated by inadequate extension and training, an absence of effective regulation of water use and quality, and input pricing and subsidy policies that made modern inputs too cheap and encouraged their excessive use.

The challenges that these technology, policy, and environmental issues create for future rice production are described in detail in the next chapter.

International rice markets

The volume of international rice trade increased almost fourfold from 7.5 million t in the 1960s to an average of 28.5 million t from 2000 to 2009 (Fig. 3.6) and reached 29.5 million t in 2011. But, rice trade was still only 6.9% of total production (up from 4.4% in the 1960s). By contrast, international trade in the 2000s of maize (81.3 million t, 11.8% of production) and wheat (114.2 million t, 18.8% of production) is much larger, tending to make these markets more stable. With 90% of the world's rice produced in Asia, most rice tends to be eaten where it is produced and does not enter international markets. Maize and wheat, on the other hand, are produced worldwide but international trade is proportionately larger as demand has expanded, especially in Asian countries, due to changes in diets and increased feed use.

Only around 7% of all rice production is exported from its country of origin.

International rice trade is also characterized by a relatively small number of exporting countries interacting with a large number of importing countries. Moreover, the concentration of exports has increased over time. In the 1960s, the top five exporters had 69% of the world market; in the first decade of the 2000s, this share rose to 81%. Since the 1980s, Thailand has consistently been the world's largest exporter of rice, with its volume of rice increasing sixfold from 1.4 million t per year in the 1960s to 8.4 million t per year in the early 2000s, and its market share increasing from 19.0% to 29.5% over the same period (Fig. 3.7). Vietnam, the second-largest rice-exporting country (4.4 million t per year, 15.5% market share in the early 2000s), became a major exporter only in the 1990s, following marketing and trade reforms. Likewise, India, the third-largest rice exporter (4.2 million t per year, 14.6% market share in the early 2000s),

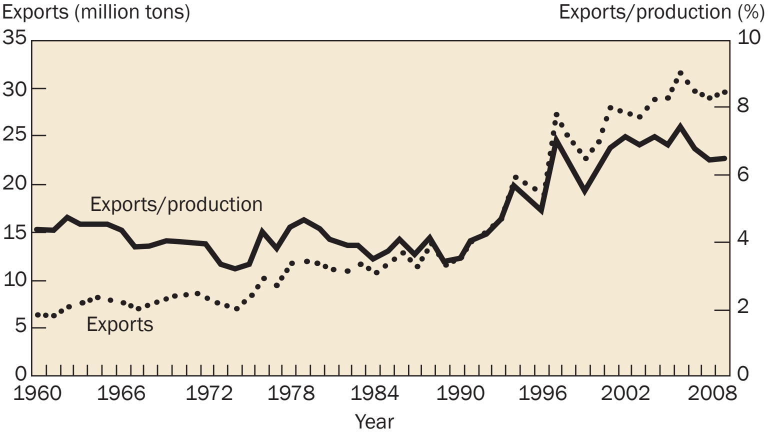


Fig. 3.6. Rice exports (million tons) and share of production (%), 1960 to 2009. Source: USDA data.

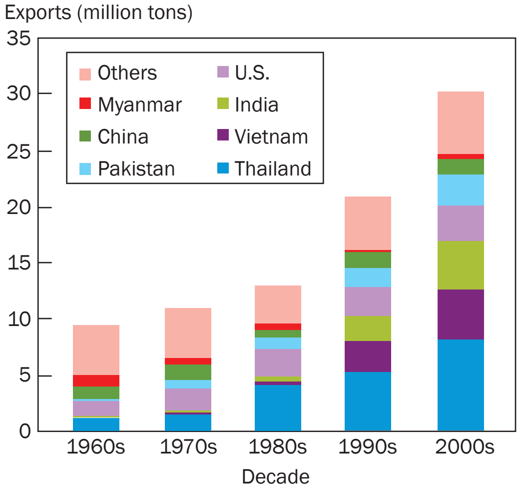


Fig. 3.7. Rice exports (million tons) by country, 1960 to 2009. Source: USDA data.

emerged as a major exporter only after a major economic liberalization in the early 1990s. Although the United States more than doubled its rice production over the same period, its share in world trade fell by nearly half, from 19.4% to 11.4%. Myanmar (Burma), the third-largest exporter in the 1960s, also more than doubled its production, but its export volumes fell by two-thirds.

The high concentration of exports in only a few countries does not necessarily indicate a lack of competitiveness in markets; there are many exporting firms. Nonetheless, it does raise the possibility of disruptions and reductions in supply by major exporting countries (including reduced exports as the result of deliberate government policy), leading to higher world prices that adversely affect net consumers in importing countries, but improve the welfare of rice net sellers. Conversely, exceptional production or subsidies on production in exporting countries could depress world prices to the benefit of rice consumers but adversely affect rice producers in importing countries. Perhaps most important, though, the high concentration of exports increases the probability that a production shock or a change in trade policy in one or more of these countries could have a major impact on world market flows and prices, such as occurred in the price crisis of 2007-08.

In contrast to rice exports, imports of rice are widely dispersed across countries (Table 3.1). Imports by the five leading countries in the first decade of the 2000s (Philippines, Nigeria, Iran, Indonesia, and the European Union) were only 27% of the world total; the share of the top 10 countries was only 44%. However, because of market segmentation, some of the larger rice importers have had major impacts on world rice prices. Large purchases by state trade in the Philippines in 2007 and 2009 are examples in which an individual importer contributed greatly to world price destabilization. Indonesia's rice imports accounted for 10% and 15% of world trade in the 1960s and 1970s, respectively (and 7.4% and 9.2% of national net availability). During these years, Indonesia's imports had major impacts on world rice markets.

Key actors in the international rice economy include private traders and millers; state trading agencies and government ministries; and producer, milling, and trade associations. The level of price competitiveness among the differentiated rice flows varies considerably, based on established trading relationships, potential export suppliers, and information costs associated with price discovery, technical and tariff trade barriers, and other aspects of trade policy.

Looking forward, a number of other countries are expecting to begin or increase rice exports, such as Argentina, Brazil, Cambodia, and Myanmar; these will help buffer future trade against some of the causes of instability described above. However, world prices are likely to remain unstable, as production shocks occur in the major exporting countries or trade policy changes in these countries. Variance in production due to climate change could also add to the instability in prices.

Future growth in trade may be slowed by pessimism regarding the reliability of international markets, however, particularly in the wake of the international price crisis of 2007-08. Adoption of some or all of the proposals to reduce international price fluctuations such as regulating trading in futures markets and establishing (physical and virtual) international stocks, could

Table 3.1. Rice imports by country, 1960-2009.

Country	Imports (million tons)					Imports/availability[a] (%)				
	1960s	1970s	1980s	1990s	2000s	1960s	1970s	1980s	1990s	2000s
Philippines	0.16	0.15	0.17	0.62	1.65	6.0	3.9	3.2	9.0	15.5
Nigeria	0.00	0.20	0.53	0.59	1.63	0.5	38.2	39.3	24.6	38.5
Iran	0.01	0.31	0.72	1.16	1.27	2.5	29.3	42.6	45.1	44.1
Indonesia	0.72	1.37	0.31	1.79	1.24	7.4	9.2	1.3	5.7	3.6
EU-27[b]	0.62	0.71	0.72	0.70	1.22	58.1	59.7	52.2	38.4	45.7
Saudi Arabia	0.13	0.24	0.50	0.76	1.20	98.7	99.3	99.6	100.0	100.0
Iraq	0.03	0.21	0.41	0.53	0.95	19.9	66.3	81.0	77.8	88.6
Bangladesh	0.32	0.32	0.31	0.70	0.84	3.4	2.9	2.2	4.0	3.3
Côte d'Ivoire	0.05	0.12	0.27	0.37	0.80	25.8	31.9	45.8	45.3	62.8
Senegal	0.15	0.21	0.33	0.49	0.77	70.4	77.4	80.7	81.7	84.6
South Africa	0.07	0.09	0.21	0.48	0.76	100.0	100.0	100.0	100.0	100.0
Malaysia	0.38	0.25	0.33	0.50	0.74	34.5	18.2	23.7	29.6	35.7
Brazil	0.00	0.11	0.31	0.81	0.70	0.0	2.4	5.2	11.6	8.9
Japan	0.36	0.03	0.04	0.54	0.67	3.5	0.3	0.5	6.7	9.2
Cuba	0.20	0.20	0.15	0.33	0.57	68.8	45.5	32.2	55.0	63.9
Mexico	0.01	0.03	0.06	0.30	0.57	2.5	8.9	15.5	58.2	76.7
U.S.	0.01	0.01	0.08	0.26	0.56	1.2	1.2	5.2	10.6	18.5
China	0.00	0.04	0.31	0.52	0.47	0.0	0.0	0.3	0.5	0.4
Others	3.69	4.34	4.93	6.58	9.83	5.4	4.9	4.3	4.5	5.5
Total	6.89	8.94	10.69	18.02	26.43	4.4	4.1	3.8	5.1	6.6

[a]Availability is estimated as production less 10% for losses, plus gross imports. No adjustment is made for changes in stocks.
[b]Data for the 1960s through the 1990s (1960-98) are for the EU-15.
Source: USDA data.

Cambodia is one of a number of countries expecting to begin or increase rice exports.

change this scenario. If international markets are perceived to have been made more reliable, countries may be encouraged to increase reliance on trade (or at least to avoid retracting from the world market). WTO reforms could also lead to substantial (up to 14% under the US proposal) increases in trade volumes of medium-grain rice (though only small increases in trade volumes of long-grain rice, an imperfect substitute for medium-grain rice).

Ultimately, poor rice consumers and net rice-deficit farmers in rice-importing countries generally benefit from trade because of lower prices and greater availability. For these hundreds of millions of households, as well as for rice producers in exporting countries, continued expansion of world trade in rice would enhance welfare and promote food security.

Domestic rice markets

The price of rice

The price of rice is a key variable for farmers, consumers, and governments in most of Asia, and in many other parts of the world. It has obvious economic importance given the widespread poverty in the region, but in many cases it is equally important politically. Although the world market price of rice has declined over time, domestic prices are more relevant for farmers and consumers.

Average farm-level prices (converted to nominal US$ per ton of paddy) in 2003 to 2007 for all 82 countries for which data are available from FAO showed large differences. Some countries—Brunei, Japan, Republic of Korea, and Turkmenistan—have extraordinarily high domestic prices that are at least 7 times the median price of US$239 per ton.

Both GDP per capita and trade status (defined as the share of net imports in domestic consumption for net importers and the share of net exports in production for net exporters, the latter as a negative number) are correlated with the level of prices. Higher GDP per capita and higher proportions of imports in domestic consumption are both associated with higher domestic prices.

Trends over time

The most striking aspects of world rice prices since 1960 are the price spike in the early 1970s and a declining trend during 1981-2001, as shown in Figure 3.8 (a linear regression of real price versus time has a slightly positive slope between 1950 and 1981). Domestic prices also typically declined, although by less than

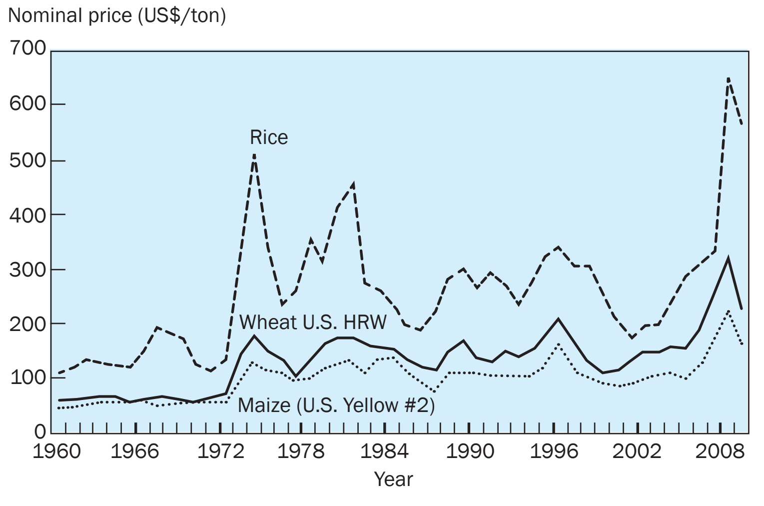


Fig. 3.8. Nominal prices of cereals (US$/ton), 1960 to 2009. The rice price is indica rice 5% brokens, 1960-2005, spliced with percentage changes in the price of Thai A1 Super (f.o.b. Bangkok) for 2006-09. Data for 2009 are the average of January-June prices. Source: Calculated from IMF and FAO commodity price data.

the decline in world price. The effect of the international price crisis of 2007-08 is also shown in Figure 3.8, affecting rice far more than other major cereals.

Assistance to producers

Governments sometimes provide forms of assistance to farmers, measured as the "nominal rate of assistance" (NRA). The NRA data for rice provide some broad insights into governments' use of trade interventions. First, the NRA estimates conform broadly with the "development paradox," which notes the tendency for poor countries to tax their agricultural sector while wealthy countries subsidize theirs.

In general, governments have intervened to raise domestic rice prices above world prices when world prices are low and vice versa when world prices are high. This is broad evidence that governments have tended to use border price interventions in an effort to shield domestic rice markets from international market price volatility

The NRA to output is affected by at least three key variables: domestic price, world price, and the exchange rate used to convert the world price into local currency terms. In most cases, changes in the NRA are being driven more by events external to the domestic rice sector (i.e., either the exchange rate or the world rice price) than by changes in the domestic price itself. In general, governments use trade interventions to stabilize domestic rice markets vis-à-vis international rice markets.

Domestic policy instruments

Free trade or price stabilization?

Rice price stabilization has been an objective of many Asian developing countries over the years, and most have been successful. The price stabilization objective goes back in many cases before World War II. The Philippines began to implement price stabilization policies as soon as it achieved Commonwealth status under the U.S. in 1935, and Indonesia practiced rice price stabilization while still a Dutch colony.

Completely free trade with zero trade taxes has been relatively rare, although Thailand practiced very minimal government intervention for more than a decade starting in 1986. The main benefits of free trade are short-term efficiency gains, more resources for other government expenditures such as public goods, and fewer opportunities for corruption. However, there have been substantial costs to many of the price stabilization programs, in terms of both foregone opportunities for investment in public goods and corruption.

The rice price dilemma: welfare effects of domestic price policies

In order to understand the importance of higher rice prices for welfare, poverty, and food security, it is first important to distinguish between net rice producers and net rice consumers. A net rice producer is someone for whom total sales of rice to the market exceed total purchases of rice from the market, whereas, for a net rice consumer,

Retail rice market in the Philippines.

the reverse is true. Net rice consumers will generally be hurt by higher rice prices, while net rice producers will benefit. It is also true that whether a given household is a net rice producer or consumer depends on market prices. Higher prices will discourage consumption, encourage more production, and possibly convert some households from net consumers to net producers. Lower prices could do the opposite.

Higher rice prices will substantially hurt poor net rice consumers because rice is typically a larger share of expenditures for the poor. In such circumstances, rice price increases can have important effects on effective purchasing power, even if they do not directly affect nominal income per se. Farmers who are net food producers are likely to benefit from higher prices, which, other things being equal, will tend to increase their incomes. Since many farmers are poor, higher prices could help to alleviate poverty and improve food security.

Another potentially important effect of rice prices occurs in labor markets. Higher rice prices, by stimulating the demand for unskilled labor in rural areas, can result in a long-run increase in rural wages, thereby benefiting wage labor households in addition to self-employed farmers.

The net effect of higher food prices on welfare and poverty at the country level will thus depend on socioeconomic structures and the national net trade position (as well as labor market outcomes). Positive impacts of higher prices are much more likely in exporting nations, since a greater percentage of households are probably net producers.

But, among rice importers, the impacts on welfare and poverty of higher prices are more uniformly negative. In addition to the short-term adverse effects of high rice prices on poverty, high rice prices also raise concerns about long-term economic growth in countries where rice is the staple food. Although there is no solid evidence in this regard, high rice prices (in countries that choose to adopt such a policy) might end up reducing their international economic competitiveness by raising the price of the wage good, thus making wage rates less competitive and discouraging investment in labor-intensive employment that promotes long-term economic growth. High rice prices may also impede diversification into labor-intensive higher-value crops.

Price policy options for the future

In general, it seems hard to justify sustained departures of average domestic prices from world market prices on either efficiency or equity grounds. Sustained deviations from the world price can lead to large misallocations of scarce resources that increase with the square of the deviation from the world price, meaning that losses increase exponentially as the deviation gets larger. In terms of dynamic efficiency, attempts to consistently enforce a domestic price higher than the world price may lock farmers into rice and out of more dynamic high-value crops, and they may lose the ability to learn and adjust dynamically to changing market conditions, a skill that will be of increasing importance for farmer-entrepreneurs in the future. Consistent price differentials also encourage corruption.

The world rice crisis of 2008 will undoubtedly encourage many governments to strive for self-sufficiency using higher rice prices. But, given the welfare costs to the poor of high prices, investments in agricultural research and infrastructure so as to improve agricultural productivity and markets would seem to be a far superior way to achieve self-sufficiency.

One policy option would be to offset high producer support prices with consumer subsidies targeted to the poor, but this faces at least two major problems. First, it is very difficult administratively to target the poor. Second, raising producer prices above market levels and lowering consumer prices below market levels incurs large fiscal costs (especially in poor countries) that crowd out spending on public goods, thus impairing the long-run growth of the economy.

The case for stabilizing prices around the long-term trend of world prices seems stronger, although it is still very controversial among economists and there is no widespread agreement on this issue. The central question is how to absorb the instability in world supply and demand that leads to changing world market prices. Trade-based domestic price stabilization policies, if successful, shield domestic producers and consumers from that instability, but at the cost of affecting world market prices and making them more unstable. Trade-based stabilization policies can lead to corruption as well, especially when the government plays a major role in conducting trade. Holding large stocks can provide a buffer, but the carrying costs of stocks can be very large, even without taking into account the quality deterioration of grain in storage.

Safety net programs are a possible solution, but they place large administrative demands on governments, can have problems achieving wide coverage, and may need to be redesigned to serve transitory instead of chronic needs.

Politically, it is hard to imagine that a poor country could tolerate the wide swings in income distribution that would result if domestic prices followed world prices on a month-to-month basis. As a result, there is no realistic chance that governments will simply abandon stable food price policies any time soon. Given this reality, it makes sense to explore ways to make price stabilization more cost-effective. This is especially important because the benefits of stabilization decline as economies grow and the importance of rice to the economy declines.

Changes in demography and the rice economy

As economies develop, the rural sector undergoes major changes. The younger members of rural communities, particularly men, leave in search of jobs in urban areas or overseas and send remittances back to their rural homes. These rural economies are becoming older and more feminized (Box 3.1), and this trend is likely to continue. In some countries, especially in Africa, HIV/AIDS is also exacting a toll on the rural labor force. As a consequence, labor availability is declining and wages are increasing in many rice-growing areas. Farm employment is less attractive, and labor is harder to find at peak periods for key operations such as transplanting, weeding, and harvesting. With rising wages and labor shortages, mechanization is becoming more common for both land preparation and harvesting, especially in irrigated areas. Also, farmers are shifting from hand weeding to the use of herbicides, and from transplanting to direct seeding. By the late 1990s, an estimated one-fifth of the rice area in Asia was direct seeded, and this proportion is expected to rise.

Box 3.1. Gender issues

As in agriculture in general, gender issues in rice production are complex and site-specific. Women participate in various degrees in the cultivation of rice and often have specific tasks such as transplanting, weeding, or harvesting. In Central and West Africa, women constitute the majority of upland rice farmers.

Increasing water scarcity and technological response options affect women in different ways, depending on whether they are paid or unpaid laborers. For example, a shift from transplanting to direct seeding may specifically affect the livelihoods of women since transplanting is their traditional task in most Asian and African societies. If they are unpaid laborers, the shift will remove the drudgery and back-breaking burden of transplanting. But, if they are paid laborers, it will deprive them of a source of income. The same reasoning holds for weeding. Water scarcity and response options such as alternate wetting and drying and aerobic rice may promote weed growth and increase the need for manual weeding. In Africa, women's preference for using water to control weeds arises from their being unpaid laborers.

Thus, it is important to include a gender perspective in the development of alternative response options or technologies of rice production. The same holds true for the development and deployment of new rice varieties. Women should be specifically included in activities such as participatory varietal selection, as they often have different perceptions of relevant crop traits, for example, grain quality and feed quality of the straw (often, women tend the livestock).

Chapter 4

The future of rice

Production challenges

Global and regional rice demand

Global rice consumption remains strong, driven by both population and economic growth in many Asian and African countries. In Asia, which accounts for 87% of global rice consumption, total rice demand continues to rise despite declining per capita consumption in many high- and middle-income countries. Among high-income Asian countries such as Hong Kong, Japan, Republic of Korea, and Taiwan, a significant decline in per capita consumption has been witnessed in the last four decades. Similar patterns have started to emerge in middle-income countries, such as China, Malaysia, and Thailand in the last two decades as their people have been consuming more meat and vegetables and less cereals. But, in many other developing Asian nations, including India, Indonesia, and Vietnam, per capita consumption in recent years has started to decline at a rather slow pace with rising income. And, in many other middle- to low-income Asian countries, including Bangladesh, Cambodia, Laos, Myanmar, and the Philippines, rice consumption per capita continues to rise over time.

Despite this variation in the Asian per capita rice consumption trend, it is widely expected that per capita consumption in a majority of Asian countries will start or continue to decline in the future with rising income as people diversify their diets. Indeed, on a global basis, total rice consumption per capita has leveled out and the trend since 1990 has been slightly downward (Fig. 4.1).

But, it is naïve to assume that all Asian countries will behave like Japan, Taiwan, and Republic of Korea in the future with rising disposable income. For a country like India with a large number of ovo-vegetarians, it is unrealistic to assume that rice consumption will follow the patterns of the Korean, Chinese, and Japanese populations with rising standards of living. Even other developing Asian countries such as Bangladesh, the Philippines, and Vietnam are likely to adopt consumption patterns different from what has been witnessed in the past. The key question is how the consumption patterns of each country will change as income rises and a rapid increase in urbanization influences food habits.

Outside Asia, where rice is not a staple yet, per capita consumption continues to grow fast. This is particularly true for most countries in sub-Saharan Africa, where high population growth with changing consumer preferences is causing rapid expansion in rice consumption. In countries such as Kenya, Niger, Nigeria, and Tanzania, people are moving away from maize and cassava to rice as their income rises. Similar strong consumption growth has been evident among Middle Eastern countries with almost doubling of rice consumption in

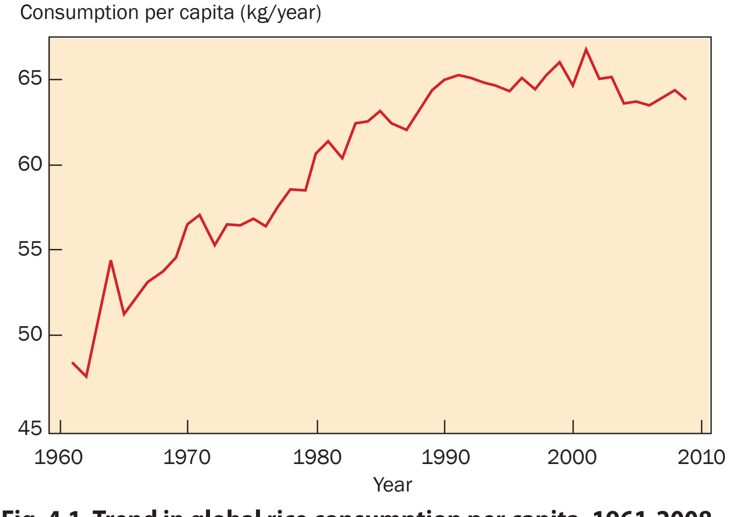


Fig. 4.1. Trend in global rice consumption per capita, 1961-2008.

the last two decades and even more rapid increases in some Pacific island countries. Along with strong population growth, the rapid rise in per capita consumption also contributed to such rapid growth in rice demand. Rice consumption also continues to grow in Latin America and the Caribbean region with a 40% increase in the last two decades as a combination of both population growth and the steady rise in per capita consumption. Even in developed countries/regions such as the United States and the European Union, per capita consumption continues to grow, partly because of switching from protein to more fibers in the diet and also immigration from Asian countries.

Using the population projections from the United Nations and income projections from the Food and Agricultural Policy Research Institute (FAPRI), global rice demand is estimated to rise from 439 million t (milled rice) in 2010 to 496 million t in 2020 and further increase to 555 million t in 2035 (Fig. 4.2). This is an overall increase of 26% in the next 25 years, but the rate of growth will decline from 13% for the first 10 years to 12% in the next 15 years as population growth drops and people diversify from rice to other foods. Among the various rice-consuming regions, Asian rice consumption is projected to account for 67% of the total increase, rising from 388 million t in 2010 to 465 million t in 2035 despite a continuing decline in per capita consumption in China and India. In addition, 30 million t more rice will be needed by Africa, an increase of 130% from 2010 rice consumption. In the Americas, total rice consumption is projected to rise by 33% over the next 25 years.

With further area expansion likely to be slow, global rice yields must rise faster than in the recent past if world market prices are to be stabilized at affordable levels for the billions of consumers. Globally, farmers need to produce at least 8–10 million t more paddy rice each year—an annual increase of 1.2–1.5% over the coming decade, equivalent to an average yield increase of 0.6 t/ha during the next decade. Over the longer run, global rice consumption growth is expected to slow down but yields will have to continue to grow faster than at present because of pressure on rice lands in the developing world from urbanization, climate change, and competition from other, high-value agriculture. Rice yield growth of 1.0–1.2% annually beyond 2020 will be needed to feed the still-growing world and keep prices affordable.

Feeding the billions

Reliance on imports or additional rice area to feed the poor is bound to fail, given incessantly growing populations in the developing world together with a tight global rice supply-demand situation and a general decline in rice lands in Asia, the major rice-producing region. Thus, there

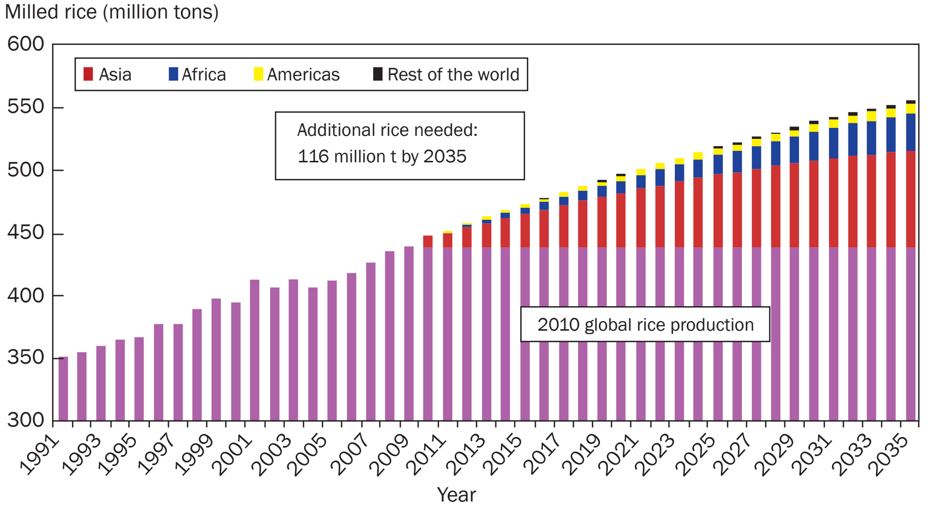


Fig. 4.2. Global rice production increases needed to meet demand by 2035.

is a compelling need to develop new rice technologies worldwide that will maintain or increase productivity sustainably on existing and newly developed rice land, and that are climate-resilient.

The constraints to increasing rice production are largely of a nature that spans borders. CGIAR centers, national systems, advanced research institutes, nongovernment organizations, and the private sector have been making uneven and fragmented progress in overcoming these constraints. Fragmentation also describes the components—research, production, and marketing—of the rice sector itself and results in unfocused research, production losses, and market distortions. Little wonder that coherent and comprehensive policies to manage the sector are frequently absent at all levels. Global problems need global solutions, but they must be flexible enough to meet local needs.

Poverty alleviation

Despite declining poverty rates in the past few decades in much of Asia, the absolute number of poor people has declined little, especially in South Asia and sub-Saharan Africa. Poverty still exists in rural areas in both the irrigated and the rainfed rice environments. Asia is rapidly urbanizing and more people will shift from being net rice producers to net rice consumers. Also, the total number of urban poor people is expected to increase. A major challenge will be not only to produce more rice, but to keep its price affordable to improve the well-being of poor people (Box 4.1). Because a low rice price depresses the profitability of rice farming, particularly for small-scale producers, the simultaneous challenge is to decrease the cost of rice production (per kilogram) to boost the profitability of rice farming. Support schemes for small farmers can also help in coping with low prices.

Box 4.1. Rice's contribution to poverty alleviation

Access to irrigation, fertilizer, and the high-yielding varieties of the Green Revolution increased productivity and profits and contributed to food security and poverty reduction among farmers with irrigated land. The growth in rice production outstripped the growth in population, thus lowering prices, which reduced the daily expenses for food of poor consumers such as the rural landless, urban laborers, fishers, and farmers of crops other than rice. The contribution of lower prices is not trivial, because many of these people spend 20–40% of their income on rice alone. Furthermore, low rice prices make labor costs in the industrial and service sectors more competitive, fueling job growth and catalyzing economic development.

But, low rice prices can hurt some farmers, especially those who have not adopted modern varieties and thus have not benefited from productivity increases. Indeed, despite the successes of the Green Revolution, poverty or hunger still occur among considerable numbers of rice farmers within irrigated areas, because, even in highly productive systems, it is difficult to escape poverty with only a small plot of land.

Poverty is still widespread among farmers in rainfed areas, especially in the remote uplands of Laos, Nepal, Vietnam, and northeastern India, and in sub-Saharan Africa. For many poor farming households, however, increasing rice productivity is often the first step out of poverty as it provides food security and frees up land and labor resources. With increased rice yields, part of the farm land can be taken out of rice production and converted into more profitable cash crops. Freed-up labor can be invested in off-farm employment. Increased income can be used to invest in the education of children, which is a potential pathway out of farming and poverty.

Climate change

Climate change is expected to raise carbon dioxide levels and temperatures and possibly also increase the frequency of extreme climatic events in some areas such as storms, droughts, and heavy rainfall in monsoon climates that will increase the incidence of flooding. Rising sea levels are expected to increase flood risk and salinity intrusion in rice-growing environments in delta areas (Fig. 4.3).

Simulations for the major rice-growing regions of Asia find that yield decreases 7–10% for every 1 ºC rise in temperature above current mean temperature at existing atmospheric carbon dioxide concentration. Elevated carbon dioxide increases yield and water productivity by increasing dry matter production, the number of panicles, and grain-filling percentage. However, elevated carbon dioxide also increases spikelet susceptibility to high-temperature induced sterility. Overall, the beneficial effect of elevated carbon dioxide on the yield and water productivity of rice disappears under high temperatures. Recently, yield reduction in rice has been correlated with increased nighttime temperatures: grain yield declines by 10% for each 1 °C increase in growing-season minimum temperature in the dry season in irrigated tropical rice.

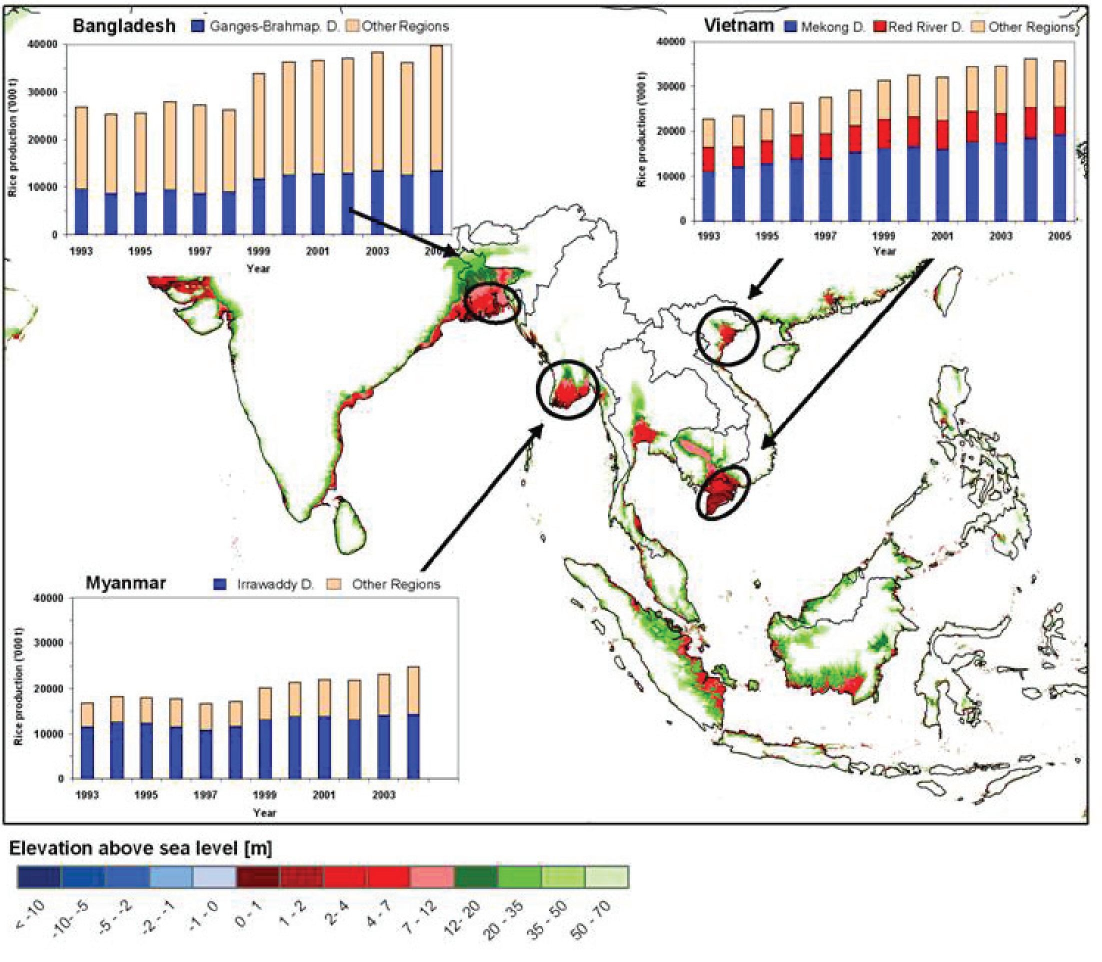


Fig. 4.3. Low-elevation areas in Asia and rice production data from deltas in Vietnam, Myanmar, and Bangladesh. Map drawn by K. Sumfleth.

Intraspecific variations in yield response to changes in carbon dioxide concentrations in rice could be exploited to maximize the beneficial effect of increased carbon dioxide. Similarly, genotypic variation in sensitivity to warm nighttime temperatures and high daytime temperatures opens up the possibility of developing rice varieties that are less sensitive to higher temperatures. Selection of rice varieties that flower early in the morning can be an effective way to avoid high daytime temperatures and reduce spikelet sterility.

Challenges for future rice cropping systems

To meet the dual challenge of producing enough food and alleviating poverty, more rice needs to be produced at a low unit cost so that producers can be ensured of reasonable profits, poor consumers can have the benefit of low prices, and the environment and ecosystem services can be safeguarded. All this needs to be achieved as urbanization, wages, and the feminization of the rural work force are increasing and the supply of labor is decreasing. At the same time, the productive capacity of rice environments is being threatened by increasing water scarcity in irrigated systems and by droughts, salinity, uncontrolled flooding, and climate change.

Labor scarcity

The increasing labor scarcity and high cost of agricultural labor drive the introduction of mechanization. In the Indo-Gangetic Plains, interest in direct seeding of rice is increasing and minimum and zero-till equipment is being tested. The challenge will be to develop appropriate equipment for rice-based cropping systems and accompanying crop management practices. An especially challenging issue will be the control of volunteer and weedy rice that may accompany the transition from transplanting to direct seeding. In various parts of South and Southeast Asia, interest is developing in mechanized transplanting—a system that has been in use in Japan, Republic of Korea, and Taiwan for decades but had so far not found a foothold in other Asian countries. The special challenge for mechanized transplanting will be putting in place the required "support" functions such as the delivery of seedlings and appropriate management practices.

Overall, a successful transition from manual operations to mechanization will need to be supported by appropriate business development in terms of supply and maintenance of equipment, business credit schemes, and services provision (contracting of field operations by specialized companies). The private sector will play an increasingly important role in the rural landscape.

Increasing labor scarcity may also drive a process of increasing landholdings. The scarcity of labor in rural villages is prompting local governments to develop schemes based on communal operations such as village farming in China and the “small farmer–large farm” concept in Vietnam. In parts of Malaysia where rural labor is costly, many farm operations are outsourced to third parties who gain the benefits of scale by being able to cover large areas with mechanized equipment (e.g., land preparation, crop establishment, application of agrochemicals, harvesting). The challenge with these schemes is to find socially acceptable models for scaling-up landholdings or the size of operations in order to bring benefits to everybody involved—farmers and service providers.

Irrigated environments

Worldwide, water for agriculture is increasingly scarce. Although there is no systematic definition, inventory, or quantification of water scarcity in rice-growing areas, evidence suggests that water scarcity is encroaching on irrigated lowlands. It is estimated that, by 2025, 15–20 million ha of irrigated rice will suffer some degree of water scarcity. Even in areas generally considered water abundant, several case studies mention local hotspots of water scarcity. This water scarcity is expected to further shift rice production to more water-abundant delta areas, to lead to crop diversification, and to result in more aerobic soil conditions in rice fields in water-short areas.

Indications are that soil-borne pests and diseases (such as nematodes, root aphids, and fungi) and micronutrient disorders occur more in nonflooded rice systems than in flooded rice systems. Rice that is not permanently flooded tends to have more weed growth and a broader weed spectrum than rice that is flooded, likely leading to more frequent use of herbicides. With less water, the numbers and types of pests and predators may change as well as predator-pest relationships. Possible shifts in the use of pesticides by farmers in response to these changes, and what this means for the environment, are as yet unknown. Less ammonia volatilization and methane emissions are expected under nonflooded conditions, but also higher nitrous oxide emissions and more leaching of nitrate.

The net greenhouse gas impact is also unknown. Although direct evidence from converted paddy fields is still missing, growing rice under increasingly aerobic conditions will likely reduce soil carbon content and release carbon dioxide into the atmosphere. This change in soil organic matter will be accompanied by changes in the microbial community, shifting from predominantly anaerobic organisms to aerobic organisms. It is not clear how these changes will affect soil fertility, if at all. The transformation of rice fields to upland crops will likewise have consequences for sustainability and the environment.

Rainfed environments

A major challenge is to minimize the negative environmental consequences of intensification in rainfed environments. Intensification through increased fertilizer use, cropping intensity, and changes in methods of crop establishment will affect soil and environmental processes. Increased productivity, based initially on better varieties and subsequently on the use of increasing amounts of inorganic fertilizer and less organic fertilizer, changes nutrient balances and increases the mining of soil nutrients. Reports of rapidly emerging severe nutrient deficiencies after intensification testify to the relative fragility of rainfed systems because of frequently low natural soil fertility and low buffering capacity.

Valuing ecosystem services of rice environments

There is growing recognition of the need for a better understanding of the ecosystem services of the rice environment. Although some methodologies have been developed to measure and estimate different services of agricultural systems, quantifying and valuing the positive and negative externalities are still major challenges. Many countries lack relevant data at the appropriate geographic level.

Postharvest operations

The postharvest sectors are still characterized by high losses. In Africa and Southeast Asia, losses generally range from 10% to 30%, caused by loss in weight through spillage, losses to pests, low milling yields, inappropriate postharvest management practices, delays in the postharvest chain, outdated postharvest equipment and infrastructure, and low operators' skills that lead to losses in quality along the chain and lower the market value of milled rice by 10–30% or more. Farmers are also often forced to sell immediately after harvest at a low price and so lose out on maximizing their returns.

Each year, hundreds of millions of tons of rice straw and husks are produced. These are commonly disposed of by burning, thus emitting greenhouse gases. Innovative uses, such as bioenergy and biochar, of husks and straw will provide local business opportunities and extra income sources for farmers, and simultaneously mitigate, instead of accelerate, climate change. Another mitigating option is improving the digestibility of the straw so that it can be used more widely as livestock feed.

Response options

Most of the increase in rice production to meet food security and alleviate poverty has to come from higher yields on existing cropland (irrigated and rainfed) to avoid environmental degradation, destruction of natural ecosystems, and loss of biodiversity. Most of the rice surplus will continue to come from irrigated environments. In some major rice-producing countries, such as Bangladesh, the Philippines, and Thailand, there is still a large gap between actual and potential yields, and efforts need to be directed at crop management technologies to narrow the yield gap. In other countries such as China, Japan, and the Republic of Korea, the yield gap is closing, and further yield increases can come only from increased genetic yield potential.

Increased yields and total production mean that, with current management practices, more water will be needed to meet increased transpiration requirements. With increasing water shortage, this means that the water productivity of rice needs to increase.

Improved varieties

Yield potential

The key attributes of the high-yielding varieties of the Green Revolution were semidwarf stature (which increased harvest index and lodging resistance) and photoperiod insensitivity. Indications are that these factors cannot easily be further exploited to significantly increase the yield potential of inbred varieties under fully irrigated conditions. For example, since the introduction of IR8 in the 1960s, the yield potential of semidwarf tropical indica inbred varieties has stagnated at about 10 t/ha. New molecular breeding approaches are trying to overcome this apparent barrier.

Yield potential improvement has recently come only from the development of hybrid rice, which has increased yield potential by 5–15% over inbred varieties in the same environment. China's "super" rice breeding program has developed several hybrid varieties that yield 12 or more tons

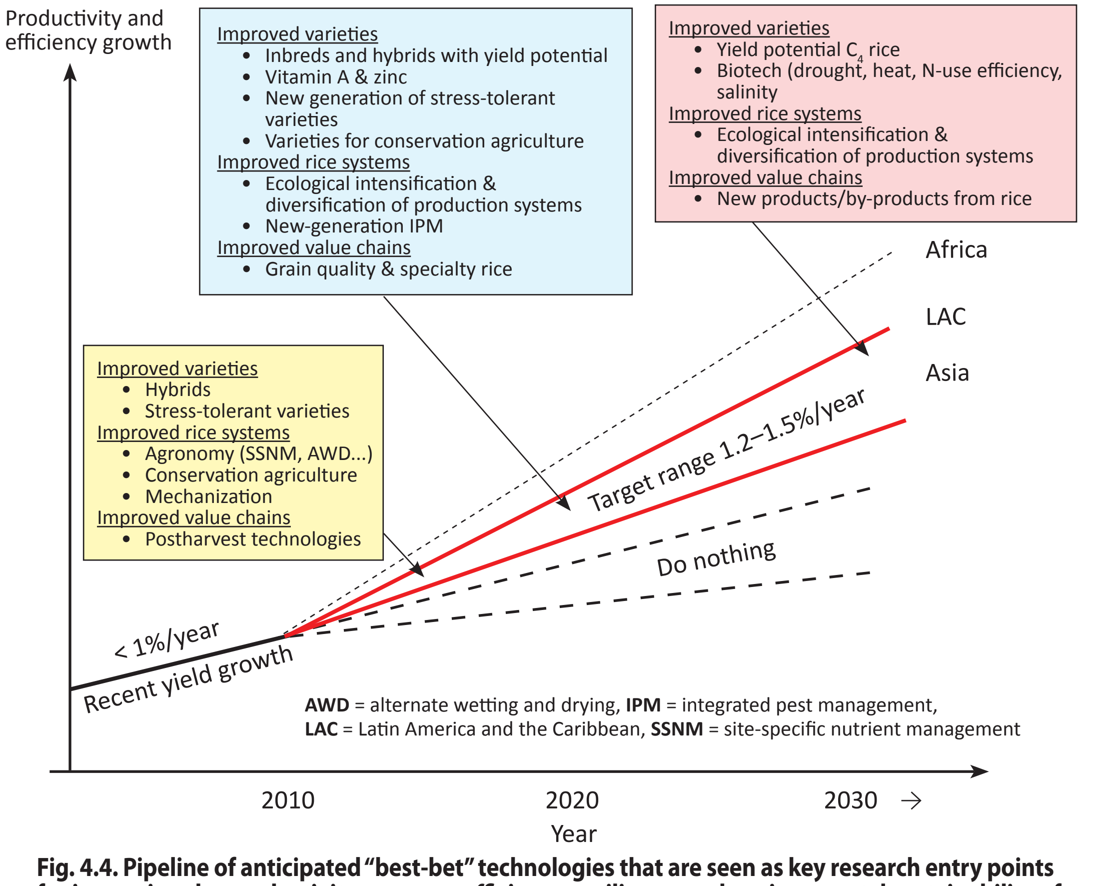


Fig. 4.4. Pipeline of anticipated "best-bet" technologies that are seen as key research entry points for increasing the productivity, resource efficiency, resilience, and environmental sustainability of rice-based systems.

per hectare in on-farm demonstration fields, which is 8–15% higher than the hybrid check varieties. The first rice hybrids were released in China in 1974 and, with substantial government support, quickly spread among farmers and, by 2007, covered almost 16 million ha, 55% of China's rice area. Adoption outside China has accelerated in recent years, particularly in India and Bangladesh, but also in the U.S. and Brazil. The hybrid rice seed market is also growing in some Southeast Asian countries, particularly Indonesia, Vietnam, and the Philippines. Hybrid rice is now grown on more than 21 million ha, or 13%, of the world's rice land.

Current research is aimed at improving the parental lines of hybrid varieties, for developing hybrids with improved resistance to diseases such as bacterial leaf blight (the principal disease of hybrid rice), and better understanding heterosis, through which it is hoped to increase tropical hybrid yields up to 20% above those of the best inbred varieties grown by farmers. Other research is aimed at improving grain quality and seed production yields.

Transforming the C_3 rice plant into a C_4 plant through genetic engineering could be a long-term approach for increasing rice yield potential, and is currently the subject of a major research endeavor by IRRI and partners. Projected potential yield gains from C_4 rice are outstanding: a 30–50% improvement in irrigated and rainfed lowland environments.

Traditional breeding programs for irrigated environments have carried out activities under conditions of continuously ponded water. With increasing water scarcity in irrigated systems, breeding programs should include selection under conditions of labor- and water-saving technologies, such as direct seeding, alternate wetting and drying, or aerobic cultivation. Some success has been recorded with the development of high-yielding aerobic rice varieties in northern China.

Grain quality

As the rate of yield growth has slowed, many rice farmers are looking to improved quality of their crop as a way to improve its value. Traits of grain quality—the combination of physical and chemical features required by different consumers—strongly influence the adoption of new varieties and retention of lower yielding traditional varieties. A major constraint to combining high yield with desired quality is the absence of appropriate tools to evaluate eating quality. Innovative ways to use the grains that break during milling would add value to milled rice. The first steps are to (i) create a phenotyping platform and tools for evaluating quality and specialty traits of grains and rice products, which should prioritize specialty rice with good eating quality for high-value markets; (ii) develop processing techniques that add value to low-grade rice; and (iii) conduct market analyses and collect information for developing and targeting specialty rice and rice products.

Water productivity

Modern improved japonica varieties have 25–30% higher transpiration efficiency than the older indica varieties, suggesting considerable variation for this trait in rice germplasm. But, the potential for exploiting this trait has not been investigated. Proposals to increase the waxiness of rice leaves to reduce nonstomatal transpiration have demonstrated no notable progress. Transforming the C_3 rice plant into a C_4 plant could potentially increase transpiration efficiency, but again, not much progress has been made.

Overall, the scope to increase the water productivity of the rice plant through transpiration efficiency seems to be small compared with the scope to increase water productivity through total water inputs (irrigation, rainfall). The shorter growth duration of modern high-yielding rice varieties has reduced outflows of evaporation, seepage, and percolation from individual rice fields. The combined effect of increased yield and reduced growth duration is that these varieties have a water productivity related to total inputs that is three times higher than that of traditional varieties grown under similar water management. A range of breeding strategies can be explored to further increase water productivity through evapotranspiration efficiency such as early vigor to reduce soil evaporation and weed suppression to lower weed transpiration.

Tolerance of abiotic stresses

Other routes to increased yields and total production are through greater tolerance of abiotic stresses, including drought, submergence, salinity, and other soil problems and temperature extremes. Rice production in such areas is very low, but with good potential to even double it in some areas once tolerant varieties are developed and deployed with packages of good management practices specific to target areas.

Drought. Most progress made in the past has come from the development of short-duration varieties that escape drought at the end of the rainy season. But, during the last decade, substantial genetic variability in grain yield under drought stress has been documented in both cultivated Asian rice, *Oryza sativa*, and its hardy African relative, *O. glaberrima*. New breeding approaches are resulting in the development of both upland and lowland rice varieties with improved tolerance of severe water stress during the sensitive stages of flowering and grain filling, while retaining the ability to produce high yields when water supplies are not limiting. A few of these varieties were recently released in South Asia, with a yield advantage of 0.7–1.2 t/ha over current farmers' varieties under drought conditions. Recently, five major quantitative trait loci (QTL; a region of DNA associated with a particular trait) were identified for higher grain yield under drought, and are being transferred into popular varieties through marker-assisted backcrossing (MABC). Two examples for upland environments are aerobic rice and NERICA (New Rice for Africa). Aerobic rice outyields traditional upland varieties and combines input responsiveness with improved lodging resistance and higher harvest index. These new varieties are designed for nonflooded, aerobic soil conditions in either rainfed or water-short irrigated environments. NERICA is the result of crossing *O. glaberrima* with *O. sativa* species at the Africa Rice Center (AfricaRice), beginning in the mid-1990s, to combine the toughness of *O. glaberrima* with the productivity of *O. sativa*. The aim was to combine resistance to local stresses with higher yield, shorter growth duration, and higher protein content than traditional rice varieties. The first NERICA series (1 to 18) were upland varieties; 8 varieties have been officially released. There are now 64 lowland NERICA varieties, 2 of which have been officially released in Burkina Faso and Mali.

Submergence. Though breeding for submergence tolerance and enhanced yield in flash-flood areas has been going on for more than three decades, only a few tolerant lines with improved agronomic characteristics have been developed so far. Since the recent discovery of the *Submergence 1* (*SUB1*) QTL that confers tolerance of complete submergence, new submergence-tolerant breeding lines with improved agronomic characteristics are being developed by transferring this tolerance into semidwarf breeding lines using marker-assisted selection. Several of the new varieties have been released in South and Southeast Asia, with a yield advantage of more than 1 t/ha over the original varieties lacking the *SUB1* QTL. Some breeding progress has been made for deepwater areas, and a few new lines with reasonable yield and grain quality have been released. Recently, three major QTLs were identified for elongation ability and two related genes were cloned, which will speed up the incorporation of tolerance into modern popular varieties through MABC. Progress has also been made in breeding varieties that can tolerate flooding during germination and early seedling growth. This trait is important for using direct seeding in rainfed areas and also for weed control in irrigated areas, where shallow flooding after direct seeding could effectively suppress most rice weeds.

Salinity. Despite a general sensitivity to salinity, rice has considerable variation in tolerance. Combining new screening techniques with conventional, mutation, and anther culture techniques, salinity tolerance was successfully introduced into high-yielding plant types. Some newly released varieties have demonstrated more than a 50% yield advantage over current salt-sensitive varieties. Breeding cultivars with much

Farmers in Benin in West Africa expect higher yields by growing NERICA varieties.

higher tolerance is possible if component traits are combined in a suitable genetic background. The opportunity to improve salinity tolerance through the incorporation of useful genes or pyramiding of superior alleles appears very promising. A major QTL, designated *Saltol*, was recently mapped. It accounted for more than 40% of the variation in salt uptake in several populations. Marker-assisted backcrossing is currently being used to incorporate this QTL into popular HYVs—some of them already completed and being field-evaluated. Progress was also made in fine-mapping additional QTLs associated with tolerance in efforts to combine them with *Saltol* for higher tolerance.

To enhance the adoption of improved varieties, farmers' preferences need to be taken into account. This was done for the delivery of all abiotic stress-tolerant varieties in Asia and Africa through participatory varietal selection. Furthermore, efforts are being extended to strengthen local seed systems in national programs, including seed corporations, the private sector, and community-based seed production systems, to ensure production of high-quality seed of these stress-tolerant varieties and their timely delivery to farmers.

Improved rice systems

Water-saving technologies

Various water-saving technologies exist or are being developed to help farmers cope with water scarcity in irrigated environments. These technologies increase the productivity of water inputs (rainfall, irrigation) mainly by reducing unproductive seepage and percolation losses and to a lesser extent by reducing evaporation. Mechanical soil compaction can reduce percolation flows in certain soil types but may be too expensive for large-scale implementation and may adversely affect the growth of any upland crop following rice. General measures such as land leveling, farm channels, and good puddling and bund maintenance, improve water control and reduce seepage and percolation outflows. Minimizing the turnaround time between wetland preparation and transplanting reduces the time when no crop is present and outflows of water from the field do not contribute to production.

Especially in large-scale irrigation systems with plot-to-plot irrigation, water losses during the turnaround time can be high when farmers maintain seedbeds in their main fields and keep the whole area flooded for the full duration of the seedbeds. The losses can be minimized by installing field channels, adopting common seedbeds, or direct seeding. With field channels, water can be delivered separately to individual seedbeds, and the main field does not need to be flooded. Common seedbeds, either communal or privately managed, can be located strategically close to irrigation canals and irrigated as one block. With direct seeding, the crop starts growing and using water from the moment of establishment onward. Direct dry seeding can also increase the effective use of rainfall and reduce irrigation needs.

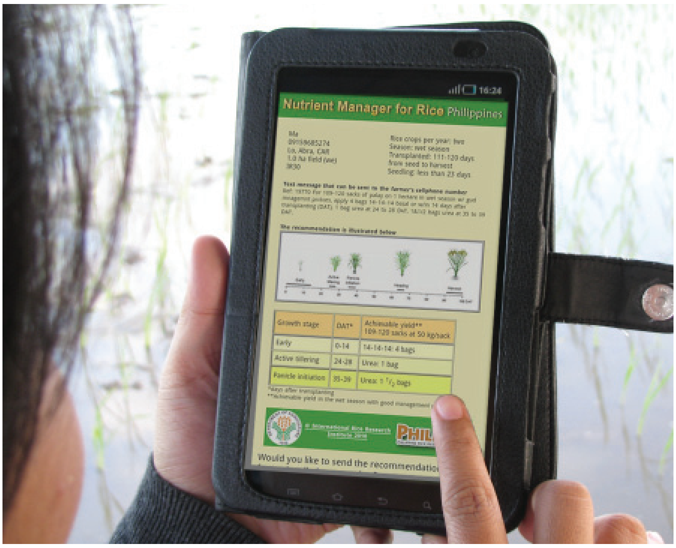
Water management techniques such as saturated soil culture and moderate alternate wetting and drying (without imposing drought stress) reduce field water application by 15–20% without significantly affecting yield and increase the productivity of total water input. For example, in experiments on alternate wetting and drying in China in a clay loam soil with shallow groundwater depths of 0.0–0.3 m, alternate wetting and drying saved 10–15% water with no effect on yield. More water can be saved and water productivity further increased by prolonging the periods of dry soil and imposing slight drought stress on the plants, but this usually comes at the expense of some loss of yield. In experiments on alternate wetting and drying in the Philippines in a silty clay loam with groundwater depths of 0.7–2.0 m, water inputs in flooded rice were relatively high, and the alternate wetting and drying treatment saved more than 50% water, though with some 20% yield loss. In an experiment on clay loam in India, with a groundwater table fluctuating between 0.1 and 1.2 m, increasing the number of days without ponded water progressively reduced both water inputs and yields.

Alternate wetting and drying reduces evaporation by 0–30%; other water savings arise from reduced seepage and percolation loss. The technique is a mature technology that has been widely adopted in China and can now be considered the common practice of lowland rice production in that country. It is also being recommended in northwestern India and parts of the Philippines.

In the system of aerobic rice, specially adapted input-responsive rice varieties are grown under dryland conditions just like wheat, with or without supplemental irrigation. In experiments in clay soil with groundwater at depths of 0.6–1.4 m in the Philippines and in sandy soil with groundwater at 20 m depth in northern China, water inputs in aerobic rice systems were 30–50% less than in flooded systems, while yields were 20–30% lower with a maximum of about 5.5 t/ha. Reductions in evaporation losses were 50–75%. Aerobic rice systems are currently being pioneered by farmers on an estimated 80,000 ha in northern China. However, the development of aerobic rice systems for irrigated environments is in its infancy, and more research is needed to develop HYVs and sustainable management systems. In aerobic rice systems, resource-conserving technologies, as practiced in upland nonrice crops, become available to rice farmers as well, such as mulching and zero or minimum tillage. Various methods of mulching are being tried in nonflooded rice systems in China and have been shown to reduce evaporation. Growing rice under aerobic conditions on raised beds shows promise but is also still in its infancy.

Site-specific nutrient management

Obtaining higher productivity and income in food production on small landholdings will increasingly require "precision farming" practices, which are tailored through information-based decisionmaking to location-specific situations. A major aspect of such decisionmaking is site-specific nutrient management (SSNM), that is, applying fertilizer in a particular location at the correct time in the correct amounts. Through an IRRI-coordinated partnership of public- and private-sector organizations, the results from more than a decade of research resulted in Nutrient Manager software, through which a computer or mobile phone is used to receive best-bet fertilizer management advice in irrigated or rainfed lowland environments, based on input from users, whether extension workers, crop advisors, or farmers. Internet-based versions have been or are being developed for many countries in Asia and Africa. In mobile phone applications, a small-scale farmer interacts with a voice recording that gives the information needed to compute the best-



A farmer uses the Nutrient Manager for Rice Mobile App for smart phones.

bet nutrient management strategy in his or her location and provides user-friendly text messages and/or images. Future applications will extend beyond SSNM to best-bet agronomic practices, and to complementary services such as microfinance, insurance, access to inputs, and market information.

Sustainability and environmental protection

The effectiveness and environmental impacts of fertilizer management technologies such as SSNM, slow-release fertilizers, and deep placement need to be evaluated under various scenarios of water availability.

Water-saving technologies can have different effects on the emission of greenhouse gases, depending on environmental site conditions and management practices (Box 4.2). With less water, weed management practices need to be developed that reduce the reliance on herbicides by anticipating weed species "shifts" and developing preventive strategies that integrate management interventions such as manual weeding, increased seed density (in direct-seeded systems), and mechanical weeding.

Little is known about changing pest and disease dynamics when field conditions change from water abundant to water short, although initial reports suggest an increase in soil-borne pests, such as nematodes. It is to be expected, however, that under fully aerobic soil conditions rice cannot be grown continuously on the same piece of land each year (as can be successfully done with flooded rice) without a yield decline. And, a suitable crop rotation will be needed as well as varieties that are tolerant of soil-borne pests and diseases. The experiences of upland rice and other dryland crops with pest and disease management have to be exploited in the development of sustainable management systems for water-short irrigated environments. Under completely aerobic conditions, salts may accumulate in the root zone as in any other dryland crop, and flooded rice could be included as a rotation crop to periodically flush out salts.

Box 4.2. Differences in greenhouse gas emissions under conventional and water-saving systems

The variability in greenhouse gas emissions from conventional flooded rice fields (control) and from two water-saving systems, unsaturated soil covered by plastic film (film) and unsaturated soil covered by straw mulch (straw), was compared in trials at three sites in China. Methane emissions were highest from flooded rice at all three sites. Nitrous oxide emissions were lowest from flooded rice in Nanjing and Guangzhou, but similar among all three systems in Beijing. When both methane and nitrous oxide emissions are converted into equivalent carbon dioxide emissions and summed, flooded rice had the lowest global warming potential at Nanjing and the highest global warming potential in Guangzhou, whereas all three systems had similar global warming potential in Beijing.

Stress-prone environments

The high variability of rainfed environments exposes farmers to great risk of yield loss. The development of stress-tolerant and input-responsive varieties will reduce this risk and increase the incentive to use external inputs and intensify the cropping system. Adjusted cropping systems and management technologies will be needed to make the most efficient use of the possibilities offered by the new varieties. The combination of the improved rice varieties that are in the pipeline and specific management technologies has the potential to increase yields by 0.5–1.0 t/ha in environments prone to drought, flood, and salinity within the next 10 years.

Rainfed lowlands

Two promising technologies are direct seeding and improved nutrient management. Direct seeding potentially offers better use of early-season rainfall, better drought tolerance, lower risk from late-season droughts, better use of indigenous soil nitrogen supply, and increased possibility for a second crop. Site- and season-specific nutrient management can reduce nutrient losses and pollution of the environment. Both technologies have already enabled substantial productivity increases in some more favorable rainfed areas. In Lombok, Indonesia, the introduction of short-duration and input-responsive varieties with direct seeding and the use of inorganic fertilizer increased and stabilized yields. In Laos, production in rainfed lowlands contributed considerably to achieving self-sufficiency in rice within a decade after the introduction of improved varieties and crop management.

Uplands

Strategies should aim at sustainable intensification to break the spiral of resource degradation caused by shorter fallow periods in shifting cultivation systems. For rice, a promising option is the establishment of lowland fields in valley bottoms in mountainous areas, also referred to as "montane paddy rice." These lowland fields could benefit from irrigation water supplied by mountain streams that converge in the valley bottoms. Rainfed lowland rice fields are also found in shallow inland valleys in sub-Saharan Africa, which have been identified as offering the greatest potential for expansion and intensification.

The aerobic rice production system offers scope where seasonal rainfall is some 600 mm or more or where farmers have access to supplementary irrigation. In the hilly regions of Yunnan Province in southern China, farmers grow rainfed aerobic rice under intensified management, realizing yields of 3–4 t/ha. The combination of aerobic rice and terraces offers even greater scope for intensification. Aerobic rice also holds promise for permanent arable production systems in rotation with other crops. In Brazil, a breeding program to improve upland rice has resulted in aerobic varieties with a yield potential of up to 6 t/ha. Farmers grow these varieties in rotation with such crops as soybean and fodder on large commercial farms with supplemental sprinkler irrigation on an estimated 250,000 ha of flatlands in the Cerrado region, realizing yields of 3–4 t/ha.

Submergence-prone environments

The new submergence-tolerant varieties need to be combined with adapted crop and nutrient management to improve seedling and plant survival as well as the ability to recover after submergence. Seedlings of submergence-tolerant varieties that are enriched in nutrients, particularly zinc and phosphorus, and possibly silicon, have a greater chance of survival. Application of nutrients after the recession of floodwater also speeds recovery, improves tillering, and boosts yield.

Salt- or sodic-affected areas

New salt-tolerant varieties need to be integrated with specific nursery, crop, and nutrient management strategies to mitigate the effects of salt stress and to improve soil quality. Soil amendments, particularly gypsum, can help in reclaiming sodic-affected soils, but they require large investments. The combined use of farmyard manure or pressmud from industrial waste with improved varieties can cut the need for gypsum by more than half. Relatively fresh irrigation water can leach salts accumulated in the root zone during previous nonrice crops.

Lowering the cost of production

There are many options to lower the costs of production, but few are directly related to water management. Where irrigation water is supplied by pumping, water-saving technologies reduce water inputs,

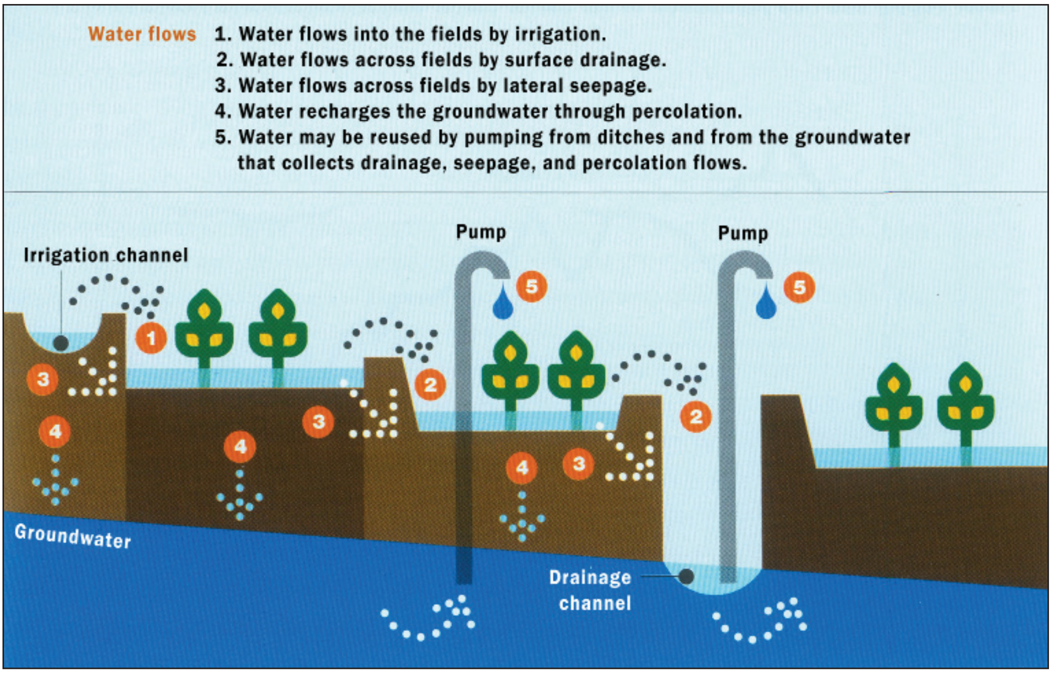


Fig. 4.5. There is great potential for reuse of water flows in a rice landscape of interconnected fields.

pumping costs, and energy consumption. Whether this actually increases profitability depends on the yield obtained and the relative price of rice and water. Reducing irrigation frequency reduces the labor used for irrigation, but, when fields are not continuously flooded, weed infestation may increase, requiring more labor or herbicides. The system of rice intensification has relatively high labor requirements and, partly as a result, there are reports of the system's abandonment in its country of origin, Madagascar. Dry seeding and aerobic rice technologies offer possibilities for mechanization of farm operations such as sowing, weed control, and combine harvesting, although adoption of these technologies seems to be driven more by labor shortage than by water shortage. Increased labor productivity also lowers the cost of production.

Options at the landscape level

Irrigation system efficiency and water reuse

Large volumes of water outflows and surface drainage, seepage, and percolation characterize irrigated rice fields. Although the outflows are losses from individual fields, there is great scope for reuse of these flows within a landscape that consists of many interconnected fields (Fig. 4.5). Surface drainage and seepage water usually flow into downstream fields and are lost only when they finally flow into drains or ditches. Even then, farmers can use small pumps to lift water from drains to irrigate fields that are inadequately serviced by irrigation canals. In many irrigation systems in low-lying deltas or floodplains with impeded drainage, the continuous percolation of water has created shallow groundwater tables close to the surface. Again, farmers can either directly pump water from the shallow groundwater or pump groundwater when it becomes surface water as it flows into creeks or drains. Recent studies of rice-based irrigation systems in China indicate that irrigation efficiency improves with increasing spatial scale because of the reuse of water. Much of this reuse is informal, as farmers take the initiative to pump up water, block drains, or construct small on-farm reservoirs for secondary storage.

Although water can be efficiently reused this way, it does come at a cost and may not alleviate inequities among farmers in irrigation systems. The current debate on the improvement of irrigation systems focuses on the benefits and costs of system modernization relative to those of mostly informal reuse of water. System modernization aims to improve the irrigation system delivery infrastructure and operation scheme to supply each farmer with the right amount of water at the right time.

Stress-prone environments

Many interventions at the landscape level are effective in alleviating abiotic stresses. On-farm water harvesting can reduce drought risk and increase productivity in drought-prone rainfed environments by making small amounts of extra water available to bridge critical periods of dry spells. Developing reservoirs and canal networks to store rainwater or freshwater from rivers before it becomes saline can extend the growing season in saline coastal areas and substantially improve productivity. Managing water by constructing large-scale coastal embankments and sluices has been reasonably successful in preventing seawater intrusion in many deltaic coastal areas, substantially reducing soil salinity in the wet season. The technology also opens up the possibility of growing high-yielding modern rice varieties, as in the coastal areas of the Mekong Delta in Vietnam.

However, water needs to be managed judiciously to avert undesirable long-term environmental consequences and local conflicts with other water users, especially landless poor people who depend on brackishwater fisheries for their livelihood. The use of pumps for shallow groundwater (as in Bangladesh) or surface water (as in the Mekong Delta) allows the cultivation of short-duration varieties in nonflooded periods in many deltas. Farmers in the flood-prone areas of the Mekong Delta also build community dikes, protecting areas of ten to a few hundred hectares and allowing them to harvest the crop before floods arrive. These dikes delay the onset of floods rather than prevent the peak of the flood from entering the protected area, thus avoiding the potentially adverse environmental consequences of absolute flood protection.

Relationships between water use at field and irrigation-system levels

The relationships between water use at the field and irrigation-system level are complex and involve hydrological, infrastructural, and economic aspects. At the field level, farmers can increase water productivity and reduce water use by adopting water-saving technologies. If they pay for the cost of the water they use, they can thereby increase the profitability of rice farming because any savings in water directly translate into savings in costs.

At the irrigation-system level, the adoption of field-level water-saving technologies by farmers will reduce the amount of evaporative losses from rice fields, but by relatively small amounts. The biggest water savings at the field level come from reducing seepage, percolation, and surface drainage flows. But, although this retains more water at the surface (in the irrigation canals), which is available for downstream farmers, it reduces the amount of water reentering the hydrological cycle and thus reduces options for informal reuse downstream. Reducing percolation from rice fields can lower groundwater tables. Although deeper groundwater tables can adversely affect yields, because rice plants may be less able to extract water from the groundwater, and increase the cost of pumping for reuse downstream, deeper groundwater tables also reduce nonproductive evaporation flows from fallow land.

Any adoption of water-saving technologies requires considerable water control by farmers. This is not much of a problem for farmers using their own pumps, but can be a problem for farmers in large-scale, unreliable, surface irrigation systems that lack flexibility in water delivery and for farmers using electric pumps for groundwater in areas where the electricity supply is unreliable. For farmers to profit from water-saving technologies, irrigation systems need to be modernized, which has an economic cost. Integrated approaches that take into account the options for reuse of water and for conjunctive use of surface water and groundwater seem to be the best way forward to improve total water-use efficiency.

Ecological engineering

In most rice landscapes, bunds and nonrice habitats occupy a substantial proportion. Some are populated with fruit trees and shrubs, or grown with vegetables. But, farmers often treat these areas as wastelands and spray them with herbicides, mistakenly thinking that they harbor pests. Ecological engineering is an approach to restore or enhance biodiversity of both floral and faunal species in the rice landscape, so that resources in the form of shelter and food for the natural enemies of rice pests are enhanced. Aside from conserving natural habitats, ecological engineering can augment biodiversity by planting nectar-rich flowers on bunds. These flowers provide nectar for bees and other species that pollinate fruit crops in rice landscapes. The nectar is also food to many hymenopteran parasitoids, especially those that regulate rice pest species such as planthoppers, leafhoppers, stem borers, and leaffolders. Experience in Vietnamese villages and in Jin Hua, China, where the approach has been used, has shown that without using insecticides, farmers are harvesting similar or higher rice yields but with a substantial increase in profits by not purchasing insecticides.

Improved value chains

Improved postharvest management options and technologies need to be researched, developed, adapted to local conditions, and made available at affordable cost. This needs to take into account the following factors that drive the transition of the rice value chain from simple to more advanced postproduction systems:

- Increasing intensity of land use and an increased number of crops per year
- The mode of rice production (subsistence, local markets, export, or a combination)
- Increasing quality consciousness and new niche quality markets
- Increased labor cost caused by labor scarcity
- Institutional changes, with an increased role of the private sector

Postharvest research and development up to the beginning of the 2000s emphasized component technologies focusing on farm-level problems and was in many cases seen as having very little impact. New institutional arrangements, business models, and information-sharing mechanisms were needed to develop more relevant technologies and speed up the uptake of research results such as a systems approach to define the problems and establish priorities; a multidisciplinary approach; better inclusion of end users in adaptive research and development; developing cooperative/partnership programs with national research centers, public and private extension systems, and manufacturers; and multiple sourcing of technology to increase the probability of impact.

Better targeting of interventions

The previous development paradigm for drying rice, "small postharvest equipment for small farmers," has often failed because it was based on social objectives and ignored the economic conditions farmers were operating in. Instead, a drying service to such farmers can be provided by a small entrepreneur. Farmers' groups, cooperatives, and contract service providers could also provide drying, harvesting, and storage services with group-owned equipment. Financial institutions and policymakers need better information about postharvest conditions to design suitable credit schemes and support policy.

Multistakeholder platforms

Postharvest learning alliances of research organizations, donors, development agencies, policymakers, and private businesses can help to increase resources, strengthen capacity, and plan, generate, and document postharvest development outcomes. Such alliances, already established in Cambodia, the Philippines, and Vietnam, can provide mechanisms to better document knowledge and make it available to extension workers, technicians, and, ultimately, farmers through, for example, rice knowledge banks.

A farmer in southwestern Bangladesh displays her use of the hermetic Super Bag for rice storage.

Public-private partnerships

More formal partnerships with the private sector can maximize joint research and development outcomes by drawing on the specific advantages of both sector players. Most commercially successful technologies in the last decade are such joint developments. For example, laser-leveling systems used by the construction sector were adapted for use in tropical agriculture in collaboration between the manufacturer and public research institutions. Other examples include the hermetic Super Bag for rice storage and the introduction of flat-bed dryers and mini-combine harvesters in Cambodia. Issues that need to be examined in this type of collaboration are related to intellectual property rights, relevance to the mandates of the public and private partners, transparency, nonexclusivity, resource sharing, and legal and regulatory frameworks.

Postharvest value chain and business models

As postharvest losses remain quite high and postharvest operations involve numerous processes and actors in the postharvest chain, a value chain approach can help identify both technical and nontechnical constraints and better target the practices and behaviors of agents along the chain. The approach is being used for organic fragrant rice in Laos, organic brown rice and white rice for local and potential export markets in Cambodia, and a certified good agricultural practice rice production chain in Thailand.

Business models can help address the sustainable adoption of postharvest technologies. As business models operate at all points of a value chain, they can be used to capture value and benefits of adoption as well as provide farmers and agents along the chain with new income-earning opportunities. "Open" or "borderless" business models further help the adoption of postharvest technologies by enabling enterprises to collaborate systematically with outside partners in the private, public, and NGO sectors to access additional resources, capabilities, and expertise.

Chapter 5

Responding to rice challenges

Neglect of the agricultural sector

Despite the remarkable gains in rice productivity and production since the 1960s, the sector has remained fragmented in all its components—research, production, and marketing. This can be seen 50 years on in continuing unfocused research, production losses, and market distortions. The result has been a leveling off of the earlier productivity gains and even declines in productivity due to lack of "maintenance" research. Development has been uneven, with almost no advances in the rainfed subsector—which also received little attention during the Green Revolution. Market and production problems took center stage during the global rice price crisis in 2007-08 and were again a factor in the conflicts in the Middle East that began in late 2010.

At the root of the problem was, until very recently, international and national neglect of the role of the agricultural sector—and agricultural research specifically—as the engine of economic growth and poverty reduction. A global complacency about agriculture following the successes of the Green Revolution led to declining growth rates in agricultural research and development (R&D) investments at both the national and global level beginning in the 1980s and worsening in the 1990s. Only the two largest rice-consuming countries, China and India, maintained adequate R&D investment growth, over 5%/year, during the two decades, while in sub-Saharan Africa, for example, R&D investment grew by only 0.6%/year on average during the same period.

Public agricultural R&D, which accounts for the great majority of investment, has become increasingly concentrated in just a handful of countries—the US, Japan, China, India, and Brazil, which together invested 48% of total global public agricultural R&D. A knowledge divide between Asia's rich and poor countries and the scientific "haves" and "have-nots" is becoming more and more visible. However, agricultural R&D expenditures in Latin America and the Caribbean rebounded in recent years following a period of contraction during the late 1990s.

There have been numerous recent calls for a new era of agricultural R&D investment to ensure food security through new, sustainable production systems.

Opportunities for a new global research strategy

The constraints to increasing rice production are largely of a nature that spans borders, particularly the new emerging challenges such as adaptation to climate change, increasing weather variability, water scarcity, and increased price volatility in global markets. Global problems in the sector need global solutions, but they must also be flexible enough to meet local needs.

Research by CGIAR centers, national systems, advanced research institutes, and the private sector has resulted in uneven progress in overcoming these constraints. A fundamental challenge for future international rice research is to re-focus it on those strategic areas in which the major research institutions can play a leading role, but ensure strong linkages with research activities by the public sector, civil society organizations, and the private sector through strategic partnerships. A harmonized global rice R&D strategy with sustained funding will be required for addressing large breakthrough opportunities, creating synergisms instead of duplication or competition, and thus achieving greater and faster impact.

Gaps between yields currently obtained by farmers and what could be achieved with improved management and varieties are still large, certainly in Africa, but also in Asia and Latin America. Postharvest losses may be as high as 20–30%. Efficiencies of nitrogen fertilizer or water remain 30–50% below levels that can be achieved with good management. Hence, closing yield and efficiency gaps, reducing postharvest losses, and adding more value to cropping or farming systems are clear opportunities to increase rice production and farmers' incomes, and do good for the environment. These "quick wins" will require mostly applied research based on solid partnerships at the grass-roots level to adapt prototype technologies to local settings and gender concerns. South-South knowledge exchange between rice-producing regions can help identify such opportunities.

Nearly all rice farmers worldwide depend on rice varieties that have been improved by scientific breeding since the Green Revolution. Rice breeding is a slow process, but new technologies have cut the time needed to test and validate new varieties by about 30%, and this trend is likely to continue to reduce the time from trait identification to varietal transfer. Scientific advances in genomics and marker-assisted breeding mean that genebank materials can be explored on a large scale to identify and embed the genes responsible for ever more complicated target traits. Transgenic technologies offer the potential to engineer new plants that were previously unthinkable such as rice using a new photosynthetic pathway. Meanwhile, improvements in sensors, processing, communications, and possibly nanotechnology offer the potential to revolutionize how field experiments are conducted, and can enable a precision agriculture revolution in input-use efficiencies. New information and communication technologies have made the time ripe for maximum exploitation of the economies of scale possible in rice research.

A global effort to increase rice production will require not only new tools; it must also change the practices and mindsets of millions of farmers to accept the challenges in their fields. Also, the adoption of rice technologies and approaches may be stalled if the policy environment is unfavorable. Harmonized and enabling rice-related legislation worldwide will be essential if farmers and other rice-sector stakeholders are to take advantage of new and improved production systems adapted to climate change.

Finally, knowledge of such production systems must reach the many, especially poor, producers. This will require increased numbers of knowledgeable extension personnel and information sources to keep them informed. And, because women play large and crucial but often unrecognized roles across the sector, extra efforts are needed to ensure they have the same opportunity as men to access new technologies.

Global Rice Science Partnership

In response to the many international and regional calls for a new era of agricultural research and development investment to ensure food security, several international research institutions, including three CGIAR centers—Africa Rice Center (AfricaRice), International Center for Tropical Agriculture (CIAT), and International Rice Research Institute (IRRI)—have combined their efforts in a global program, the Global Rice Science Partnership (GRiSP). The other major partners are Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), Institut de recherche pour le développement (IRD), and Japan International Research Center for Agricultural Sciences (JIRCAS), and, through the networks of these and other major institutions, collaboration has been established with 900 other research and development partners worldwide.

GRiSP's mission, in accordance with that of the CGIAR, is to reduce poverty and hunger, improve human health and nutrition, reduce the environmental footprint, and enhance the ecosystem resilience of rice production systems through high-quality international rice research, partnership, and leadership. The program also includes education and training to ensure continued availability of high-caliber scientists to address future problems in the sector, and improvement in information availability and its communication to all rice stakeholders.

GRiSP has three basic objectives, aligned with CGIAR strategic objectives:

1. To increase rice productivity and value for the poor in the context of a changing climate through accelerated demand-driven development

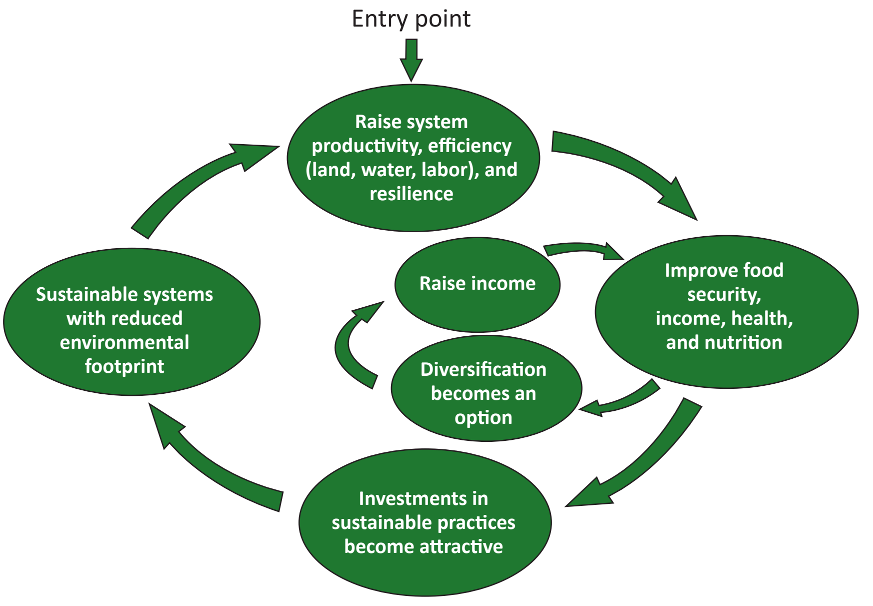


Fig. 5.1. GRiSP focuses on enhancing productivity, resource efficiency, and resilience of rice-based production systems as the key entry point for enabling farmers to enter a virtuous circle of sustainable production and living.

of improved varieties and other technologies along the value chain.

2. To foster more sustainable rice-based production systems that use natural resources more efficiently, are adapted to climate change and are ecologically resilient, and have reduced environmental externalities.
3. To improve the efficiency and equity of the rice sector through better and more accessible information, improved agricultural development and research policies, and strengthened delivery mechanisms.

The key entry points for achieving the GRiSP mission lie in lifting the productivity, resource efficiency, and resilience of rice production systems to unprecedented levels. This will enable farmers to enter a virtuous circle, allowing them to also invest more in diversification and sustainable, eco-efficient management (Fig. 5.1).

GRiSP research themes

GRiSP is being implemented through six interlinked global themes, each of which has 3–6 product lines with a total of nearly 100 research and development products, as well as new frontiers research to explore potential breakthroughs and products.

Theme 1: Harnessing genetic diversity to chart new productivity, quality, and health horizons. This research aims to uncover new traits in the rice genome—particularly traits related to water stress, because water is the main concern for future rice-cropping systems—and make them available to breeding programs worldwide. Theme 1 will also address research areas with very large long-term impact potential, such as re-engineering photosynthesis in rice to create a C_4 rice.

Theme 2: Accelerating the development, delivery, and adoption of improved rice varieties. Theme 2 uses the products of theme 1 in international and regional breeding programs to speed up the development and delivery of improved and climate-resilient germplasm. The aim is to transform public-sector breeding programs to become better targeted to the demands of different stakeholders—farmers, consumers, processors, and the marketing sector—but also better serve the needs of private-sector breeding programs that use germplasm from GRiSP.

Theme 3: Ecological and sustainable management of rice-based production systems. Theme 3 sits at the core of GRiSP because advances in rice production and optimizing the environmental footprint of rice will require developing integrated options for managing production systems. Hence, theme 3 provides feedback to and uses the new varieties from theme 2 to develop and extend rapidly to farmers' improved management technologies that make rice systems more energy-efficient, more profitable, more sustainable, and more resilient to stresses. Rice ecosystem services and greenhouse gas emissions from rice and their fate under different future scenarios will be examined with a view to finding the right balance between productivity growth and environmental impact.

Theme 4: Extracting more value from rice harvests through improved quality, processing, market systems, and new products. This theme builds on and provides feedback to themes 2 and 3 by investigating ways to increase harvest value and developing mechanisms to support and harmonize the activities of producers, processors, and marketers, while ensuring equitable benefits for poor male and female farmers.

Theme 5: Technology evaluations, targeting, and policy options for enhanced impact. Theme 5 provides important feedback to all other themes in GRiSP by helping to clearly understand the needs of male and female farmers from different socioeconomic categories and other actors, as well as the likely consequences of labor-saving technologies for their employment and income. Theme 5 also aims to influence policymakers and other decisionmakers to improve the functioning of the rice sector.

Theme 6: Supporting the growth of the global rice sector. Although international agricultural research centers cannot play a major role themselves in scaling-up new technologies to millions of farmers, they can make significant contributions to supporting the growth of the rice sector through (1) a technical and human resource base to enable a far better interface for the research products and regional, national, and within-country investment programs for food security; (2) catalyzing and initially also facilitating public private-sector partnerships for delivery that involve multiple sectors at the subnational level; (3) supporting extension capacity development; and (4) providing coherent, up-to-date knowledge in a format that is most useful for extension specialists and farmers.

New frontiers research. GRiSP will make significant investments in research for the next generation of future rice production systems—the scientific breakthroughs that will be needed 20 or 30 years from now to ensure food security and enable better environments. Priorities will be continuously assessed and new opportunities will be aggressively pursued, leading to an evolution of the GRiSP portfolio over time.

Partners and partnerships in rice research and development

The global rice research and development program that is needed if we are to increase the world's supply of rice in a sustainable manner involves participation of many institutions across the rice sector as partners. Partnerships among these institutions along the two-way research-to-development continuum will contribute to iterative cycles of research priority setting, technology development, adaptive research and diffusion, monitoring and evaluation, and impact assessment and funding. A goal of GRiSP is to harness the synergies of as many international, regional, national, and subnational partners as possible along the rice supply chain from upstream research organizations to local civil society organizations and private companies with expertise in product development and dissemination.

Major international research organizations

The three main CGIAR centers that undertake rice-related research, IRRI, AfricaRice, and CIAT, have an excellent track record in generating international public goods through upstream areas of rice improvement, through their ability to

Researchers visit rice plots at CIAT's headquarters in Colombia as part of a GRiSP Yield Potential Workshop.

conduct upstream and downstream research on production systems across borders, their research on environmental issues, aspects of socioeconomic and policy research, providing information, and science capacity development. They preserve most of the world's rice genetic resources and their collections are already seamlessly integrated with breeding and gene discovery programs, leading to new lines and varieties of rice that are made widely available to the poor. These three CGIAR centers are also experienced in leading strategic research across the rice sector. They have built up partnerships and regional networks of rice scientists over decades that enable knowledge exchange across countries; in support of this, they are also experienced in bringing rice information together and making it widely available. Research networks and consortia coordinated by the three centers already weave virtually every rice-producing country in the world into a rich partnership fabric. CGIAR centers are viewed as "honest brokers" by a wide range of stakeholders, a role that will be important with increasing involvement of the private sector and also essential to help move innovations beyond boundaries, so that advances by leading national research and extension systems can become global public goods.

Some developed countries host research and development institutions that work internationally in the rice sector. The major institutions are CIRAD and IRD in France, and JIRCAS in Japan.

Descriptions of these six major international research organizations follow.

AfricaRice

The Africa Rice Center (AfricaRice) is a leading pan-African research organization with a mission to contribute to poverty alleviation and food security in Africa through research, development, and partnership activities aimed at increasing the productivity and profitability of the rice sector, while ensuring the sustainability of the farming environment.

AfricaRice was created in 1971 by 11 African states as an autonomous intergovernmental research organization. Today, its membership comprises 24 countries, covering West, Central, East, and North African regions, namely, Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Democratic

Republic of Congo, Egypt, Gabon, the Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Niger, Nigeria, Republic of Congo, Senegal, Sierra Leone, Togo, and Uganda. AfricaRice is also a member of the CGIAR.

In partnership with the national agricultural research and extension systems (NARES), AfricaRice operates through a continent-wide task force mechanism based on specific broad research themes relating to rice. It collaborates with many advanced research institutes to complement the range of expertise needed to tackle the key research for development questions in Africa, such as CIRAD, IRD, JIRCAS, and several universities. It also works with nongovernment organizations (NGOs) and farmers' associations.

AfricaRice's strategic plan, 2011-20, focuses on the following seven priority areas, which were identified in close consultation with its key partners and stakeholders:

1. Conserving rice genetic resources and providing smallholder farmers climate-resilient rice varieties that are better adapted to production environments and consumer preferences.
2. Improving rural livelihoods through sustainable intensification and diversification of rice-based systems.
3. Achieving socially acceptable expansion of rice-producing areas, while addressing environmental concerns.
4. Creating market opportunities for smallholder farmers and processors by improving the quality and the competitiveness of locally produced rice and rice products.
5. Facilitating the development of the rice value chain through improved technology targeting and evidence-based policymaking.
6. Mobilizing co-investments and linking with development partners and the private sector to stimulate uptake of rice knowledge and technologies.
7. Strengthening the capacities of national rice research and extension agents and rice value chain actors.

The strategy is aligned with the Comprehensive Africa Agriculture Development Program (CAADP). It will be mostly implemented under the umbrella of the CGIAR Research Program (CRP) of GRiSP, with other CRPs contributing to specific priority areas. GRiSP, led by IRRI, effectively aligns rice research activities worldwide and its activities in Africa are under the responsibility of AfricaRice.

AfricaRice's headquarters is temporarily based in Cotonou, Benin. It has four outreach stations: Bouaké, Côte d'Ivoire; Ibadan, Nigeria; Saint-Louis, Senegal; and Dar-es-Salaam, Tanzania. AfricaRice has about 300 staff, including support personnel.

CIAT

The mission of the International Center for Tropical Agriculture (CIAT), is to reduce hunger and poverty, and improve human health in the tropics through research aimed at increasing the eco-efficiency of agriculture.

With support from the Colombian government and Rockefeller, Ford, and Kellogg foundations, the center was formally established in 1967 and began research in 1969. CIAT currently has 200 agricultural scientists, who work with national partners in Latin America and the Caribbean (LAC) from headquarters in Cali, Colombia; in 28 countries of sub-Saharan Africa from a regional office in Nairobi, Kenya; and in five Southeast Asian countries from a regional office in Hanoi, Vietnam.

CIAT conducts research mainly through nine programs grouped in three areas. The first area, agricultural biodiversity, centers on selected crops—cassava, common bean, rice, and tropical forages—that are critical for global food security. Research in the second area, tropical soils, seeks to reverse rampant soil degradation, which is a fundamental obstacle to sustainable improvement of agricultural systems across the tropics. Research in the third area deals more broadly with rural landscapes and economies, employing the latest simulation modeling techniques to provide a better basis for decisions and policies concerning climate change adaptation and mitigation in agriculture as well as other challenges.

CIAT's rice research primarily serves LAC, where the crop is a major staple food, but also contributes to global efforts through GRiSP. In addition to breeding improved varieties through conventional recurrent selection methods, CIAT scientists use various genomic tools for making rice breeding more efficient. They are also exploring possibilities to expand the genetic variability of the crop through the use of related wild species and African cultivated rice and to improve specific traits, such as nitrogen-use efficiency, through a better understanding of the genetics and transgenesis of rice lines.

The center's Rice Program works with a wide range of national and international partners. One particularly valuable ally is the Latin American Fund for Irrigated Rice (FLAR, its acronym in Spanish). This is an innovative public-private partnership involving 15 countries, which funds rice improvement as well as the development and dissemination of better crop and resource management practices.

CIRAD

The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a French targeted research center working with developing countries and regional and international organizations to tackle international agricultural and development issues. Its operations, from field to laboratory and from local to global scale, are based on development needs. Its 800 scientists have joint operations with more than 90 countries. CIRAD provides the national and global scientific communities with extensive research and training facilities in Montpellier and several platforms overseas.

Rice is the first target plant/crop/commodity for some 60 CIRAD scientists, of whom 25 are outposted in Africa, Asia, and Latin America. CIRAD's rice R&D activities focus on:

1. Understanding the biological bases (molecule to population) of rice adaptation and development
   - Evaluation, management, and promotion of genetic resources
   - Rice adaptive development
   - Rice phenotypic plasticity and adaptation
   - Development of improved rice varieties for target agro-systems with strong food security and climate change concerns
   - Rice-pathogen interactions
   - Evolutionary biology of rice pathogenic fungi (*Magnaporthe grisea*)
   - Bioinformatics and data integration
2. Improvement of rice-based production systems (on a plot and farm level) and of rice processing systems
   - Sustainable farming and rice cropping systems
   - Systems and agricultural engineering
   - Automated identification of weed species in rice fields using techniques for the recognition of visual content
   - Promotion of rice co-products
   - Integrated approach for grain quality
3. Knowledge and tools to support decisionmaking by rice-related players, from rural areas to society, from local management to public policy
   - Water management, players, and usage
   - Technical and organizational changes on farms
   - Management of natural resources and the environment
   - Markets, organizations, institutions, and operators' strategies
   - Spatial information and analysis for territories and ecosystems

As a member of Agreenium, CIRAD is also the gateway for mobilizing other French agriculture-related research and higher education establishments for the benefit of rice science.

IRD

L'Institut de recherche pour le développement (IRD, formerly known as ORSTOM) is a public science and technology research institute, reporting to the French ministries in charge of research and development cooperation. Working throughout the tropics, IRD conducts three missions (research, training, and consultancy) in close cooperation with its numerous partner countries to contribute to the economic, social, and cultural development of the countries of the South. IRD has outposted staff at CIAT. IRD researchers aim to respond to the major development challenges regarding societies, health, environment, and living resources through priority topics such as nutrition, emerging diseases, education, migration and poverty reduction policies, environmental hazards, global warming, management of marine and continental ecosystems, desertification, water resources, and food security. IRD has important facilities and equipment in dedicated research centers in France and in French overseas territories but also in 22 intertropical countries. IRD is strongly involved in the national research system, including universities and other advanced research institutes (INRA-CNRS-INSERM). Recently, IRD was entrusted with the founding and the management of AIRD (the Interestablishment Agency for Research for Development) to intensify and coordinate French scientific policy concerning the development of southern countries through research. IRD has a long past research experience on rice in the domains of genetic resource preservation and evaluation mainly in Africa and in collaboration with CGIAR centers.

IRRI

IRRI's mission is to reduce poverty and hunger, improve the health of rice farmers and consumers, and ensure environmental sustainability through collaborative research, partnerships, and the strengthening of national agricultural research and extension systems.

IRRI was established in 1960 by the Ford and Rockefeller foundations with the support of the government of the Philippines, and consists of laboratories and training facilities on a 252-ha experimental farm in the Philippines. The Institute has about 1,300 staff members located at its headquarters in the Philippines and offices in 16 other countries. There are also teams in country offices working with national programs in Asia and Africa.

IRRI's goals are to

- Reduce poverty through improved and diversified rice-based systems.
- Ensure that rice production is sustainable and stable, has minimal negative environmental impact, and can cope with climate change.
- Improve the nutrition and health of poor rice consumers and rice farmers.
- Provide equitable access to information and knowledge on rice and help develop the next generation of rice scientists.
- Provide rice scientists and producers with the genetic information and material they need to develop improved technologies and enhance rice production.

IRRI pursues its mission and goals through interdisciplinary thematic and system-based programs; scientific strength in major research disciplines; anticipatory research initiatives; conservation and responsible use of natural resources, including rice genetic resources; sharing germplasm, technologies, and knowledge; participation of women in research and development; partnership with farming communities, research institutions, and other organizations; and continued efforts in improving staff development and welfare.

IRRI's research is carried out in six programs that are identical to the six themes of GRiSP (see pages 68-69). The programs are staffed by interdisciplinary teams drawn from three research divisions—plant breeding, genetics, and biotechnology; crop and environmental sciences; and social sciences—and four centers: genetic resources, grain quality and nutrition, C_4 rice, and training.

Most of IRRI's work is carried out through international partnerships: research consortia, research and technology evaluation networks, joint ventures, shuttle research (exchange of scientists), bilateral collaboration, and direct consultation. Research consortia include the Hybrid Rice Development Consortium (HRDC), Irrigated Rice Research Consortium

(IRRC), Consortium for Unfavorable Rice Environments (CURE), and Temperate Rice Research Consortium (TRRC). Networks include the Cereal Systems Initiative for South Asia (CSISA), the International Network for the Genetic Evaluation of Rice (INGER), the International Network for Quality Rice (INQR), and Stress-Tolerant Rice for Africa and South Asia (STRASA).

IRRI's research and development work is now being channeled mainly through GRiSP, in which partnerships are being enhanced and expanded. Such global partnerships are necessary to tackle the emerging challenges in the sector, particularly climate change, as well as greatly increasing the relevance, efficiency, and impact of the work of individual institutions.

JIRCAS

The Japan International Research Center for Agricultural Sciences (JIRCAS) is an incorporated administrative agency under the Ministry of Agriculture, Forestry, and Fisheries (MAFF) of Japan. The mission of JIRCAS is to improve technologies for agriculture, forestry, and fisheries in developing regions. It conducts a number of joint research projects on an equal footing with collaborative partners in 25 countries of Asia, Africa, and Latin America. Among the 107 JIRCAS researchers, 23 work on important rice research issues such as molecular biology, breeding, agronomy, modeling, water management, food science, and socioeconomics. The improvement of rice production in Africa also has high priority for JIRCAS.

Research, development, and other partners

Other international institutions and organizations involved in R&D in the rice sector include several additional CGIAR centers, United Nations agencies, and autonomous agencies such as CABI, Coherence in Information for Agricultural Research for Development (CIARD), and International Center for Development-oriented Research in Agriculture (ICRA). Additionally, many international and regional economic development organizations and fora include the sector in their mandates. Most rice-growing countries have national research and extension systems, with some of them emerging as strong R&D centers in their own right. Civil society is also involved through NGOs and farmers' groups.

CGIAR centers

Several other CGIAR centers have expertise and experience in related R&D, for example:

- The International Food Policy Research Institute (IFPRI) undertakes research on food supply-demand modeling, adoption studies, cereal systems in South Asia, aspects of nutrition and nutritionally enhanced crops, value chains, and policy concerns.
- The International Maize and Wheat Improvement Center (CIMMYT), International Livestock Research Institute (ILRI), International Center for Agricultural Research in the Dry Areas (ICARDA), and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) participate in research on improving cereal-based systems in South Asia, including diversification and crop-livestock interactions.
- The International Water Management Institute (IWMI) and International Institute of Tropical Agriculture (IITA) participate in the sustainable development of inland valley systems in West and Central Africa.
- The WorldFish Center offers potential to collaborate in projects in coastal zones and other aquatic systems that involve rice and fish.

International organizations and centers, regional fora, and development organizations

FAO has expertise in good agricultural practices, rice information systems, knowledge management for dissemination, and innovative information and communication approaches. CIARD has virtual information and communications technology (ICT) networks, and expertise in large-scale dissemination of new seeds and management technologies in Asia and Africa. CABI (and through it benefits for its 44 member countries) is experienced in the production of unique global ICT products and capacity development for plant health. ICRA can provide experience in capacity development for persons working in multistakeholder platforms for technology development or dissemination.

Major regional fora and economic communities with a major interest in development of the rice sector include

- Regional fora involved in the Global Forum on Agricultural Research (GFAR) (e.g., Forum for Agricultural Research in Africa (FARA), Forum for the Americas on Agricultural Research and Technology Development (FORAGRO), and Asia Pacific Association of Agricultural Research Institutions (APAARI) at the continental level, and West and Central African Council for Agricultural Research and Development (CORAF) and Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) in Africa at the subregional level).
- Higher-level political bodies and development initiatives targeting food security and poverty such as the Comprehensive Africa Agriculture Development Programme (CAADP), Center for Agricultural and Rural Development (CARD), Association of Southeast Asian Nations (ASEAN), South Asian Association for Regional Cooperation (SAARC), and Asia-Pacific Economic Cooperation (APEC).
- Regional economic communities such as the Economic Community of West African States (ECOWAS). These communities can assist with policy formulation and building of rice research and extension capacity in regions where rice is considered a priority commodity (such as in West Africa).
- International and regional development funds and banks, including International Fund for Agricultural Development (IFAD), the World Bank, Asian Development Bank (ADB), and African Development Bank (AfDB). Many of these directly contribute to international rice R&D as donors through the CGIAR Fund/Consortium mechanisms.

National agricultural research and extension systems

National agricultural research and extension systems (NARES) have been the key partners of CGIAR centers for decades, primarily through collaborative projects, networks or consortia, and science and extension capacity development. These partners range from NARES that emerge from national conflicts (such as Liberia) and thus require major assistance, to NARES with strong national rice capabilities in Africa (e.g., Egypt), Asia (e.g., China, India, others), and Latin America (e.g., Brazil) that will play a key role in global rice R&D. Many partnerships with NARES and other sectors exist through regional networks, projects, and consortia, which, through their steering committees composed of a wide range of partners, also play an important role for setting priorities and linking international R&D with national systems and investments.

Examples of such collaboration in Asia are the CSISA, IRRC (11 countries in Asia), CURE (South and Southeast Asia), and the TRRC (12 countries, global). Examples for Africa are the Inland Valley Consortium (IVC, 10 countries in West Africa, AfricaRice, CIRAD, IITA, ILRI, FAO, and others). A key steering mechanism in Latin America is FLAR (15 members). On a global scale, various networks connect hundreds of scientists from many countries, for example, in the INGER (global) and the INQR, which also connects NARES researchers with many advanced research institutes.

An example is the ongoing project on STRASA, led by IRRI and AfricaRice. This project operates mainly through research and delivery partnerships, with some 200 partners in the public and private sector, and civil society, that are engaged, mostly part-time, in project activities. Many of those are development partners involved in seed production.

Some countries have become major actors in rice R&D. The national rice research systems in Brazil, China, and India, have made rapid advances in recent years. In Africa, Egypt has excellent rice R&D capacity that has resulted in the highest average rice yield in the world; this experience needs to be tapped in irrigated rice-based systems in sub-Saharan Africa.

Advanced research institutes and universities in developed countries

Numerous advanced research institutions and universities in Europe, North America, Asia, and Australia are undertaking basic research in the rice sector, conducting research that is beyond the capacities and comparative advantages of the CGIAR and other rice-related institutions. Most of the partnerships with these institutes will be bilateral, but some also represent larger upstream research networks that include advanced research institutes in both developed and developing countries. Key examples for such worldwide partnerships in basic research are the C_4 Rice Consortium, the International Rice Functional Genomics Consortium, the OryzaSNP Consortium, and the INQR.

Civil society organizations

Civil society organizations (CSOs), including NGOs, farmers' associations, farmer clubs, and many others, are widely involved at the downstream end of rice production and value chains and will be essential partners for dissemination. They also play an important role in providing feedback to researchers and policymakers on setting the right research and investment priorities in order to meet the needs of poor farmers. Some international NGOs, such as the World Wildlife Fund and Catholic Relief Services, are also involved in more upstream aspects of rice development and environmental issues. Generally speaking, CSOs have a comparative advantage in operating at the grass-roots level and are thus well placed to ensure full participation of farmers and other stakeholders. ROPPA (the Network of Farmers' and Agricultural Producers' Organizations of West Africa) has observer status at AfricaRice's Council of Ministers and National Expert Committee meetings.

The private sector and public-private partnerships

Private companies and industry associations contribute to progress in specific research areas. In the past, the private sector mostly focused on developing pesticides, fertilizers, and machinery for rice cultivation and rice processing/new products from rice. In recent years, the ability of private firms to appropriate gains from rice R&D has increased, which has induced companies to start investing in rice breeding, mainly in hybrid rice and in developing patent biotechnology innovations.

Hybrid rice. Although hybrid rice was developed by the public sector in China, private Chinese firms are officially allowed to produce and sell seed under the 2000 Seed Law. Private firms are now adding rice breeding programs to their activities. Following the Chinese success, governments and companies in many countries have made major efforts to commercialize hybrid rice. Many large multinational as well as national companies are now engaged in rice seed production and the development of hybrids.

The role of the public sector in hybrid rice has become that of a prebreeding and general research provider rather than trying to commercialize products itself. For instance, IRRI has been a major source of restorer lines for the Chinese hybrid rice programs and revived its own hybrid rice breeding program in 1979. Through the efforts of IRRI, public research institutes in India, Indonesia, the Philippines, and Vietnam established their own hybrid rice programs in the 1990s, which led to the release of a first generation of public-sector hybrids.

Biotechnology. A second factor leading to increased private-sector interest in rice breeding is the ability to develop and patent biotechnology inventions. In the 1990s, Monsanto and Syngenta invested substantial amounts of money in mapping the rice

IRRI and partners in Asia have led the development and use of hybrid rice technology in the tropics.

genome, which was partially contracted out to universities, built on research networks financed by the Rockefeller Foundation and the Japanese government.

The potential for future earnings from transgenic traits in rice has attracted most of the major agricultural seed-biotechnology firms to invest in rice biotechnology research both in-house and through collaboration with public institutes. DuPont/Pioneer, Bayer, Syngenta, and BASF have in-house basic biotechnology programs that include rice and have located biotechnology research facilities in China, Europe, India, Singapore, and the United States. Some of these companies have partnerships with small biotechnology firms to develop yield traits for rice. These companies also engage in collaborative biotechnology rice research with the public sector in many countries, most extensively in China, and with IRRI.

The private sector is also involved in international consortia that involve a large number of public- and private-sector partners. For example, since 1997, three international fertilizer industry associations have provided additional support to the IRRC, which receives its main funding from several public-sector donors. These funds were used by IRRI and its national partners to conduct research on new approaches for efficient, sustainable nutrient management in rice-based systems. Another example is the HRDC (Box 5.1).

The expansion of the rice seed sector is leading to an increased diversification of rice R&D systems. The private sector is making substantial investments in specific rice R&D areas such as gene discovery and molecular breeding for hybrid rice development, crop protection, new machinery, and rice processing/new products from rice. It is thus generating intellectual property that could also be of advantage to the public sector. Moreover, private companies are developing and operating increasingly sophisticated delivery channels through which it may also be possible to disseminate certain public sector know-how better and faster. Hence, new formal research partnerships and contractual relationships are emerging among the public and the private sectors.

Box 5.1. Hybrid Rice Development Consortium (HRDC)

Worldwide, about 13% of all rice grown is hybrid rice—varieties in which seeds of the first generation of crosses have higher yield potential—commercially marketed to farmers. Since the initial release of hybrid rice in the mid-1970s in China, IRRI and its national partners in Asia have led research, development, and use of hybrid rice technology in the tropics for almost 30 years. Many large multinational and smaller national seed companies are now engaged in hybrid rice breeding and commercialization. Thus, the public sector should now focus on fostering public-private partnerships in which public institutions concentrate more on prebreeding, basic research on key traits, information, and capacity development, whereas commercialization is mainly done by small and large private enterprises, which need to have equal access to new traits, hybrid parental lines, pilot hybrid varieties, information, and other technologies developed by the public sector.

For this reason, the HRDC was established by IRRI as a new model for public-private partnerships in 2008, with current membership of more than 30 seed companies, more than 30 public-sector agencies, and one NGO. Private-sector members include large multinational companies such as Bayer, Syngenta, and DuPont, and other companies from India, China, Bangladesh, Indonesia, Pakistan, Malaysia, Belgium, Bolivia, and the United States. Private-sector members of the HRDC provide the demand-driven feedback for IRRI's hybrid rice research, but also the financial support needed for sustaining it, in collaboration with IRRI's national partners. They receive the products of this research through fee-based, nonexclusive licensing mechanisms, whereas the public sector continues to have free access. This has allowed IRRI to triple its hybrid rice breeding capacity. HRDC members can also participate as sponsors of specific projects and seek bilateral collaboration with IRRI through scientific know-how and exchange programs, which focus on joint research and capacity development.

Key models for collaboration with the private sector include

- Joint bilateral research, focusing on research areas of mutual interest, intellectual product sharing, scientist-to-scientist interaction, and capacity development for young scientists.
- Multilateral, public-/private-sector consortia with innovative, self-sustained business models for such partnerships and managing intellectual property in the interest of all participants and to the benefit of poor rice farmers and consumers.
- Licensing of intellectual products from the private sector to the public sector and vice versa. This is an emerging area and it requires clear guidelines for product stewardship and for joint licensing, in cases where several partners may have contributed to a discovery or development of a product.
- Local delivery partnerships that capitalize on expertise and networks for delivering products and services effectively and efficiently to farmers. By working with private-sector partners on a nonexclusive basis, another channel for delivering public research solutions is enabled.

Chapter 6

Rice around the world

Rice and food security in Asia

More than 90% of rice is produced and consumed in Asia. Thus, most of the descriptions in the early chapters of the almanac on the importance of rice relate to Asia. In terms of food consumption, what distinguishes Asia from the rest of the world is its great dependency on rice: it is the basic staple for the majority of the population, including the region's 560 million poor. Other regions rely more heavily on other cereals.

Indeed, as a poor person's food, rice is a sensitive topic in many Asian countries; governments can "make or break" themselves with the fall and rise of rice prices. In many of these countries, rice is deeply engraved in their rich culture and tradition. Asian countries also take immense pride in having a vibrant rice farming system, and the reaffirmation of many countries after the 2008 rice price crisis to revitalize the domestic rice sector and achieve food security through rice self-sufficiency is a good example of what rice means to many countries in the region.

The introduction of high-yielding varieties in the late 1960s, which marked the beginning of the Green Revolution, has more than tripled Asian rice production in the past four-plus decades, from 200 million t (paddy equivalent) in the early 1960s to more than 600 million t in 2010. This has been possible with the introduction of modern varieties in tandem with assured irrigation, subsidized inputs (such as fertilizer, fuel, and pesticide), and guaranteed prices. During this period, more than 1,000 modern varieties were released to farmers in Asian countries, with adoption going from 30% in 1970 to about 70% in 1990.

The success of the Green Revolution in the 1960s witnessed a steady rise in Asia's per capita rice consumption from 85 kg in the early 1960s to nearly 100 kg by 2010; on the other hand, global per capita consumption rose from 50 to 65 kg during the same period (Fig. 6.1). The rising per capita consumption in combination with the growing population resulted in a tripling of total Asian rice consumption during this period from 150 to 450 million t (milled rice equivalent).

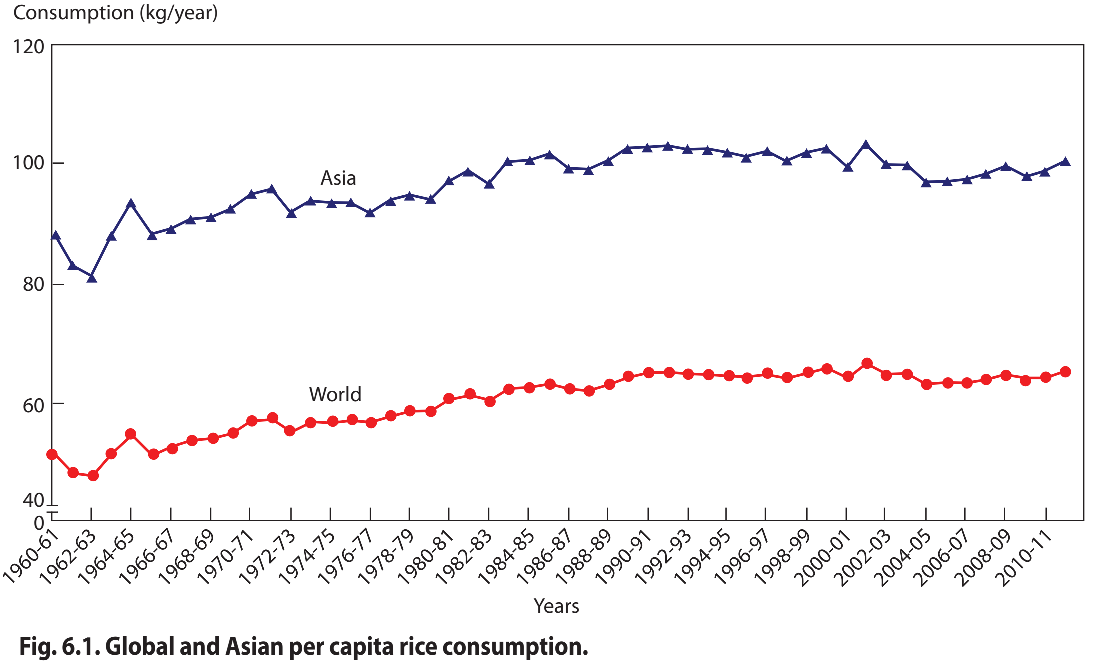


Fig. 6.1. Global and Asian per capita rice consumption.
Data sources: PSD online database (USDA) and FAOSTAT population database (FAO).

In line with the rising rice consumption, per capita calorie intake also increased by more than 40% from 1,891 in 1960 to 2,706 in 2009. Similarly, life expectancy and infant mortality witnessed significant improvements during the post-Green Revolution era. Although the contribution of rice to total calorie intake dropped in Asia during this period (from 38% in 1970 to 29% in 2009), it still accounts for 45–70% of the total calorie intake in many rice-consuming countries in the region, including, Bangladesh, Cambodia, Indonesia, Vietnam, and many other Asian countries (Fig. 6.2).

Changing consumption patterns

Since the early 1990s, strong economic growth in many Asian countries, particularly in China and India, halted the upward trend in Asian per capita rice consumption as consumers diversified their diet from rice to high-value foods such as meat, dairy products, fruits, and vegetables. Between 1992 and 2005, per capita rice consumption in Asia as a whole declined from 103 to 96 kg. Per capita rice consumption in India began to decline after the economic liberalization in the early 1990s. In China and India, per capita consumption declined by 10 and 8 kg, respectively, between 1992 and 2005. Nevertheless, total rice consumption in Asia has continued to rise on the back of population growth and the rise in per capita rice consumption in other Asian countries.

However, the declining trend in per capita rice consumption in large countries such as China, India, and Indonesia has been reversed in the last few years and per capita consumption has started rising again (Fig. 6.3). This upswing contributed to the recent surge in total annual Asian rice consumption by 40 million t over 7 years. Household consumer expenditure data collected by India's National Sample Survey Organization confirm the flattening in per capita consumption in recent years from the declining trend in the 1990s in all four regions of India.

In other Asian countries such as Bangladesh and the Philippines, per capita rice consumption remains strong across income groups in both urban and rural areas. National representative household consumption survey data collected between 2000 and 2010 from both the Philippines (Family Income and Expenditure Survey) and Bangladesh (Household Income and Expenditure Survey) confirm this trend.

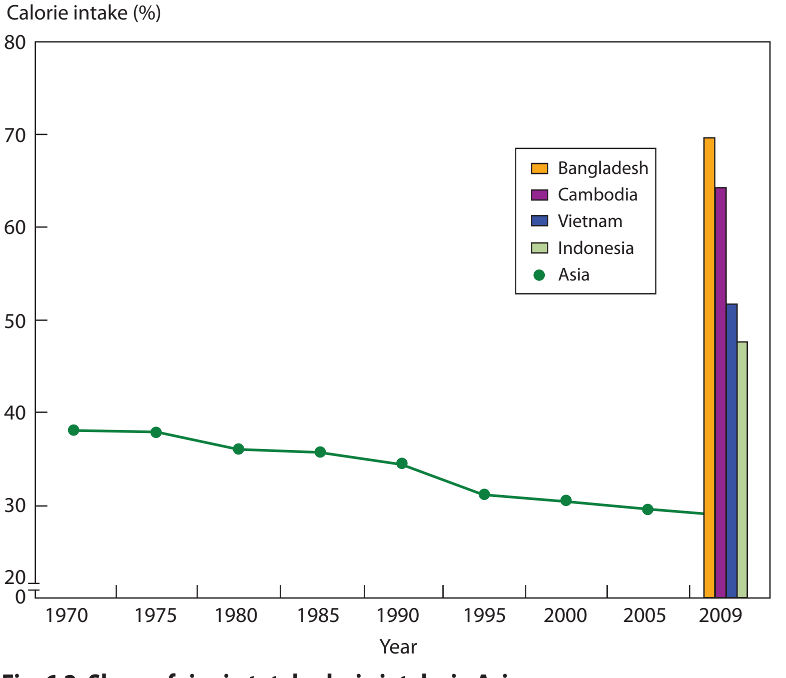


Fig. 6.2. Share of rice in total calorie intake in Asia.

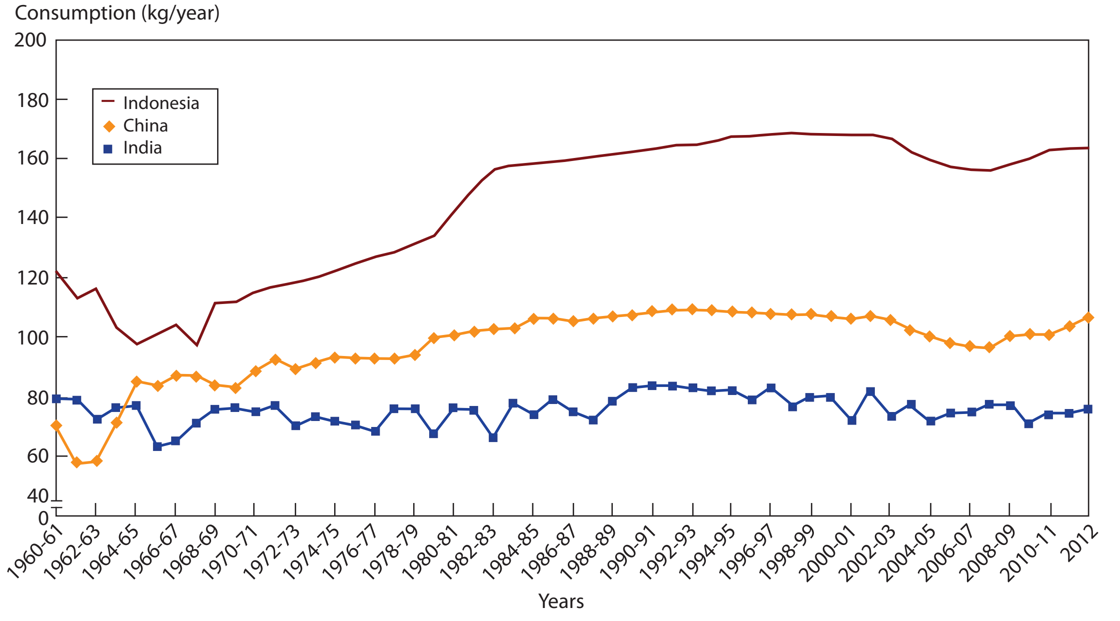


Fig. 6.3. Per capita rice consumption in Indonesia, China, and India.
Data sources: PSD online database (USDA) and FAOSTAT population database (FAO).

Even high-income groups in both rural and urban areas consume more rice with a rise in income. Unlike the Philippines and Bangladesh, per capita rice consumption is on a downward trend in other Asian countries such as Malaysia, Thailand, and Vietnam.

Future consumption trends

As we look ahead, income growth, urbanization, and other long-term social and economic transformations are likely to influence the composition of the future food basket. Normally, one would expect diversification away from rice to more high-value foods such as meat, dairy products, fruits, and vegetables in the diet as income rises. But, the diversification rate in many Asian countries will also be influenced by the extent of government interventions in price control and subsidized food grain distribution.

India is a good example, where the government has a new and elaborate food subsidy program to provide highly subsidized food grains (rice and wheat) for 65 million below-poverty-line households, including nearly free food grains to 20 million Antyodaya Anna Yojna households, the poorest of the poor households. Each of the 65 million households receives 35 kg of grains every month at 74–86% below the procurement cost. The above-poverty-line families are also given 15–35 kg of grain every month depending on availability at less subsidized prices. In 2011-12, the food subsidy bill amounted to nearly $14 billion.

Overall, it may be reasonable to assume that diversification away from rice will be slow in many Asian countries and the minimum threshold level of rice consumption for each country will be different.

In addition, 700 billion more people will have to be fed in the next 30 years, based on the United Nations' 2010 population projections—the Asian population will reach nearly 5 billion by 2035 and 5.15 billion by 2050. If Asian per capita rice consumption follows the trend it has seen in the past two decades, total consumption will grow at the rate of population growth. Total consumption growth may even exceed population growth if the recent uptrend in per capita consumption in the "big three" countries (China, India, and Indonesia) continues.

The bottom-line message is that, if food diversification in Asia is slow and not widespread, it is almost certain that the total demand for rice in Asia will continue to rise. However, the opposite will be true and total Asian consumption may start declining if Asian countries follow a rapid diversification path. Global rice consumption will probably rise from 439 million t (milled rice) in 2010 to 555 million t in 2035 and Asia will account for 67% of the total increase, rising from 388 million t in 2010 to 465 million t in 2035.

Future supply prospects

In the first three decades of the Green Revolution, the higher productivity growth, more than 2% annually, provided incentives for farmers to bring additional area into rice production. Part of the area expansion has been possible because of greater cropping intensity through the adoption of short-duration varieties. A combination of productivity growth and area expansion provided the production growth needed to keep rice prices affordable and meet global needs. However, yield growth has slowed significantly, falling below 1% by the early 2000s but increasing again after 2005. The effect of the overall decline is evident with two food price spikes since 2007 and a steady rise in rice prices since 2001. From 2001 to 2007, rice prices nearly doubled primarily because of the supply-demand imbalance. Between November 2007 and May 2008, the rice market witnessed the tripling of international rice prices. Although prices went down quickly after May 2008, they settled at a much higher level of $500–600 per ton vis-à-vis $300–400 before the crisis.

The current rice area is at an all-time high at around 160 million ha compared with 120 million ha in the early 1960s. Further expansion of rice area in the future is not a viable option for most Asian rice-growing countries, where additional land is no longer available and pressure on the existing rice land from urbanization and other nonagricultural uses is growing rapidly. For example, China's rice area has declined by more than 5 million ha (15%) in the past three decades and this downtrend may continue. Although a similar downtrend has not been evident in other rice-growing countries in the region because of government interventions, it is hard to foresee how governments can continue with such interventions in the face of rising costs, water shortages, and growing pressure from competing sectors.

The few exceptions could be countries such as Cambodia and Myanmar that were left out of the Green Revolution for varying reasons, but they could be stimulated to expand rice production by developing infrastructure and providing better market linkages.

Without the possibility of further area expansion in the future, yield growth will have to be maintained at 1.2–1.5% to about 2020 and at 1.0–1.2% annually beyond 2020 to be able to meet growing global needs and keep prices affordable. But, unfortunately, the approaches adopted that led to the success of the first Green Revolution may not be applicable now. During the first Green Revolution, many Asian countries provided incentives to farmers through subsidized inputs and assured markets for their products to expand rice production. Farmers responded by adopting input-responsive high-yielding modern varieties and bringing additional land into crop production.

Fertilizer use in Asian countries has increased markedly in the past four decades (Fig. 6.4). In China, fertilizer application per hectare in NPK equivalent increased from 38 kg in 1970 to close to 400 kg in 2009. Similarly, Vietnam witnessed a fivefold increase in fertilizer use during this period, from 46 kg in 1970 to 217 kg in 2009. Indian fertilizer use has also increased, but still remains low compared with that in China and Vietnam at 156 kg/ha. However, the variations among Indian states are very large: in Punjab and Haryana, NPK use is 200 kg/ha, while in states mostly left behind by the Green Revolution, it is much lower—50 kg in Orissa and 10 kg in Arunachal Pradesh.

Similarly, the use of groundwater for irrigation purposes has also increased in many Asian countries, most notably in India, Indonesia, and Bangladesh. In India, water withdrawal for agriculture increased by more than 70% in the past three decades (Fig. 6.5), and a recent study concluded

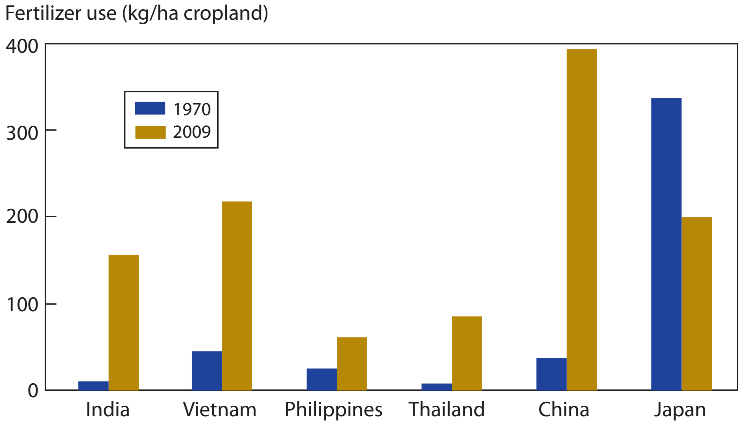


Fig. 6.4. Fertilizer (NPK) use in agriculture, 1970-2009.
Data sources: International Fertilizer Industry Association (IFA) and (FAO).

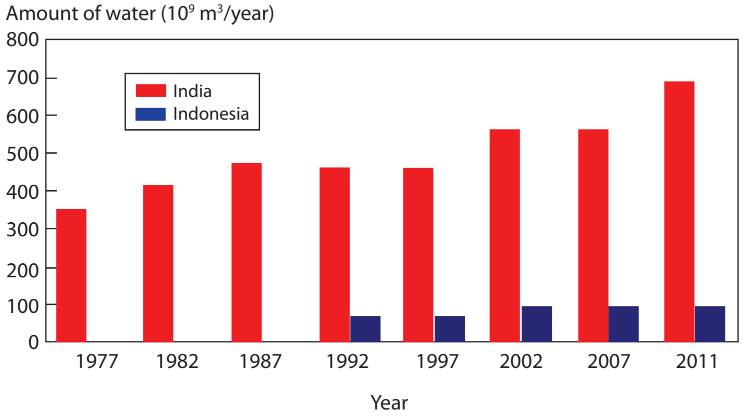


Fig. 6.5. Agricultural water withdrawal.
Data source: World Bank Indicators online 2013.

that this rate of withdrawal in northwestern India is unsustainable: the water table is falling by 4 cm per year. Agricultural water withdrawal in Indonesia increased by nearly 25% between 1990 and 2000. Yield improvements in the future need to be achieved in the face of these emerging constraints such as land and water scarcity, environmental degradation, and rising input prices.

Climate change

Apart from the various constraints described above, the anticipated changes in global climate in the form of rising temperature, increasing amount of carbon dioxide in the atmosphere, greater frequency of extreme weather events (e.g., floods and droughts), and greater incidence of pests and diseases are likely to make things more complicated for rice production. A large share of rice production is already lost to various abiotic stresses (flood, drought, and salinity) and biotic stresses (pests and diseases). Among the abiotic stresses, drought is the strongest constraint, affecting nearly a third of the total rice area in Asia and causing significant economic losses to poor rice producers in the region. The average production loss due to drought in three regions (eastern India, northeastern Thailand, and southern China) adds up to $200 million annually. Floods regularly cause severe rice yield damage on 16 million ha of flood-prone rice in Asia. The annual loss in rice production in South Asia alone is estimated to be 4 million t. Salinity, though not as big a stress as drought and flood, still affects 10 million ha of coastal and inland areas. But, growing rice is the only option available to farmers in the saline-prone coastal regions where nothing else can be grown, and this crop is critical to the food security of these resource-poor farmers.

Crop losses are likely to be greater in the future with changing climate that will make flood, drought, and salinity problems more frequent and severe. Rising sea levels due to climate change are expected to spread the salinity problem to a wider growing area where rice is cultivated under favorable conditions now, especially in the Mekong River delta, which accounts for nearly half of Vietnam's total rice production. Saline conditions may also spread beyond the coastal areas and deltas to some groundwater irrigation agriculture in interior regions. The excess withdrawal could increase salinity in groundwater, making it unsuitable for rice production. Similarly, drought losses could be much greater in the future, with many rainfed areas experiencing more intense and more frequent drought events.

In addition, rising temperatures will also negatively affect yield and grain quality in the future, when the temperature will become higher during the reproductive phase, particularly at flowering. In the past three decades, nighttime minimum temperature has been rising rapidly and this trend is expected to continue. It is estimated that yield will decrease by 7–10% for each 1 °C temperature rise above the present mean temperatures at current carbon dioxide concentration in the atmosphere.

Apart from direct production losses because of the occurrence of extreme weather events and rising temperature, farmers in stress-prone environments also practice less intensive agriculture by applying less inputs. They receive lower yields, even in normal years. The rise in frequency of extreme weather due to climate change is likely to make these farmers even more risk-averse, causing a further decline in yield in normal years.

Projections using the IMPACT model developed by the International Food Policy Research Institute suggest that climate change will lower global rice production in 2050 by 12–14% relative to the 2000 level. In terms of absolute change in rice production, South Asia would be the worst affected region, with rice production projected to change from 169 million t in 2050 under the no-climate-change scenario to slightly above 100 million t under a climate-change scenario, a difference of more than 65 million t. This would result in higher prices and lower consumption, which eventually would lead to lower calorie intake and an increase in child malnutrition. Overall, the study suggests that developing countries would be worse off than developed countries for all crops, including rice.

A study of three major rice ecosystems in India (Odisha, Kerala, and Tamil Nadu) found varying impacts of climate change on rice production. In Kerala and Odisha, the decrease in yield due to rising temperature is likely to be offset by an increase in yield due to high atmospheric carbon dioxide concentration, but, in Tamil Nadu, where currently grown varieties show a much greater decline in yield due to the higher temperature, rice production is more vulnerable to climate change. In Thailand, rice yield is estimated to be about 18% lower by 2020 because of climate change.

In addition to these abiotic stresses, many biotic stresses, such as pest and disease incidence and weed infestation, would also be triggered by climate change. A map for Asia (Fig. 6.6) with bacterial leaf blight severity shows that, under current climate conditions, many parts of Asia are already adversely affected by this disease. These effects are predicted to become more severe with climate change that would bring about frequent extreme weather, water scarcity, and uneven rainfall, not just for bacterial leaf blight, but also other pests, diseases, and weed infestations.

One of the most important adaptation strategies is to develop varieties that can withstand extreme weather conditions to enable them to perform better than current modern high-yielding varieties. Thus, future efforts should be directed toward developing varieties that can withstand multiple stresses, such as drought and flood, in the same season. This is extremely important for rainfed lowland areas where the likelihood of both flood and drought occurring in the same season is expected to

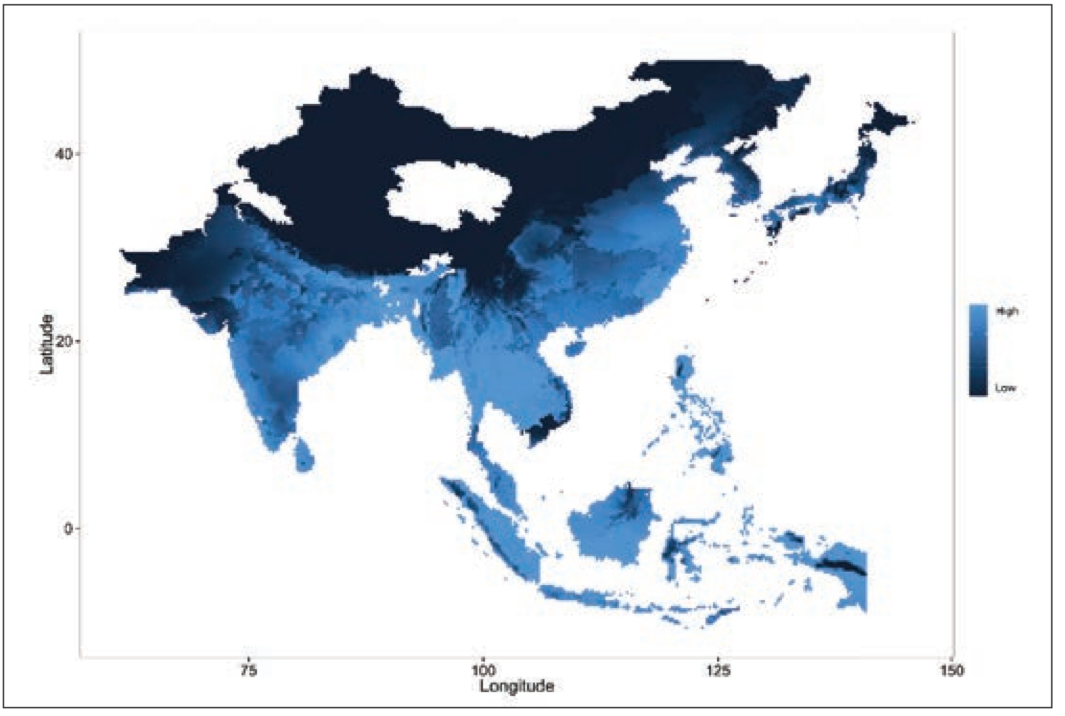


Fig. 6.6. Predicted occurrence and severity of bacterial blight in Asia during 2001-2010 in the absence of disease control. The map is based on prevailing weather conditions in the primary growing season as determined by the IRRI GIS laboratory.

Source: A. Sparks, IRRI.

be higher in the future with the changing climate.

Apart from planting stress-tolerant varieties, Asian rice farmers need to modify their management practices to counter the negative effects of climate change. First and foremost, water-saving technologies such as alternate wetting and drying, land leveling, improved tillage, bund preparation, and direct seeding can make a significant difference in keeping plants standing in the face of water shortage and irregular rainfall. Similarly, farmers should be educated on pest dynamics and the benefits of diverse ecosystems to keep pests at a distance in order to minimize pesticide overuse. This cannot happen without the active participation of government agencies that can make policy reforms to prevent excessive use of pesticides.

Market distortions

Historically, rice production in Asia has been subjected to extensive market distortions because of its strategic and political importance. For decades, governments in the major rice-growing countries in the region have attempted to minimize the market risk faced by farmers through various policy measures such as subsidized inputs (fertilizer, seed, fuel, pesticide, machinery, etc.) and a guaranteed price for paddy. The goal was to support farm income and at the same time keep rice affordable for millions of urban poor. To make domestic programs work, most Asian countries have tried to insulate the domestic market from global uncertainty through a slew of trade measures, including state trading, export bans, import bans, import tariffs, export quotas, and others. However, since the rice price crisis in 2007, countries have renewed their efforts to expand rice production by raising support prices at a much faster rate than in the past. For example, in India, the minimum support price (the price at which the government purchases crops from the farmers) for rice increased by 75% between 2007 and 2011, whereas it took from 1994 to 2006 for the minimum support price to increase by a similar proportion (Fig. 6.7).

The global rice market is small—only 6.9% of production in 2009—and, in most

Asian markets, trade is an afterthought when domestic need and an adequate buffer stock are achieved. However, the volume of global rice trade increased by 150% between 1990 and 2010 after remaining stagnant for three decades, on the back of trade liberalization by many countries in the late 1980s and the General Agreement on Tariffs and Trade in 1994.

The recent rice price crisis in 2007 has forced many rice-growing countries to take measures to achieve food security through self-sufficiency and move away from their dependence on foreign rice, a trend that will depress rice trade in the future. Exporters such as Pakistan, Thailand, and Vietnam would cut back on their production to reduce the exportable surplus and use their land for planting other profitable crops. A smaller market will lead to greater price volatility, with a rapid rise in rice prices in years of low production and vice versa. This will particularly affect the food security of poor countries that cannot afford to buy rice at higher prices from the international market.

Toward a food-secure Asia

Rice continues to remain a political commodity in Asia. Countries in the region are still extremely concerned about rice food security and treat it very differently from other food commodities. Despite the economic boom in the region in the past three decades and the rise in income and prosperity, rice consumption remains strong across countries with some diversification away from rice in a few countries. Overall, rice consumption in Asia is projected to rise in the next two decades even with declining population growth and increasing food diversification in some Asian countries.

The future growth of rice supplies, however, seems to be on shaky ground, with several emerging uncertainties, including a possible rice area decline, a further slowdown in productivity growth, and climate change. Most experts predict that the area under rice in Asia is likely to fall because of population pressure, water shortage, and competition from other crops. In addition, the ongoing structural transformation of Asian agriculture with aging farmers and out-migration of rural youth may also influence rice farming. Ultimately, the onus falls on policymakers to adequately fund agricultural research and on scientists to develop technologies that are climate-proof and that enable farmers to grow more with less inputs and a smaller environmental footprint.

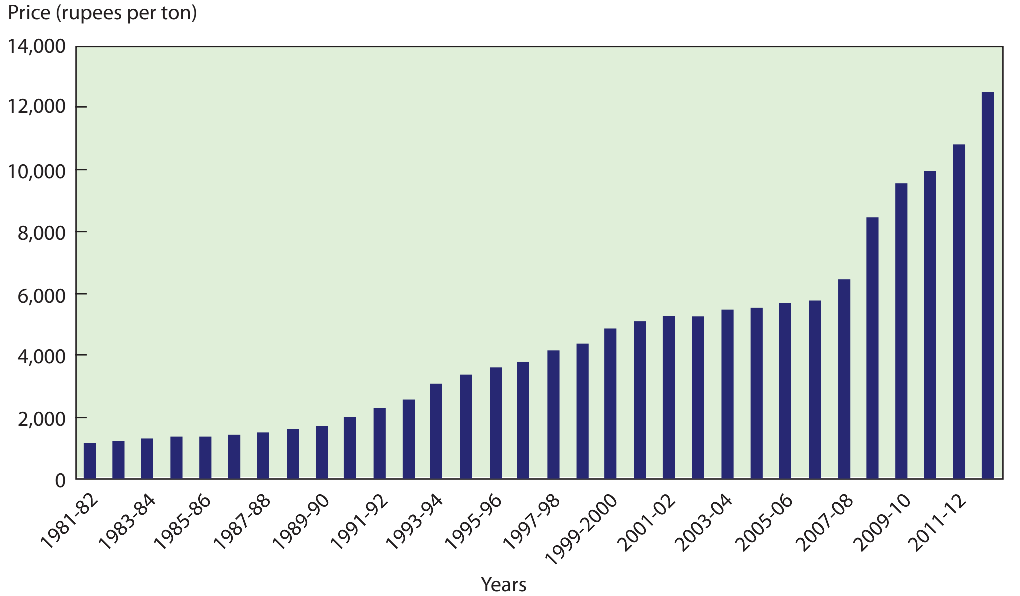


Fig. 6.7. Indian paddy minimum support price (common varieties).
Data source: Department of Agriculture and Cooperation, India.

Rice in Latin America and the Caribbean

Rice is a staple food crop in Latin America and the Caribbean (LAC). The region's per capita annual consumption increased from about 9 kg of milled rice in 1924-28 to about 30 kg in 2008-10. Rice consumption is concentrated in the tropical countries of the region, which had a total population of 582 million in 2010. Tropical Latin Americans consume an average of 37 kg of milled rice yearly—equal to about 1.3 cups of cooked rice daily. After sugar, rice is their single most important source of daily calories, supplying 11.5% of daily caloric intake. In Ecuador, Guyana, Haiti, Panama, and Peru, rice provides 20% more calories than any other crop. Rice is also a leading source of protein for the poorest 20% of the tropical population, supplying more per capita than beans, beef, or milk. Rice is income elastic in the region: consumers tend to increase consumption as their incomes rise. Rice is preferred by the poor because it is cheap, nutritious, appealing, easy to prepare, and easy to store and transport.

From 1967 to 1995, increasingly efficient production, triggered by the adoption of modern semidwarf varieties that were more input-sensitive, caused the real price of rice to decline by 50%. However, during the last decade, the price of rice has become highly variable.

Rice is particularly important from the standpoints of growth and equity. Poverty in LAC is extensive: in 2010, 30.4% of the total population was poor and 12.8% desperately poor. Most of the poor live in urban areas; they spend about 15% of their income on white rice. Their well-being is therefore affected by the amount, quality, security of supply, and price of the rice they eat.

Pushed by large debt burdens, fiscal and trade imbalances, and high inflation rates during the 1970s and 1980s, most of the region's countries have developed self-sufficiency policies for rice production to maintain low and stable prices for urban consumers.

Source of agricultural development

Rice was a leading pioneer crop for area expansion and colonization until the 1980s, when the trend in agriculture reverted to more intensive practices as a result of more open trade practices and the need to increase efficiency and competitiveness. During 2000-10, rice production in LAC expanded annually at 2.8%, fueled by a 2.1% annual growth in yield, while the cultivated area expanded annually at 0.3%. The area under irrigated rice has continued to grow steadily but there has been a decline in the area under upland rice. Higher yields are the result of the shift to irrigation as well as the continuous release of improved varieties.

Such growth in production has provided many opportunities for reactivating local rural economies. By the mid-1990s, local feed and food industries were using nearly 4 million t of rice by-products per year.

Urbanization and economic liberalization are forcing the integration of regional rice markets and agribusiness. Demand for healthy, diversified, rice-based

convenience foods is increasing. Most countries do not rely on rice imports to meet domestic needs. In 2010, 3.7% of the world's rice production and 3.5% of the cultivated area were in LAC. From 1966 to 2008, rice production increased from 9.8 million t to 26.2 million t. In the mid-1990s, 6.7 million ha in Latin America were under rice. Of these, 3.1 million ha were upland, 1.1 million ha rainfed lowland rice, and 2.5 million ha irrigated rice.

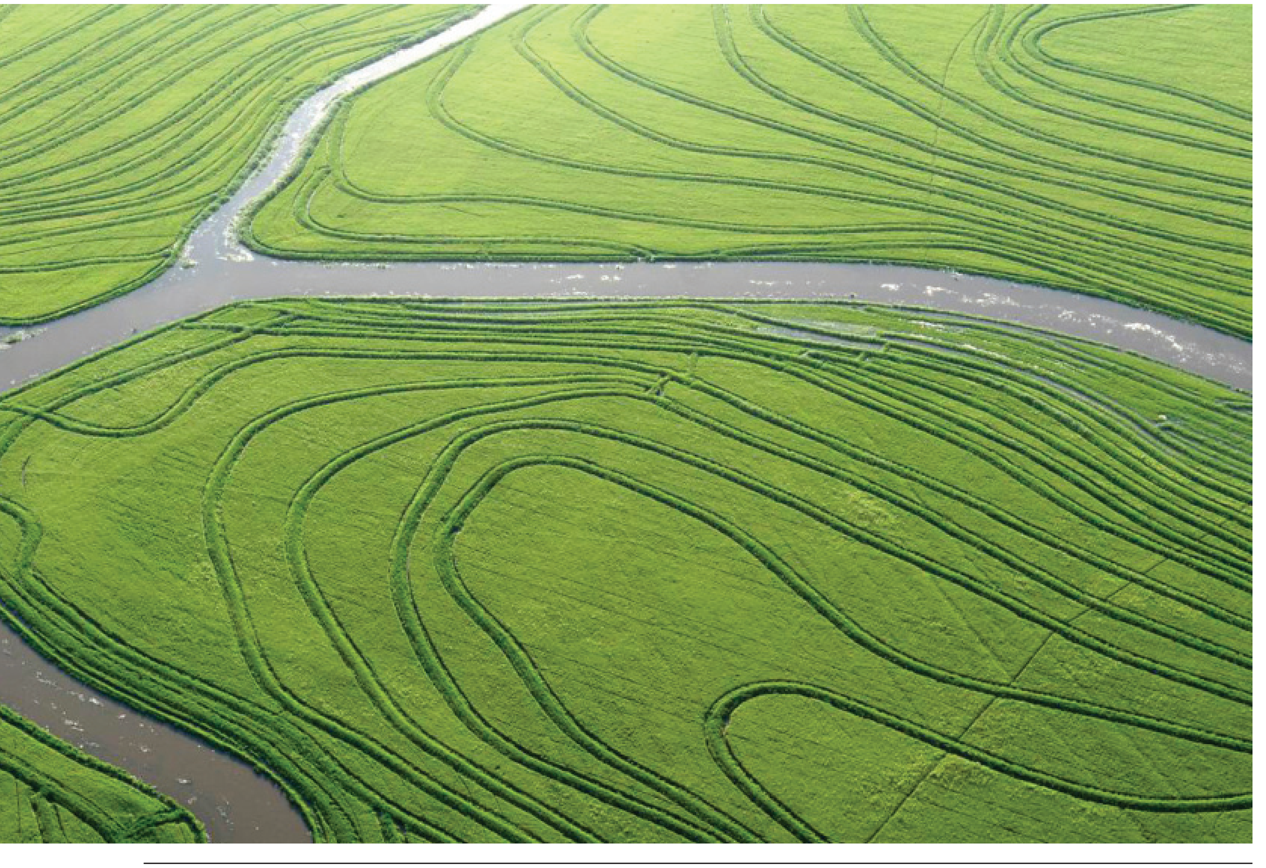
About one million farmers in the region depend on rice as their main source of energy, employment, and income. Of these, about 0.8 million are resource-poor smallholders, planting less than 3 ha. They cultivate rice manually, producing only 6% of the total rice output in LAC. The other 0.2 million rice growers produce 94% of the rice on larger (15–50 ha on average) mechanized farms.

Geographical features of rice cultivation in Latin America

More than two-thirds of Latin America's arable lands are in lowland ecosystems. Rice is well adapted to the wet soils common in lowlands. Opportunities exist for lowland rice expansion in the vast wetlands of Brazil (with a potential of 24 million ha), the Andean countries (Bolivia, Ecuador, Peru, and Venezuela), the River Plate Basin (Argentina, Paraguay, and Uruguay), Guyana, and Central America.

Another ecosystem with potential is the high-rainfall savannas, with aerobic upland acid soils, found in Bolivia, Brazil, Colombia, Guyana, Suriname, and Venezuela. Rice is more tolerant of acidity than are other grain crops. New technologies (more input-responsive rice varieties) and production systems (upland rice-pasture cultivation) can encourage the establishment of improved pastures and relieve pressure for food production from more fragile environments.

After heavy rains, drainage channels carry water away from rice fields outside of Vergara, Uruguay, near the Brazilian border.



Rice grown under irrigation provides 59% of total rice production on just 37% of the total rice area, with average yields of 5.0 t/ha. For rainfed lowland rice, the corresponding figures are 22%, 16%, and 3.9 t/ha, respectively; and for upland rice, 19%, 46%, and 1.3 t/ha, respectively. Brazil accounts for 65% of all the rice area in LAC. Brazil produces 52% of all irrigated rice, 38% of all rainfed rice, and 92% of all upland rice in the region. The rice area in Brazil is 62% upland, grown on acid soils, whereas, outside Brazil, most rice is irrigated on richer soils.

In contrast with other rice-growing regions in the world, rice cultivation on larger farms in tropical Latin America and the Caribbean is predominantly mechanized. Direct seeding and purchased inputs are used across ecosystems. These features fit fairly well with the characteristics of the region—abundant flat land and scarce labor—and enhance its comparative advantage in efficient rice production compared with more labor-intensive cultivation systems elsewhere in the world.

A direct-seeded culture

In contrast to Asia, where rice is commonly transplanted, rice in Latin America is mostly direct-seeded, a practice that developed because of increasing labor costs. The Asian transplanting system is used on only 6% of the region's total rice area.

About two-thirds of irrigated rice has been developed by diverting water from streams, rivers, and wells. The new short-duration varieties, developed regionally, and capital inputs and water have helped farmers deal successfully with weed populations and with the more demanding water, fertilizer, and pest management needs for direct-seeded rice.

Research challenges

One problem common to LAC and other regions is the stagnation of crop yield potential. In many places, significant yield gaps exist, which can be exploited through better agronomic practices. Diseases and pests are other problems, tackled with excessive applications of agrochemicals. To help overcome these problems, rice scientists have been working on (1) developing higher-yielding rice varieties using advanced techniques with conventional plant breeding, (2) investigating methods that allow faster breeding processes, and (3) reducing production costs and environmental hazards through genetically resistant varieties and better crop management practices to achieve higher efficiency in the use of inputs. The last factor encourages farmers to maintain or increase their cultivated area, despite low rice prices, and to reduce agrochemical use.

Research and development in Latin America

Nearly 100 publicly funded agricultural research and development institutions work on rice in LAC. Each follows one of four models: (1) as part of a research department in the Ministry of Agriculture, (2) as part of a decentralized agricultural research institute, (3) as an association with a rice development project, or (4) as a decentralized rice research institute. Rice research is also carried out by farmers' organizations, private companies, universities, and regional institutions, their opportunities having increased since the internationalization of most countries in the region during the 1990s. Helping researchers to benefit from collaboration and to improve their capacity are networks such as INGER (International Network for Genetic Evaluation of Rice), FLAR (Fondo Latinoamericano de Arroz de Riego), and CRIDNet (Caribbean Rice Industry Development Network). From 1975 to 1995, 250 rice varieties were released in the region. About 70% of these varieties were introduced to the countries through INGER. A further 152 varieties were released during 1996-2012, of which 43 were released by FLAR. The high return to international and national rice research in LAC is equivalent to an annual interest rate of 69%. This is extremely attractive, compared with the interest rate of about 10% earned on commercial investments.

Rice in West Africa

Revolutionary change in the preferences of West African consumers has created a wide and growing imbalance between regional rice supply and demand. The major trends in consumption, production, and imports of rice are illustrated in Table 6.1. Since 1973, regional demand has grown at 6.0% annually, driven by a combination of population growth (2.9% growth rate) and substitution away from the region's traditional coarse grains. The consumption of traditional cereals, mainly sorghum and millet, has fallen by 12 kg per capita, and their share in cereals used as food from 62% in the early 1970s to 50% in the early 1990s.

In contrast, the share of rice in cereals consumed grew from 15% to 25% over the same period, and from 12% to 18% in calorie terms from the 1960s to the end of the 1990s. Much of this dramatic shift occurred in the late 1970s and 1980s. Per capita rice consumption has been increasing at more than 3% annually since the late 1990s. Accounting for population growth, this suggests that total rice consumption increased at nearly 6% per year during 2006-10.

The most important factor contributing to the shift in consumer preferences away from traditional staples and toward rice is rapid urbanization and associated changes in family occupational structure. As women enter the work force, the opportunity cost of their time increases and convenience foods such as rice, which can be prepared more quickly, rise in importance. Similarly, as men work at greater distances from their homes in the urban setting, a greater proportion of meals is consumed from the market, where the ease of rice preparation has given it a distinct advantage.

These trends have meant that rice is no longer a luxury food, but has become a major source of calories for the urban poor. Urban consumption surveys in Burkina Faso, for example, have found that the

Table 6.1. West Africa's major trends in consumption, production, and imports of rice.

Indicator	1973	1983	2000	2010
Yield (t/ha)	1.24	1.46	1.7	1.80
Production (million t)	2.3	3.5	7.1	11.0
Import quantity (million t)	0.6	1.8	2.3	5.8
Import value (US$ million)	151	567	565	2,433
Food consumption quantity (million t)	1.9	3.8	7.3	10.3
	Average 1961-70	Average 1971-80	Average 1973-83	Average 1983-2000
Yield (t/ha)	1.2	1.3	1.4	1.62
Production (million t)	1.8	2.7	3.0	5.7
Import quantity (million t)	0.4	0.8	1.2	2.1
Import value (US$ million)	49	276	432	570
Food consumption quantity (million t)	1.3	2.2	2.8	5.4
	Trend 1961-70	Trend 1971-80	Trend 1973-83	Trend 1983-2000
Yield (%)	3.7	0.8	1.2	0.3
Production (%)	5.2	4.3	4.4	4.1
Import quantity (%)	5.0	17.5	18.7	2.2
Import value (%)	6.3	32.8	21.6	3.0
Food consumption quantity (%)	6.0	8.6	9.6	3.9

Source of data: FAOSTAT.

poorest third of urban households obtains 33% of its cereal-based calories from rice. For that same group, rice purchases represent 45% of its cash expenditures on cereals, a share that is substantially higher than for other income classes. Similar findings have been obtained in several other West African nations, demonstrating that rice availability and rice prices have become a major determinant of the welfare of the poorest segments of West African consumers who are the least food-secure.

Production and imports

In comparison with the rapid growth in demand, regional rice production rose at 4.6% annually from 1973 to 2000. Although this rate was high vis-à-vis the performance of other major crops, it meant that regional rice production only barely exceeded population growth, and was meeting only two-thirds of the increments in demand. The source of the increases in rice production carries the important danger signal that such growth is not likely to be sustainable. Regional rice yields, which average slightly over 40% of the world mean, have risen at only 1.5% per year since 1983, at 2% per year since 2001, and at 5.2% since 2007. The major source of growth has been the expansion of cultivated area, which has grown at a remarkable 3.6% annually from 1973 to 2000.

The widening gap between regional supply and demand has been met by imports. The rapid increase in demand and much slower growth in production from 1973 to 1983 contributed to a dramatic jump in imports, which rose at more than 20% annually from 0.6 million t in the early 1970s to 2.2 million t a decade later. Since 1983, growth in imports has decelerated as domestic production has improved, leading to a much more modest 2.5% annual increase in imports, which averaged 2.8 million t in the early 1990s. Imports reached more than 3 million t in 1999, costing more than $800 million in scarce foreign exchange. Imports of this magnitude represent a major brake on broader development efforts.

Rice economy liberalization and privatization

The acceleration in per capita rice consumption since the mid-1990s is due to the liberalization of rice imports combined with a downward trend of the price on the world market. Rice trade liberalization has also opened the door to the importation of low-quality rice that can be purchased by the poorest groups.

Although production efficiency is improving in irrigated areas where local farmers' organizations have taken over previously public institutions, the disruption of input supply and the unfinished reform of rural financial systems have resulted in a stagnation of yield in other areas. Most of the increase in irrigated rice production will rely on improved resource-use efficiency and rehabilitation of existing irrigation schemes. In the short term, the largest share of production will be in rainfed rice-based systems, which require labor-saving technologies. For the mid-term, intensification in rainfed lowlands through the adoption of appropriate water management technologies offers a large and sustainable potential to increase rice production.

The privatization of the government-managed rice commodity chain has also allowed the emergence and fast growth of small-scale processing units in place of parastatal industrial mills. This has resulted in decreasing rice processing costs, thus improving the overall competitiveness of local rice vis-à-vis imported rice. But, this change has also led to a degradation of average local rice quality, which is becoming quite variable. Consumers used to favor lower-quality imported rice, because it is cleaner and more homogeneous, thus requiring less time for preparation. The future of the West African rice economy depends highly on improving local rice processing to meet the demand for consistent quality.

Rice as women's crop

In many areas of West Africa, rice is produced primarily by women farmers, thus representing an important share of their

An upland rice farmer in Benin harvests a NERICA variety introduced by the Africa Rice Center.

income. Women's income tends to benefit children and other vulnerable groups more than does the income of men. Despite this fact, past efforts to develop and transfer new rice technologies have most often bypassed women farmers. Thus, although rice research can be particularly effective in improving the welfare of rural groups at risk, it needs to be explicitly structured and focused to deal with complex gender issues.

Rice, environmental degradation, and sustainable intensification

In highly populated areas of West Africa, rising cropping intensity in fragile upland ecosystems has already begun to degrade the resource base, with environmental damage and loss in production potential. Rice has a key role to play in providing options for sustainable intensification. Rice is uniquely well adapted to flooded lowland ecosystems where the soils are least fragile and best able to support continuous cultivation. The development of profitable lowland rice technologies is therefore a central element in strategies to induce farmers to reduce pressure on rapidly degraded uplands by shifting cultivation to lowland ecosystems. Relative to other cereals, rice also responds more to improved management and to higher inputs of nutrients, water control, and labor, and is thus favored as production systems intensify.

Rice-growing environments

Rice in West Africa is grown in several ecosystems and in a wide range of production systems.

The humid and subhumid "continuum" environment

This continuum is composed of several contiguous ecosystems in which rice can be grown within the warm subhumid and warm humid tropics of Africa.

Rainfed upland ecosystem. Rice in this ecosystem is sown on approximately 2.7 million ha, representing 47% of the total rice area and 40% of regional production. Although there is large scope for area expansion regionally, in locations where access to good arable soils is limited, expansion of upland rice cultivation can occur only by shifting out of other crops, by reducing the fallow period, or by exploiting soils less well suited to rice cultivation. Farm-level yields are low, averaging about 1 t/ha, and vary as a function of local soil and rainfall conditions. Moderate technical potential for increasing yield exists through improved management. Progressive farmers applying moderate input levels can now achieve yields of 2.5 t/ha, and yields of 4 t/ha and greater are commonly achieved on research stations.

Rainfed lowland/hydromorphic ecosystem. The rainfed lowland ecosystem comprises floodplains and inland valleys. Overall, rice is grown on about 1.9 million ha of rainfed lowlands representing 34% of the total rice area and 36.4% of regional production. Average yield across the rainfed lowlands is 2.0 t/ha. In the floodplains, rice can be grown on residual and water-table moisture in the broad, flat areas adjacent to rivers prone to seasonal flooding. Enormous technical potential exists to expand rice production in inland-valley lowlands, as currently only 10–15% of these areas are cultivated. It is estimated that sub-Saharan Africa has approximately 130 million ha of inland-valley lowlands and their hydromorphic fringes within which rice can be cultivated. Of this total, West Africa may have 20–30 million ha. The diversity of inland valleys is large. Although regional yields average around 1.4 t/ha, they vary according to local soil, landform, and hydrological conditions. Potential yields in unfavorable lowlands are around 2.5 t/ha, increasing to more than 5 t/ha in favorable lowlands.

Lowland irrigated ecosystem. This ecosystem covers about 142,000 ha in West Africa, representing 3% of the total area and 5.5% of regional production. The large technical potential for area expansion is constrained primarily by high investment costs. Current yields average around 3.0 t/ha. Progressive farmers employing moderate to high input management can obtain yields of 5 t/ha, and yields of 7 t/ha can be achieved on research stations.

The Sahelian irrigated environment

Irrigated rice in the Sahel forms the second most important rice-producing environment in West Africa, covering 440,576 ha (7.7% of total rice area) and producing 8.5% of regional production. Irrigation potential is much greater, estimated at more than 3 million ha along the Senegal, Niger, Black Volta, Chari, and Logone rivers. This enormous technical potential has attracted large public investments: the first irrigation schemes were constructed in the Sahel in the 1920s. Until the recent introduction of privatization policies, the state has played a lead role in developing and managing irrigated rice schemes, with over 75% of the areas currently under parastatal control. The remainder is managed by a growing and increasingly dynamic private sector.

Because irrigated rice was an introduced production system in the Sahel, there were no traditional varieties or cultural practices upon which to build. Management skills in water control and rice cultivation vary widely. Mean paddy yields are currently about 4.5 t/ha, but vary widely from as low as 1 t/ha, rising to 4–6 t/ha if water is available throughout the season, to as high as 8 t/ha with modern input-responsive varieties and optimal management. Although rice-rice double cropping is currently practiced on only about 20% of the total area, by using varieties with appropriate duration and adaptation, an annual yield potential of 15 t/ha can be achieved.

The mangrove swamp rice environment

Rice is also grown on approximately 147,000 ha of mangrove swamps, representing 3% of the total area and producing roughly 4% of the region's output. Located on tidal estuaries close to the ocean, most mangrove swamps experience a salt-free growing period during the rainy season when freshwater floods wash the land and displace tidal flows. As a result, the rice-growing period is directly related to distance from the ocean, varying between less than 4 months in the nearest estuaries to more than 6 months in those more distant. Soils are generally more fertile than in the other environments since they benefit from regular deposits of silt left during annual flooding. However, the soils are also characterized by high salinity and sulfate acidity. Lower rainfall during the last two decades has reduced seasonal flushing substantially, further accentuating both problems. Although West Africa has approximately 1 million ha of potentially cultivable mangrove swamps, the high labor costs associated with clearing and potentially negative environmental effects pose major constraints to further area expansion.

The deepwater/floating rice environments

Deepwater and floating rices represent a large but increasingly marginalized production system for which area and production figures are generally poor and vary widely. Estimates of sown area in the mid-1970s varied from 187,000 to 630,000 ha. It is generally believed that, with the control of river flooding because of the construction of dams and with lower rainfall, areas under these ecosystems have probably declined during the last 20 years. The estimated area under deepwater rice in West Africa at the end of the 1990s was 373,000 ha, or 8% of the rice-growing area, producing 5% of production at an average yield of 1.0 t/ha.

The major zones of production are located along the Niger valley around Mopti in Mali and Birnin Kebbi in Nigeria, and in northern Guinea. Deepwater rice ecosystems can be defined as those where flooding achieves a depth of from 60 to 100 cm, and floating rice systems as those where flooding exceeds 100 cm. These production systems are among the least developed in West Africa, with very little use of fertilizer or mechanization and dominated by the use of *Oryza glaberrima* and tall traditional *O. sativa* cultivars. As a result, yields are among the lowest in the region, and highly variable across sites and years. Research to improve these systems has made little progress.

Enormous potential exists to expand rice production in the inland-valley lowlands of West Africa.

Rice in East and Southern Africa

Although rice has been grown in many East and Southern African (ESA) countries for more than 500 years, it has only been in the last two decades that consumption has increased significantly. In most of the ESA countries, rice was traditionally eaten as a delicacy on special occasions, but now it is often eaten daily. Because of urbanization and many women going back into the paid work force, rice has now become a regular part of the daily diet. The time taken for and ease of preparation, and the availability of better quality rice, have been contributing factors.

The production of rice in ESA increased by 57% from 1.19 million t in 2000 to more than 1.87 million t in 2010. During this period, the average yield increased by 17.5% from 1.52 t/ha to 1.78 t/ha and the area of production increased by 37% from 782,000 ha to 1.047 million ha.

In Burundi, Kenya, Mozambique, Rwanda, Tanzania, and Uganda, total rice consumption in 2010 reached more than 3 million t or 19 kg/person/year. Rice imports amounted to 1.2 million t per year in paddy equivalent, or more than 40% of all rice consumed in the region.

In Madagascar, rice production increased from 2.48 million t in 2000 to more than 4.74 million t in 2010 and annual consumption is now more than 170 kg/person. In Madagascar, imports account for only approximately 150,000 t, or 4%, of consumption.

Many of the rice varieties that are now grown originated in Asia. They have medium to long grains that are translucent and not sticky when cooked. Aroma is also considered an important trait. Most of the older varieties have long duration, taking 140–160 days to mature, and they do not respond well to the addition of fertilizer.

Rice environments

ESA has three major rice ecosystems: rainfed lowlands, rainfed uplands, and irrigated.

Rainfed lowlands

Rainfed lowlands are the predominant rice-growing ecology in ESA, making up more than 60% of the area. Rice is grown on relatively flat fields with surrounding bunds or levy banks to maintain water in the fields. Field sizes are small, normally 0.1–0.2 ha, located on river plains and higher elevation valley floors, which have heavier textured soils. Current yields in rainfed fields are 1.0–1.5 t/ha. Better management could increase this to 2.5 t/ha. In many ESA countries, marshlands are now being turned into rice fields. In these areas, yields are 3–4 t/ha and rice is grown as part of a crop rotation, normally with beans, maize, and vegetables. In most rainfed environments, only one rice crop is grown per year.

Irrigated

Rice grown under irrigation or supplementary irrigation covers approximately 25% of the total rice area. Many old schemes are being rehabilitated and yields average 3–4 t/ha. Potential yield is 5–6 t/ha and two crops could be grown per year in many areas. Salinity is a major problem in many of these older schemes as drainage systems have not been well maintained. Continuous cropping is also being used in many areas because of insufficient water availability. This is creating management and disease problems and new varieties are required. The cost of development for irrigated schemes in ESA is very high, with many costing more than $10,000/ha to develop.

Rainfed uplands

In ESA, rainfed uplands account for 15% of the total rice area. These areas are normally on sloping land where the soils are much lighter; the fields do not have bunds or levies. Yield is less than 1 t/ha. With the introduction of new NERICA varieties, the area of upland rice has expanded significantly in such countries as Uganda.

Transplanting time in Burundi.

Constraints to production

With the increase in popularity of rice as a food staple, many ESA countries have adopted a policy to double rice production over the next 10 years. Although a proportion of this increase will come from additional land under rice cultivation, improved varieties and better crop management will also be needed. The major constraints to production are poor crop management, the lack of disease-resistant varieties, and unavailability of labor at critical times. Poor land preparation, a lack of good-quality seed, high levels of plant diseases (especially bacterial leaf blight and blast), insufficient water at crucial times, poor weed control, and high postproduction losses during harvesting and processing all contribute to lower than expected production.

Although the introduction of farm equipment to overcome labor shortages and improve the timeliness of operations is a proven technology, it has not been successful to any significant degree in the region.

New varieties are now being released in a number of countries. These are the first new varieties released in more than 15 years. Breeding programs are being more closely aligned with market requirements and disease resistance is a high priority in variety selection.

The potential to increase rice production in ESA is high as there is a ready market, large tracts of very fertile soil, and a good supply of water. However, for this potential to be realized, governments need to support the introduction of farm machines and new varieties and build local capacity to support their farmers.

Rice in North America

Rice in North America is grown in the U.S. and Mexico. The following description focuses mainly on the major producer, the U.S.

The United States

The U.S. population was approximately 310 million in 2010. The country is highly industrialized. The populace is employed principally in manufacturing and service industries, with only 1.5% directly involved in agriculture. Agriculture represents only 1.2% of the gross domestic product.

U.S. rice production in 2010 was 11 million t, accounting for about 1.6% of total world production. The rice was grown on 1.46 million ha, with an average yield of 7.5 t/ha. Rice is grown in seven states, but three states—Arkansas, California, and Louisiana—together accounted for about 82% of U.S. rice area and production. Long-, medium-, and short-grain types are grown throughout the U.S. rice areas; however, the southern states grow predominately long-grain types whereas California grows mostly medium-grain types. Most rice farms in the southern states are now planted to hybrid rice whereas California varieties remain mostly conventionally bred varieties.

Arkansas is the main U.S. rice-growing state, producing about 42% of U.S. production. Arkansas harvested 3.6 million t on 467,000 ha in 2011. California was second, harvesting 2.2 million t on 234,000 ha; followed by Louisiana, 1.2 million t on 169,000 ha; Mississippi, 0.5 million t on 64,000 ha; Texas, 0.59 million t on 73,000 ha; and Missouri, 0.38 million t on 52,000 ha. Florida and some other states also grow small amounts of rice.

Exports

The U.S. exported about 3.8 million t of rice, mostly milled, in 2010. That is about 12% of all world exports, making the United States the fourth-largest exporter of rice (after Thailand, Vietnam, and China). The main markets for U.S. rice are Canada, Haiti, Japan, Mexico, Saudi Arabia, and Turkey.

Consumption

Although low compared with most Asian countries, annual per capita U.S. rice consumption more than doubled from 1980 to an all-time high of 12.3 kg per person in 2000, but fell to 8.3 kg by 2009. Direct food use accounts for 63% of U.S. consumption; processed foods, including pet food and baby food, 22%; and beer, 15%. Part of the increase in direct food use is because of marked increases in Asian and Hispanic populations, who prefer rice, which has broadened the general interest in rice as a food. Imported rice constitutes 18% of direct food consumption; most is aromatic Thai jasmine and Indian and Pakistani basmatis, consumed by ethnic Asians and increasingly appreciated by the general American population. Arborios are also imported from Italy.

Brewing

The brewing company Anheuser-Busch is the largest purchaser of U.S. rice, buying about 8% of the annual crop. The brewing giant owns its own rice mills in Arkansas and California. Budweiser, its most popular beer brand, uses rice as an adjunct. Rice and corn flour are used in other Anheuser-Busch beers. Coors is also a rice-based beer.

Wild rice

In Asia, weedy and wild types of rice are often referred to as wild rice. However, American "wild rice," favored by gourmets, is not rice at all; it is *Zizania palustris*, a semiaquatic cousin to rice and a grass native to the Great Lakes region of the U.S. and Canada. Native North Americans have gathered and eaten wild rice for thousands of years. It is still harvested wild, although domestication in Minnesota began in the 1950s—perhaps the first cereal to be domesticated by humans since the time of the pharaohs. It is still comparatively wild with regard to plant variability and seed shattering. Wild rice is grown commercially in Minnesota, California, and Canada. In the U.S., wild rice is now grown in much the same way as "real" rice, in flooded fields, with yields of up to 1.6 t/ha in Minnesota and twice that amount in California. In

Canada, commercial production is mainly from leased lakes that are seeded; the leaseholder is given exclusive harvesting rights and much of the harvesting is done using airboats. Wild rice is a recalcitrant seed and thus cannot be dried for storage. In Minnesota and Canada, shattering onto wet soils provides the seed for next year's crop. In California, wild rice planting seed must be kept in bins saturated with water and placed in cold storage over winter.

Rice environments

Rice production data show that rice in the U.S. is grown in three principal areas: the Grand Prairie and Mississippi River Delta of Arkansas, Louisiana, Mississippi, and Missouri from 32° to 36°N; the Gulf Coast of Florida, Louisiana, and Texas from 27° to 31°N; and the Sacramento Valley of California from 38° to 40°N. The climate varies from semiarid California, with less than 50 mm of rainfall during the growing season, to the humid subtropical Gulf Coast of Louisiana, Texas, and Florida, where rainfall may total 700–1,000 mm. In all these environments, rice is grown as a single crop per year, but can be ratooned in the warmest, southernmost regions of the Gulf Coast states. Approximately 40% of Texas and southwestern Louisiana rice area is ratooned annually. All rice in the U.S. is irrigated and direct-seeded. In California, pregerminated seed is sown into standing water by aircraft. Southwestern Louisiana is also wet-seeded. Dry seeding with a mechanized grain drill is the most common method of planting in the southern U.S.

Rice is grown on natural flatlands. Nearly 100% of these flatlands in California and much of the southern U.S. have been further leveled by laser-directed machinery.

In rice monocrop systems, the land may be leveled to a slope of 0.02 to 0.05 m/100 m. In rice–row crop systems, grades of 0.1 to 0.2 m/100 m are required for drainage or irrigation of the rotation crop. Precision leveling has greatly facilitated water management and is considered second only to the introduction of semidwarf varieties as contributing to increased rice yields.

In California, where the rain-free environment and high latitude provide maximum solar radiation and low disease pressure, farm yields average 8–9 t/ha. In the humid southern rice environments, disease (primarily blast and sheath blight), warm nights, cloudy days, and frequent thunderstorms at heading limit average yields to about 6.5 t/ha.

Problems and opportunities

Although U.S. yields are high, several problems constrain production:

- In the humid subtropical climates of the Gulf Coast and Mississippi River Delta areas, diseases (particularly blast and sheath blight) limit yields.
- Because all areas are direct-seeded, weeds and poor stand establishment are significant problems. The number of weeds resistant to herbicides has greatly increased in the last 20 years, making weed control the number-one production problem for most farmers.
- In the southern U.S., many share-crop arrangements are short term and tenant farmers are reluctant to spend capital for long-term improvements to productivity.
- An indirect production constraint is embodied in concern about agriculture's role in environmental degradation. All U.S. agriculture now operates within a stringent and costly regulatory environment. One critical concern is maintaining high-quality surface water and groundwater with respect to potable water, the health of aquatic organisms, and recreational uses.
- In some areas, especially California, degradation of air quality from burning rice straw is highly regulated and rice straw disposal is a production problem.
- Concerns are increasing about the impact of rice production on global warming and climate change through methane and nitrous oxide emissions and the potential regulatory impact.

Rice research and extension are an integral part of the U.S. Department of

Agriculture and University Land Grant system, supplemented by private research and development, primarily by commercial seed and agricultural chemical producers. All of the principal rice-growing states have well-staffed and -equipped public-sector rice research stations. Scientific exchange among these institutions is linked by the U.S. Rice Technical Working Group. Linkages to IRRI and other international programs on rice are scientist-to-scientist, mostly on an ad hoc basis.

The challenges for U.S. rice production are to maintain high yields and quality as well as the sustainability of the rice-based cropping system, in the context of maintaining and improving soil, air, and water quality in an increasingly regulated environment. Improved technology and equipment for land and irrigation management and for harvesting and handling high-quality rice; varietal improvement through the integration of genetic engineering and conventional breeding programs; integrated pest and crop management; and the development of sophisticated pest control technology will be key elements in future production opportunities.

Summary data on U.S. rice production are given on page 258.

Mexico

Maize is the main staple of the 114.8 million (2011) inhabitants of Mexico, but the country currently produces more than 200,000 t of rice annually. Rice is grown in at least 17 states, the three major states being Sinaloa, Campeche, and Veracruz, each of which contributes slightly more than 20% of the nation's total rice production. Other states producing significant amounts of rice (2% to 6%) are Tabasco, Colima, Tamaulipas, Morelos, Nayarit, Michoacán, and Jalisco.

Production varied during 1980-2000 with little discernible trend. Since then, production has been gradually declining, from 351,000 t in 1980 to 217,000 t in 2010. During 1980-2000, the harvested area decreased from 127,000 ha to 84,000 ha, indicating gradual yield improvement in that period. Subsequently, the harvested area fell by about 40%, as did the harvest, suggesting little further yield gains in recent years.

Annual per capita consumption of rice fell from around 8 kg in 2000 to about 6 kg in 2009. Nevertheless, consumption is not sustained by domestic production. Imports of rice grew from less than 100,000 t in 1980 to more than 400,000 t in 2000, and have continued to increase, to 572,000 t in 2010. Most is imported from the U.S. for which Mexico is the largest export market.

More details on Mexican rice production are given on page 237.

Mechanized rice harvesting in California, USA.

Rice in Europe

Though neither a staple food nor a major crop in Europe, rice has an important sociocultural significance and ecological importance in several Mediterranean countries of Europe. Per capita annual consumption ranges from 3.5 to 5.5 kg of milled rice in nonrice-growing countries of northern Europe to 6–18 kg in southern Europe. The total rice-growing area within the 27 European Union (EU) member countries is about 450,000 ha, the average annual production about 3.1 million t of paddy rice, and average annual rice imports about 1.1 million t. EU self-sufficiency in rice is about 70%. Some 80% of EU rice production takes place in Italy and Spain, with a further 12% in Greece and Portugal. The remainder is in four other countries: France, Romania, Bulgaria, and Hungary. Outside the EU, rice is also grown in the Russian Federation (120,000 ha in the Krasnodar region and 50,000 ha in the far east region of Vladivostok) as well as in Ukraine (25,000 ha).

Sociocultural and ecological importance

Rice was introduced in Greece following Alexander the Great's expedition to Asia, as far as the banks of the Indus, in about 320 B.C. The Arabs introduced rice in the south of the Iberian Peninsula in the eighth century. Rice was then a rare foodstuff, reserved for royal tables! There is evidence of rice growing in Portugal in the thirteenth century and it was re-launched by the Portuguese navigators after the opening of the route to the Indies in the late fifteenth century. Rice doubtlessly spread to Italy from Portugal, first in the Kingdom of Naples and then in the plain of the river Po, where the crop became definitively established. With the succession of generations, each region has developed its own rice culinary specialities: *riz au gras* in the Camargue, the many Milan-style *risottos* in Italy, and the *paella valenciana* in Spain, etc. Rice has thus participated in the economic development of initially very underprivileged zones and in the emergence of social and cultural traditions that contribute to the reputation of these regions today.

European rice-growing areas resulted from the drainage of regions long considered as being unhealthy and inhospitable (the deltas of major rivers and alluvial plains) but that had abundant water resources. Rice was introduced, after substantial development work, as a "pioneer" crop that leaches the soil, making it suitable for other crops (grapevines and grain crops). Today, rice cropping plays an important role in the maintenance of ecological equilibrium and biological richness of these fragile ecosystems.

Major economic traits

Rice production is regulated through the Common Agricultural Policy (CAP) of the EU. That means financial incentives for production but also requirements in terms of environment-friendly agricultural practices: for example, with regard to water management and pesticide and fertilizer use.

The number of rice farms diminished dramatically in the last 25 years in all European countries. For instance, the total number of farms decreased to one-half in Italy and to one-fifth in Valencia, Spain. In the same period, the mean surface area per farm increased in rough proportion to the reduction in the number of farms (from 20 to 47 ha in Italy and from 1. to 4.7 in the Valencia area). In France, rice farms range from 50 to 500 ha, with holdings with more than 150 ha accounting for more than 75% of the total rice-growing area. The trend in the increase in average farm dimensions was accompanied by particularly high mechanization. espite the increase in working capacity, production costs (US 360–410 ha) remain much higher than in most Asian countries and in the U.S. This difference is largely due to the high costs of inputs: water, fertilizer, crop protection products, seed, machinery, fuel, and labor.

In application of the "Uruguay Round agreements," the liberalization of rice markets in Europe came into effect in 200 .

Mauro Centritto (right) from Consiglio Nazionale delle Ricerche, Rome, Italy, helps an IRRI technician measure photosynthesis using a Li-Cor LI-6400-40 Leaf Chamber Fluorometer.

Geographical features and major cultivation constraints

Italy is the leading European producer with a total of 220,000 ha under rice. The crop is grown mainly in the Po basin (the Piedmont, Lombardy, Venetia, and the Romagna). The other regions (Tuscany, Latium, Sardinia, etc.) provide only a complement. The second European rice producer is Spain with 117,000 ha. The two main rice-producing regions are Andalusia and Estremadura, where yields vary considerably from year to year because of the capricious water resources. Rice is also produced in Valencia, the Ebro delta, and the Navarre region that enjoy more stable water supply. Greek rice production area used to be very scattered but is now concentrated around Thessaloniki (25,000 ha). Portuguese production, also 25,000 ha, is concentrated in three regions—Coimbra, the Tagus plain northeast of Lisbon, and the Sado and Guadiana valleys. In France, the whole production (18,000 ha) is concentrated in the Camargue region situated in the delta of the Rhone River. So is the case for other EU small rice-growing countries, Bulgaria, Romania, and Hungary.

All these rice-growing areas are at the northern limit of the natural rice cultivation zone and suffer from the same constraints: a short cultural season (May to September), low temperatures at the extremities of the cycle, and irregular sunshine and harvests frequently hindered by rain. Specific varieties have therefore been bred, using mainly the temperate japonica genetic group. These have short cycles (100 to 120 days), very good cold tolerance at all stages, and good resistance to the main pests and diseases. Regarding edaphic conditions, rice is primarily grown on fine-textured, poorly drained soils with impervious hardpans and claypans that are not really suitable to other crops. Some of the soils are sandy on the surface but are underlain with hardpans.

Two other major constraints are (1) the looming water shortage and the associated increase in weed pressure and soil salinity, especially in the coastal areas, and (2) the tougher EU regulations regarding the use of pesticides, thus drastically reducing the number of families of chemicals for crop protection.

Market and consumer demand

The main components of rice quality have been defined by the EU “Regulation on the common organisation of the market in rice” (Council regulation No. 1785/2003). Quality components are mainly related to the shape, color, and integrity of the grain. Other important components are milling quality, cooking and processing behavior, and grain fissuring. The regulation distinguishes four categories, based on grain length (L) and length/width (L/W) ratio: Long A: L >6.0 mm, L/W<2.1–3.0; Long B: L >6.0, L/W = 3.0; Medium: L>5.2, L/W<3.0; Short: L <5.2, L/W <2.0.

Rice varieties grown in Europe mostly belong to the japonica group, initially associated with round to medium-long grains that readily become sticky when cooked. Local specialty varieties are highly appreciated in local markets, especially when they are associated with an *Appellation of Protected Origin* emphasizing their local origin and the environment-friendly specification of the cropping practices. However, demand for long indica-type grain, for exotic specialty rice such as Basmati and Jasmine rice, and for organic rice is rapidly growing with the increase in rice consumption in Europe, 6% per year.

Research challenges

Research challenges are to help European rice production move toward ecological intensification while diversifying grain quality to better meet consumer and industrial demand.

The impact of rice growing on the environment tends to be considered as beneficial as a result of the volumes of water applied to the land. But, as water resources are becoming increasingly scarce, the European rice-growing sector must reduce the amount of irrigation. It also has to reduce the amount of chemical fertilizers, herbicides, pesticides, etc., used in order to make the environmental impact of rice cropping as neutral as possible. This means creating new varieties with improved resource-use efficiency and resistance to biotic stresses (mainly blast and stem borers), and with indica-type grain quality. This also means new cropping practices based on conservation agriculture and the adaptation of organic rice cultivation practices to European rice-growing conditions. As the European rice sector also needs to improve its economic competitivity vis-à-vis imported rice, the new varieties should also have an improved yield potential. As an increasing number of rice farmers switch to organic rice production systems, specific varieties with enhanced weed competitiveness need to be produced. Last but not least is the management of weedy red rice.

Research and development in Europe

The EU and the FAO Mediterranean rice network encourage the research sector to work in partnership with the different countries. The FAO network includes all the rice-growing countries on the Mediterranean in the EU (Spain, France, Greece, Italy, and Portugal) and outside it (Bulgaria, Egypt, Hungary, Morocco, Romania, Russia, and Turkey). Through technical consultation and seminars, this network is making a strong contribution to the development of scientific and technical exchanges between its members, leading to collaboration in many areas: genetic resources, control of red rice, quality improvement, etc. The network has also established effective relations with rice-growing countries in other temperate zones, particularly in Australia, the United States, and Latin America.

Public research institutions with rice-dedicated teams include IVIA, Central Institute of Freshwater Aquaculture (CIFA), and Institute for Food Research and Technology (IRTA) (Spain); National Agricultural Research Foundation (NAGREF) (Greece); Computing Research Association (CRA) and Esercito Nazionale Repubblicano (ENR) (Italy); EAN (Portugal); VNIIRISA (Russia); and Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), L'Institut de reserche pour le développement (IRD), and Institut national de la recherche agronomique (INRA) (France). These research teams are collaborating with professional organizations of the rice sector in their own country. Two French research institutions (CIRAD and IRD) also have international research mandates and are members of the Global Rice Science Partnership (GRiSP).


Myanmar


Nigeria


Thailand

Selected rice-producing countries

Following are detailed descriptions of selected rice-producing countries in the three main rice regions (Asia, Latin America and the Caribbean [LAC], and Africa). Of the top 10 countries in the world during 2005-09, nine are in Asia, in order: China, India, Indonesia, Bangladesh, Vietnam, Myanmar, Thailand, Philippines, and Japan. Completing the top 10 Asian countries is Cambodia.

With fewer countries producing rice in the other regions, descriptions of five selected producers in LAC and in Africa are presented. For LAC, they are Argentina, Brazil (the 10th largest rice producer in the world), Colombia, Peru, and Uruguay. In sub-Saharan Africa, the selected rice-producing countries presented are Madagascar, Mali, Nigeria, Senegal, and Tanzania.

The top 10 countries (9 in Asia and Brazil in LAC) together account for 86% of world production.

Notes:
- For all country descriptions: GNI = gross national income, PPP = purchasing power parity.
- In all data tables, *paddy* refers to unmilled rice.


Bangladesh


Philippines


Japan

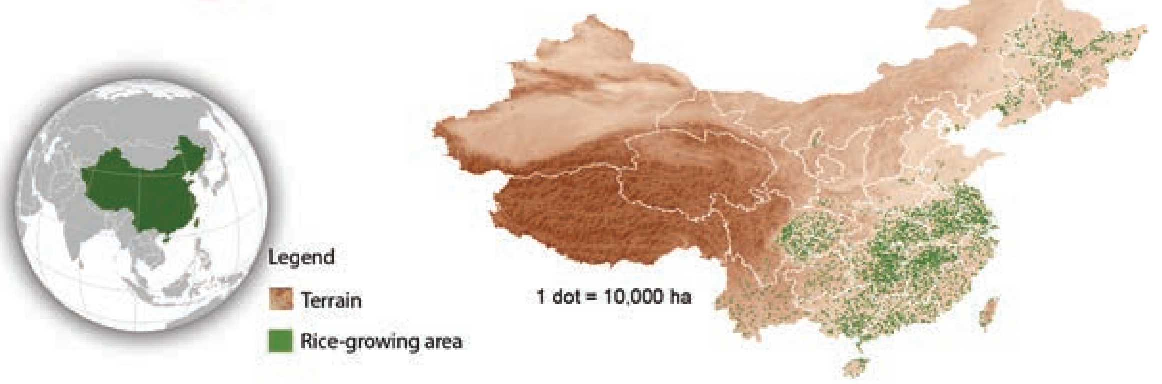

China


Vietnam


Colombia


Brazil

CHINA



General information

- GNI per capita PPP$2, 2011: 8,390
- Internal renewable water resources, 2011: 2,813 km^3/year
- Incoming water flow, 2011: 27.32 km^3/year
- Main food consumed, 2009: rice, wheat, meat, maize, starchy roots, fruits, oil crops, fermented beverages
- Rice consumption, 2010: 76.8 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Early	Feb-May	Jun-Oct
Intermediate	Feb-May	Jun-Oct
Late	Jun-Jul	Oct-Nov
Main, north	Apr-Jun	Sep

The People's Republic of China is the second-largest country in the world by land area and is either the third- or fourth-largest by total area after Russia, Canada, and the United States. It has the longest land borders in the world, measuring 22,117 km from the mouth of the Yalu River to the Gulf of Tonkin. Marked by topographical variety and complexity, China's landmass is made up of mountains (33%), plateaus (26%), basins (19%), plains (12%), and hills (10%).

China's climatic features include a pronounced monsoon climate with a hot summer and a cool winter, marked seasonal variations in precipitation, and a distinctive continental climate with large annual temperature fluctuations. The climate types are so varied and complex that high rainfall, cold waves, and typhoons are all important climatic phenomena. China can be divided from the coastal areas to the northwest interior into four regions according to moisture regime: (1) the humid region south of the Qinling Mountains and Huaihe River, comprising 32% of total land area; (2) the subhumid region including most of northeastern and central China, 15%; (3) the semiarid region, 22%; and (4) the arid region, 31%.

China is the most populous country in the world. The 2010 population on the mainland was nearly 1.4 billion, with about 53% living in rural areas. Three-fourths of the nation's population is concentrated in the northern, northeastern, eastern, and south-central areas, which make up only 44% of the nation's land area. The remaining one-fourth of the population is dispersed in the southwestern and northwestern parts. Because of an active family planning program, including some restrictions on family size, annual population growth slowed from 2.6% per annum in the late 1960s to just 0.5% per annum in 2005-10.

China is one of the fastest growing economies in the world; it has sustained a healthy average growth rate of about 10% per annum for the past several years. Since 2010, it ranks as the world's second-largest economy after the United States. The three most important sectors of the economy are industry, services, and agriculture. China also emerged as the largest exporter of goods in the world. The country's per capita GDP (PPP) rose to US$7,568 in 2010 from a mere US$1,504 (PPP) in 1995.

China is not only the world's largest producer of rice but is also the principal source of other crops such as wheat, maize, soybeans, groundnuts, cotton, and tobacco. It is currently emerging as the largest producer of a number of industrial and mineral products such as cotton yarn, coal, crude oil, and countless other consumer products such as footwear, toys, electronics, and clothing.

Recent developments in the rice sector

China is the world's largest producer and consumer of rice in the global economy. It accounts for 30% of total world production and consumption. Except for Japan and the Republic of Korea, rice yields in China are the highest in Asia (about 6.5 t/ha in the last 3–4 years), due in part to favorable growing conditions and the widespread adoption of hybrids. China is second to India in total rice area. Rice area harvested has continued to decline from its peak of 37 million ha in the mid-1970s to just over 31 million ha in 1995 to about 30 million ha in 2010. The decline in area has been due to both economic reforms that reduced government requirements to grow rice and economic development that increased the opportunity cost of land. In recent years, much of the decrease in rice area has occurred in coastal provinces such as Guangdong and Zhejiang. Hunan is the largest rice-producing province, and most rice production is in the Yangtze River Valley (or farther south) where ample supplies of water are available. However, rice production in northern China has increased substantially in recent years, with its share of national production doubling from 7.5% in 1995 to 15% in 2009. Much of this increase has come from Heilongjiang and the other two northeastern provinces of Jilin and Liaoning, but production has also expanded noticeably in Henan and Shandong.

Rice is the staple food of two-thirds of China's population. However, wheat is more important in some areas, especially in the north. Although rice is still a large part of people's diets, its importance has declined considerably in the past 15 years. The latest data available showed that rice consumption per capita declined from 78 kg per year in 1995 to 76.3 in 2009. Since 1995, the share of total calories obtained from rice fell from 29.2% (809 grams per capita) to 26.2% (794 grams per capita) in 2009. In terms of protein, rice accounted for 19.1% of total protein intake in the late 1990s, but during 2009 this share further declined to 15.7% at 14.7 grams per capita.

China regularly imports and exports rice each year. Imports exceeded exports in 1995 and 1996 but China has been a net exporter since then. In 1998 and 1999, it was the world's fourth-largest rice exporter, and its exports helped to stabilize world market rice prices in the face of a strong El Niño that severely disrupted production in Indonesia and the Philippines. However, exports became erratic but declining starting in 2000 until 2004 and 2005 when exports and imports were almost equal. China became a net exporter again in 2006 but, in 2010, at a much smaller amount at 615,900 t. Rice importing is through the state-owned enterprise China National Cereals, Oils and Foodstuffs Corporation (COFCO). China usually exports rice of medium to low quality. COFCO manages the country's rice exports and has a monopoly on rice imports as well. The trading companies are granted 50% of the rice permits. The in-quota tariff is 1% and the out-quota tariff is 65%. For rice imports, a majority are Thai fragrant rice varieties consumed in high-end hotels or restaurants located in well-off coastal cities.

China has implemented a series of programs to promote rice productivity and it imposes trade restrictions and policies aimed at raising farmers' income while managing the food demand of its growing population. Since 2004, China has begun to subsidize and remove taxes on agriculture.

To encourage production, the Chinese government introduced a machinery subsidy, which is monetary assistance granted by the government to a farmer for buying agricultural machinery. Farmers are offered a 30% discount on agricultural machinery purchased, with a maximum subsidy ranging from $7,720 to $30,879 per item (50,000 to 200,000 yuan). These subsidies target grain producers.

Presently, farmers growing superior rice varieties receive subsidies from $22 to $33 per hectare. The Agriculture and Cooperatives Ministry has been assigned to set a suitable paddy price based on capital cost and a suitable return for farmers and to quickly complete the registration of farmers joining the rice price guarantee program. The rice price guarantee scheme is as good as a typical insurance wherein an insurance buyer will be compensated if problems arise. If no problems are encountered during the harvest period, the price guarantee can be considered as a hedging cost.

The government floor price for rice (2011) for early indica and japonica varieties was set at $319.67 per ton (2,040 yuan per ton) and $401.57 per ton (2,560 yuan per ton). However, this price support program applies to only the 13 major grain-producing provinces in China: Heilongjiang, Jilin, Liaoning, Inner Mongolia, Shandong, Hubei, Henan, Anhui, Jiangsu, Shanxi, Hunan, Hubei, and Jiangxi. The guaranteed price of 50-kg bags for early indica is $15.50 (102 yuan), for middle-late indica $16.26 (107 yuan), and for japonica $19.45 (128 yuan).

When China joined the World Trade Organization (WTO) in 2001, part of its commitment was to lower the tariff rate to 65% for rice imports. However, to ensure the protection of domestically produced rice in the country, the Chinese government implemented the grain tariff rate quota (TRQ) for rice in 1996, which set a 5.3 million t quota for both private traders and state enterprises, each having a 50% allocation.

Rice environments

Rice-growing conditions in China vary because of topography and weather, but the crop is basically irrigated. In southeastern China, high temperature and adequate rainfall make an ideal environment for rice during a long growth period, and many areas grow two crops of rice per year. In the Yangtze River Valley, much of the land is planted to a rice-wheat rotation. In northeastern China, low temperature, a short growth period, little rainfall, and a lack of water limit the rice area. The varieties grown in this area are typically japonica and are considered to be of higher quality than the rice grown in other areas. Some scattered rice areas are found in arid and semiarid regions of northwestern China.

Production constraints

Area harvested to rice has declined during the past 25 years because of crop diversification. Rice accounted for 26% of all crop area harvested in the mid-1970s, but more recently the share is just 20%. At the same time, population continues to grow by about 13 million people per year. Until per capita rice consumption declines because of rising wealth accompanied by dietary diversification (as has happened in Japan, the Republic of Korea, Malaysia, and Thailand), rice yields will need to increase to meet consumption demand without resorting to imports.

Rice production in China has more than tripled in the past five decades mainly because of increased grain yield rather than increased planting area. The increase has come from the development of high-yielding varieties (including hybrid varieties) and improved crop management practices such as nitrogen fertilization and irrigation. The average yield is about 6.5 t/ha compared with the world average of only 4.3 t/ha.

As its population rises, China will need to produce about 20% more rice by 2030 to meet domestic needs if rice consumption per capita stays at the current level. This is not easy—several trends and problems in the Chinese rice production system constrain a sustainable increase in total rice production. These include a decline in arable land, increasing water scarcity, climate change, labor shortages, and increasing consumer demand for high-quality rice (often from low-yielding varieties). The major problems confronting rice production in China are as follows.

Narrow genetic background. The low genetic diversity in commercially grown rice cultivars has led to vulnerability to biotic stresses (pests and diseases) and abiotic stresses (such as drought and salinity). The situation is particularly troublesome in China because 50% of the rice-planting area is occupied by hybrid rice, which is developed using only a few varieties as the female parent.

Overfertilization. In 2002, the average rate of nitrogen (N) fertilizer application for rice production in China was 180 kg/ha, about 75% higher than the world average. Only 20–30% of this N is taken up by the rice plant, with a large proportion lost to the environment. In some cases, overapplication of N fertilizer may actually decrease grain yield by increasing the plant's susceptibility to lodging (falling over) and damage from pests and diseases.

Overuse of pesticides. On average, Chinese rice farmers—who tend to grossly overestimate crop losses caused by pests—are overusing pesticides by more than 40%. In many cases, overuse of pesticides actually contributes to pest outbreaks because it reduces the biodiversity of rice ecosystems, killing natural predators of pests as well as the pests themselves.

Breakdown of irrigation infrastructure. China's irrigation infrastructure was established mainly in the 1970s. Since then, maintenance of existing irrigation systems and building of new facilities have been very limited. Coupled with declining freshwater resources, this problem may greatly reduce the area planted to flood-irrigated rice in China.

Oversimplified crop management. Because of labor migration and increases in labor wages, decreased labor input for rice production has resulted in compromised crop management that may contribute to lower yields.

Weak extension system. Because of insufficient financial support, many extension workers earn part of their salary by selling agrochemicals to farmers, which may promote the overuse of fertilizers and pesticides. Furthermore, the weakness of the system means that improved technologies may not reach farmers.

Water shortages in the north are another important production constraint. Although northern China has only 24% of the nation's water resources, it contains more than 65% of China's cultivated land. Although water shortages constrain production in some areas, flooding is a problem. Land salinization and soil erosion also pose challenges for continued development.

The population is still growing, but increased labor demand in urban areas is drawing many people out of agricultural production and hurting yields. As a result, labor-saving technologies such as direct seeding (or seedling throwing) are becoming more common. Future trade liberalization under the WTO may also affect grain production, especially for wheat and maize, because domestic prices for these grains are substantially above world prices. For rice, however, domestic prices are approximately equal to world prices, and no large influx of imports is anticipated.

Production opportunities

Chinese scientists recently became the first in the world to prepare a draft sequence of the genome for the indica race of rice. Indica rice is by far the most widely planted in Asia, and this achievement has the potential to create many benefits for Asian producers and consumers of rice.

In seeking to alleviate the main constraints of land and water, Chinese scientists have also made substantial progress in improving yields and water productivity. China has developed the most successful varieties of hybrid rice in the world, and more than one-third of the total rice area is planted to hybrids. More recently, scientists have developed irrigation techniques for rice that reduce water consumption by allowing intermittent drying of the paddy field, without sacrificing grain yields. The successful adaptation of aerobic rice (rice that is grown as an upland crop but still exhibits a substantial response to nitrogen fertilizer) to new areas would also allow rice to be grown in water-short environments. In the future, the construction of canals from southern to northern China may also help to alleviate water shortages in the Yellow River Basin.

In other fields, there is also potential for improved fertilization strategies that increase nitrogen-use efficiency by improving the splitting of nitrogen and reducing the amounts of nitrogen application. Opportunities also exist for reducing pesticide applications to improve farmer health and the quality of drinking-water supplies.

Since 1980, China and IRRI have cooperated on several research projects of mutual concern such as the exchange of rice germplasm to strengthen breeding programs; hybrid rice research to exploit heterosis in rice; shuttle breeding to speed the development of rice varieties with high yield potential, good quality, multiple resistance to insects and diseases, and wide adaptability; and natural resource management studies to improve fertilizer- and water-use efficiencies.

Despite the challenges, good research strategies can drive increased rice production in China. These include the following.

Increasing yield potential. China has been at the forefront in attempting to develop high-yielding semidwarf, hybrid, and new plant type varieties. Further progress in increasing rice yield potential is possible when new breeding techniques such as marker-aided selection and genetic engineering are combined with conventional breeding.

Drought and heat tolerance. Drought and heat stress are increasingly important constraints to rice production in China, mostly due to variation in rainfall patterns from year to year, uneven distribution of rainfall in the rice-growing season, and higher temperatures resulting from climate change. Chinese scientists have identified and mapped genes for drought and heat tolerance, and are developing new varieties.

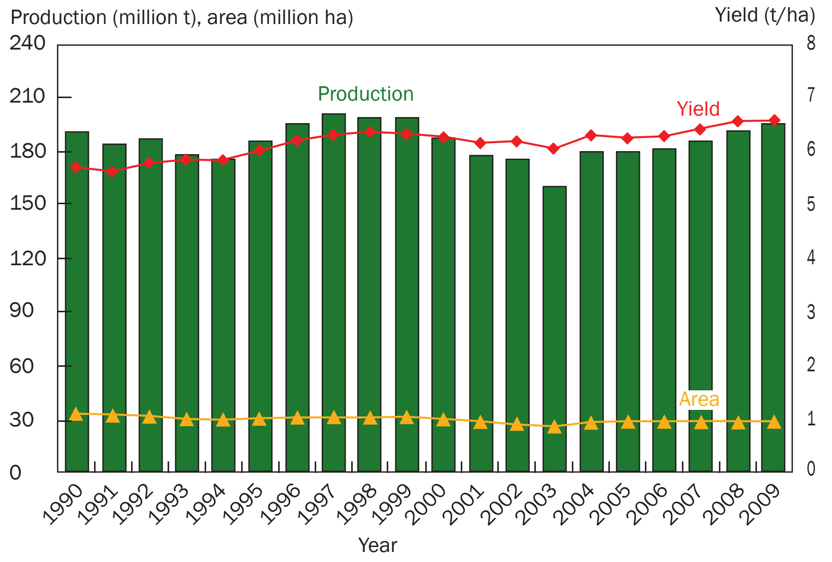
Disease and insect resistance. Huge yield losses occur because of biotic stresses every year. Chinese scientists have isolated and cloned from cultivated and wild rice species many genes that contribute to disease and insect resistance, and have transferred these into local varieties.

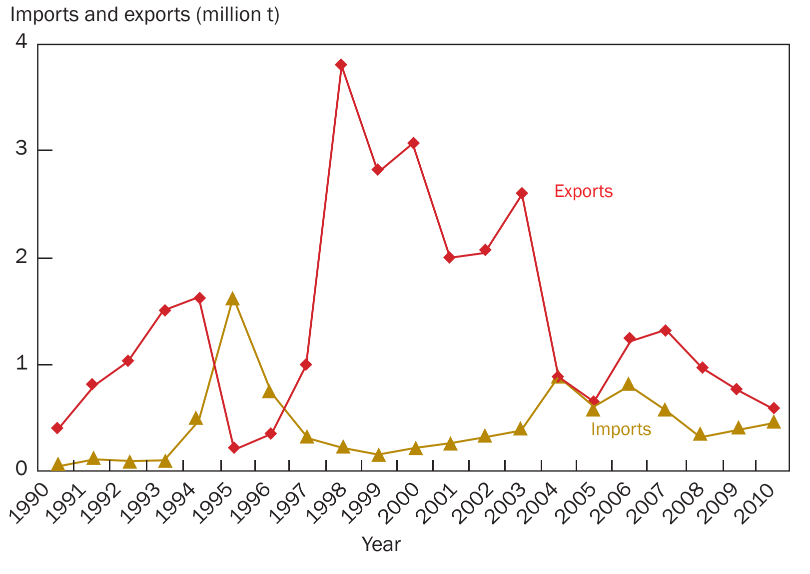
Integrated crop management. New crop management technologies need to be developed using whole-system approaches. Synergy among fertilizer, water, and pest management can maximize the overall efficiency of the production system. Sustainability of the rice production system can be maintained only when the natural resource base is protected and the health of the rice ecosystem is maximized.

Basic statistics, China

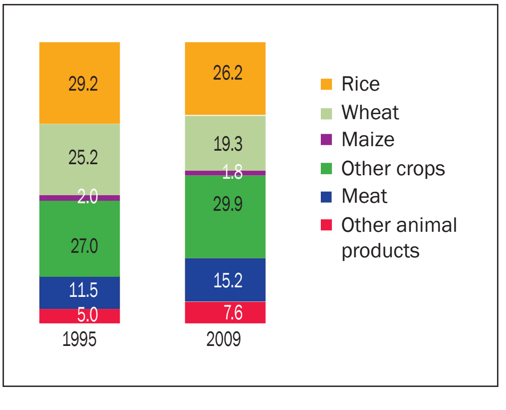
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land ($\times 10^3$ ha)	122,069	120,971	118,347	118,143	109,335	108,617	109,999	
Rice area ($\times 10^3$ ha)	31,107.5	30,301.5	29,116.4	29,557.9	29,179.1	29,493.4	29,881.6	30,117.3
Share of rice area irrigated (%)	>93	>93	100	100	100	100	100	100
Share of rice area under MVs (%)			100	100	100	100	100	100
Paddy yield (t/ha)	6.02	6.26	6.25	6.20	6.42	6.55	6.58	6.55
Paddy production ($\times 10^3$ t)	187,298.0	189,814.1	182,055.1	183,276.1	187,397.5	193,284.2	196,681.2	197,212.0
Milled production ($\times 10^3$ t)	124,928	126,606	121,431	122,245	124,994	128,921	131,186	131,475
Rice imports ($\times 10^3$ t)	1,645.8	244.7	580.8	827.3	598.7	361.9	419.7	486.1
Rice exports ($\times 10^3$ t)	235.9	3,070.6	667.4	1,231.9	1,324.8	971.2	782.7	615.9
Total rice consumption ($\times 10^3$ t)	122,955	128,686	121,316	124,704	124,754	128,745	131,182	
Fertilizer usage (NPK) (kg/ha of arable land)	291	283	409	434	487	468	488	

Source: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

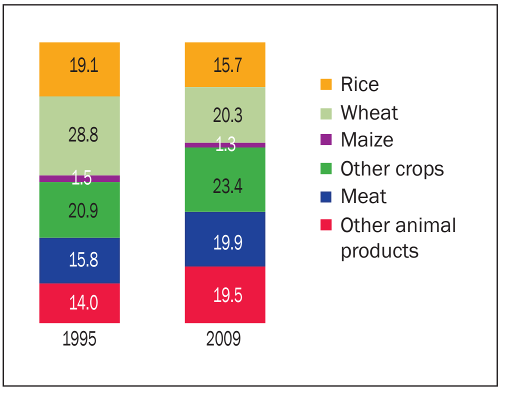




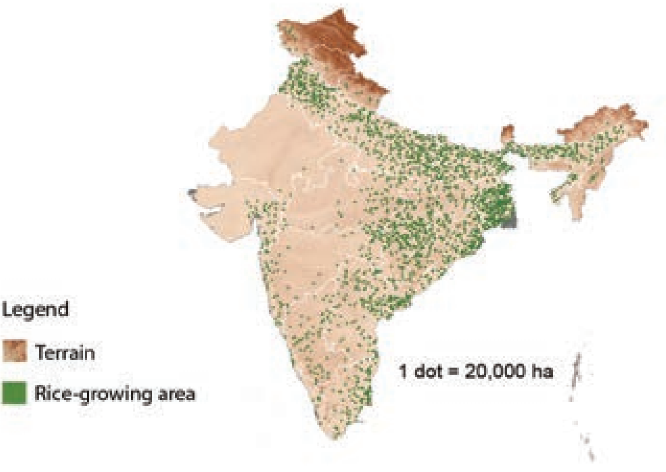
Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



INDIA



General information

- GNI per capita at PPP$, 2011: 3,590
- Internal renewable water resources, 2011: 1,446 km^3/year
- Incoming water flow, 2011: 464.9 km^3/year
- Main food consumed, 2009: milk, vegetables, including oils, rice, wheat, fruits, starchy roots, pulses, sugar and sweeteners
- Rice consumption, 2009: 68.2 kg milled rice per person per year

India, in South Asia, has a land area of 3,287,590 km^2. It measures 3,214 km from north to south between the extreme latitudes and 2,933 km from east to west between the extreme longitudes. It has a land frontier of about 15,200 km. The mainland comprises four regions: the great mountain zone, plains of the Ganges and the Indus rivers, the desert region, and the southern peninsula. On its northern frontiers, India is bounded by the Great Himalayas, which are three almost parallel ranges interspersed with large plateaus and valleys, such as the Kashmir and Kullu valleys, that are very fertile.

The climate of India can be described as tropical monsoon. There are four seasons: winter (December-February), summer (March-May), rainy southwestern monsoon (June-September), and postmonsoon, also known as northeastern monsoon, in the southern peninsula (October-November).

Production seasons

	Planting	Harvesting
Kharif early	Mar-May	Jun-Oct
Kharif medium	Jun-Oct	Nov-Feb
Rabi	Nov-Feb	Mar-Jun

The time of onset of winter and summer periods differs in different regions.

Four broad climatic regions are identified based on rainfall. The whole of Assam and the west coast of India lying at the foot of the Western Ghats and extending from the north of Mumbai (earlier Bombay) to Thiruvanthapuram (earlier Trivandrum) are areas of high rainfall. The Rajasthan desert extending westward to Gilgit is a region of low precipitation. In between are two areas of moderately high and low rainfall, respectively. The area of high rainfall is a broad belt in the part of the peninsula merging northward with the Indian plains and southward with the coastal plains. The low-rainfall area is a belt extending from the Punjab plains across the Vindhya Mountains into the western part of the Deccan region, widening considerably in the Mysore plateau.

India is the world's second-largest rice producer and second most populous nation, with a population in 2010 of more than 1.2 billion, which grew at 1.4% per year from 2005 to 2010. The rural population in 2010 was above 0.8 billion, a 70% share of the total population.

India's economy is developing into an open market economy. The service sector accounts for more than half of the country's output. The country has become a major exporter of information technology services and software workers. The other two key sectors of the economy are industry and agriculture. Traditional village farming, modern agriculture, handicrafts, extensive modern industries, and an assortment of services make up India's diverse economy. Although agriculture contributes only 18% of the country's GDP, it provided employment to more than half (51%) of the active labor force in the country in 2010. The service sector engaged 27%, while industry had a 22% share of the workforce during the same period.

Recent developments in the rice sector

Rice is the staple food for more than half of the total population and hence a key pillar for food security. It comprised 42% of total food grain production in 2008-09. Food grains include cereals such as rice, wheat, sorghum, pearl millet, and maize as well as pulses. Important commercial crops are cotton, jute, sugarcane, and tobacco. Average annual rice consumption has declined since the late 1990s and early 2000s, a period of moderate economic growth. This is one of the reasons India is able to maintain self-sufficiency in rice in spite of slowing growth in production. Rice consumption per capita decreased from 74.5 kg per year in 1995 to 68.2 kg per year in 2009. Caloric consumption per capita from rice declined from 32.5% (739 kcal per day) in 1995 to 29.1% (676 kcal) per day in 2009. Similarly, per capita protein intake from rice declined slightly from 24.8% (13.9 grams) per day in 1995 to 22.4% (12.7 grams) per day in 2009.

Rice production increased from about 115.4 million t in 1995 to nearly 144 million t in 2010. The highest amount of rice production was in 2008, 148.8 million t. However, monsoon problems and a slight contraction in rice area the following year caused production to fall but still be higher than in 1995.

With the support of state governments, India has embarked on various rice development schemes such as the Special Rice Development Program (SRPP) and National Food Security Mission (NFSM) Promotion of Hybrid Rice. The Indian government carries out domestic price support, procurement, and the distribution program in rice.

The Indian government implemented several policies to boost rice production. Numerous subsidies, ranging from fertilizer to irrigation, electricity, seeds, machinery, and food, are available. The government subsidizes agricultural inputs to keep farm costs low and increase production. Irrigation and electricity are supplied directly to farmers at below production costs. The subsidy rate for pump sets, seed drills, rotavators, knapsack sprayers, power weeders, and transplanters is 50%. Power tillers are distributed at 25% subsidy to a maximum of $989. In April 2010, a new nutrient-based subsidy scheme was implemented in which farmers are given incentives to use a better mix of nutrients. It provided a subsidy on nutrient nitrogen (N), phosphorus (P), potash (K), and sulfur (S) contents for 2010-11. There is also an additional subsidy on fertilizers carrying other secondary nutrients and micronutrients. Around 120 million farmers rely on this fertilizer subsidy. Since 2005-06, India's Ministry of Agriculture has been implementing the Production and Distribution of Quality Seeds Scheme with the target of ensuring timely availability of quality seeds of various crops at affordable prices. Under the NFSM scheme, rice farmers are provided with a subsidy of 1,000 rupees per quintal or 50% of the cost of seeds, whichever is less, for certified hybrid seeds, and 500 rupees or 50% of the cost, whichever is less, for seed distribution of certified high-yielding varieties, and the full cost of seed minikits for high-yielding varieties.

Through the Food Corporation of India (FCI), the government implements price policy through procurement and public distribution operations. The agency buys rough rice and milled rice for which a minimum support price is announced well before the commencement of the rabi and kharif seasons. They buy paddy rice directly from farmers and maintain huge rice stocks at all times. These stocks are then subsidized by the government and distributed to poorer communities across the country.

On the trading side, commitments on rice import tariffs under the Uruguay Round Agreements Act (URAA) for India are bound at 0% since 2009 up until the first quarter of 2012. The government imposed a total ban on exports of nonbasmati rice in October 2008, partially lifted it in April 2011, and removed the ban in September 2011.

Rice environments

The major rice-growing states are West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Orissa, Bihar, and Chhattisgarh, which together contribute about 72% of the total rice area and 75% of total rice production in the country. Based on India's agriculture statistics, the three largest rice-producing states are West Bengal, Andhra Pradesh, and Uttar Pradesh. These states contributed about 43% of the country's rice production in 2008-09.

Uptake of modern rice varieties has increased; the share of rice area under modern varieties grew from 64% in 1995 to 82% in 2006. Rice yield rose slightly from 2.7 t/ha in 1995 to 3.3 t/ha in 2010. The Indian Agricultural Research Institute (IARI) released the country's first F_1 hybrid basmati rice, RH-10. This hybrid has a yield potential of 7 t/ha and is presumed to yield 45% higher than Pusa Basmati. Two high-yielding varieties, Changan and Dhanu, have been released by the Kerala Agricultural University's research station at Onattukara in Alappuzha District. Also, the Central Rice Research Institute (CRRI) has released a long-duration hybrid rice, CR Dhan-701, which matures in 142 days, has superior yield over existing varieties, and is resistant to leaf blast disease.

Fertilizer use in India nearly doubled, from 86 kg/ha NPK in 1995 to 168 kg/ha in 2009. This level of fertilizer application nationally is not high but is close to optimum in the rice-growing states.

Rice production constraints

Although the proportion of rice area irrigated has improved slightly from about 50% in 1995 to almost 59% in 2008, large rice areas are still affected by uneven rainfall distribution. Erratic rainfall can cause drought or, in some cases, untimely submergence or flooding in some rice-growing areas. Other major constraints to rice production that the country faces are land, labor, and other inputs (e.g., fertilizer, herbicides, and pesticides). The latest rice program and policies that India is implementing focus on these constraints. Some support is also provided to lessen the difficulty that farmers face to access inputs and to transport their produce.

Other constraints relate to the land and soil. Soil acidity is a problem in southern and eastern India, whereas, in northern India, soil salinity and alkalinity are the problem. Low soil fertility and P and Zn deficiency are widespread.

Stem borer, brown planthopper, gundhi bug, leaffolder, green leafhopper, and gall midge are major insect pests that cause large yield losses. Bacterial blight, blast, sheath blight, and brown spot are important diseases. With increases in wage rates, weeds are becoming a major factor constraining productivity and profitability in rice farming.

Rice production opportunities

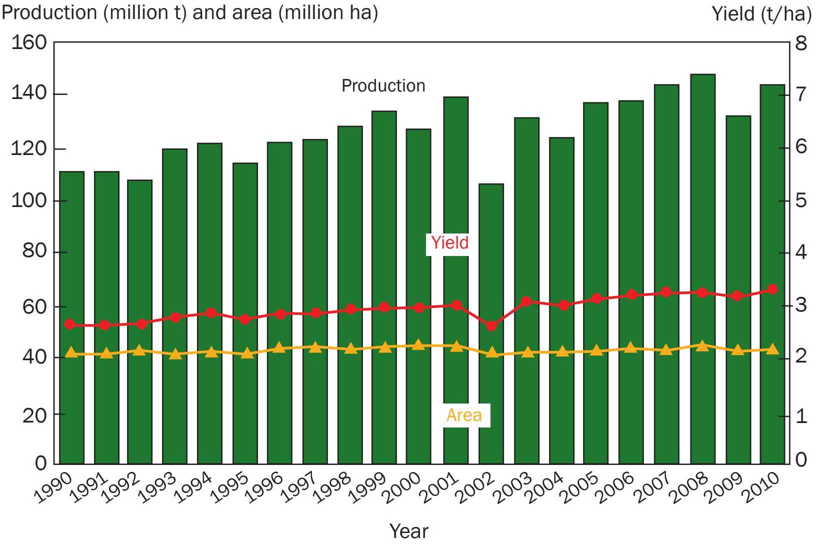
There is great scope for increasing productivity since rice yields are well below potential yield and variation is large in rice productivity among the main rice-producing states. Improvement can possibly be attained through further expansion of irrigation facilities and subsidies for irrigation, fertilizer, seeds, machinery, and appropriate technologies for increasing rice productivity in both irrigated and rainfed areas.

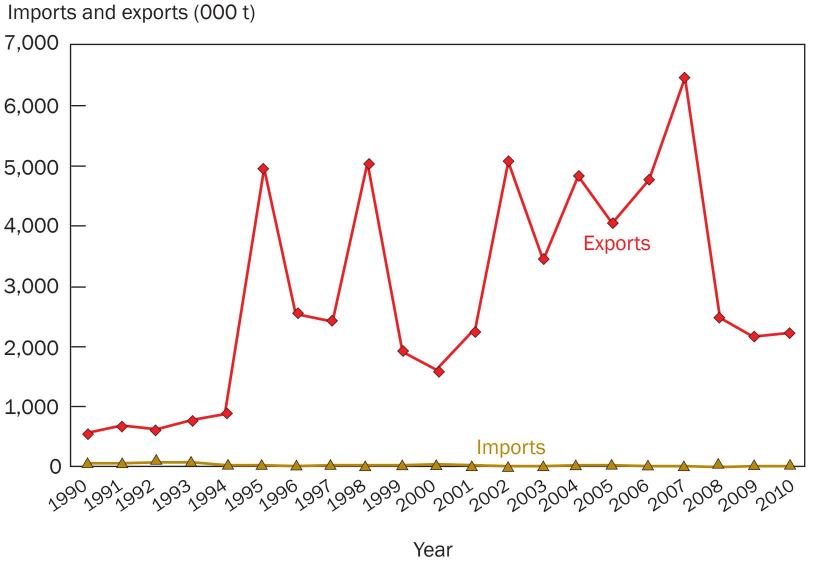
Indian rice farmers pause along the road in Odisha state.

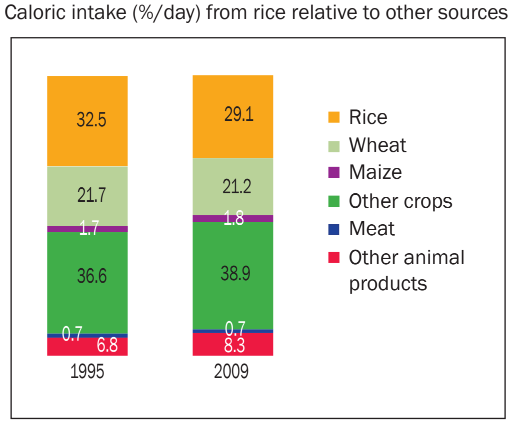
Basic statistics, India

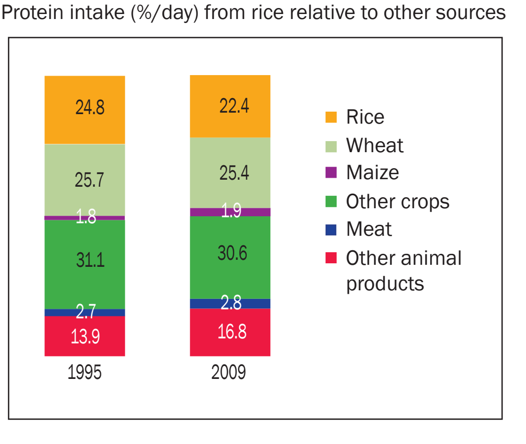
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	161,750	162,717	159,213	158,720	158,104	158,030	157,923	
Rice area (×10^3 ha)	42,800	44,712	43,660	43,810	43,910	43,540	41,850	36,950
Share of rice area irrigated (%)	49.9	53.6	56	56.6	56.9	58.7		
Share of rice area under MV (%)	64.2 (1990)	74		82.3				
Paddy yield (t/ha)	2.70	2.85	3.15	3.18	3.29	3.27	3.19	3.38
Paddy production (×10^3 t)	115,440.0	127,465.0	137,690.0	139,137.0	144,570.0	148,770.0	133,700.0	143,963.0
Milled production (×10^3 t)	76,998	85,019	91,839	92,804	96,428	99,230	89,178	95,975
Rice imports (×10^3 t)	0	13	0	0	0	0	0	0
Rice exports (×10^3 t)	4,913	1,533	4,063	4,740	6,450	2,484	2,148	2,225
Total rice consumption (×10^3 t)	78,175	82,478	87,772	88,062	87,960	93,727	89,038	
Fertilizer usage NPK (kg/ha of arable land)	86	103	128	136	143	158	168	

Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of August 2012.

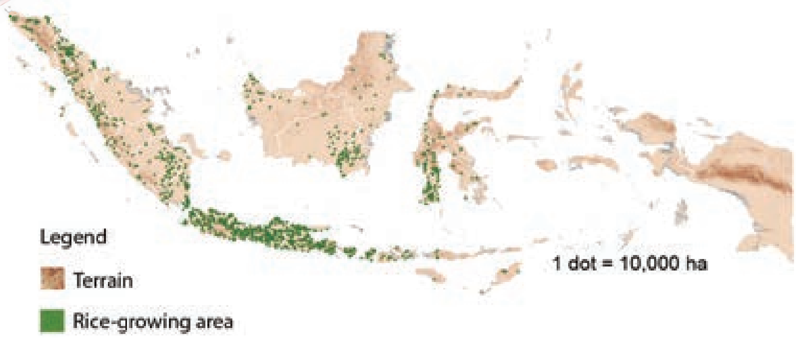

Production (million t) and area (million ha)
Yield (t/ha)
Production
Yield
Area
Year


Imports and exports (000 t)
Exports
Imports
Year


Caloric intake (%/day) from rice relative to other sources
32.5
21.7
1.7
36.6
0.7
6.8
1995
29.1
21.2
1.8
38.9
0.7
8.3
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
24.8
25.7
1.8
31.1
2.7
13.9
1995
22.4
25.4
1.9
30.6
2.8
16.8
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

INDONESIA



General information

- GNI per capita at PPP$, 2011: 4,500
- Internal renewable water resources, 2011: 2,019 km^3
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: rice, starchy roots, maize, vegetables, fruits, oil crops, fish, wheat
- Rice consumption, 2009: 127.4 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Main, Java and South Sumatra	Oct-Mar	Feb-Jun
Main, Sulawesi	May-Jun	Aug-Oct
Main, Sumatra	Jul-Sep	Nov-Dec

The Indonesian archipelago covers about 2,000 km from north to south and 5,000 km from east to west. There are more than 13,000 islands, including five of the world's largest: Sumatra, Kalimantan (the Indonesian part of Borneo), Irian Jaya (western New Guinea), Sulawesi (Celebes), and Java.

Most of Indonesia has a moist tropical climate, with abundant rain and high temperatures. Annual rainfall ranges from 1,000 to more than 5,000 mm, with more than 90% of the country receiving an average rainfall of more than 1,500 mm. December through March are the months with the highest rainfall.

Indonesia is the world's fourth most populous country with almost 240 million people in 2010. Because of rapid economic growth and a continuing active family planning program, population growth declined from 1.47% per annum during the late 1990s to 1.02% per annum between 2005 and 2010. The United Nations forecasts the country's population growth rate to drop to less than 1% by 2015. The mean population density of Indonesia was 121 per km² in 2010. Java, where nearly 60% of the population lives, is the most densely populated island in the world. The share of the population in urban areas has grown to 53.7%.

Indonesia's economy had a huge turnaround, from a negative GDP growth of 13% and high unemployment rate of 15–20% in the aftermath of the 1997-98 financial crises to a real growth of 6.3% in 2007, and 6.5% growth in 2010. The industrial sector has the largest contribution to GDP, 47%; the service sector makes up 38%; and the agricultural sector 15%.

Indonesia is now a member of the G-20 economies.[1] As a G-20 member, Indonesia

[1]The G-20 is a group formed in 1999 to allow developing nations more voice in shaping the global economy. This group of countries represents 90% of the world's economy. Its members are 8 leading industrialized countries (G-8)—the United States, Japan, Germany, United Kingdom, France, Italy, Canada, and

has taken an active role in the group's coordinated response to the global economic crisis.

The government has 141 state-owned enterprises and controls prices on several basic goods: fuel, rice, and electricity. The Ministry of National Development Planning (BAPPENAS) released a medium-term development plan targeting an average growth for the country of 6.3–6.8% for 2010-14.

Besides rice, other major crops produced in Indonesia are sugarcane, cassava, maize, sweet potato, spices, soybean, peanut, coffee, cocoa, banana, palm oil, coconut, rubber, mangoes, and oranges. The country also has an extensive variety of mineral deposits and production, including bauxite, silver, copper, nickel, gold, and coal.

Recent developments in the rice sector

Indonesia is the world's third-largest rice producer and also one of the world's biggest rice consumers. The country's rice area expanded from 11.4 million ha in 1995 to 13.2 million ha in 2010, which represented 24% of the total agricultural area. Rice yield increased slightly from 4.3 t/ha in 1995 to 5 t/ha in 2010.

Rice is the most important food crop in the country. Relative to other sources, the share of per capita caloric intake from rice fell a little from 50.7% (1,260 kcal per day) to 47.6% (1,259 kcal per day) in 2009, while rice accounted for 42.9% per day of per capita protein requirements in 1995, which likewise decreased slightly to 39.6% per day in 2009.

Rice imports declined from 3.2 million t in 1995 to about 0.69 million t in 2010. There have been concerns, however, that rice imports may surge in the future due to the continuing increase in population. Annual per capita rice consumption of 127.6 kg/year in 1995 remained almost the same as in 2009 at 127.4 kg/year. IRRI estimates that Indonesia will require 38% more rice in 25 years, which means that the present average rice yield of 4.6 t/ha must increase to more than 6 t/ha to fill the gap. To avoid huge imports, most rice policies in Indonesia have been aimed at achieving rice self-sufficiency by increasing production. The government set a production target of 10 million t of annual rice surplus for 2015 and it provides fertilizer subsidies to rice farmers cultivating less than 0.5 ha of land.

Aside from the above, the Indonesian government has had two major initiatives to increase rice production:

1. *Rice transmigration scheme 2009*: a revival of the Suharto-era transmigration scheme wherein large numbers of farmers from Java would be provided land on the outer islands to grow rice. In 2009, the newly appointed agriculture minister instructed the National Land Agency (BPN) to find ways to make as much as 6 million ha of suitable land available to rice farmers. (But no concrete plan had been developed or land made available as of 2012).
2. *Merauke Integrated Food and Energy Estate (MIFEE) 2009*: wherein the government is targeting a remote section of the province of Papua (Merauke Regency) for major commercial-scale agricultural activities, including rice, maize, sorghum, sugarcane, palm oil, timber, livestock, poultry, and fish. There is a proposed allocation of 1.2–2.5 million ha for commercial companies to produce food and energy crops with a 12-ha minimum farm size. (A land suitability study was conducted in 2008 but, as of 2010, only 500 ha of rice farms had been developed.)

A thorough review of these initiatives is needed in order to determine weaknesses/problems so that remedial measures can be applied to achieve the goals set.

To ensure that prices are stabilized, Indonesia's national logistics agency (BULOG) maintains grain stocks for the government by selling stocks when rice prices are too high or buying from farmers

Russia; 11 emerging market and smaller industrialized countries—Argentina, Australia, Brazil, China, India, Indonesia, Mexico, Saudi Arabia, South Africa, Republic of Korea, Turkey; and the European Union (EU).

when prices drop below specific levels. BULOG is in charge of carrying domestic purchases of rough rice and milled rice. It is also in charge of distributing subsidized rice for poor and vulnerable people and retaining and managing the national rice reserve stock. BULOG procures around 7% of rice production and sells this at a subsidized rate.

Rice environments

Rice is grown by approximately 77% of all farmers in the country (25.9 million) under predominantly subsistence conditions. The average farm size is less than 1 ha, with the majority of the farmers cultivating landholdings of 0.1–0.5 ha. Rice production is heavily concentrated on the islands of Java and Sumatra; nearly 60% of total production emanates from Java alone. Rice is cultivated in both lowlands and uplands throughout Indonesia, with the upland crop typically being rainfed and receiving only low amounts of fertilizer. Irrigated lowland rice is both well watered and heavily fertilized. According to the Ministry of Public Works, approximately 84% of the total rice area in Indonesia in 2012 was irrigated while the remaining 16% relied on rainfall. Rice is grown year-round, with some farmers being able to grow three crops a year, but it is common to grow two rice crops a year.

Five new rice varieties were released in Indonesia in the late 2000s: Hipa-5 Ceva Hybrid, Inpago 4, Aek Sibundong, Hipa 12 SBU Hybrid, and Inpara 4. These varieties have high yield potential and/or improved resistance to pests and diseases.

Data from the International Fertilizer Industry Association (IFA) reveal that the country's fertilizer consumption increased enormously from 0.14 million t in 1961 to 4.47 million t in 2009. FAO recorded that about 52% of all fertilizer use in Indonesia is for rice.

Production constraints

Indonesia is particularly vulnerable to the vagaries of the El Niño Southern Oscillation (ENSO) phenomenon. In years when surface-water temperatures rise substantially in the western Pacific Ocean, signaling an El Niño event, rice production suffers a serious shortfall, with most of the effects coming from a reduction in rice area planted (as opposed to lower yields). The reduction in area occurs even in systems that are usually irrigated, as lower rainfall leads to a reduced availability of irrigation water.

In upland rice areas, erosion is a serious problem because on steep slopes the fields are neither bunded nor terraced. This can cause serious sedimentation problems in lowland irrigation systems. Alley cropping as well as terracing have been introduced in some areas to reduce these problems. Upland soils are also more weathered and leached, leading to problems of aluminum toxicity and phosphorus deficiency that combine to reduce yields. Soil acidity is serious in tidal swamps because of acid-sulfate soils. These are accompanied by iron toxicity as well as some deficiencies of phosphorus and micronutrients.

Other constraints to rice production are:

- Annual loss of paddy land due to land conversion to nonagricultural use (commercial, industrial, urban), estimated at about 100,000 ha per year.
- Greater population pressure on every available hectare in the major rice-growing areas and decreasing average farm size due to traditional inheritance practices.
- Low budget for irrigation infrastructure development and repair, both centrally and provincially.
- Inadequate capital for poor farmers.
- Slow varietal replacement and slow uptake of high-yielding varieties.
- Inadequate number of highly qualified and educated crop extension and pest management officers, and lack of performance incentives for government personnel who implement major agricultural programs.

Yield growth slowed by about 0.5% per year between 1990 and 2010 and this is causing great concern. Likewise, growth in rice area weakened from 2% per year in 1960-98 to less than a 0.1% increase per year in 1999-2010. Both stagnating growth trends threaten the capability of local producers to supply enough rice to domestic markets in the coming years.

Production opportunities

Indonesia has developed a cadre of researchers capable of undertaking rice research and collaborating with colleagues in other countries. The Indonesian Center for Rice Research (ICRR), formerly the Research Institute for Rice (RIR), located in Sukamandi, West Java, is the main institute conducting biophysical rice research. Some trials and assessments on rice are also conducted by the regional institute of the Assessment Institute for Agricultural Technology (AIAT) at the provincial level. The Center for Agro-Socio-Economic Research (CASER), located in Bogor, has a long tradition of conducting socioeconomic research on rice and the broad agricultural sector.

Together with all concerned institutions, the government should exert every effort to develop more rice varieties that are high-yielding, disease-resistant, and tolerant of drought and soil toxicities; and continue the development of improved nutrient management strategies.

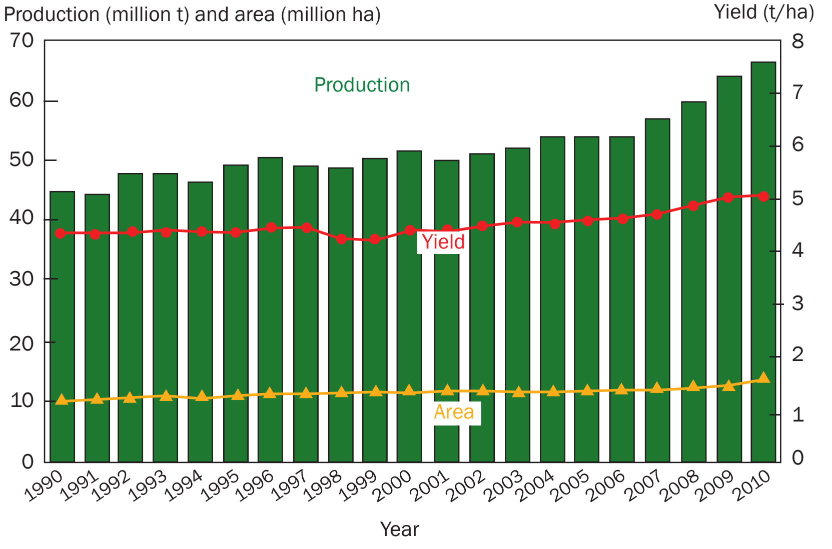
In addition, extension personnel need to be mobilized to promote and disseminate the new varieties to prevent or overcome stagnation of rice production. Performance incentives could be given to the government's extension staff.

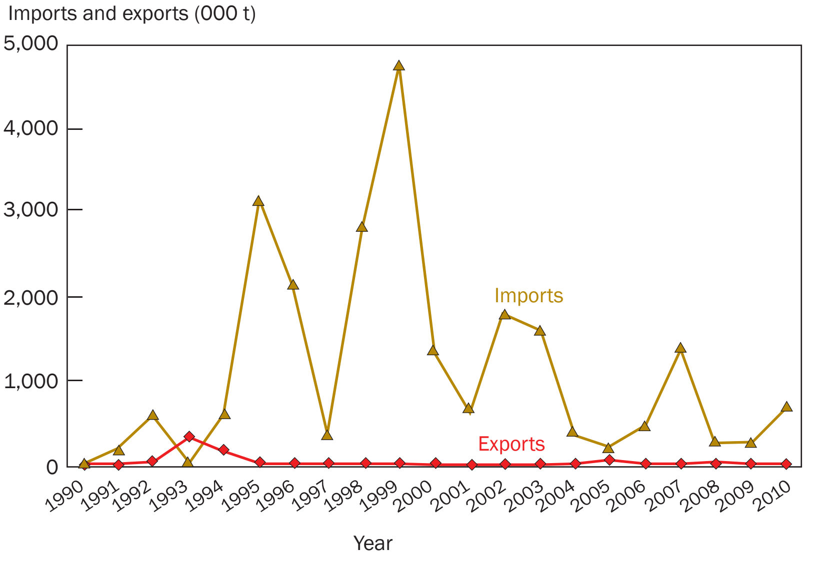
Simultaneous soil tilling and transplanting in a central Java lowland rice field.

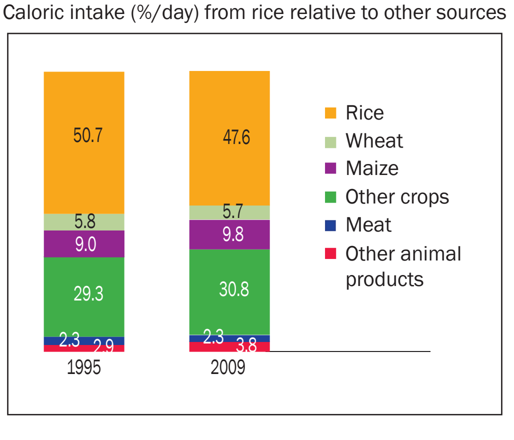
Basic statistics, Indonesia

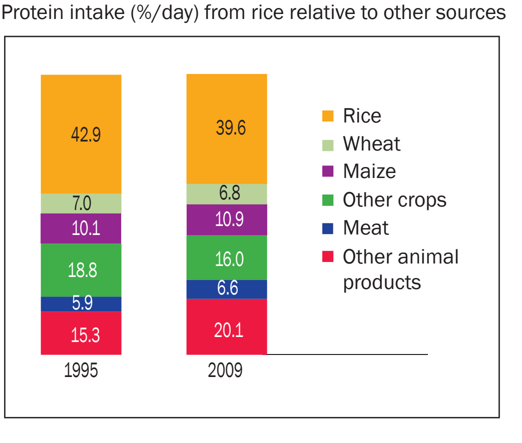
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land ($\times 10^3$ ha)	17,342	20,500	21,946	21,500	22,000	22,700	23,600	
Rice area ($\times 10^3$ ha)	11,438.8	11,793.0	11,839.1	11,786.4	12,147.6	12,309.2	12,883.6	13,253.5
Share of rice area irrigated (%)		60.1	90.7					
Share of rice area under MV (%)			84					
Paddy yield (t/ha)	4.35	4.40	4.57	4.62	4.71	4.89	5.00	5.02
Paddy production ($\times 10^3$ t)	49,744.1	51,898.0	54,151.1	54,454.9	57,157.4	60,251.1	64,398.9	66,469.4
Milled production ($\times 10^3$ t)	33,179	34,616	36,119	36,321	38,124	40,188	42,954	44,297
Rice imports ($\times 10^3$ t)	3,157.7	1,355.0	188.9	456.1	1,406.3	288.4	248.5	686.1
Rice exports ($\times 10^3$ t)	0.0	1.2	42.3	0.9	1.2	1.9	2.4	0.3
Total rice consumption ($\times 10^3$ t)	35,389	36,076	36,274	36,062	37,798	41,203	42,183	
Fertilizer usage (NPK) (kg/ha of arable land)	146	122	151	158	168	183	181	

Source: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

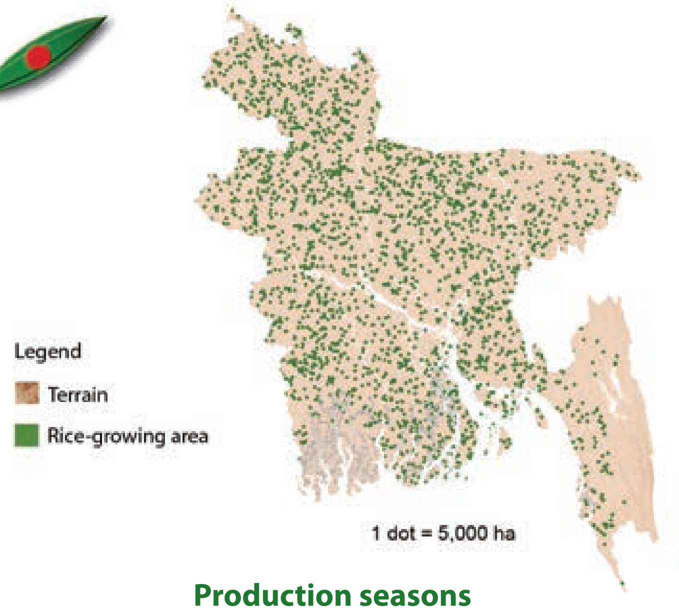

Production (million t) and area (million ha)
Yield (t/ha)
70
60
50
40
30
20
10
0
8
7
6
5
4
3
2
1
0
Production
Yield
Area
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Imports and exports (000 t)
5,000
4,000
3,000
2,000
1,000
0
Imports
Exports
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Caloric intake (%/day) from rice relative to other sources
50.7
5.8
9.0
29.3
2.3
2.9
47.6
5.7
9.8
30.8
2.3
3.8
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
42.9
7.0
10.1
18.8
5.9
15.3
39.6
6.8
10.9
16.0
6.6
20.1
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

BANGLADESH



General information

- GNI per capita at PPP$, 2011: 1,940
- Internal renewable water resources, 2011: 105 km^3/year
- Incoming water flow, 2011: 1,122 km^3/year
- Main food consumed, 2009: rice, potatoes, vegetables, including oil, fruits, milk, fish, wheat
- Rice consumption, 2009: 173.3 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Aus	Apr-May	July-Aug
Aman	Apr-May	Nov-Dec
Boro	Dec-Feb	Apr-May

Bangladesh lies in northeastern South Asia with a land mass of 144,000 km^2. The country is bounded by India on the west, north, and northeast; by Myanmar on the southeast; and by the Bay of Bengal on the south.

Except for the hilly regions in the southeast and some in the northeast, and patches of highlands in the central and northwest regions, Bangladesh consists of low, flat, fertile land. About 230 rivers and their tributaries, with a total length of 24,140 km, flow across the country down to the Bay of Bengal. The alluvial soil is continuously enriched by heavy silt deposited by the rivers through frequent flooding during the rainy season.

The country enjoys a subtropical monsoon climate. Summer, monsoon, and winter are the most prominent of six distinct seasons. Winter, which is pleasant, extends from November to February, with minimum temperature ranging from 7 to 13 °C; in summer, maximum temperature ranges from 24 to 41 °C.

The monsoon starts in June and lasts until October and accounts for 80% of the total annual rainfall, which varies from 1,200 to 2,500 mm. Maximum rainfall is recorded in the coastal areas and in the northern Sylhet and Mymensingh districts, adjacent to Assam and Meghalaya, India. Minimum rainfall is observed in the districts of Jessore, Kushtia, and Rajshahi in the western parts of the country.

Bangladesh is among the most populous countries in the world. The population in 2010 was 148.7 million, nearly half of which was in rural areas. Agriculture covers 70% of the country's land area.

Bangladesh has a rapidly developing market-based economy, which has grown at 6–7% per annum over the past few years. The service sector generated more than half of the country's GDP, while nearly half of the people are engaged in the agricultural sector. Foreign exchange earnings come from remittances from overseas workers (mainly in the Middle East) and exports of garments and textiles. Shipbuilding and cane cultivation also contribute significantly to growth. Sound fiscal policies further encourage GDP growth. The per capita GDP (PPP) more than doubled, from $675 in 1995 to $1,652, in 2010.

The main produce is rice, along with jute, fish, fruits, and vegetables. Wheat production has increased in recent years. The poultry industry is expanding and has encouraged maize production. Other goods produced in the country are textiles, leather and leather goods, ceramics, and ready-made garments.

Recent developments in the rice sector

Bangladesh is the fourth-largest rice producer. In spite of the decline in the country's arable land since its independence in 1971, the rice area harvested increased from almost 10 million ha in 1995 to nearly 12 million ha in 2010. Rice yield also improved in the last decade, from a low of 2.7 t/ha in 1995 to almost 4.3 t/ha in 2010. These increases in rice yield and area harvested contributed to growth in rice production, which nearly doubled from over 26 million t in 1995 to 50 million t in 2010.

Rice is the staple food of Bangladesh's 149 million people. Average annual milled rice consumption was 173.3 kg in 2009. The daily per capita calorie intake from rice has been falling, from 74.8% of total calories in 1995 to 69.6% in 2009. Rice's contribution to per capita protein intake also fell, from 65.3% to 56.2%, in the same period.

Bangladesh has been increasing rice production over many years and is now relatively self-sufficient in rice production. The country's rice imports declined from about 1 million t in 1995 to a mere 0.017 million t in 2009 but increased to 0.66 million t in 2010. Exports of rice began in the 2000s. Some rice is still imported, however, mainly to control domestic prices. Major rice policies have been implemented by the government to increase production and to reduce imports. Subsidy support for rice producers is provided on different agricultural inputs to keep their price within the purchasing capacity of the rice farmers. In 2010, the equivalent of $712 million was disbursed for subsidy assistance. The government provided cash subsidies to small and marginal farmers through an input distribution card that could be used to obtain cash subsidies for electricity and fuel for irrigation, fertilizer, and other forms of government support.

The government has attempted to stabilize rice prices through open market sales since 2004. This was established when the cost of food in Bangladesh began to increase sharply as a result of global price increases. This allowed people to buy rice at reduced prices from thousands of centers in district towns and union-level dealers across the country.

Rice environments

The major rice ecosystems in Bangladesh are upland (direct-seeded premonsoon aus), irrigated (mainly dry-season boro), rainfed lowland (mostly monsoon-season transplanted aman, 0–50 cm), medium-deep stagnant water (50–100 cm), deepwater (>100 cm), tidal saline, and tidal nonsaline. Bangladesh receives about 400 mm of rain during the premonsoon months of March to May, which enable farmers to grow a short-duration drought-resistant crop.

Rice area in Bangladesh expanded slightly during 2001-10; however, rice area under irrigation increased from about 30% to 73% from 1995 to 2008. During the same period, its share under modern varieties also increased from 52% to almost 80%. Two flash-flood-resistant varieties, BRRI dhan51 (Swarna-Sub1) and BRRI dhan52 (BR11-Sub-1) for submergence-prone areas; and an early-maturing variety, BINA Dhan7, were released. BRRI dhan51 was developed in 2004 when IRRI scientists implanted a submergence resistance gene in a popular high-yielding Indian rice variety. This variety has become very popular in submergence-prone areas in the country. The high-yielding rice variety BINA Dhan7 can be harvested a month earlier than other rice varieties and, hence, can avoid drought stress. This variety has high quality so it can command higher grain prices. Farmers can also get a better price for rice straw because feed is in shortage when this variety is harvested.

The urea deep placement (UDP) technology, an option for increasing nitrogen-use efficiency, involves the placement of 1–3 urea supergranules or briquettes at 7–10-cm soil depth a week after transplanting. In 2008-09, the Bangladesh Department of Agricultural Extension (with IFDC assistance) disseminated UDP technology to 0.5 million ha and achieved an annual increase in rice production of about 0.3 million t. UDP use reduced Bangladesh's urea imports by 0.05 million t in 2008.

Production constraints

Bangladesh has almost attained self-sufficiency in rice. However, sustaining this level in the coming years may be difficult considering that the country's population continues to rise ominously and rice production growth has to be achieved with fewer resources (e.g., land and water).

Sustainability is always a problem where intensified cropping systems are followed and crop residues are removed for fuel and feed. Cow dung, a traditional source of fertilizer, is being used as fuel in rural areas. The spread of modern rice varieties is associated with an increased use of chemical fertilizer. However, the removal of fertilizer subsidies in the late 1980s caused imbalances in fertilizer use, wherein there was excessive consumption of N and less P due to unfavorable prices of largely imported P and K. The increased cost of fertilizer, chemicals, and fuel accounted for the high costs of rice production in Bangladesh relative to other Asian rice producers (e.g., India, Indonesia, Thailand, and Vietnam).

Drought is a common problem although the northwestern region of the country is more prone to it than elsewhere. Farmers deal with drought through supplemental irrigation during the late monsoon. Subsurface groundwater is available throughout the country. Irrigation by small-scale tube wells and low-lift pumps commenced in the late 1970s and spread extensively when the importation of agricultural machinery was liberalized in the late 1980s. Overexploitation of groundwater, however, is becoming an environmental concern with adverse effects on the supply of drinking water; there are suspected links to arsenic-contaminated water.

Although flooding occurs yearly, it causes severe damage only about once every 10 years. Usual flooding is merely a part of the ecosystem and helps maintain soil quality. The flood-prone areas are mainly suited for boro rice, since water is available during the dry season and the cost of irrigation is low.

Soils in coastal areas are affected by salinity. Most soils are low in organic matter (many less than 0.5%) and subsequently low in N. Zinc and sulfur deficiencies are prevalent; replacement amounts of P and K are inadequate.

Production opportunities

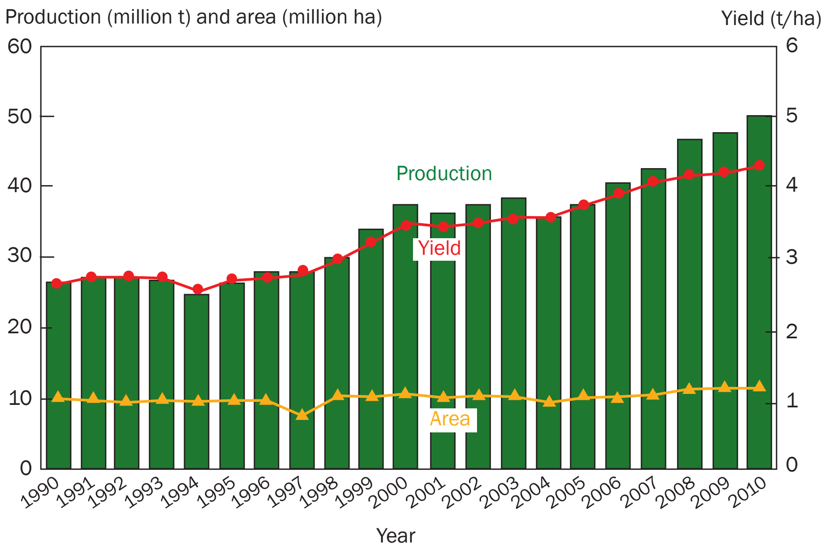
Targeted breeding works well in Bangladesh's diverse environments. The development of more high-yielding, different maturity period, drought-tolerant, salt-tolerant, disease-resistant, submergence-resistant, and possibly nutrient-rich varieties will further boost rice production and nutrition. Effective fertilizer and other crop management strategies will likewise enhance rice production. Hence, the government should increase investment in rice research and extension to further improve yield and reduce the costs of rice production in the long run. Providing a subsidy to reduce the cost of groundwater irrigation will encourage risk-averse and resource-poor farmers to continue to engage in rice production.

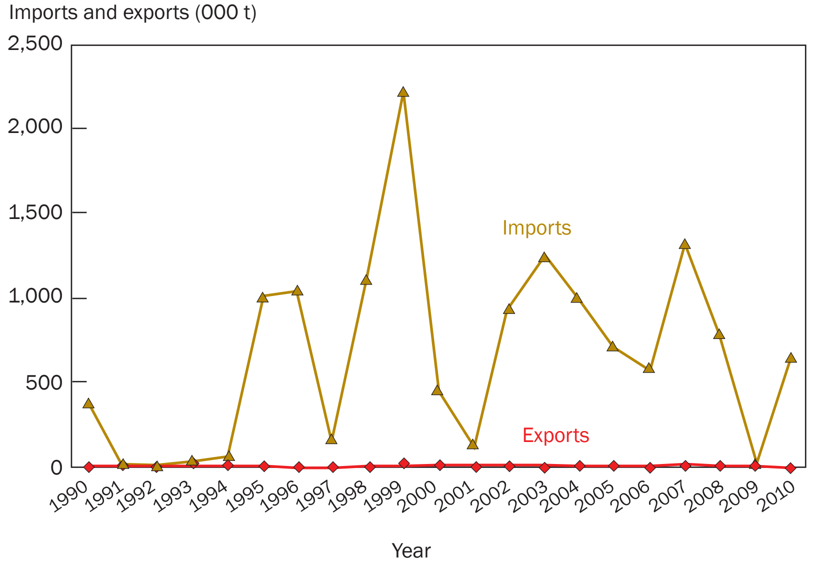
Sun drying of rice in Jessore.

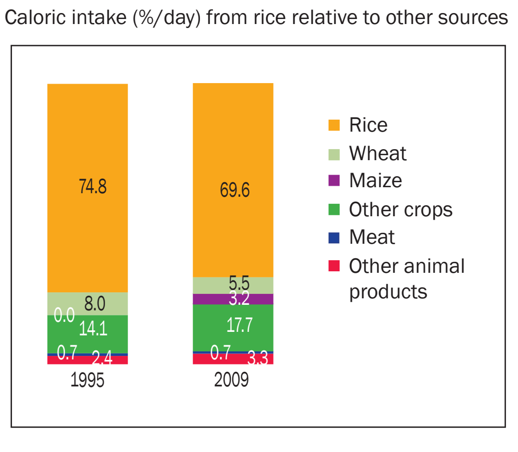
Basic statistics, Bangladesh

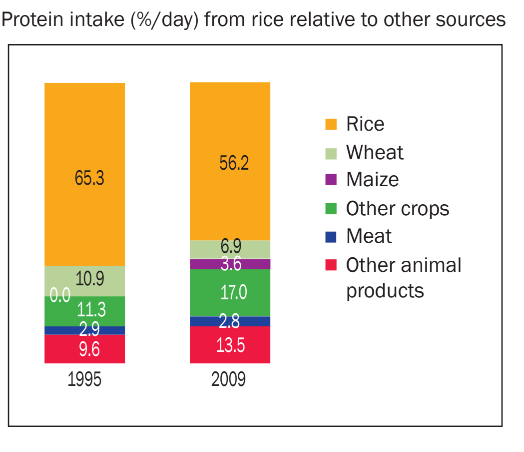
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	8,404	8,380	7,931	7,910	7,838	7,532	7,569	
Rice area (×10^3 ha)	9,951.7	10,801.2	10,524.1	10,579.0	10,575.0	11,280.0	11,353.5	11,700.0
Share of rice area irrigated (%)	29.5	31.9	43			73		
Share of rice area under MV (%)	52.2	63.2	72.2	75.0	79.9	79.7	79.4	
Paddy yield (t/ha)	2.65	3.48	3.78	3.85	4.08	4.14	4.20	4.28
Paddy production (×10^3 t)	26,399.0	37,627.5	39,795.6	40,773.0	43,181.0	46,742.0	47,724.0	50,061.2
Milled production (×10^3 t)	17,608	25,098	26,544	27,196	28,802	31,177	31,832	33,374
Rice imports (×10^3 t)	995.9	452.1	709.4	577.1	1,328.3	789.5	16.8	656.8
Rice exports (×10^3 t)	0.1	0.7	4.6	16.3	18.8	8.8	5.2	3.9
Total rice consumption (×10^3 t)	19,768	23,616	26,191	28,176	29,395	29,669	30,824	
Fertilizer usage NPK (kg/ha of arable land)	142	158	197	192	184	173	282	

Source: FAOSTAT, AQUASTAT database of the FAO, and national statistical sources as of September 2012.

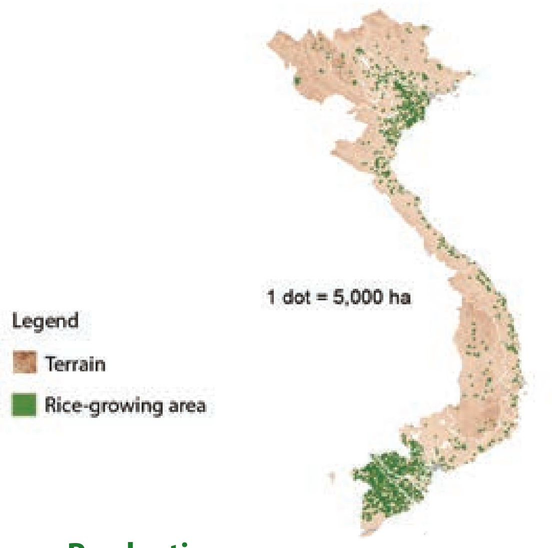

Production (million t) and area (million ha)
Yield (t/ha)
60
50
40
30
20
10
0
6
5
4
3
2
1
0
Production
Yield
Area
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Imports and exports (000 t)
2,500
2,000
1,500
1,000
500
0
Imports
Exports
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Caloric intake (%/day) from rice relative to other sources
74.8
8.0
0.0
14.1
0.7
2.4
69.6
5.5
3.2
17.7
0.7
3.3
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
65.3
10.9
0.0
11.3
2.9
9.6
56.2
6.9
3.6
17.0
2.8
13.5
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

VIETNAM



General information

- GNI per capita at PPP$, 2011: 3,250
- Internal renewable water resources, 2011: 359.4 km^3/year
- Incoming water flow, 2011: 524.7 km^3/year
- Main food consumed, 2009: rice, vegetables, fruits, meat, fish, starchy roots, wheat, sugar and sweeteners
- Rice consumption, 2009: 141.2 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Main	May-Aug	Sep-Dec
Winter-spring	Dec-Feb	Apr-Jun
Summer-autumn	Apr-Jun	Aug-Sep

Vietnam is located along the eastern margin of the Indochina peninsula in Southeast Asia, covering an area of 331,051 km^2. It is bounded by Cambodia, Laos, China, and the South China Sea.

Over 30% of the country is forested and about 17% is cultivated for seasonal crops, with another 5% under permanent crops. Climate varies from humid tropical in the southern lowlands to temperate in the northern highlands. There are two monsoon seasons: the northeastern winter monsoon and the southwestern summer monsoon. Destructive typhoons sometimes develop over the South China Sea during hot weather. Mean annual sea level temperatures range from 27 °C in the south to 21 °C in the extreme north.

Mean annual rainfall ranges from 1,300 to 2,300 mm. Rainfall is usually evenly distributed through June to October or November. In the Mekong Delta, the summer monsoon brings 5–6 months of rainfall above 100 mm/month. October is the wettest month of the year.

The population of Vietnam was about 87 million in 2010, with an average density of 263 people per km^2. The population grew at 1.1% per year during 2005-10. Seventy percent of the population lives in rural areas, mainly in the two rice-growing deltas: the Red River Delta in the north and the Mekong River Delta in the south. The Red River Delta's population density (939/km^2) was higher than that of the Mekong River Delta's (426/km^2) and elsewhere. The country's total labor force was above 47 million, with more than half engaged in agriculture.

The economy continues to improve, although agriculture's share of economic output (GDP) dropped from about 25% in 2000 to almost 21% in 2010, as the share of the industrial sector surged to 41% and the service sector to 38% of GDP in the same period.

The country's primary produce is rice, coffee, rubber, cotton, tea, pepper, soybeans, cashews, sugarcane, peanuts, bananas, fish, seafood, and poultry.

Recent developments in the rice sector

Vietnam is the world's fifth-largest rice-producing country. Rice production has continuously increased, from 25 million t in 1995 to almost 40 million t in 2010. This increase can be attributed to some expansion of rice harvested area and higher yield. Rice yield improved to 5.3 t/ha in 2010 from 3.7 t/ha in 1995. The use of input-responsive modern varieties, sufficient fertilizer, and an increase in the proportion of rice area (93.4%) under irrigation account for the high yields in recent years. Although the rice area harvested expanded from 6.8 million ha in 1995 to 7.5 million ha in 2010, annual growth was only 0.5% from 2005 to 2010.

Rice remains the staple food. Average annual per capita consumption rose to 141.2 kg in 2009 from 138.8 kg in 1995. However, the share of total calories per person obtained from rice decreased to 51.7% (1,390 kcal) per day in 2009 from 66.6% (1,407 kcal) per day in 1995. Similarly, the per capita protein intake from rice fell to 38% (28.3 g) per day in 2009 from 56.7% (28.7 g) per day in 1995. These declines are due to an increase in consumption of other sources such as wheat and meat. The shares of both wheat and meat as sources of calories and protein increased during 1995-2009.

Vietnam is one of the world's leading rice exporters. The country's rice exports reached 5.3 million t in 2005 and almost 6.9 million t in 2010. The decline in exports to an average 4.7 million t during 2006-08 led the head of the Ministry of Cultivation in 2009 to raise concern about the conversion of agricultural land into commercial land: too much rice land was being converted for housing projects and golf courses. He argued that, if this continued, coupled with fast-increasing population, the country would have difficulty in meeting the demand for rice exports by 2020.

Vietnam has changed from a highly centralized planned economy to a socialist-oriented market economy that uses both directive and suggestive planning. With the country's commitment to economic liberalization and international integration, it employed structural reforms required to modernize the economy and to create more competitive export-driven industries. Vietnam joined the World Trade Organization in January 2007, which secured the country's link to the global market and fortified the domestic economic reform process.

Moreover, Vietnam became an official partner in developing the Trans-Pacific Partnership trade agreement in 2010. This agreement brings together a significant number of Asia Pacific Economic Cooperation (APEC) economies under a single free trade agreement.

Present rice policies in Vietnam are a balance between maintaining domestic food security and promoting rice exports. Government intervention is limited in the domestic market and a majority of rice exports in the country are made through state-owned trading enterprises (50% share), particularly by the Vietnam Food Association (VFA). VFA buys rice from farmers to keep the price of rice stable and also to prevent rice importers from haggling for prices too low during the harvest season.

Rice environments

The Mekong River Delta produces most of Vietnam's rice. The other rice-growing regions are the Red River Delta, northeast, and the north-central coast. The Mekong Delta has three major cropping seasons: spring or early season; autumn or midseason; and winter, long-duration wet-season crop. The largest rice area is cropped during the autumn season followed by a spring crop; only a small area is cropped in winter. Farmers in this region adopt a direct-seeding method of crop establishment to save labor costs.

Soils in the Mekong River Delta are highly variable, but alluvial, acid-sulfate, and saline soils dominate. Alluvial soils predominate in 30% of the Mekong Delta, mostly along the banks of the Tien (Mekong) and Hau (Bassac) rivers. This is the best soil in the delta, wherein 2–3 crops can be grown each year. The Red River Delta, which is densely populated, has very small landholdings and has long been

Planting missing hills in the Mekong Delta.

practicing very intensive double-crop rice cultivation.

Rice production constraints

Rice production in Vietnam faces the following constraints:

- Shrinkage in rice area for rice cultivation due to land conversion to commercial lands, which will result in a decrease in total rice production.
- Inadequate credit facilities, which limit farmers' input use due to insufficient capital.
- Limited access to inputs.
- Inadequate water during summer-autumn seasons.
- Soil degradation brought about by a long-term high cropping intensity, which could deplete soil fertility.
- High inflation rate (about 11%), which increases input costs.
- Small landholdings, which restrict farmers' ability to produce rice for export.

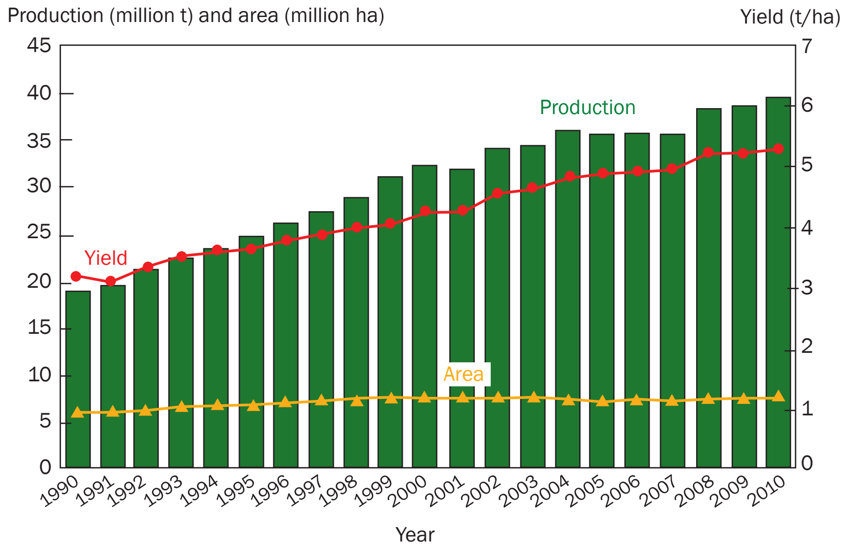
Rice production opportunities

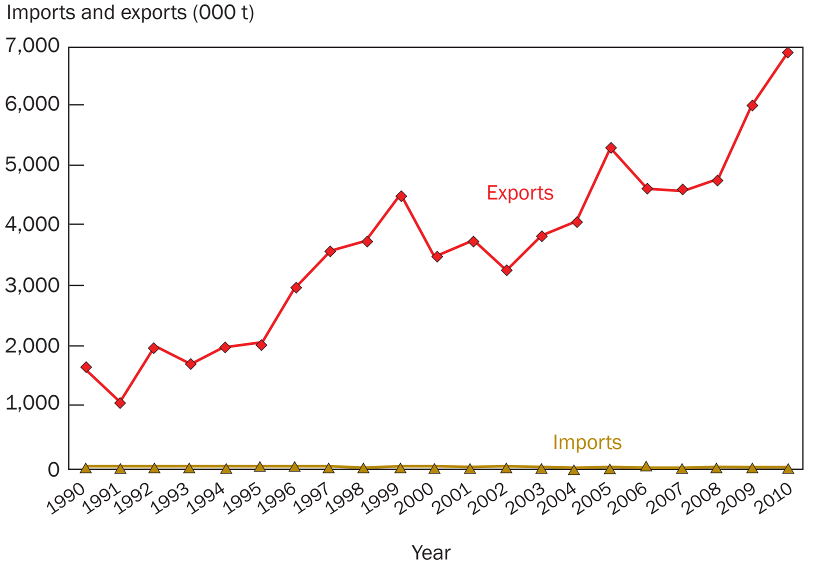
In spite of these production constraints, there are great opportunities to overcome them. For instance, increased development and deployment of high-yielding varieties can offset the decline in rice area due to urbanization; improved crop management technologies can possibly avert soil degradation.

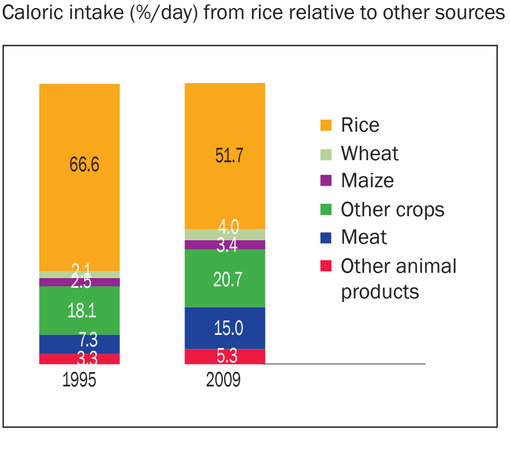
Basic statistics, Vietnam

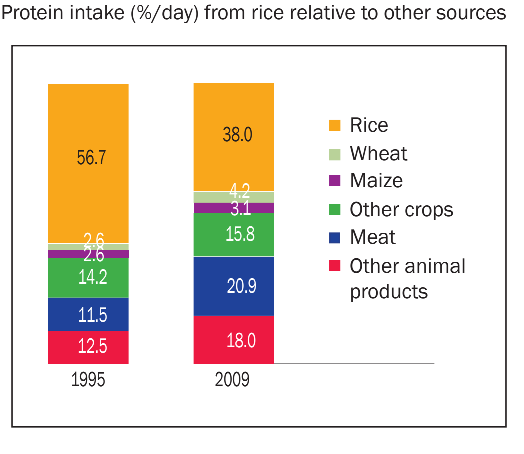
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	5,403	6,200	6,358	6,348	6,310	6,283	6,280	
Rice area (×10^3 ha)	6,765.6	7,666.3	7,329.2	7,324.8	7,207.4	7,400.2	7,437.2	7,513.7
Share of rice area irrigated (%)	64	85 (2002)	93.4					
Share of rice area under MVs (%)	76	94.2 (2002)						
Paddy yield (t/ha)	3.69	4.24	4.89	4.89	4.99	5.23	5.24	5.32
Paddy production (×10^3 t)	24,963.7	32,529.5	35,832.9	35,849.5	35,942.7	38,729.8	38,950.2	39,988.9
Milled production (×10^3 t)	16,651	21,697	23,901	23,912	23,974	25,830	25,943	26,659
Rice imports (×10^3 t)	11.0	0.0	0.3	0.6	2.1	0.7	0.8	1.0
Rice exports (×10^3 t)	1,988.0	3,477.0	5,250.0	4,642.0	4,558.0	4,735.2	5,968.8	6,886.2
Total rice consumption (x10^3 t)	14,221	16,647	17,837	17,857	18,106	20,691	19,934	
Fertilizer usage (NPK) (kg/ha of arable land)	226	366	292	300	353	306	402	

Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

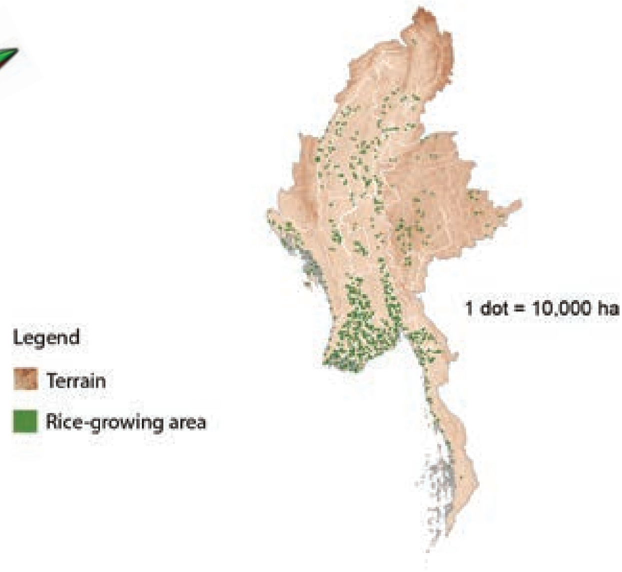

Production (million t) and area (million ha)
Yield (t/ha)
Production
Yield
Area
Year
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
0 5 10 15 20 25 30 35 40 45
0 1 2 3 4 5 6 7


Imports and exports (000 t)
Exports
Imports
Year
0 1,000 2,000 3,000 4,000 5,000 6,000 7,000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


Caloric intake (%/day) from rice relative to other sources
66.6
2.1
2.5
18.1
7.3
3.3
1995
51.7
4.0
3.4
20.7
15.0
5.3
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
56.7
2.6
2.6
14.2
11.5
12.5
1995
38.0
4.2
3.1
15.8
20.9
18.0
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

Myanmar



General information

- GNI per capita at PPP$, 2010: 1,950
- Internal renewable water resources, 2011: 1,003 km^3/year
- Incoming water flow, 2011: 165 km^3/year
- Main food consumed, 2009: rice, vegetables, fish, fruits, meat, pulses, oil crops, sugar
- Rice consumption, 2009: 140.8 kg milled rice per person per year

Myanmar is the largest country of Southeast Asia's mainland. It has a common boundary with Bangladesh, India, China, Lao PDR, and Thailand. There are six distinct regions: the western, northern, and eastern mountain ranges; the delta area of the Ayeyarwady and Sittoung rivers; the coastal strips; and the central plain or dry zone. The land area is about 66 million ha, of which only 11 million ha are under cultivation for annual crops. There is a potential for reclamation of substantial arable land.

Generally, the country receives rain from the southwest monsoon, which normally starts in May and ends in October. Being on the windward side, coastal strips and deltaic regions receive heavy rains, from 2,560 to 6,150 mm annually. The leeward central plain or dry zone receives lower and erratic rainfall, 700 to 1,200 mm annually. Mean annual rainfall is 2,341 mm.

Production seasons

	Planting	Harvesting
Main	Jun-Aug	Nov-Jan
Dry	Nov-Dec	Apr-May

Of the population of 48 million, 67% are in rural areas and depend on agriculture, which generates 36% of GDP, as a source of livelihood. Many of the remainder (23%) are engaged in the services sector.

Myanmar is a resource-rich country. Aside from rice, it produces beans, pulses, sesame, groundnuts, sugarcane, fish and fish products, wood products, and garments. It is endowed with natural gas, petroleum, timber, tin, antimony, zinc, copper, tungsten, lead, coal, marble, limestone, and precious stones.

Recent developments in the rice sector

Myanmar is the world's sixth-largest rice-producing country. Rice is the country's most important crop and is grown on over 8 million ha, or more than half of its arable land. The country's rice production increased from around 18 million t of milled rice in 1995 to over 22 million t in 2010. Some area expansion and yield increase accounted for the improved rice production.

However, it will be some years before the country can regain its former position as one of the world's largest rice exporters. Myanmar's rice exports dropped from about 0.4 million t in 1995 to 0.12 million t in 2010. The country has been importing about 0.02 million t annually in recent years.

In spite of a decreasing use of fertilizer, rice production grew at 3% per year in 2005-10. Modern varieties are cultivated extensively but, because lower amounts of inputs (e.g., fertilizer and herbicide) are applied, farmers are not achieving the yield potential of these modern varieties. Rice yield rose to 4.1 t/ha in 2010 from about 3 t/ha in 1995 and yield growth was 1.9% per year in 2005-10. Rice yield reached 4 t/ha in 2008 and the stagnation since then could be due to the lower amount of fertilizer applied by rice farmers.

Rice remains the staple food in Myanmar. The country's annual per capita rice consumption declined slightly from 170 kg in 1995 to 141 kg in 2009, but total rice consumption increased by more than 60% in the same period, due to the surge in population size. Parallel to the small drop in per capita rice consumption, caloric intake per person from rice declined from 68.4% (1,451 kcal) per day in 1995 to 48.3% (1,204 kcal) in 2009, while the share from other crops increased from 23.7% per day to 34.3% per day in the same period; daily protein intake per capita from rice fell sharply from 63.6% to 34.5%.

In January 2010, there was a major reorganization in Myanmar's domestic rice industry. The Myanmar Rice Industry Association (MRIA) was established by the country's leading rice producers, traders, and exporters from three separate organizations[1] that joined forces to make Myanmar's rice industry more competitive with rival countries such as Thailand and Vietnam.

To further enhance production, the government provides credit programs for low-income farmers in the Mandalay region. Similarly, the government encourages private companies to provide microfinance to rice farmers to buy rice seeds and other agricultural inputs.

Rice environments

The rice ecosystems of Myanmar include irrigated lowland, rainfed lowland (including late-sown and *Mayin* area), deepwater, and upland. Late-sown rainfed lowland is the area sown during the monsoon period; *Mayin* rice can be transplanted only after the monsoon when floodwater recedes.

Rainfed lowland (the largest of the ecosystems) and deepwater rice are confined to the delta region and coastal strip of Rakhine State. Nearly 60% of the delta region, including the Ayeyarwady, Bago, and Yangon region of Lower Myanmar, is cultivated with rainfed rice. Because of rainfall and hydrologic patterns, irrigation is critical in Myanmar's central dry zone, whereas, in the delta, there is more concern about drainage and flood protection. The country's upland area is mostly in Mandalay, Sagaing, and Shan states. Some upland area in Shan State occupies sloping land, which becomes cold in the northern winter.

Fertilizer use in Myanmar is decreasing and notably very low. On average, farmers applied only 5 kg NPK per ha of arable land in 2009, which was about a quarter of the amount applied in 1995. This indicates a much lower level for rice.

Rice production constraints

Insufficient capital due to limited access to formal sources of credit forces farmers to apply less farm inputs, particularly fertilizer, which makes their rice crop less productive.

Inadequate infrastructure (e.g., irrigation, farm-to-market roads) and postproduction facilities (e.g., mills, storage) hinder growth in rice production. The lack of better farm-to-market roads causes rice farmers to incur higher transportation costs for their produce. Products have to cross the Thai border and pass along the Ayeyarwady River. The railroads are very old, with very few repairs made since construction in the 1800s. Most highways are unpaved except in major cities. Grain quality is affected by

[1]The three former separate associations were the Myanmar Rice and Paddy Traders' Association, Myanmar Rice Millers' Association, and the Myanmar Paddy Producers' Association.

Myanmar has the potential to become a major rice exporter.

the country's simple storage facilities and antiquated mills. As a result, rice farmers in Myanmar are getting only 30% of the export price of rice received by their counterparts in other Southeast Asian countries such as Vietnam for their better-quality rice.

Rice production opportunities

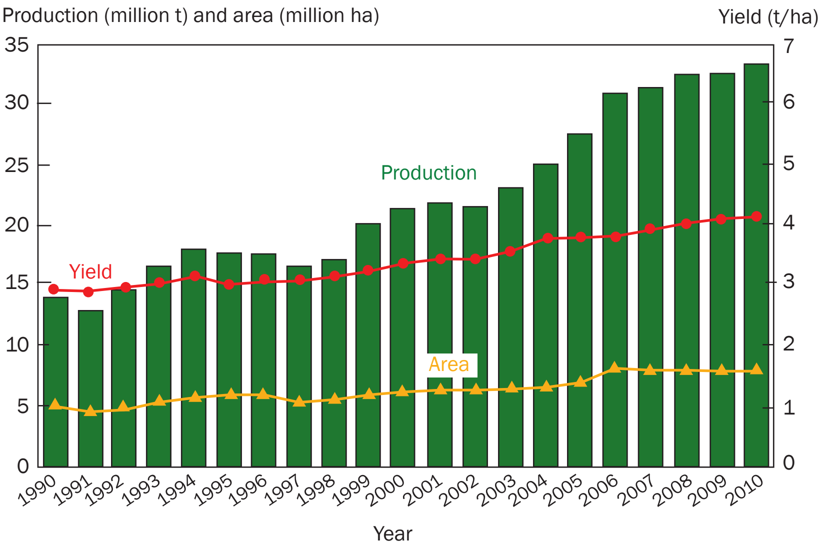
Rice yield can be further improved with the use of more inputs, especially fertilizer. A provision of credit facilities would enable farmers to buy the inputs needed to achieve higher yield/production. Adequate irrigation facilities are required for a steady supply of water, rather than depending solely on erratic rainfall in the central plain or dry areas. Better rice mills, storage facilities, and farm-to-market roads would ensure high-quality milled rice for export, a premium price, and lower transportation costs for farmers' produce. These would result in improved income for farmers, giving them incentives to continue rice farming.

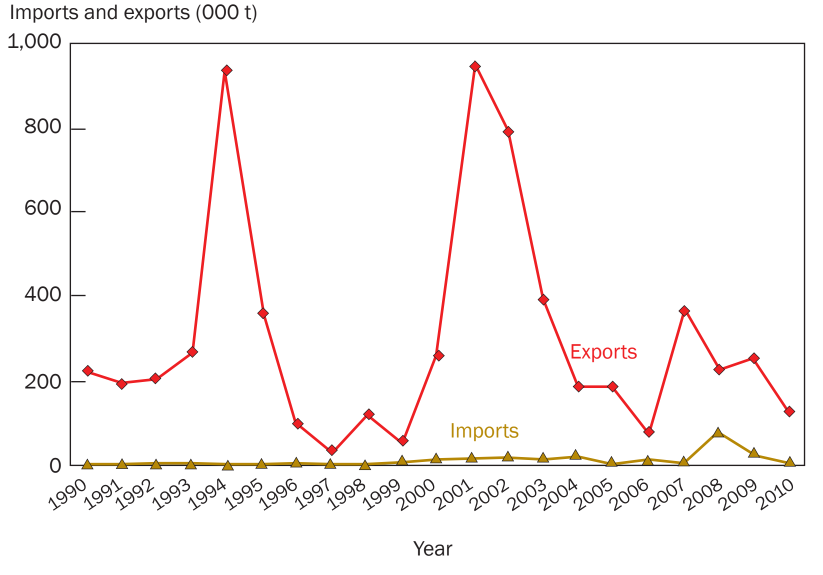
The following set of interventions would improve the country's agricultural economy: (1) increase access to credit for farmers, traders, and millers; (2) increase the farm-gate price of paddy in order to encourage farmers to produce more paddy; and (3) provide finance for small-scale village infrastructure projects to increase demand for wage labor for the rural poor.

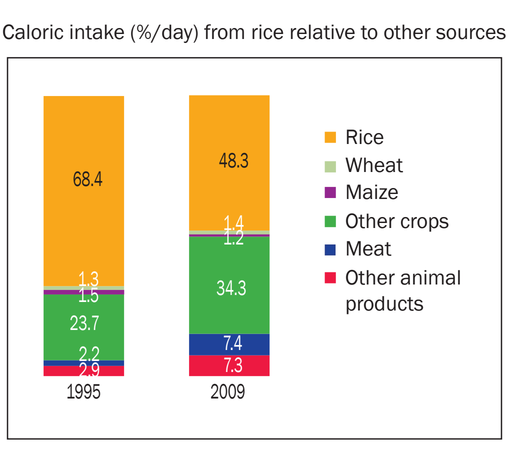
Basic statistics, Myanmar

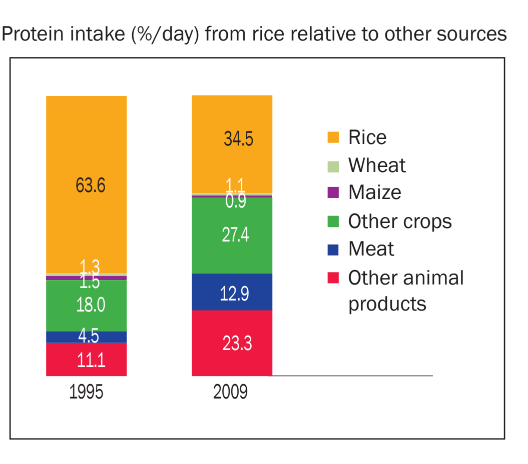
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	9,540	9,909	10,059	10,336	10,577	10,872	11,035	
Rice area (×10^3 ha)	6,032.7	6,302.5	7,384.0	8,074.0	8,011.0	8,078.0	8,000.0	8,051.7
Share of rice area irrigated (%)				23.0				
Share of rice area under MVs (%)			76 (2003)					
Paddy yield (t/ha)	2.98	3.38	3.75	3.83	3.93	4.03	4.09	4.12
Paddy production (x10^3 t)	17,956.9	21,323.9	27,683.0	30,924.0	3,1451.0	32,573.0	32,682.0	33,204.5
Milled production (x10^3 t)	11,977	14,223	18,465	20,626	20,978	21,726	21,799	22,136
Rice imports (×10^3 t)	0.0	10.1	2.1	10.5	3.1	81.0	23.0	1.6
Rice exports (×10^3 t)	353.8	251.4	180.2	71.3	358.7	221.9	250.3	121.9
Total rice consumption (×10^3 t)	11,570	13,066	18,260	20,556	20,569	20,608	21,313	
Fertilizer usage (NPK) (kg/ha of arable land)	19	21	7	9	16	7	5	

Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

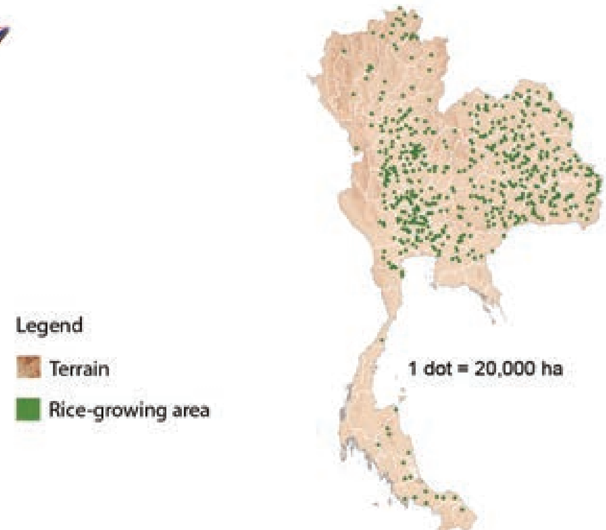

Production (million t) and area (million ha)
Yield (t/ha)
35
30
25
20
15
10
5
0
7
6
5
4
3
2
1
0
Production
Yield
Area
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year


Imports and exports (000 t)
1,000
800
600
400
200
0
Exports
Imports
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year


Caloric intake (%/day) from rice relative to other sources
68.4
1.3
1.5
23.7
2.2
2.9
48.3
1.4
1.2
34.3
7.4
7.3
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
63.6
1.3
1.5
18.0
4.5
11.1
34.5
1.1
0.9
27.4
12.9
23.3
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

THAILAND



General information

- GNI per capita at PPP$, 2011: 8,360
- Internal renewable water resources, 2011: 224.5 km^3/year
- Incoming water flow, 2011: 214.1 km^3/year
- Main food consumed, 2009: rice, fruits, vegetables, sugar and sweeteners, meat, fish, wheat, oil crops, starchy roots
- Rice consumption, 2009: 133 kg milled rice per person per year

Production seasons

	Planting	Harvesting
North and Central, major	May-Jul	Nov-Dec
North and Central, minor	Dec-Jan	May-Jun
South, major	Sep-Nov	Mar-May
South, minor	Apr-May	Aug-Sep

Thailand is a peninsular country in Southeast Asia sharing boundaries with Myanmar in the west, Laos and Cambodia in the northeast, and Malaysia in the south. The South China Sea touches the east coast, while the Indian Ocean and Andaman Sea border the west coast. Thailand has a land area of 51 million ha, of which one-third is cultivated for annual crops and about 7% is under permanent crops.

Four seasons are recognized: southwest monsoon from May through September, a transition period from the southwest to the northeast monsoon during October, the northeast monsoon from November through February, and a premonsoon hot season during March and April.

Temperatures in the Central Plain during the rainy season (May to November) average 27 °C, with only 8–10 °C between the daily minimum and maximum. There is a brief cool period (December and January) with temperatures as low as 2–3 °C in the northern highlands.

Economic growth in nonagricultural sectors over the past three decades greatly reduced the relative importance of agriculture as a contributor to gross domestic product (GDP) and export earnings. However, agriculture remains a significant economic activity in rural Thailand. In spite of having an industrialized economy, 66% of the population in Thailand is still rural. The country's population was 69.1 million in 2010 and grew at 0.76% per year in 2005-10. The population density was 132 per km^2 in 2010.

The Thai economy is export dependent, in which exports—which include rice—account for more than half of GDP. Aside from rice, the country's major agricultural exports are tapioca, rubber, maize, pineapple, durian, longan, palm oil, and herbs. The leading manufactured exports are computers and computer accessories, integrated circuits, textiles, electronics, automobiles and spare parts, gems and jewelry, and televisions and television accessories. GDP fell to –2.3% in 2009 during the global economic crisis but rebounded to 7.8% in 2010. However, in 2011, growth was again low at 0.1%. In 2010, industry accounted for 44.6% of GDP, services shared 43%, while agriculture contributed 12.4%. Although agriculture has the lowest contribution to GDP, it employs about 42% of the total labor force.

Recent developments in the rice sector

Thailand's arable land declined from 16.8 million ha in 1995 to 15.3 million ha in 2009. However, the area harvested to rice improved to 10.9 million ha in 2010 from 9.1 million ha in 1995. Higher prices of rice in the world market are encouraging farmers to grow more rice per crop year. In general, rice yield is low because of the prevalence of rainfed ecosystems and farmers' preference to grow high-quality, low-yielding traditional varieties that command a premium price in the domestic and world markets. Rice yield, 2.9 t/ha in 2010, diminished by 0.5%/year in 2005-10. Nevertheless, with the expansion in the area harvested to rice, rice production has improved in recent years, from 22 million t in 1995 to about 32 million t in 2010, and it grew at 1.2% per year in 2005-10.

Liberalization of rice policies in Thailand in the past decade seemed to have been quite similar. In 2001, the government implemented a rice price guarantee policy that functioned as a mortgage program, wherein farmers could obtain government loans at a low interest rate. With this policy, farmers could sell their paddy to government agencies and also buy it back within 90 days at 3% interest rate. The program was managed by the Bank of Agriculture and Agricultural Cooperatives (BAAC) and supervised by the Ministry of Finance. Since the guaranteed price was set much higher than the market price, the policy became too costly for the government because it ended up with very large procurements. Consequently, the program was suspended for two years. But the succeeding government relaunched it for the first harvest of 2008 and even increased the pledged price for the second harvest of 2008—at about 20% higher than the market price. The price support helped farmers increase their income and it gained support from millers who also benefited from the price support. However, the pledged prices resulted in distortions in production and caused trade problems. Rice-importing countries delayed their imports to await cheaper rice from other rice-exporting countries.

Aside from the above policies on prices, the government also supports rice production through its crop insurance program, through which subsidized fertilizers are available. However, farmers are required to register with BAAC to enable them to join the program. Farmers can either buy fertilizers on a cash basis or borrow from BAAC at 7% annual interest.

Rice is the staple food, with an average per capita consumption of 133 kg per year in 2009, comparatively much higher than in 1995, which is only 96.4 kg per year. As a result, per capita caloric intake increased from 42.8% (960 kcal) per day in 1995 to 46.2% (1,323 kcal) per day in 2009, while wheat's share increased from 2.9% in 1995 to 4.1% in 2009. In terms of protein requirements, per capita intake from rice increased from 29.2% per day in 1995 to 36.9% per day in 2009, whereas wheat's share of intake increased from 3.6% per day in 1995 to 5.9% per day in 2009.

Thailand is not only one of the world's largest rice producers; it also remains the world's largest rice exporter. Its rice exports surged from around 6.2 million t in 1995 to 8.9 million t in 2010 and grew at about 4% per year in 2005-10.

Rice environments

Rice production in Thailand can be classified into four ecosystems; irrigated, rainfed lowland, deepwater, and upland. Rainfed lowland is the most predominant, followed by irrigated, deepwater, and upland.

Administratively as well as geographically, Thailand is divided into four regions: central, north, northeast, and south. Each region has different rice-growing environments.

Northeastern region. The northeastern region is also known as the Khorat plateau, a saucer-shaped tableland situated at 90–200 meters above sea level. Almost one-third of the land area and nearly half the rice land of Thailand are located in this region; the average size of rice farms is smaller than in other regions. Irrigation potential in the region is limited due to undulating topography. Moreover, soil erosion and drought during the dry season are acute. The water-holding capacity of the soil is extremely poor. The northeastern region produces both long-grain and glutinous rice.

Central region. The central region is an intensively cultivated alluvial area. During the rainy season, rice covers the major part of the region, which accounts for about one-fifth of the total cultivated rice land of the country in the wet season. The average farm size is large, and a large proportion of the rice land has access to irrigation facilities, allowing many farmers to grow two rice crops during the year. Almost 75% of the dry-season rice grown under irrigated conditions is located in this region. Farm operations are almost entirely mechanized, and farmers adopt the direct-seeding method of crop establishment to save labor. This region produces mostly long-grain rice. The main rice surplus comes from this region.

Northern region. The northern region contains almost one-third of the land area of Thailand. Upland rice is grown in the lower altitudes of high hills and in upland areas. Lowland rice is grown mainly in lower valleys and on some terraced fields where water is available. The northern region has about 20% of the total rice land in the country.

Southern region. The southern region, touching the west and east coasts of the peninsula, constitutes about 14% of the total area of the country. The region has only 6% of the total rice land. The soil is acidic. With limited rice fields under cultivation, there is always a shortage of rice for local consumption.

Rice production constraints

Even though the country is still one of the world's largest rice producers and the largest rice exporter, its rice sector faces the following production constraints:

- The major production constraints are rainfall variability, drought, submergence, and inherently low soil fertility. These constraints affect the different rice ecosystems to varying degrees and imply that the production systems are very vulnerable to climate change, which will exacerbate extreme climate events. Drought at the early vegetative phase and long-term deep flooding from the late vegetative phase to early ripening phase and weed competition are the most important production constraints in the deepwater ecosystem. Drought and poor soil fertility affect upland systems the most.
- In irrigated ecosystems, production constraints are generally not related to climatic factors but to biotic factors such as pests and diseases. Water scarcity in the dry season is another important constraint in irrigated environments.
- Stagnating yield is both a short-term and long-term problem. Mean rice yields nationally for the last 10 years were almost constant, ranging from 2.8 to 2.9 t/ha.
- Labor shortages during peak periods because of better employment opportunities in urban areas are a further constraint, especially in the central region, where industrial employment is higher. However, this constraint is partly being solved through mechanization.

Rice production opportunities

The Rice Research Institute of the Department of Agriculture is the major government institution directly involved in rice research, primarily in increasing productivity through continuous development and deployment of high-quality varieties with varying maturity periods to suit different production conditions, acid-tolerant rice varieties, and varieties with added attributes such as disease and pest tolerance, designed to improve rice yields. The institute also has the mandate for research and extension activities for better crop protection and water and soil management technologies that can help improve yields.

The National Science and Technology Development Agency (NSTDA) under the Ministry of Science and Technology is also involved in rice research. Their Rice Program aims to increase the rice industry's competitive capability throughout the production chain while reducing the environmental impact. Key operation plans include[1]

- Developing technologies to increase rice production efficiency, for example, breeding rice varieties that are resistant to pests and can adapt to climate change caused by global warming, transferring high-quality grain production technology to farmers, developing and transferring agricultural equipment and machine production technology for higher efficiency and lower planting and harvesting costs, and developing information and communication technology to monitor rice disease and pest outbreaks;
- Improving milling and drying efficiency, and reducing energy use and milling waste for small and medium-sized enterprises; and
- Developing production process technology and rice-based products.

Rice varieties developed outside the country are also proving useful in improving productivity. An IRRI submergence-tolerant variety was recently found to perform well also in mildly improved (with the application of a small amount of lime) acid-sulfate soil in Narathiwat Province, southern Thailand, giving significantly higher yield than two Thai varieties used in the area.[2]

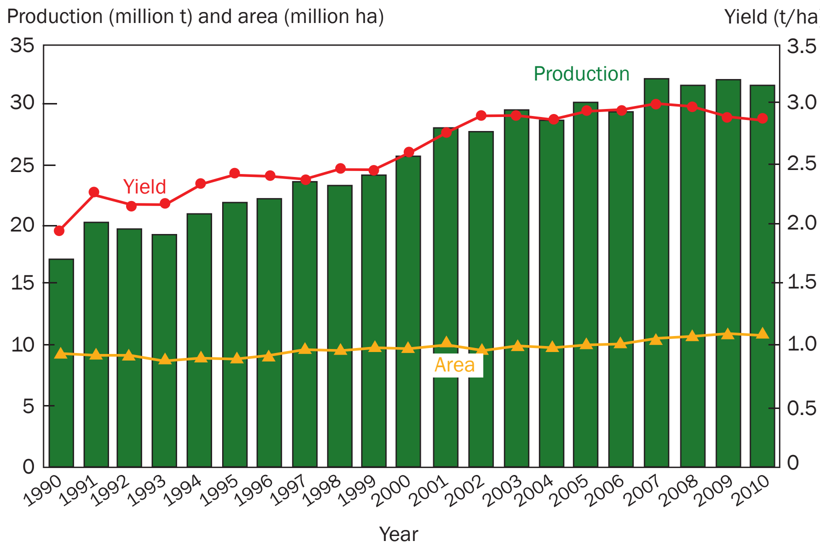
[1]Adapted from NSTDA, Thailand Web site; 2007 irrigated data based on FAO Aquastat data.

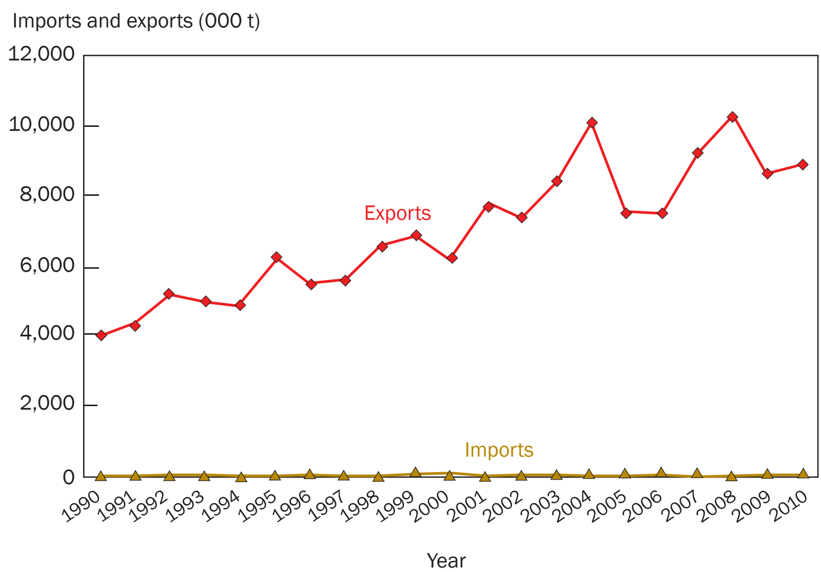
[2]The rice variety was IR53650, which was developed by the late D. Senadhira (IRRI plant breeder), and the study was conducted by Dong-Jin Kang and others.

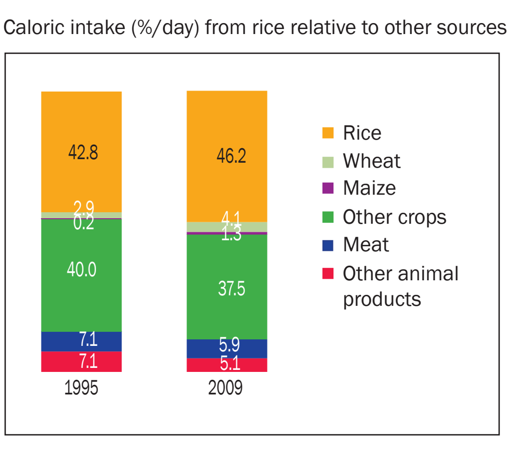
Basic statistics, Thailand

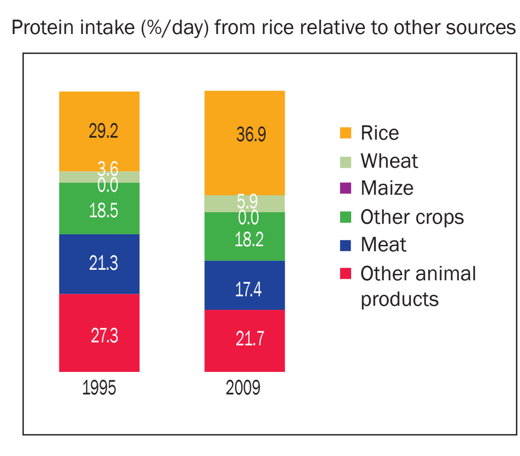
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	16,839	15,654	15,200	15,200	15,200	15,200	15,300	
Rice area (×10^3 ha)	9,113.0	9,891.2	10,225.0	10,165.2	10,668.9	10,683.5	11,141.4	10,990.1
Share of rice area irrigated (%)	23.8	25.5	25.6		58.8			
Share of rice area under MVs (%)	15.5		30					
Paddy yield (t/ha)	2.42	2.61	2.96	2.92	3.01	2.96	2.88	2.88
Paddy production (x10^3 t)	22,015.5	25,843.9	30,291.9	29,641.9	32,099.4	31,650.6	32,116.1	31,597.2
Milled production (x10^3 t)	14,684	17,238	20,205	19,771	21,410	21,100	21,411	21,065
Rice imports (×10^3 t)	0.1	0.5	2.5	1.6	3.2	13.6	20.8	5.3
Rice exports (×10^3 t)	6,198.0	6,141.4	7,537.1	7,433.6	9,195.6	10,216.0	8,619.9	8,939.6
Total rice consumption (x10^3 t)	8,549	10,437	11,555	11,617	11,782	12,314	12,965	
Fertilizer usage (NPK) (kg/ha of arable land)	89	100	113	117	137	131	125	

Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

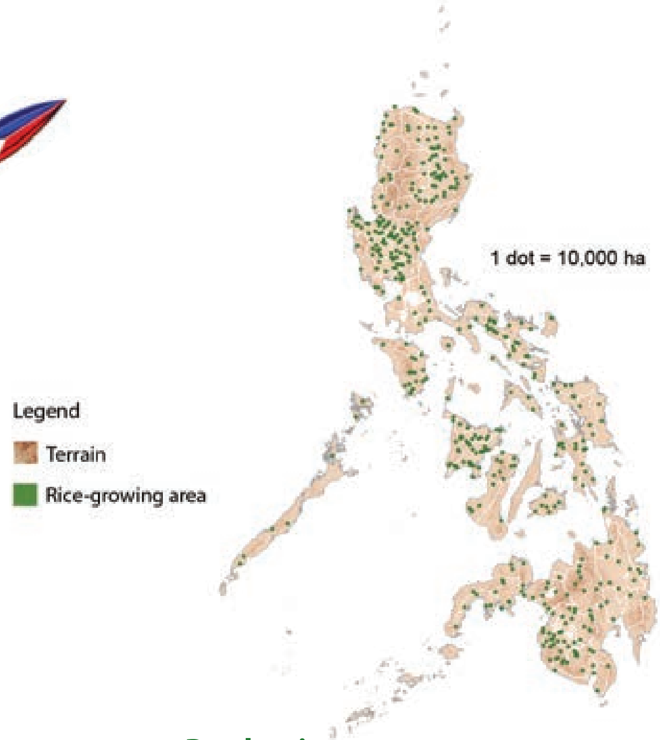

Production (million t) and area (million ha)
Yield (t/ha)
Production
Yield
Area
Year


Imports and exports (000 t)
Exports
Imports
Year


Caloric intake (%/day) from rice relative to other sources
42.8
2.9
0.2
40.0
7.1
7.1
1995
46.2
4.1
1.3
37.5
5.9
5.1
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
29.2
3.6
0.0
18.5
21.3
27.3
1995
36.9
5.9
0.0
18.2
17.4
21.7
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

Philippines



General information

- GNI per capita at PPP$, 2011: 4,140
- Internal renewable water resources, 2011: 479 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: rice, fruits, vegetables, fish, meat, starchy roots, wheat, sugar and sweeteners
- Rice consumption, 2009-10: 123.3 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Wet, north	May-Jul	Oct-Dec
Dry, north	Jan-Mar	May-Jun
Wet, south	Oct-Dec	Mar-May
Dry, south	May-Jun	Nov-Dec

The Philippines is an archipelago of some 7,107 islands located between 4° and 21° N latitude and 116° and 127° E longitude. The country is bounded by the South China Sea to the west, the Pacific Ocean to the east, the Sulu and Celebes seas to the south, and the Bashi Channel to the north.

It is divided into three main geographic areas: Luzon, Visayas, and Mindanao. The climate is tropical marine, which is mainly moderated by the surrounding seas, with a November to April northeast monsoon and a May to October southwest monsoon. Climate varies within the country because of the mountainous topography. There are four general climatic types: (1) two pronounced seasons, dry from November to April and wet the rest of the year (Central Luzon, western Visayas), (2) absence of a dry period, but with maximum rains from November to January (eastern Luzon, eastern Visayas, and northeastern Mindanao), (3) dry from November to February and wet the rest of the year (central Visayas, western Bicol, northern Mindanao), and (4) more or less even rainfall distribution throughout the year (central Mindanao).

The population of the Philippines has more than tripled since IRRI developed the first high-yielding variety and released it in the mid-1960s. Back then, the population was only 32.7 million. The country's population surpassed 93 million in 2010, with about 313 per km^2. The population grew at 1.9% per year for 2005-10, which was lower than the 2.4% for 1985-95. Urbanization has continued in recent years. The proportion of the urban population increased from 57% in 2000 to around 65% in 2010. Employment in the agricultural sector accounts for 31% of the about 39 million-person labor force.

Rice harvest in Banaue, Ifugao.

The Philippine economy is vastly dependent on service and manufacturing. The country's most vital industries are food processing, textiles and garments, electronics, and automobile parts. It also has substantial reserves of chromite, nickel, copper, coal, and recently discovered oil. The nation's GDP rose from $2,056 in 1995 to $3,952 in 2010. About 13% of GDP is contributed by the agricultural and fishery sector.

In addition to rice, the Philippines produces other major crops such as sugarcane, coconut, banana, pineapple, mango, coffee, maize, and cassava.

Recent developments in the rice sector

The Philippines is the world's eighth-largest rice producer. Its arable land totals 5.4 million ha. Rice area harvested has expanded from nearly 3.8 million ha in 1995 to about 4.4 million ha in 2010. However, the country's rice area harvested is still very small compared with that of the other major rice-producing countries in Asia. More than two-thirds (69%) of its rice area is irrigated. The country's production increased by a third, from 10.5 million t in 1995 to 15.8 million t in 2010. Seventy-one percent of rice production came from irrigated areas. Although yield improved from 2.8 t/ha in 1995 to 3.6 t/ha in 2010, it was still way below the yield potential of modern varieties.

Rice is a staple food for most Filipinos across the country. The nation's per capita rice consumption rose from 93.2 kg per year in 1995 to 123.3 kg per year in 2009. Similarly, per capita caloric intake from rice rose from 917 kcal per day in 1995 to 1,213 kcal per day in 2009. Protein requirements from rice, on average, increased from 29.7% in 1995 to 34.8% per person per day in 2009.

The Philippines imports about 10% of its annual consumption requirements. In 2010 and 2011, the country was the biggest rice importer. Its rice imports amounted to 2.38 million t in 2010, mostly coming from Vietnam and Thailand. Despite these imports, rice prices for consumers are some of the highest in developing Asia (as are farm-gate prices for farmers). The high prices are enforced through an import control by the National Food Authority (NFA), a government agency, which also procures paddy from farmers at a government support price. The NFA is also involved in rice distribution by selling rice through the agency's licensed and accredited retailers/wholesalers in strategic areas at a predetermined price.

Although rice is the main staple in the country, it is a highly political commodity. The Philippine rice sector has always been the center of the government's agricultural policies. The focal points of the policies revolve around promoting rice self-sufficiency and providing high income to farmers while making rice prices affordable to consumers.

One of the most significant programs of the government for the rice sector is "The Philippine rice master plan 2009-13—enhancing provincial rice self-sufficiency." This rice master plan envisions a 100% self-sufficient rice economy by 2013 through improved rice productivity, and increased income of rice farmers. This plan pursues location-specific interventions that can help farmers achieve higher yield. It focuses on how interventions can improve productivity toward sufficient yield. These include improvement of the effectiveness and efficiency of irrigation systems through rehabilitation; the use of high-quality hybrid and inbred seeds and farmers' varieties; integrated and sustainable crop management technologies; the provision of soft loans for the establishment of shallow tube wells and surface water pumps; and delivery of extension support services. Rice seed subsidy schemes for farmers were implemented to acquire high-yielding varieties, including hybrid rice varieties.

The government also extends support for farm mechanization through its Rice Mechanization Program. It aims to procure and distribute postharvest (drying and milling) units and on-farm machinery through a financing scheme wherein the government shoulders a big part of the cost.

Rice environments

The major rice-producing parts of the country are Central Luzon (18.7%), western Visayas (11.3%), Cagayan Valley (11%), Ilocos region (9.8%), SOCCSKSARGEN (7.5%), and Bicol region (6.8%). SOCCSKSARGEN is a newly created region in central Mindanao comprising North Cotabato, Sarangani, South Cotabato, and Sultan Kudarat provinces.

Almost 70% of the total rice area is irrigated and the remaining 30% is rainfed and upland. Much of the country's irrigated rice is grown on the central plain of Luzon, the country's ricebowl. Rainfed rice is found in the Cagayan Valley in northern Luzon, in Iloilo Province, and on the coastal plains of Visayas and Ilocos in northern Luzon. Upland rice is grown in both permanent and shifting cultivation systems scattered throughout the archipelago on rolling to steep lands.

Because of their higher profitability for farmers, modern high-yielding varieties account for the vast majority of rice production, with less than 3% of production coming from traditional varieties. Labor use on rice is lower than in many developing Asian countries at about 60 person-days/hectare/crop. Some of the reasons for the relatively low labor use are the widespread use of direct seeding and the mechanization of land preparation and threshing in many parts of the country.

Farm-level rice yields in the Philippines have grown in the last decade without a significant change in inputs (fertilizer, herbicides) and crop establishment methods. This progress in rice yields could be related to the use of good-quality seeds: hybrid and certified seeds. With strong partnership and support from IRRI, the country recently released a rice variety for irrigated lowlands, the IRRI-bred Tubigan 18 (NSIC Rc222 or IRRI 154), which yields up to 10 t/ha and has an average of 6 t/ha, 12–13% higher than that of the popular and widely used rice variety PSB Rc82, also bred by IRRI and known as IRRI 123. The high-yielding Tubigan varieties are recommended for irrigated lowland areas but tests done nationwide showed that they can also perform well in rainfed areas, particularly during the wet season.

The Philippine Rice Research Institute (PhilRice) has also recently produced one aromatic rice variety, Mabango (NSIC Rc128), and four glutinous rice varieties: Malagkit 1 (NSIC Rc13), Malagkit 2 (NSIC Rc15), Malagkit 3 (NSIC Rc17), and Malagkit 4 (NSIC Rc19).

Rice production constraints

Climate change, growing population, declining land area, high cost of inputs, and poor drainage and inadequate irrigation facilities are the major constraints to rice production in the Philippines. Some of these constraints are interrelated. Unabated conversion of some agricultural land to residential, commercial, and industrial land reduces the area devoted to rice production, which leads to a shortage in domestic supply.

Climate change and the vulnerability of crop production to drought and heavy rainfall, especially during the typhoon season, severely affect production. The Philippines bears the brunt of typhoons coming in from the Pacific Ocean. Successive heavy rains cause severe drainage problems in paddy fields, thus resulting in a significant reduction in rice yield and quality. There is also concern about the deterioration of irrigation systems at least partially because of a lack of funding for maintenance. Rainfed lowland rice suffers from uncertain timing of the arrival of rains, and drought and submergence—often in the same fields over the course of a single season or in different fields within a farm over the same season. Weeds, drought, diseases (blast), acidic soils, and soil erosion are major problems of upland rice in the Philippines. The high cost of inputs, particularly fertilizer, hinders farmers from applying optimal fertilizer amounts to input-responsive high-yielding varieties.

Rice production opportunities

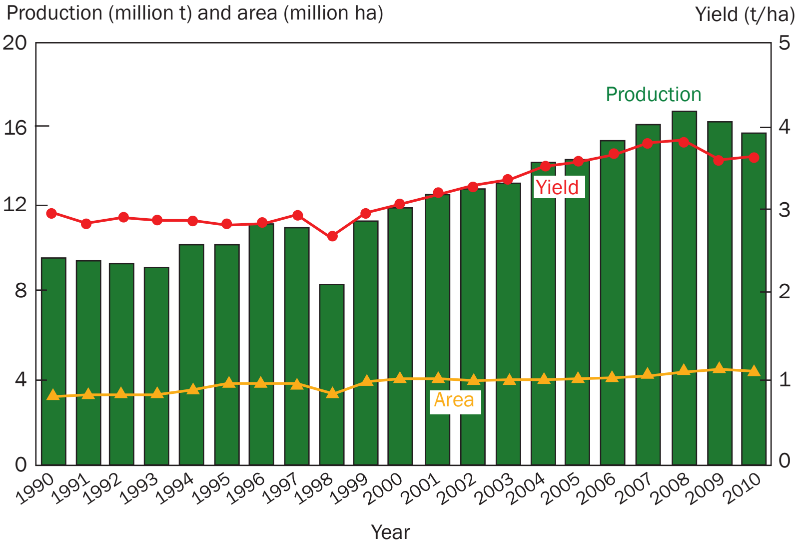
For the Philippines to become self-sufficient in rice, it has to adopt existing technologies such as improved varieties and know-how to have yield increase by 1–3 t/ha. Better-quality seed combined with good management, including new postharvest technologies, is the best way to improve rice yields and the quality of production.

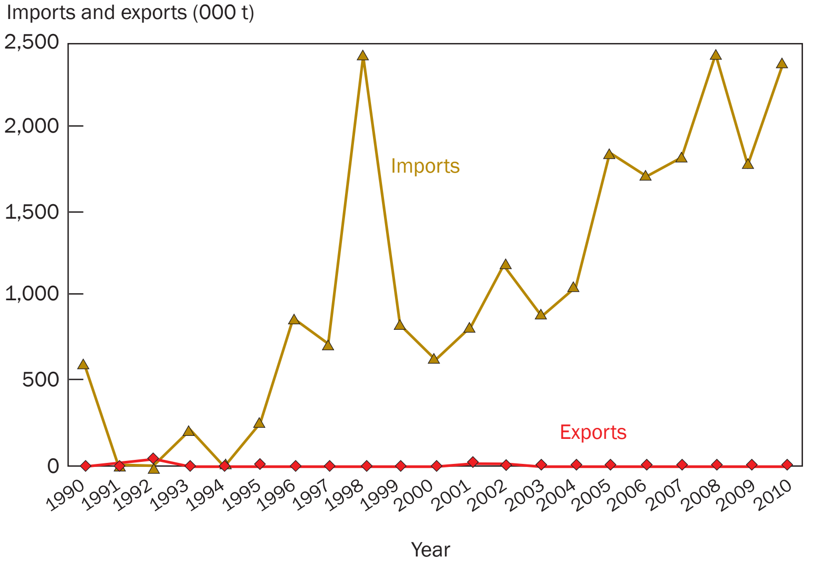
Since current rice yield is way below the yield potential of most modern varieties, improved fertilizer use and crop management, better irrigation facilities, and high-yielding varieties can boost the country's rice output. The main source of additional rice production is improved yield growth. However, the government must implement a strategy to reduce population growth since the actual volume of rice produced by the country is not enough to match rice demand because of the high increase in population. If population growth will be higher than the growth in yield, the country will continue to import rice from other countries to meet domestic demand for rice in the coming years.

Basic statistics, Philippines

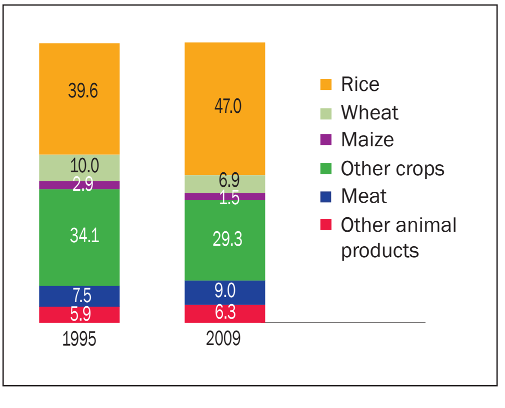
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	5,285	5,034	5,000	5,100	5,200	5,300	5,400	
Rice area (×10^3 ha)	3,758.7	4,038.1	4,070.4	4,159.9	4,272.9	4,460.0	4,532.3	4,354.2
Share of rice area irrigated (%)	62.1	66.9	68.6	68.0	68.3	68.0	67.4	69.1
Share of rice area under MVs (%)	90.8	96.3	91.1	93.4	99.0	97.3	97.9	97.2
Paddy yield (t/ha)	2.80	3.07	3.59	3.68	3.80	3.77	3.59	3.62
Paddy production (×10^3t)	10,540.6	12,389.4	14,603.0	15,326.7	16,240.2	16,815.5	16,266.4	15,771.7
Milled production (×10^3 t)	7,031	8,264	9,740	10,223	10,832	1,1216	10,850	10,514
Rice imports (×10^3t)	263.3	642.3	1,821.6	1,716.3	1,805.6	2,432.0	1,775.3	2,378.0
Rice exports (×10^3t)	0.0	0.2	0.2	0.1	0.6	0.8	0.2	0.2
Total rice consumption (×10^3t)	7,100	8,793	11,200	11,470	12,283	12,695	12,132	
Fertilizer usage (NPK) (kg/ha of arable land)	113	146	152	140	139	125	140	

Source: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

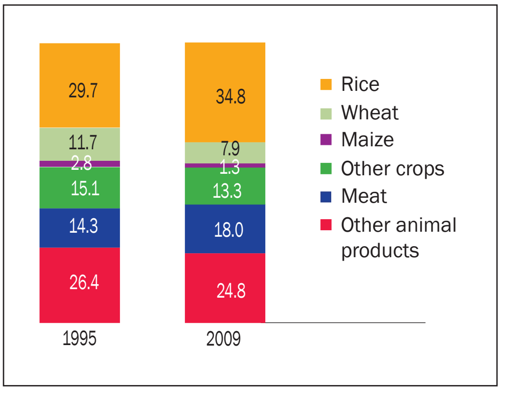




Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



JAPAN

General information

- GNI per capita at PPP$, 2011: 35,330
- Internal renewable water resources, 2011: 430 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: vegetables, milk, seafood, rice, fruits, wheat, meat, soybean
- Rice consumption, 2009: 54.0 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Main, North	May-Jun	Aug-Sep
Main, Central	Apr-May	Aug-Oct
Main, South	Apr-May	Sep-Nov

The Japanese islands lie off the eastern coast of Asia, roughly in a crescent shape. The country consists of four main islands with about 4,000 smaller ones. The northern limit of rice cultivation is 44° N. Rice is grown up to 1,400 m altitude in the central region of the main island.

The climate is humid temperate and oceanic with four distinct seasons. Rainfall during the rainy season in June and July is indispensable to rice cultivation. The temperature and solar radiation from April to October are ideal for rice growing.

The country's population in 2010 was nearly 127 million with a density of 337 per km^2. The agricultural population declined from about 29 million in 1960 to about 3 million in 2010 due to diversification of the economy and very slow population growth during recent decades. The country's population grew at barely 0.02% per year in 2005-10.

Japan has few natural resources; its industrial sector greatly depends on imported raw materials and fuel. The economy is technologically developed and very efficient in foreign trade. In 2010, 73.8% of the country's GDP came from the service sector; the industrial sector contributed 24.8% whereas agriculture contributed only 1.2%.

Recent developments in the rice sector

Japan continues to be self-sufficient in rice. Rice remains important and is embedded in Japanese culture. With the shift in people's diet, rice consumption has fallen since the 1970s. Annual per capita rice consumption declined from 63 kg in 1995 to 54 kg in 2009. Consequently, per capita caloric intake from rice fell from 23.1% (675 kcal) per day in 1995 to 21.3% (581 kcal) per day in 2009, while the share of wheat rose slightly from 12.3% per day in 1995 to 14.2% per day in 2009. In parallel, per capita protein intake from rice declined from 12.3% per day in 1995 to 11.5% per day in 2009, whereas wheat accounted for 10.0% per day in 1995 and 11.9% per day in 2009.

The small agricultural sector is heavily subsidized and protected. The rice sector is supported by high prices paid by consumers that allow many farm households to maintain small farms. The government controls trade through a tariff quota, with a high tariff on imports outside the quota. The country has a crop diversion (or rice area reduction) program wherein farmers are paid to substitute rice with other crops (e.g., wheat, soybean) or let the land remain fallow, so that the rice supply will not exceed demand at market price levels.

Because of the government's restrictions on rice area, the area harvested to rice fell from 2.1 million ha in 1995 to 1.6 million ha in 2010; this contraction amounted to 1.1% per year in 2005-10. Rice yield grew by only about 0.2% per year in 2005-10. The mean rice yield in 2010 was 6.5 t/ha, very close to the 6.3 t/ha harvested in 1995. The overall result was a 1% per year fall in rice production in 2005-10.

Japan's rice exports improved slightly from 10,000 t in 1995 to 38,000 t in 2010. Under the auspices of the World Trade Organization (WTO), Japan allows market access to imported rice of 8% of the country's rice requirement. Hence, rice imports increased from 30,000 t in 1995 to 660,000 t in 2010. Most of these rice imports, however, are not released directly to the domestic market but are placed into government stocks and later used in the form of aid to developing countries or sold as an input to food processors.

Below are some of the major policies of the Japanese government that directly affect the rice economy:

1. For decades, Japan pursued the goal of food self-sufficiency by using a number of commodity programs such as a producers' quota, income stabilization policies, deficiency payments, and rice diversion programs.
2. To revitalize the agricultural sector, younger segments of the population are encouraged to take up farming activities through incentives.
3. The New Food, Agriculture, and Rural Areas Basic Plan, developed in March 2010, is a major change in agricultural policy to swiftly renew and revitalize food and communities. This plan sets 50% as the target for the food self-sufficiency ratio on a supplied calorie basis and 70% on a production output basis to be achieved in 2020. This policy provides government subsidies to support farmers whose main agricultural products are rice and other cereals at a level depending on certain production targets that are decided by prefectural and city governments and municipalities based on a food self-sufficiency target rate. The subsidies are calculated based on the difference between the nationwide average production cost and the nationwide average retail price. Every farmer participating in this scheme has been given a basic subsidy of 1 million yen per hectare.

Rice environments

Rice ecosystems in Japan cover an extensive range of latitudes, including subtropical, temperate, and subfrigid areas. Most rice fields are on the plains of the major river basins. Many are also located in terraces and valleys.

Japan's rice culture is characterized by cultivation in the higher latitudes. To handle the cold weather in the northern part of the country, early-maturing cold-tolerant varieties were developed. Rice cultivation in the cold area is based on good-quality older seedlings for early transplanting, deepwater irrigation to protect crops from low night temperature, windbreak nets, and the application of organic matter to improve soil fertility.

Rice is grown under irrigated conditions. Japanese paddies feature concrete irrigation ditches largely constructed as public works projects. Many paddies have underground drainage systems that allow water to drain into the canals during the off-season. These paddies are easy to manage but can affect wildlife.

Nearly 85% of the 2.3 million farms in Japan cultivate rice. Farming is highly mechanized. Average landholding is very small, about 0.8 ha. Most farmers with smaller farm size consider rice farming a part-time job.

Japan's northernmost island, Hokkaido, is the country's leading rice producer. Also, the broad coastal plain of Shonai near the Sea of Japan has plenty of water and nutrient-rich soil and is considered to be one of Japan's most fertile granaries.

Improved varieties of japonica rice are planted in most of the prefectures or regions in the country. The popularity of a rice variety in the country depends on its taste. Hokkaido's Yumepirika variety and Niigata's Koshihikari are popularly known for their palatability and command a premium price in the market.

Rice production constraints

Japan has an aging population and very low population growth, which could result in labor shortages and will likely constrain future rice production. Many rice fields are being abandoned after the owners die or become too old to cultivate them. With the changing level of education, rice farming is not attracting the younger generation. As of April 2010, 23% of the population was aged 65 or older. Projections made in 2006 indicated that the population of 127 million would decline to 90 million by 2055, when 41% of the population would be 65 or older.

Rice farmers are often also engaged in nonagricultural employment due to the small size of landholdings used for rice farming.

Because of global warming, high summer temperature and erratic rainfall are reducing yields. Some farmers are trying heat-resistant varieties but their taste is significantly different. Some experts say that it may take many years for consumers to accept heat-resistant, high-yielding varieties.

In spite of substantial farm subsidies and price support provided by the government, rice farming cannot compete with other economic activities, and income from it is lower than from nonagricultural earnings. Despite mechanization, production costs are many times higher than in tropical Asia because of exorbitant land prices and the high opportunity cost of farm labor.

Rice production opportunities

Japanese rice research will also help solve problems in neighboring low-income rice-growing countries of South and Southeast Asia, while regional research by IRRI and partners will benefit Japanese rice farming also. Reducing production cost, increasing productivity through the application of advanced technology, and multipurpose use of rice fields in agriculture are important for sustaining rice cultivation in Japan.

Using rice as alternative flour in making bread and noodles can stimulate demand for rice. The potential of rice as poultry and livestock feed can also help increase the demand for rice and hence more farmers would be encouraged to engage in rice farming. As a result, the country would maintain its self-sufficiency in rice and attain food self-sufficiency as well. The government can export rice in excess of domestic demand to other countries that have a shortfall in rice production.

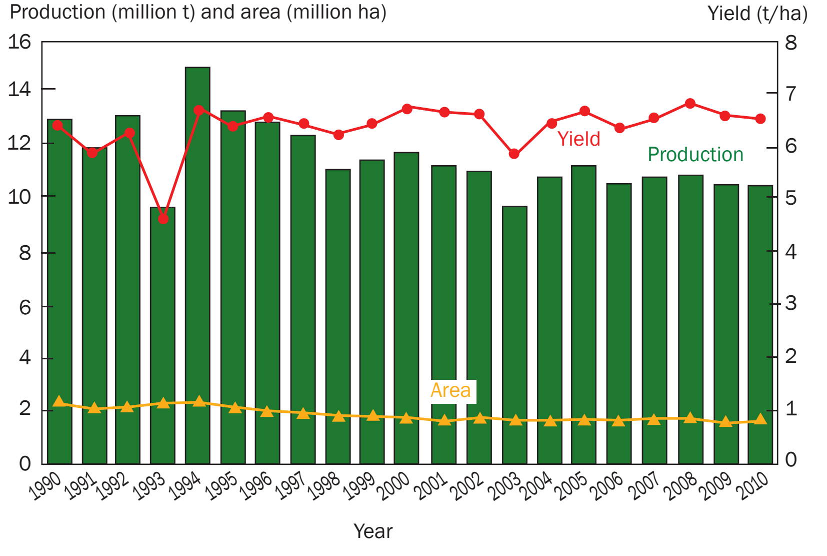
The population projections suggest that the government may have to consider immigration as a solution to unbalanced worker-retiree ratios to augment the possible labor shortages in coming years. Rice farming would benefit from strategies to encourage working couples to have children.

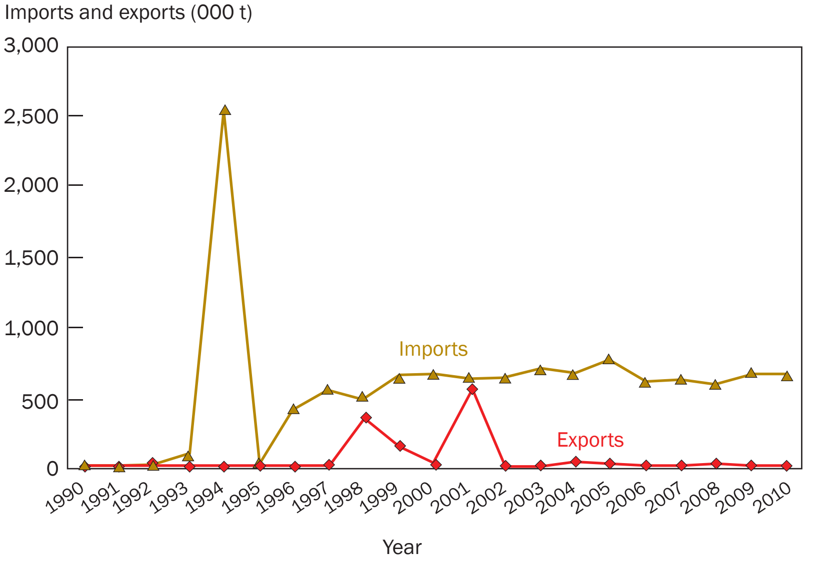
Rice harvest in Wakayama Prefecture.

Basic statistics, Japan

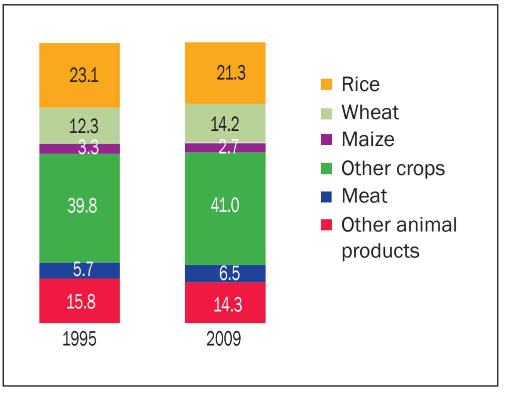
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	4,630	4,474	4,360	4,343	4,326	4,308	4,294	-
Rice area (×10^3 ha)	2,118.0	1,770.0	1,706.0	1,688.0	1,673.0	1,627.0	1,624.0	1,628.0
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	6.34	6.70	6.65	6.34	6.51	6.78	6.52	6.51
Paddy production (×10^3t)	13,435.0	11,863.0	11,342.0	10,695.0	10,893.0	11,028.8	10,590.0	10,600.0
Milled production (×10^3 t)	8,754	8,961	7,913	7,565	7,134	7,266	7,356	7,064
Rice imports (×10^3 t)	29.0	655.8	787.3	606.6	643.4	596.6	671.0	664.4
Rice exports (×10^3 t)	12.6	42.1	12.1	22.6	18.6	40.5	16.9	38.2
Total rice consumption (×10^3 t)	9,298	8,262	7,811	7,725	7,790	7,515	7,421	-
Fertilizer usage (NPK) (kg/ha of arable land)	354	325	348	333	350	278	235	-

Source: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

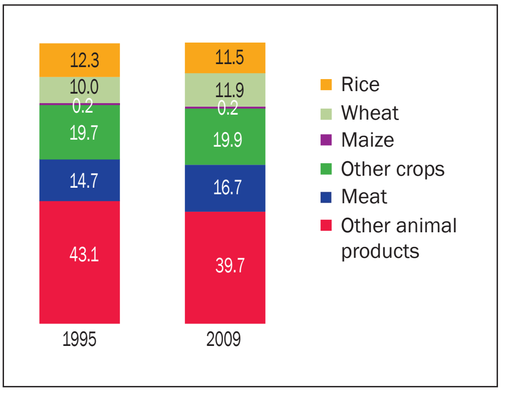




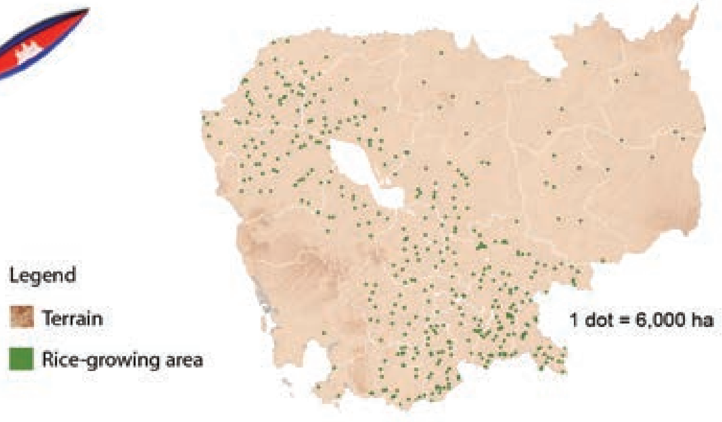
Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



CAMBODIA



General information

- GNI per capita at PPP$, 2011:2,230
- Internal renewable water resources, 2011: 120.6 km^3/year
- Incoming water flow, 2011: 355.5 km^3/year
- Main food consumed: rice, fish, vegetables, cassava, maize, bananas, meat
- Rice consumption, 2009: 160.3 kg milled rice per person per year

Cambodia lies in the Mekong Peninsula of Southeast Asia, with a total land mass of 178,520 km^2, of which about 22% is arable. The country is bounded by Laos to the north, Thailand to the west, and Vietnam to the east; it faces the lower Gulf of Thailand in the south. Much of the country is taken up by a central plain, in the middle of which is the huge freshwater lake Tonle Sap. This plain is the country's grain basket; it is bounded by mountain ranges in the southwest and northeast.

The climate is tropical monsoonal; there is a short rainy season, prolonged dry season, and irregular rainfall both from year to year and within years. Most rain falls from May to mid-November. Often, a 10- to 15-day dry spell (called the short dry season) occurs in July or August.

The population in 2011 was 14.3 million. An estimated 66% of the population is dependent on farming. Agriculture made up 36.7% of GDP in 2011. The main agricultural products are rice, rubber, maize (corn), vegetables, cashew, cassava, and silk.

Production seasons

	Planting	Harvesting
Main	Jun-Jul	Nov-Jan
Dry	Dec-Jan	Apr-May

Rice is the country's staple food, providing 65–75% of the population's energy needs.

Cambodia's economy has been driven more by other sectors in recent years, particularly garment manufacture, as well as construction and tourism. Oil and mineral deposits hold promise of future major contributions to the country's GDP.

Recent developments in the rice sector

As a result of food shortages in the late 1970s, many Cambodian farmers were forced to eat their rice seed and traditional varieties were lost. In the 1980s, IRRI reintroduced more than 750 traditional Cambodian rice varieties to the countryfrom its seed bank in the Philippines—a vivid demonstration of the foresight that created the seed bank in the 1960s. With assistance from the Australian Agency for International Development (AusAID), IRRI also introduced improved rice varieties, better crop management, and extensive training programs, as a result of which Cambodia became self-sufficient in rice in the 1990s for the first time in 30 years.

On average, Cambodia's rice yield has increased at 5.4% per year since 1994, from 1.6 t/ha between 1994 and 1997 to 2.3 t/ha between 2003 and 2008; average yield in 2010 reached nearly 3 t/ha. This yield increase has been largely attributed to improvements in access to fertilizers and other inputs. The productivity of dry-season crops is much higher than for those of the wet season, mainly due to the use of higher-yielding seeds and better water management during the dry season. However, rice is mainly produced during the wet season, which accounts for more than 75% of the total paddy output per year. Dry-season paddy cultivation remains an important component of rice cultivation, particularly for consumers with a clear preference for dry-season varieties.

Cambodia became a rice-exporting country in the late 1990s, with a modest export of 6,000 t in 2000, climbing to 51,000 t in 2010. However, the country imports more rice than it exports, between 30,000 t and 80,000 t annually since 1995.

Rice environments

Rice in Cambodia is grown in four different ecosystems: rainfed lowland, rainfed upland, deepwater, and irrigated. The rice area has been expanding since the 1990s, from about 1.9 million ha in 1995 to 2.8 million ha in 2010. The proportion of rice area under irrigation increased from 15% in 2006 to 25% in 2010.

The rainfed lowlands of Cambodia are bunded fields that are almost completely dependent on local rainfall and runoff for water supply. Rainfed lowland rice is cultivated in all provinces. The largest concentration is around Tonle Sap, the Tonle-Basaac River, and the Mekong River.

The rainfed uplands are unbunded fields that depend entirely on rainfall. They are generally found scattered on rolling lands, some of which are mountainous forested areas. They form only a small proportion of the total rice land in Cambodia.

Deepwater rice is grown in low-lying areas and depressions where maximum water depth can reach more than 3 m. The floodwaters originate from Tonle Sap and the Mekong and Tonle-Basaac rivers and their tributaries.

Production constraints

Reports from the Asia Foundation and the United States Department of Agriculture point to several constraints to rice production growth in Cambodia:

- Extremely low production and availability of improved rice seed compared with other Asian countries.
- Underuse and nonusage of arable land. Most Cambodian farmers cultivate one paddy rice crop each year.
- The lack of a farm credit system affects not only rice farmers but also the milling industry, resulting in low use of fertilizer and uptake of farm mechanization, at both the production stage (planters, harvesters) and processing stage (mills, grain dryers, storage facilities).
- Poor transportation and related infrastructure such as roads, railways, and milling and handling equipment for the rice sector.
- A lack of good and effective agricultural crop extension programs, primarily due to a lack of funding. This has resulted in a severe lack of educated and experienced extension officers, as well as insufficiency of on-farm technology transfer and farming systems training and assistance.
- Inadequate funding for scientific agricultural research. The government relies almost totally on international donors for crop research.

Production opportunities

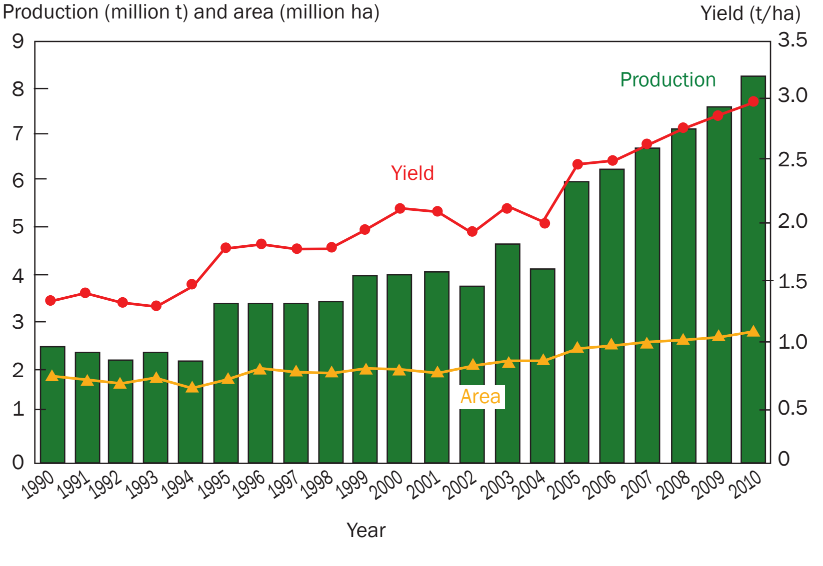
Cambodia has sufficient land and water resources to enhance productivity and increase rice production. Sufficient investment in irrigation infrastructure can further increase cropping intensity and crop productivity. International donors could be tapped for irrigation development, in line with the government's goal of becoming self-sufficient in rice and a rice exporter.

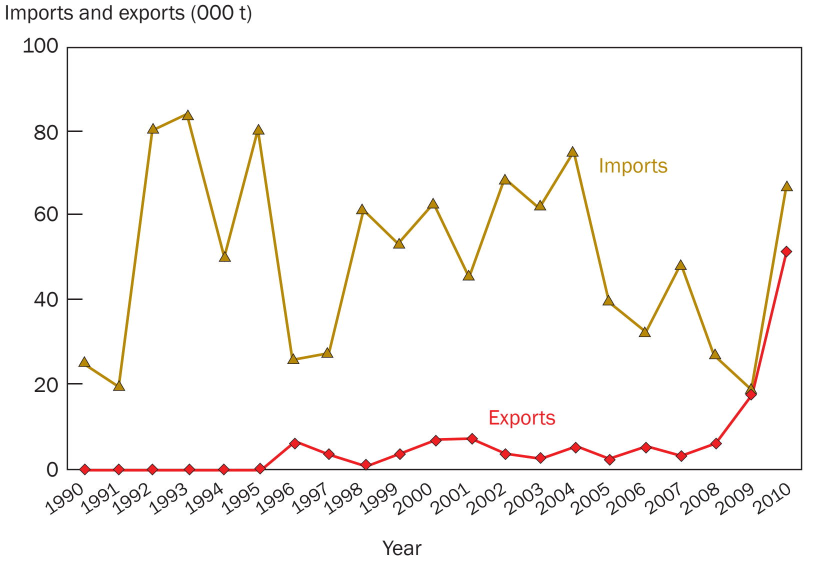
The government recently adopted a new rice policy to promote growth in paddy production and milled rice exports to match the growth seen in the garment and service sectors. This new rice policy will aim to introduce new technologies, improve agricultural practices, and provide incentives to commercial banks to increase loans for agriculture.

Basic statistics, Cambodia

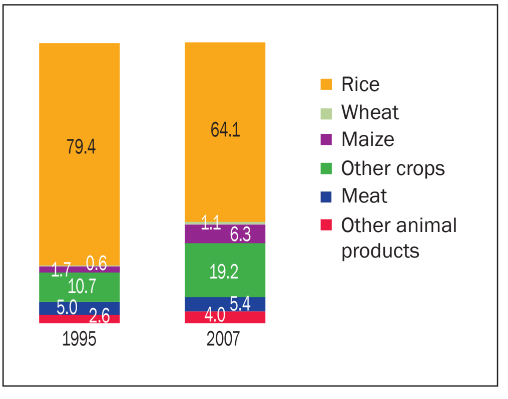
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	3,700	3,700	3,700	3,800	3,800	3,900	3,900	
Rice area (×10^3 ha)	1,924.0	1,903.2	2,414.5	2,516.4	2,566.0	2,613.4	2,674.6	2,776.5
Share of rice area irrigated (%)				15	17	20		25
Share of rice area under MVs (%)	11 (1994)					19		
Paddy yield (t/ha)	1.79	2.12	2.48	2.49	2.62	2.75	2.84	2.97
Paddy production (×10^3 t)	3,447.8	4,026.1	5,986.2	6,264.1	6,727.0	7,175.5	7,585.9	8,245.3
Milled production (×10^3 t)	2,300	2,685	3,993	4,178	4,487	4,786	5,060	5,497
Rice imports (×10^3 t)	81.0	63.6	40.2	32.9	48.9	27.6	19.8	67.2
Rice exports (×10^3 t)	0.0	6.4	2.4	5.4	3.1	5.6	17.5	51.2
Total rice consumption (×10^3 t)	2,242	2,547	3,705	3,771	4,367	4,565	4,833	
Fertilizer usage in NPK (kg/ha of arable land)	3	0	8.11	7.79	8.75	7.25	9.58	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

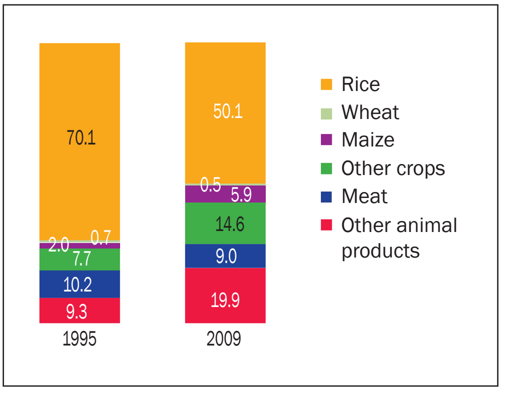




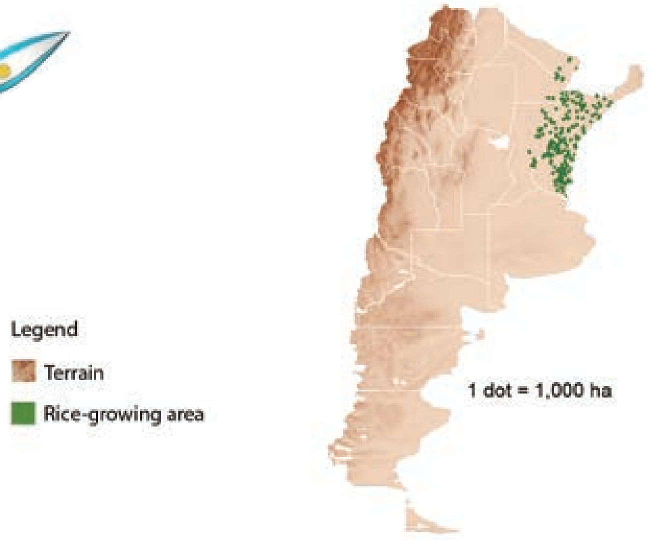
Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



ARGENTINA



General information

- GNI per capita PPP$, 2011: 17,130
- Internal renewable water resources, 2011: 276 km^3/year
- Incoming water flow, 2011: 538 km^3/year
- Main food consumed, 2009: milk, meat, wheat, fruits, vegetables, including oils, sugar, starchy roots, oil of sunflower
- Rice consumption, 2009: 7.9 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Aug-Dec	Feb-May

Argentina, located in southern South America, lies between 22 and 55° south latitude and 53 and 73° west longitude. It has an area of 3,761,274 km^2 and from them 2,791,810 km^2 correspond to the American continent and 969,464 km^2 to the Antarctic continent, including the South Orcadas (Orkney) Islands, South Georgia, and South Sandwich Islands. Argentina's topography is highly diverse and contrasting, showing northwest plateaus, forest, and glaciers in the Patagonia region, immense eastern plains, and the Andes Mountains in the west, where the highest peak of America can be found: the 6,959-m-high Aconcagua. Argentina's landmass is made up of 54% plains (savannas and grasslands), 23% plateaus, and 23% mountains and glaciers.

Argentina has subtropical and temperate climates that can be classified into four main types: warm, moderate, arid, and cold; each of them displays changing features due to the extension of the country and the presence of mountain chains. The warm climate with average temperatures above 20 °C is characteristic of Argentina's north region.

Argentina is the fourth biggest country in America and the seventh in the world. According to the 2011 census, its population increased from 36.3 million in 2001 to 40.1 million in 2010, going from a density of 9.7 to 10.7 persons per square kilometer during the same period. In contrast, the agricultural population had a negative growth rate equal to −11.1% for 2000-10 and went from 3.5 million in 2001 to 3.1 million in 2010. In 1990, the urban population represented 86.9% and for 2011 it corresponded to 92.4% of the total population; only 7.6% was rural, and this is expected to be only 5.4% by 2030.

Recent developments in the rice sector

In Argentina, rice production is on a large scale with a minimum farm size of 50 ha, which is highly mechanized. Rice is grown mainly in rotation with cattle grazing and also in rotation with pastures. The uniqueness of this rice production system is that the seed is drilled into the dry soil and water is pumped from the rivers Paraná, Bermejo, and Uruguay.

High-yielding japonica and indica varieties from *Oryza sativa* are cultivated and two grain types are preferred: large-thin and large-wide. However, the first grain type is the most widely planted, corresponding to 95% of the rice area.

Paddy rice occupies the thirteenth place in Argentina's commodities, with 5.2% of total grain production after maize (51.6%), wheat (29.7%), sorghum (7.1%), and barley (5.4%), and represents 0.6% of the primary crops. Even though rice is not one of the main commodities, its production, harvested area, and yield have increased markedly, going from 428,100 t, 116,620 ha, and 3.7 t/ha in 1990 to 1,240,600 t, 215,053 ha, and 5.8 t/ha in 2010, respectively. This remarkable production increase is related to an expansion in harvested area, increase in yield, mechanization, and better agricultural practices.

In 2010-11, growth in harvested area and production continued, as national rice area grew 20%. As a result, the largest national rice production was obtained with 1,753,200 t during the 2010-11 harvest. This increase is the result of the technology applied by INTA-Proarroz, the use of new rice varieties obtained in Entre Ríos, good agricultural practices such as appropriate sowing date and seed population, adequate fertilization, and better irrigation management. The implementation of these measures started in 1994 with the Corrientes Rice Project and in 2004 it was strengthened with the association of FLAR with the program called Management for High Yields.

Argentina is among the countries with low rice consumption per capita. The diet in this country is based on fewer than 10 products that contribute 80% of the calories required, including bread, flour, pasta, beef, sugar, cheese, potato, and rice. Cereals contribute 33% of the dietary calories, while rice provides less than 3% of calories and 2% of protein. However, rice calorie and protein shares have increased in the last 20 years by more than 37%.

Even when rice is not one of the main foods produced or consumed in Argentina, it is relevant in the international market, being an exportable product, especially to Mercosur countries. For instance, per capita consumption in 2009 was only 8 kg/year versus 76 kg/year in China. The rice trade in Argentina is characterized by export quantities that sharply exceed import quantities. Almost 60% of the rice production is exported and, from 1990 to 2009, rice exports increased by about 8 times, going from 75,227 t to 612,927 t. In 2009, Argentina was the second export country of paddy rice with 67,866 t after the United States (1,467,130 t), but ranked eleventh among milled rice-exporting countries and among rice-exporting countries with 359,278 t and 427,144 t, respectively.

Rice environments

In Argentina, three agricultural regions can be distinguished. The humid region covers 25% of the country, the semiarid region 15%, and the arid region accounts for 60% of the total area. Rice production in Argentina is concentrated in the humid region, the northeast part of the country, where the climate varies from temperate to humid subtropical. Two main rice-producing regions can be distinguished: the South Littoral and North Littoral. The South Littoral includes Entre Ríos and the North Littoral encompasses Corrientes, Formosa, Chaco, and Santa Fe. In those provinces, production is distributed in this way: Corrientes has 40%, Entre Ríos 38%, Santa Fe 16%, Chaco 3%, and Formosa 3%.

In Argentina, the predominant production system for commercial rice is irrigated, but there are some small areas of upland rice in Tucumán (for self-consumption). As a consequence, for rice production, the location and extension of production areas are dependent on water availability rather than on soil quality. The irrigation system used differs between provinces. Since the 1990s in Entre Ríos, water is extracted from deep wells using a pump instead of taking it from rivers and streams. In Corrientes, water for irrigation comes mainly from dams and rivers. In less than 10% of the area, deep wells are used. In

Santa Fe, Formosa, and Chaco, water is still taken from rivers and streams.

Production constraints

In the North Littoral, the main production constraints are lower soil fertility and the low pH that affect crop yield. On the other hand, in the South Littoral, water availability at sowing time is the most determinant factor. For instance, in 2010-11, rice production in Corrientes was remarkably high because of the water accumulated in dams.

Rice production in Corrientes is enough to feed Argentina's people. It has good quality and yield; however, it must face some inconveniences in the international market because stability of the dollar is not proportional to the inflation in U.S. currency that affects activity in inputs such as labor and machinery. As a consequence, while production cost grows, international prices show a tendency to fall. In addition, the export taxes imposed by the new government affect the competitiveness of rice prices and prevent producers from reaping the true benefit of stronger international commodity prices. For rice, export taxes are 10% for paddy rice and 5% for processed rice.

Other important constraints in Corrientes are the absence of a shipping port on the Paraná River to ship rice production and the use of diesel to pump irrigation water from pumps and rivers. This together with taxes, freight, and withholdings negatively affect rice prices and, now, in some cases, production is generating losses. For instance, those rice producers that consume more than 150 liters of diesel for their gasoline pumps have large economic losses and are almost out of the rice production business.

In addition to the explained constraints, each province must face its own difficulties. In the case of Santa Fe, for example, insufficient funding and a shortage of storage rooms and of drying equipment are the main limitations. As a consequence, rice producers have to sell their rice during the production period, it being impossible to keep it until prices rise.

Finally, the increase in soybean cultivated area had negatively affected rice production area and, in 2010, 18,130,900 ha had soybean crops in comparison with the 221,728 ha of rice. Soybean is more attractive to producers than rice because crop management is easier and the cost of crop establishment is lower.

Production opportunities

Argentina's government is looking forward to increasing rice production by 129% in 2020 according to the "Strategic Plan for Agro-industrial Development." The main objective is to make Argentina a large food factory with added value, and social and environmental sustainability. In rice, the objective is to increase yield per hectare, the number of harvested hectares from 220,000 to 357,000 (62%), and production from 1.2 to 2.8 million t (129%).

In 2011, rice production costs decreased for some farmers as a result of the implementation of electric irrigation systems. This infrastructure improvement was available for 15% of Corrientes' rice producers and is expected to benefit more people due to the construction of a high-voltage power line in the Upper Paraná. As a consequence, it is expected to decrease irrigation costs by about 60%. However, until now, less than 40% of the rice production area has electricity and the rest still uses gasoline or diesel. As a consequence, Argentina's rice sector risks a complete loss of competitiveness in the future.

In addition, the construction of a port for the transportation of grains is expected to occur in the near future in order to decrease shipping costs. Feasibility and infrastructure studies will be carried out in 2013.

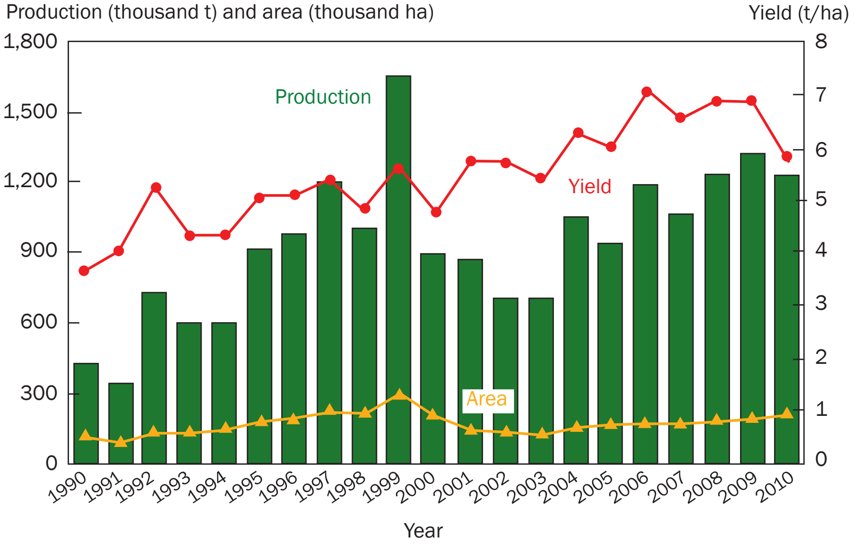
Regarding the international market, the main importer of Argentina's rice is Brazil; however, Argentina is making big advances in rice production in order to supply the domestic market. Argentina, as well as the other Mercosur countries, has an important advantage because it has a 10–12% import tariff exemption. Argentina's rice also excels in quality and transportation costs are low.

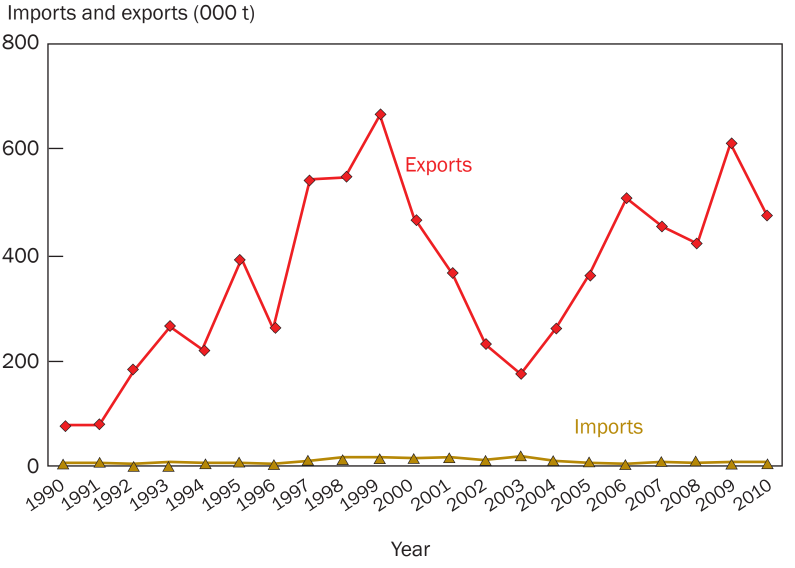
Even with the advantage of being a member of Mercosur together with Brazil, Argentina has to start looking for new markets. As a result, a cooperation treaty between Argentina and Mozambique is in negotiation and one of the promising products to be sent to Mozambique is rice.

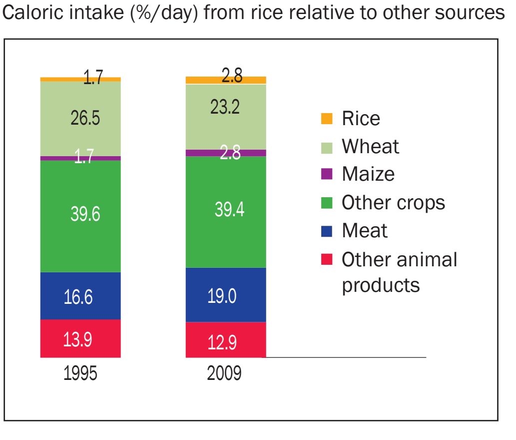
Basic statistics, Argentina

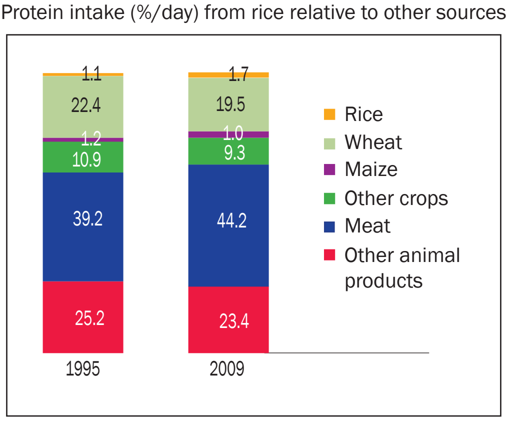
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	27,000	27,900	29,500	31,500	33,000	32,000	31,000	
Rice area (×10^3 ha)	184.1	189.1	158.9	169.0	164.6	182.5	193.8	215.1
Share of rice area irrigated (%)	6							
Share of rice area under MVs (%)								
Paddy yield (t/ha)	5.03	4.78	6.02	7.06	6.56	6.83	6.88	5.77
Paddy production (×10^3 t)	926.2	903.6	956.3	1,193.5	1,080.1	1,245.8	1,334.2	1,240.6
Milled production (×10^3 t)	618	603	638	796	720	831	890	827
Rice imports (×10^3 t)	7.1	15.7	6.3	5.5	9.3	8.4	6.5	8.2
Rice exports (×10^3 t)	390.1	467.0	362.2	507.3	451.3	423.2	612.9	473.4
Total rice consumption (×10^3 t)	227	250	295	313	332	385	391	
Fertilizer usage in NPK (kg/ha of arable land)	19	31	41	46	54	39	25	

FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

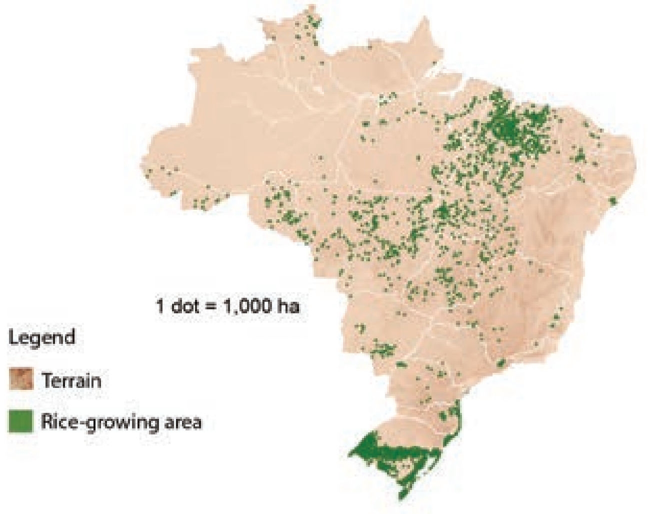



Imports and exports (000 t)
800
600
400
200
0
Exports
Imports
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Caloric intake (%/day) from rice relative to other sources
1.7
26.5
1.7
39.6
16.6
13.9
1995
2.8
23.2
2.8
39.4
19.0
12.9
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
1.1
22.4
1.2
10.9
39.2
25.2
1995
1.7
19.5
1.0
9.3
44.2
23.4
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

BRAZIL



General information

- GNI per capita at PPP$, 2011: 11,420
- Internal renewable water resources, 2011: 5,418 km^3/year
- Incoming water flow, 2011: 2,815 km^3/year
- Main food consumed, 2009: milk, fruits, cereals (rice, wheat, maize), meat, starchy roots, fermented beverages, vegetables, sugar and sweeteners, soybean oil
- Rice consumption, 2009: 34.6 kg milled rice per person per year

Production seasons

	Planting	Harvesting
South, main	Aug-Dec	Mar-Apr
Northeast, main	Mar-May	Aug-Nov
North, main	Nov-Dec	Apr-Jun

Brazil, the fifth-largest country in the world, is located in east-central South America and occupies almost 50% of the continent. Its national territory covers 8,514,599 km² and includes archipelagos of Fernando de Noronha, Trindade and Martim Vaz, and São Pedro e São Paulo, and the Rocas Atoll. The Atlantic Ocean borders the entire east coast, with a length of 10,959 km. Brazil has country borders with Guyana (1,731 km), Venezuela (2,078 km), Suriname (438 km), French Guyana (664 km), Uruguay (1,044 km), Bolivia (3,338 km), Peru (2,241 km), and Colombia (1,532 km).

Brazil has a population of nearly 196 million (2011), increasing from about 150 million in 1990. The most populated regions are the southeast, which has 41% of the Brazilian population, the northeast with 28%, and the south with 14%. Those are also the regions with the highest population density: 84, 47, and 33 persons per km², respectively. In contrast, the agricultural population decreased by 40%, while the agricultural area increased, from 241,608 ha in 1990 to 264,500 ha in 2009.

The economy, based on well-developed agriculture, mining, manufacturing, and service sectors, is expanding and stands out among Latin American countries. The GNI per capita at PPP$ grew from 8,810 in 2006 to 11,000 in 2010 alone. The national poverty rate declined from 30.8% in 2005 to 21.4% in 2009, while external debt (% of GNI) fell from 47.5% in 2002 to 16.9% in 2010.

In 2006, perennial crops occupied 3.5% of the total land area, field crops 13.2%, natural pastures 17.1%, cultivated pastures 31.3%, forests and conservation units 26.0%, cultivated forest (silviculture) 1.4%, and nonarable land 1.8%. In the 2011-12 season, approximately 50.3 million ha were cultivated and produced 157.5 million t of cereals and oilseeds. The main food crops are rice, maize, and soybeans, representing 90.7% of total production, using 83.1% of the cultivated area.

Five regions can be distinguished: north, northeast, south, southeast, and center-west. The north is the largest region, covering almost 45% of the country, including the Amazon's tropical forest. The climate is hot and humid with an average temperature of 26 °C and 1,500–3,000 mm rainfall. The northeast includes the semiarid lands characterized by an irregular rainfall pattern of 250–750 mm per year. The south is in the temperate zone and includes the Uruguayan savanna. This area has cool-dry winters and warm-moist summers. The southeast is characterized by milder winters and rainy summers with temperatures between 18 and 24 °C and 900–4,400 mm rainfall; the Atlantic forest is included even though less than 10% of its original area remains because of farming, ranching, and charcoal making. Finally, the center-west includes the vast tropical savanna ecoregion known as "cerrados" that account for 21% of Brazilian territory. It is the richest tropical savanna region in the world and has a semihumid tropical climate with 22–26 °C average temperature and 1,250–3,000 mm rainfall.

The basic staple foods in Brazil are rice, cassava, and beans; however, lately, beans and cassava have lost favor and wheat consumption has increased. At present, rice calorie intake is around 11% of total calorie intake and protein intake is almost 8%. Wheat and meat contribute more calories and protein than rice, with values of more than 12% each.

Rice is cultivated in almost all 558 micro-regions of the country. In 2010, only 129 micro-regions did not produce any rice. In that year, 81.8% of production was concentrated in the states of Rio Grande do Sul (61.1%), Santa Catarina (9.2%), Mato Grosso (6.1%), and Maranhão (5.2%). A number of states produce more than they consume.

Rice production has increased in the last 20 years, from 9.5 million t in 1991 to 13.5 million t in 2011, an increase of about 30%. However, rice farming area fell from 4.1 million ha in 1991 to 2.7 million ha in 2011.

Irrigated rice is the most important system of production. In 2010, the irrigated system covered 50.1% of the total area under cultivation and accounted for 78.0% of the production; upland rice occupied 49.1% of the area and produced 21.4% of the total; while rainfed lowland rice occupied 0.8% of the area and produced 0.6% of the total. The production increase is the result of a combination of adequate technology investments, yield improvement, and climate. Upland rice area decreased, associated with its low productivity, in comparison with lowland rice, attributed to dry spells during the crop season, low soil fertility, and high risks due to rainfall dependence.

The average annual rice consumption per capita varies from 15 to 90 kg among the Brazilian states. The national average was 34.6 kg in 2009. The country can be divided into six regions in terms of rice production and consumption: Region 1: Maranhão and Piauí states, with high per capita consumption and local production enough to ensure local supply. However, consumer preferences regarding quality and the competitiveness of brands from other states affect this balance. Region 2: states with low per capita consumption but insufficient local production to supply local demand. Region 3: states where local production is higher than local demand; the surplus goes to other regions, mainly 1, 2, and 5. Region 4: including 50% of the population, with the highest GDP but insufficient rice production to satisfy demand. Region 5: areas with a deficit in rice production and a population with low per capita income. Consumers here prefer 1-kg bags of parboiled rice, while consumers in the other regions prefer 5-kg bags of rice. Region 6: the main producing region, where the major processors are located. Per capita consumption is lower than in the other regions.

International agricultural trade has increased since 1990. In recent years, Brazil has become one of the main producers and exporters of food and vegetable fibers. The main exports are soybean, raw sugar, maize, chicken, green coffee, beef, and tobacco, reaching markets worldwide as well as within South America.

Recent developments in the rice sector

Brazil is the ninth-largest rice-producing country and largest outside Asia, with 11.3 million t in 2010, 1.7% of the world's rice production. Because of several factors (e.g., Mercosur agreement, large country size, and market openings), Brazil is an importer as well as exporter of rice, being the largest South American rice importer at 590,000 t of milled rice and 82,146 t of paddy rice in 2009. The imported rice comes principally from Uruguay, Argentina, and Paraguay, which in 2009 sent 186,239, 131,926, and 58,440 t of milled rice and 29,913, 4,720, and 47,510 t of paddy rice, respectively.

Brazil became rice self-sufficient in 2002-03 and began exporting in 2004, with 36,717 t of milled rice, climbing to 511,919 t in 2008. Exports, which were less than 5% of rice production, were mainly for African countries such as Benin (108,138 t), Nigeria (80,998 t), South Africa (50,525 t), and Cameroon (16,547 t). Paddy rice was exported mainly to Venezuela (29,880 t).

In order to ensure domestic supply and minimum prices to farmers, the federal government intervenes whenever supply is higher than domestic demand, using a minimum price guarantee policy, which has a set of measures to influence markets.

Rice environments

Rice production systems vary from small nonmechanized farmers in the north and northeast to highly technical, large-scale production in the south and southeast. Planting methods involve direct sowing, minimum cultivation, conventional sowing, and pregermination. The first method is commonly used in upland rice production systems in areas repeatedly planted; the conventional method is used in rice areas recently opened and in the north and northeast, where agriculture is only for subsistence. In Santa Catarina, pregerminated seeds are preferred.

In the north and northeast, a small area of lowland rice is located in the humid coastal strip. However, most of the region has subsistence agriculture. In the north, irrigation needs are minimal, but, in the northeast, water is scarce and uncontrolled water extraction has dried some rivers and streams.

In the south, rice production is on a large scale, mechanized, and integrated with cattle grazing. Irrigation systems have been developed for flooding the lowlands. The main rice-producing state is Rio Grande do Sul, where rice production is completely mechanized and the farms are at least 200 ha in size. Santa Catarina is the other main Brazilian rice-producing state, also located in the south; there, the average farm size is 10 ha and the use of family labor is common.

Upland rice is sown in several Brazilian states, mainly in the central-west (Mato Grosso and Goiás), northeast (Ceará and Piauí), southeast (São Paulo and Minas Gerais), and in the "cerrados" where it was the pioneer crop when agriculture began there during the 1980s. Production peaked in 1988 at 4.5 million t and has since declined. In 1999, the rice area was 2.4 million ha, or 64% of the total rice area and 38% of the total production. In recent years, the central-west planting area has declined from 15% to 11% of the total.

The southeast is one of the best regions for agriculture. It has great advantages over the south, where frost prevents cropping in winter. Because of the milder climate and some irrigation also being possible during the winter, the southeast has two growing seasons over the year. This has increased the living standards in the southeast. The northern and northeastern regions are the poorest in Brazil.

According to the Ministry of Agriculture, Livestock, and Food Supply in March 2012, a total of 251 varieties of rice were registered with the ministry. Long slender-grain rice with good cooking quality and high commercial value has been prioritized.

Production constraints

Other crops. Soybean farming is expanding in the savanna region, while the agronomic and commercial challenges faced by upland rice are being neglected by both policymakers and agribusiness agents;

the rice-growing area is decreasing. Also, there is no clear framework for the future of rice in the country regarding such issues as consumption trends, increasing the international market share, and, above all, the real possibilities of using rice by-products.

Production costs. Record national production in 2011 resulted in an excess of rice, which revealed some logistical constraints, especially transportation costs, which increased domestic rice prices. The government introduced subsidies to cope with cheaper rice imported from Uruguay.

According to the Instituto Rio Grandense do Arroz, rice production costs in Brazil are the highest in Latin America at US$2,200 per ha, especially in relation to these costs in Argentina ($1,300) and Uruguay ($1,600). Producers in Brazil fear that the increase in Argentina's rice production along with lower interest rates and easy credit will make Brazilian rice even less competitive. A similar situation occurred with wheat being cheaper to import from neighboring countries such as Argentina. If this situation persists, rice producers may change to more profitable crops such as soybean. However, for the moment, they are reluctant to change, mainly because of their investments in rice irrigation systems.

Weeds. One of the biggest biological constraints to Brazilian irrigated rice production is the weed "red rice," a major problem in rice-growing regions everywhere and affecting all production areas, especially Rio Grande do Sul, where it is critical. The problem is more common in direct-seeded areas and arises because red rice germinates later than domestic varieties, and the seed bank in the soil is replenished before the grain is harvested. Additionally, red rice and white rice are genetically close, so most products used for eliminating red rice will also affect white rice.

Production opportunities

Exports. The success of the southern region in rice production has been due to yield increase and improvements in quality of grains. Irrigated Brazilian rice can compete in the international market and, although Brazilian rice has increased its international market share in recent years, it makes up only 4% of traded rice.

New markets. Brazil has been exporting white rice to South Africa since 2009. In 2011, the first shipment of parboiled rice was sent and Brazil is expected to ship approximately 1,000 t monthly.

Importation. Since 2011, the government is requiring countries that export rice to Brazil to undertake residue analysis before it purchases the rice. This has affected the rice trade between Brazil and the two main rice providers, Argentina and Uruguay. The purpose is to protect Brazil's national rice production, especially when there is a surplus.

Diverse rice-producing regions. Irrigated rice produced in southern Brazil reaches other regions of the country at competitive prices due to economies of scale, and is preferred by consumers. The main asset of rice from the southern states is the stronger organization of the production chain.

The main winner for irrigated rice production is Brazilian society. But rainfed production continues to have an important role in local supply, where brands from southern states are more expensive and less accessible to lower-income communities. Additionally, production in different regions may become more important for food security in future years if irrigated systems are affected by environmental threats. Therefore, it is economically and environmentally important to maintain rice production in several regions of the country.

Rice surplus. The excess rice production in 2011 and the challenges to trade forced rice growers to look for new uses for the surplus stocks as animal feed and even biofuel. In addition, surplus rice can be distributed as humanitarian assistance to eradicate hunger in the country.

Weed control. Red rice was controlled through minimum tillage in infested fields; however, a new hybrid rice resistant to herbicides named BRS Sinuelo Cl l was released by Embrapa and BASF in 2011, as part of the "Clearfield Production System;"

with this hybrid, herbicides can be used to control red rice populations. Hybrid breeding was first launched in 1985 by Embrapa and IRAT (France) and continued later by IRGA and Fazenda Ana Paulo. In 2004, Embrapa began a collaborative breeding program with CIRAD (France). The future of hybrid rice in Brazil depends now mainly on improving grain quality.

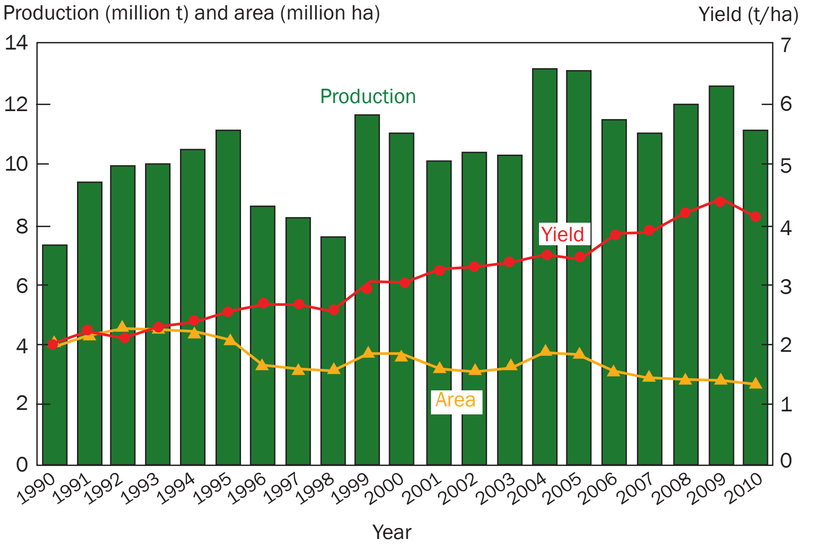
Research. In 1998, Embrapa began zoning the areas for rice cultivation in the states of Goiás, Mato Grosso, Mato Grosso do Sul, Tocantins, and Minas Gerais. This is the main tool in defining the best timing and most suitable areas for planting upland rice along with the formulation of policies on production incentives in areas identified as having lower climatic risk. A water-balance model was used to estimate climatic risk, considering rainfall, potential evapotranspiration, crop coefficient, water storage capacity of the soil, and crop phenological stages. Zoning of irrigated rice in Rio Grande do Sul and Santa Catarina has also been carried out.

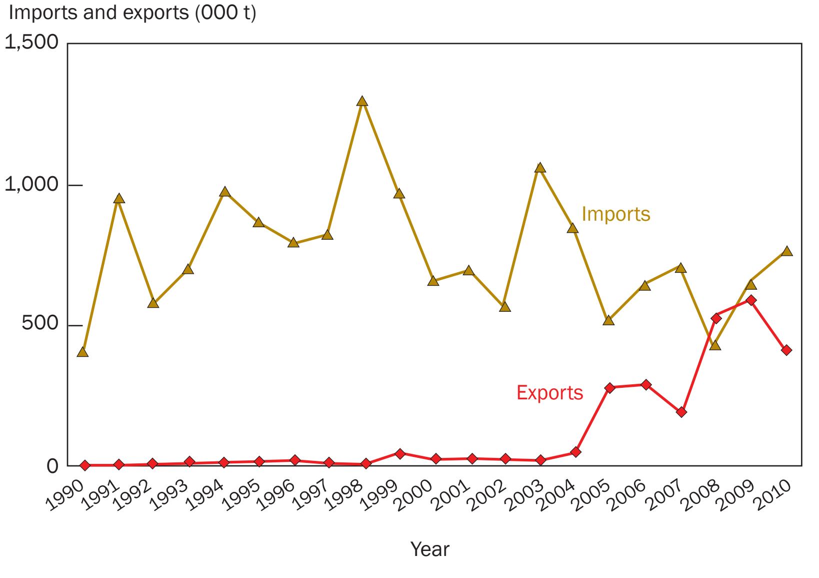
Brazil is the tenth largest rice producer in the world.

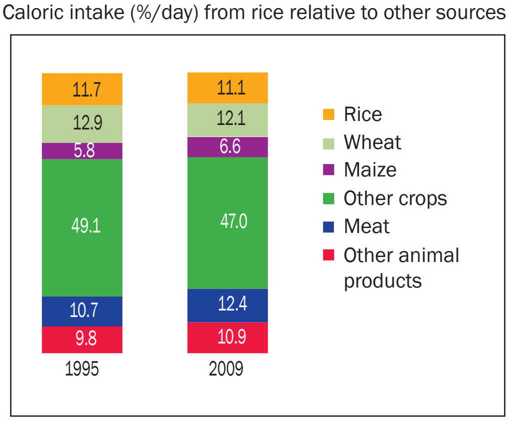
Basic statistics, Brazil

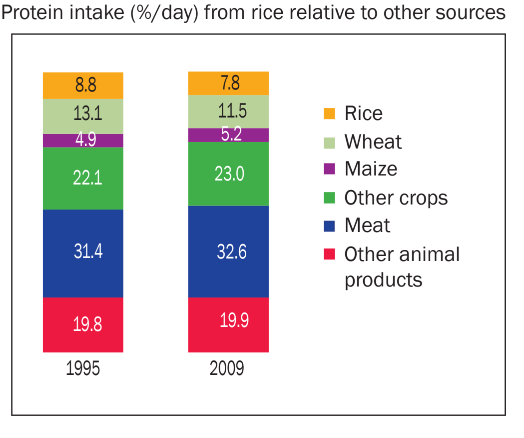
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	58,059	57,700	61,000	61,000	61,000	61,200	61,200	
Rice area (×10^3 ha)	4,373.5	3,655.3	3,915.9	2,970.9	2,890.9	2,850.7	2,872.0	2,722.5
Share of rice area irrigated (%)								50.1
Share of rice area under MV (%)								94*
Paddy yield (t/ha)	2.57	3.03	3.37	3.88	3.83	4.23	4.40	4.13
Paddy production (×10^3 t)	11,226.1	11,089.8	13,192.9	11,526.7	11,060.7	12,061.5	12,651.1	11,236.0
Milled production (×10^3 t)	7,488.0	7,397.0	8,800.0	7,688.0	7,377.0	8,045.0	8,438.0	7,490.7
Rice imports (×10^3 t)	870.5	659.5	517.0	642.1	704.5	430.9	645.6	763.2
Rice exports (×10^3 t)	18.5	26.4	272.3	290.1	201.4	511.9	591.6	422.6
Total rice consumption (×10^3 t)	6,582.0	7,980.0	8,998.0	8,089.0	7,838.0	8,117.0	8,457.0	
Fertilizer usage NPK (kg/ha of arable land)	72	114	136	141	185	165	125	

Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.*CIAT in Focus, 2012.

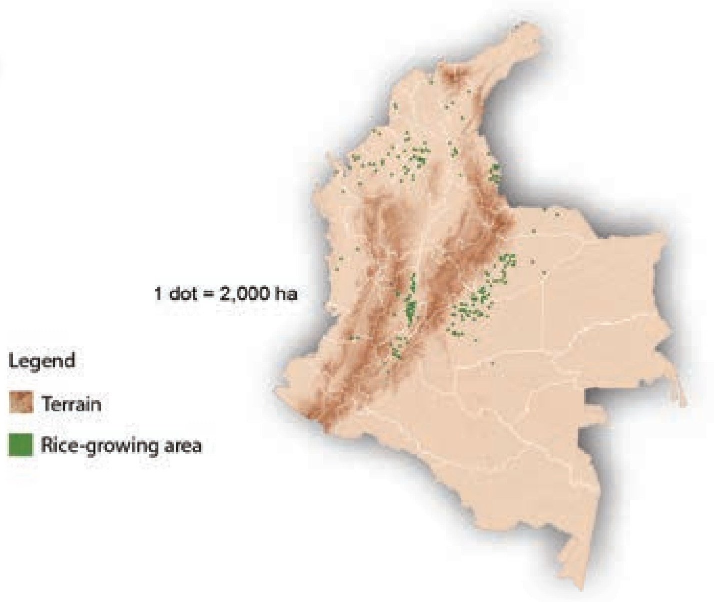

Production (million t) and area (million ha)
Yield (t/ha)
Production
Yield
Area
Year


Imports and exports (000 t)
Imports
Exports
Year


Caloric intake (%/day) from rice relative to other sources
11.7
12.9
5.8
49.1
10.7
9.8
1995
11.1
12.1
6.6
47.0
12.4
10.9
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
8.8
13.1
4.9
22.1
31.4
19.8
1995
7.8
11.5
5.2
23.0
32.6
19.9
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

COLOMBIA



General information

- GNI per capita PPP$, 2011: 9,560
- Internal renewable water resources, 2011: 2,112 km^3/year
- Incoming water flow, 2011: 20 km^3/year
- Main food consumed, 2009: milk, starchy roots, plantains, meat, sugar, maize, rice, wheat
- Rice consumption, 2009: 35.2 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Summer	Mar-Apr	Jul-Aug
Winter	Aug-Oct	Jan-Mar

Colombia lies in the northwest of South America. Its national territory covers 1,138,910 km², of which the land mass is 1,038,700 km². Colombia has coasts on the Atlantic and Pacific oceans with a coastline of 3,208 km (Caribbean Sea 1,760 km and North Pacific Ocean 1,448 km). Two-thirds of the country is composed of inter-Andean valleys and plateaus, the remainder being highly mountainous, including the Andes and the Sierra Nevada de Santa Marta.

Five geographic regions can be distinguished: the Andean region in the central part of the country, including three Andean mountain ranges and their inter-Andean valleys, with five temperature zones from hot lowlands to subzero glacial lands more than 4,000 m above sea level; the Caribbean lowlands coastal region, also known as Atlantic region, in the north of the country, with tropical savanna climate and one or two dry periods each year; the Pacific lowlands coastal region located to the west of the Andes, with a tropical monsoon climate; the eastern region that extends to the east of the Andes, characterized by its great plains; and the Amazon region in the south of the country, which includes the Amazon forest, generally warm and highly humid with high rainfall.

Colombia's population in 2010 was 46.3 million, with 75% living in urban areas. The total population has increased at an annual rate of 1.16%, while the rural population decreased from 8.86 million in 1990 to 6.97 million in 2010.

The Colombian economy is expanding due to government policies, aggressive promotion of free trade agreements, and direct foreign capital investment, especially in the oil sector. This expansion produced a significant decrease in poverty and unemployment in the last decade: poverty decreased from 49.4% of the population in 2002 to 37.2% in 2009, while unemployment declined from 14.5% in 2002 to 9.8% in 2011. The agricultural sector grew by 9.6% and played an important role in lowering unemployment: rural unemployment dropped to 5.5% during the period. However, economic development has slowed down because of inadequate infrastructure, and was further weakened in 2010 and 2011 by major floods and by inequality and high unemployment.

Recent developments in the rice sector

Colombia occupies 25th place among rice-producing countries, and is third in Latin America after Brazil and Peru. Rice is the fourth most important crop after sugarcane, oil palm fruits, and plantains and is the fourth most consumed food after plantains, sugar, and potatoes. Rice is third in crop area after coffee and maize, with 13% of the total sown area and 30% of the temporary crop area. Rice production represents 10% of the value of agricultural activity and is a basic food for the poorest people in the country.

Rice is cultivated in five zones: central, eastern, low Cauca, north coast, and the Santanderes. The two main rice environments are irrigated and rainfed (mostly lowland), using both mechanized and manual/traditional methods; about 70% of the rice area is mechanized.

Rice farming is concentrated in the central zone, with average annual production of 780,333 t during the last 20 years. Tolima, Huila, Meta, and Casanare departments are responsible for 72% of national rice production; the two Santanderes have the lowest production.

National rice production increased from 2.12 million t in 1990 to 2.41 million t in 2010. Growth was constant between 1990 and 1999 and has become variable since then. During 2004-10, irrigated rice production fell from 1.59 million t to 1.32 million t; rainfed rice fell less, from 877,341 to 752,515 t.

The decline in rice production is partly related to a decrease in the total rice harvested area of almost 56,300 ha since 1990 (from 521,100 ha in 1990 to 464,794 ha in 2010), nearly all in the irrigated area. Rainfed rice area increased from 157,779 ha in 2000 to 173,058 ha in 2010.

The yield of rice, however, grew from 4.1 to 6.3 t/ha during 1990-2008, although it fell to 5.2 t/ha in 2010. The rise is partly the result of new improved rice varieties such as Fedearroz 50 obtained from the cross of CIAT rice varieties. The yield increase was more pronounced in irrigated areas, from 4.9 t/ha in 1990 to 6.0 t/ha in 2008. In rainfed areas, the values were 3.5 and 4.3 t/ha in 1990 and 2008, respectively. The relationship between yield and production region is also important: the highest yields are in the central zone (5.8 t/ha on average) while the lowest are in low Cauca (3.5 t/ha).

Colombia is actually more a rice importer than an exporter. This is because the national industry buys all the rice produced. It can store 473,080 t of paddy rice and its milling capacity is 180% of the national requirements. Rice imports have varied considerably since 1990, with the highest in 1998 (292,744 t) and the lowest in 1990 (90 t). The maximum imported quantity corresponds to 23% of the rice produced in the country.

The rice industry in Colombia occupies an important place in the economy. In 2009, the earnings of the rice industry were US$2.5 billion, or 1.87% of GDP. In producing municipalities, rice accounts for 60% of GDP, 48% of employment, and 80% of people's income.

Colombia is seventh in rice consumption in South America (after Guyana, Suriname, Peru, Ecuador, and Brazil) at 35.2 kg/capita/year in 2009. Calorie and protein intakes from rice did not change significantly between 1995 and 2009 at around 11.1% to 13.2% and 9% to 10.3%, respectively.

The rice sector in Colombia is highly organized. It is included in one of the agro-chains of the Ministry of Agriculture and Rural Development. The chain is composed of the National Federation of Rice (FEDEARROZ), which represents rice producers; ANDI-Induarroz that represents the rice industry; the national Association of Rice Millers (MOLIARROZ); Colombian Association of Seed Producers (ACOSEMILLAS); and Fenalco for rice traders and other regional associations.

The Colombian government shows great interest in developing the rice sector because of its importance in agriculture and the national economy through co-financing rice processing plants, encouraging the establishment of new irrigation districts through easy access to credit, and implementing government policies against rice smuggling.

Production constraints

Production costs. High production costs are caused by the high cost of inputs, water, and fuel, but especially by the unavailability of new agricultural areas equipped with irrigation; in the last 30 years, no new irrigation district has been built. As a consequence, agricultural land with irrigation has become a speculative good. Additionally, land cost has increased as watersheds deteriorate, the number of tenants is increasing (58% of rice producers are tenants), and the number of short-cycle crops to rotate with rice is falling because imported products have become cheaper.

Prices. One of the biggest problems of the rice sector is the change in price between seasons. In the first production season (March-August) and beginning of the second, the price drops as a result of overproduction during the first season. Then, after a season with very favorable prices, new investors appear, causing an artificial demand for quality land with good infrastructure, thus increasing production costs and supply while causing the price to drop again. A related problem is oligopsony: more than 60% of the rice produced is bought by five industries and, after processing, only a few trading companies buy and sell it.

International treaties. International treaties, especially those between Colombia and other South American countries, have harmed the rice industry by allowing the import of cheaper products during the rice harvesting time or when a rice surplus exists. In addition, in neighboring countries such as Ecuador and Peru, investment costs in developing irrigation districts and in infrastructure and fuel are lower than in Colombia, making the prices of imported rice products cheaper.

Climate change. Extremes of minimum and maximum temperature and unusual rainfall patterns have decreased rice yields by 50%, especially in the low Cauca, central, north coast, and eastern zones. For instance, since 2009, in Tolima, average temperatures have risen 3 degrees, affecting pollen sterility and spikelet fertility and increasing the incidence of some rice diseases.

Diseases and pests. Blast, rice hoja blanca virus, *Togasodes oryzicolus*, crinkling virus, *Rhynchosporium*, and *Helminthosporium* are the main rice threats. Increasing temperature and humidity in the Usocello irrigation district have favored certain fungi and decreased rice production from 140 bags/ha to 80–100 bags/ha. In Norte de Santander, the use of foreign rice varieties has increased the incidence of rice hoja blanca virus, reducing production by 10–25% and threatening rice production in border areas and plant sanitary security.

Other constraints. Other constraints to rice production in Colombia are smuggling, competition from weeds and red rice, infertility, aluminum-toxic soils in the eastern plains, and the increasing numbers of tenant farmers.

Production opportunities

Technology adoption. A program for massive adoption of technology (AMTEC) to be implemented initially in Tolima includes identifying the time of year with maximum sunlight to sow rice to improve yield. In addition, the technology will help in identifying the production constraints in each rice production zone. AMTEC will also allow producers to adopt several technologies—better terrain leveling, the use of ridges to retain moisture longer, the use of precision-sowing machines, the use of good agricultural practices, and access to new rice varieties—at the same time in order to be more competitive.

Infrastructure. The Colombian government will present to the Congress a proposal called "Irrigation and drainage policy" in order to rehabilitate and upgrade irrigation districts built more than 50 years ago. The aim is also to give incentives to private industries to invest in and modernize the rice sector.

Generic inputs. The new regulation that allows the use of generic inputs in rice crops has lowered production costs, as prices are lower than for branded inputs.

Genetic background. FEDEARROZ is establishing its own germplasm bank with germplasm from CIAT and FLAR in order to broaden the genetic base. Twelve varieties from this bank have been released and some of them are resistant to higher temperatures and/or tolerant of important bacteria.

Research. Research in the rice sector is still a priority and new alliances between FEDEARROZ and BASF with the Clearfield (high-yielding varieties combined with broad-spectrum herbicides) system, with RiceTec for hybrid rice, and with CIAT and FLAR have been signed.

Rice quality. The rice industry in Colombia is technologically advanced as indicated by grain yield after milling, which is similar to the United States standard.

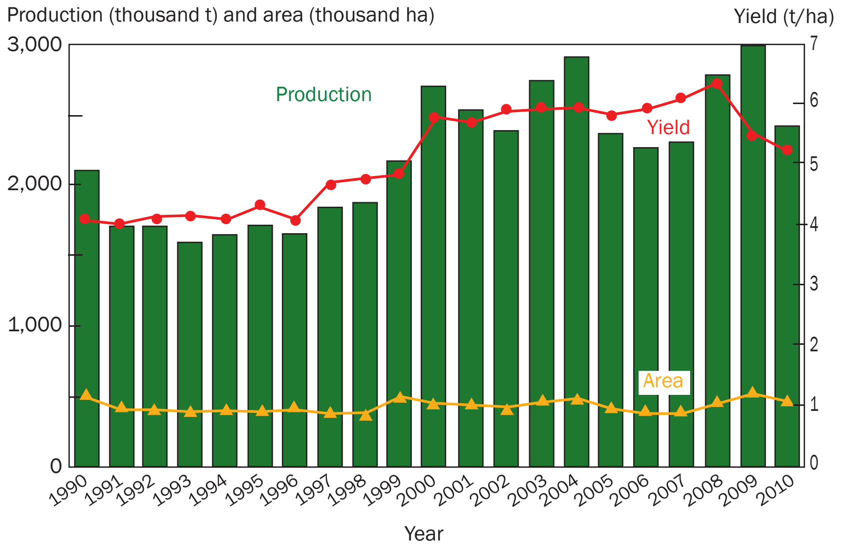
Climate change. A multidisciplinary group from FEDEARROZ has been working on the causes of low rice productivity in Tolima in recent years, designing a program for research and technology transfer, and identifying indicators to be used to identify agronomic problems that hinder rice production.

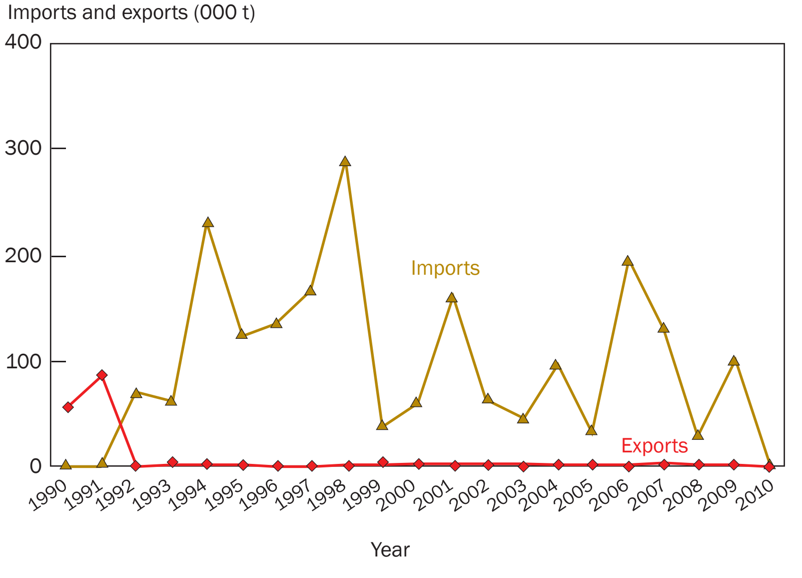
International treaties. FEDEARROZ is implementing different strategies to strengthen the rice sector for free trade areas, for instance, the building of drying silos in some areas. Additionally, a software called SACFA (Administrative System for Rice Farms) will be released in order to improve rice farm management. Finally, the use of AMTEC and the implementation of precision agriculture will allow Colombian rice to compete with imported rice and guarantee food security for the poorest in Colombia.

Basic statistics, Colombia

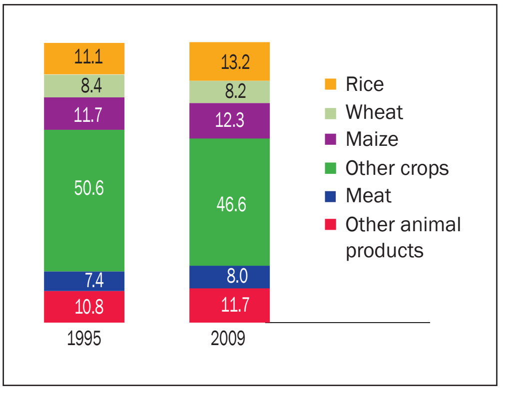
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land ($\times 10^3$ ha)	2,399	2,818	2,026	1,905	1,998	1,830	1,775	
Rice area ($\times 10^3$ ha)	406.8	469.7	409.0	380.4	383.7	443.6	543.1	464.8
Share of rice area irrigated (%)		66	67					63
Share of rice area under MVs (%)		94 (2001)						
Paddy yield (t/ha)	4.28	5.74	5.80	5.91	6.03	6.29	5.50	5.19
Paddy production ($\times 10^3$ t)	1,742.6	2,693.9	2,371.9	2,248.0	2,313.3	2,792.2	2,985.2	2,412.2
Milled production ($\times 10^3$ t)	1,162	1,797	1,582	1,499	1,543	1,862	1,991	1,608
Rice imports ($\times 10^3$ t)	122.5	58.8	32.1	197.0	135.3	29.5	101.9	6.3
Rice exports ($\times 10^3$ t)	0.3	0.0	0.2	0.0	0.2	1.0	0.0	0.1
Total rice consumption ($x10^3$ t)	1,266	1,851	1,712	1,693	1,676	1,891	2,093	
Fertilizer usage of NPK (kg/ha of arable land)	203	234	445	571	546	492	497	

Source: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

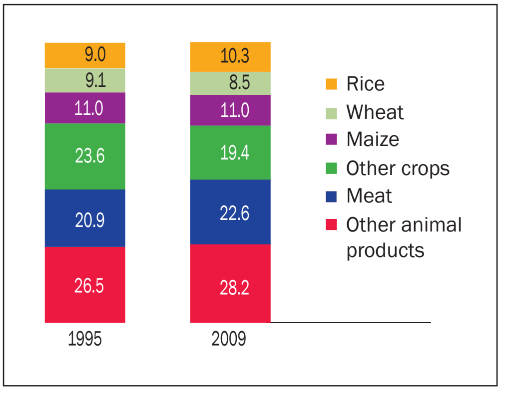




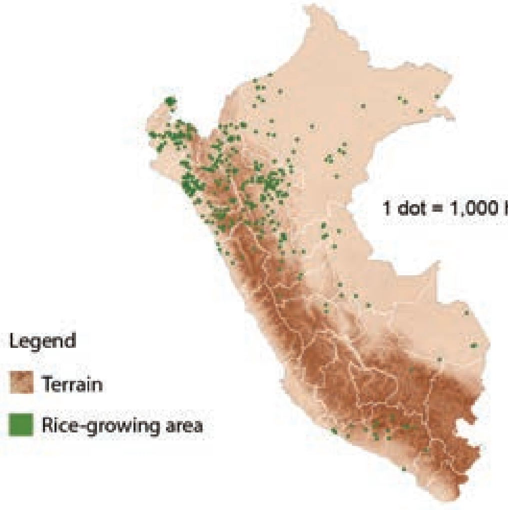
Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



Peru



General information

- GNI per capita PPP$, 2011: 9,440
- Internal renewable water resources, 2011: 1,616 km^3/year
- Incoming water flow, 2011: 297 km^3/year
- Main food consumed, 2009: starchy roots, milk, vegetables, wheat, rice, plantains, sugar and sweeteners, fish, meat, maize
- Rice consumption, 2009: 48.7 kg milled rice per person per year

Peru is located in west-central South America, with a land mass of approximately 1.28 million km^2 and 5,220 km^2 of water. Three geographic regions can be differentiated: coastal, mountain, and forest. The coastal region is a narrow 2,414-km flat, mainly arid and partly desert strip between the Pacific Ocean and the Andes Mountains. Good-quality farmlands are found only in the valleys of the seasonal rivers. The mountain region, in the Andes Mountains, is divided into western, central, and eastern mountains rising up to 6,780 m above sea level. Most of this area is composed of valleys and plateaus. Lake Titicaca, the world's highest navigable lake, is in the eastern mountains. The forest region is east of the Andes and includes part of the Amazon forest, divided into high forest—a belt lying between 700 and 3,600 m on the east side of the Andes Mountains—and low forest, composed of uninterrupted forest.

Peru's climate is tropical with abundant rainfall, high temperatures, and lush

Production seasons

Department	Planting	Harvesting
Amazonas/Cajamarca/Loreto/ San Martín/Tumbes/Ucayali	Au-Jul (year-round)	Aug-Jul (year-round)
Ancash	Oct-Mar	Nov-Mar
Ayacucho/Pasco	Sep-Jan	Aug-Feb
Cusco/Junín	Sep-Jan	Aug-
Arequipa	Oct-Feb	Oct-Feb
Huánuco	Aug-Jun	Aug-July (year-round)
La Libertad	Nov-Apr	Nov-May
Lambayeque	Dec-Mar	Aug-May
Piura	Aug-Apr, Jul	Aug-July (year-round)
Puno	Aug-Dec	Sep-Jan
Madre de Dios	Aug-Jan	Aug-Jan

vegetation. However, it varies from west to east, being dry-desert in the coastal region and temperate in the highland valleys. The coastal regions have a mean temperature of 18 °C and total absence of rainfall during summer. Some parts of the coast grow vegetation thanks to the *garúa*, or winter fog. In the mountainous region, temperature decreases with altitude, from north to south and east to west. The forest region has a humid tropical climate with rainfall of 1,500–3,000 mm per year and 80% humidity.

Peru has a population of more than 29 million, of whom almost 50% are concentrated in the coastal region at densities of 186–5,774 persons per km², in contrast to the forest and mountain regions with 1–9 and 10–25 persons per km², respectively. The population growth rate declined from 1.5% in 2000 to 1.1% in 2010 and it is expected to continue decreasing. Only 28% of the population, almost 7 million people, lives in rural areas.

The Peruvian economy has experienced ups and downs depending on the world economy. In 2008, for example, it grew 10% but, in 2009, less than 1% as a result of the world recession, a fall in private investment, and a decrease in government spending. The economy bounced back in 2010, achieving 9% growth. The most important economic sector in Peru is services, comprising 56% of GDP. The economy also depends on exports of minerals and metals, while the contribution of the agricultural sector to GDP is 8.5% (2010). Peru continues attracting foreign investment; this investment, rapid economic expansion, the government's conditional cash transfers, and other government programs together helped to reduce the national poverty rate from 44.5% in 2006 to 31.3% in 2010.

Recent developments in the rice sector

Rice crops are an important component of the agricultural sector, making up 9.4% of the gross value of national agricultural production and occupying 18.3% of the total cultivated area. Rice is a major source of rural employment; 1.5% of the economically active population works in the rice subsector. The consumer price index is highly dependent on rice prices.

Rice is a staple food in Peru and in some regions is even more important than potato in the diet; together, potato and rice have the most extensive cropping area in the country. Rice is also used for feeding livestock and making alcohol, acetic acid, acetone, oil, pharmaceutical products, fuel, and compost. Rice consumption in Peru is the third highest of South America after Guyana and Suriname, with 48.7 kg per capita per year in 2009. The caloric and protein intakes from rice grew 4% and 3%, respectively, during 1995-2009, while those of maize and wheat fell around 4%.

Peruvians prefer two types of rice. The elite favor packed long grain, white, grainy rice of high volume expansion. In contrast, the majority prefer rice in bulk, more tender, slightly sticky, and not very white. More than 30 rice varieties are consumed, their source being the rice breeding program of the National Rice Research Program of Peru, derived from rice varieties developed by IRRI-Philippines and CIAT-Colombia.

The rice crops are located mainly in the north valleys, forest rim, and forest region. Peruvian rice production tripled from 0.97 million t in 1990 to 2.83 million t in 2010. Production is concentrated in the north (52%, or 1.48 million t), followed by the high forest (40%, or 1.14 million t). The increase in national rice production is the result of water abundance, favorable weather conditions, economic policies, and increases in planted area and grain yield. The harvested area doubled from 0.18 million ha in 1990 to 0.39 million ha in 2010 while yield surged from 5.3 to 7.3 t/ha. The highest average yields in 2009 were in the south coast with 13 t/ha, followed by the north coast with 9.2 t/ha; the forest region had the lowest yield with 6.7 t/ha. These high yields are the result of improved technology, availability of quality seeds, research, and technology transfer. Peru has the highest rice yields in Latin America and is seventh in the world ranking. Its 750 registered mills have a capacity of 8 million t per year.

Nevertheless, Peru imports rice, although imports fell from 0.46 million t in 1992 to 0.21 million t in 2011, less than 5% of present requirements. Most (90%) is from Uruguay and Vietnam (8%). Peru also exports increasing quantities of rice, from only 48 t in 2005 to 47,908 t in 2009.

Irrigated rice production costs are closely related to yield, and vary with input costs, estimated at US$244–256 per ton. Such high costs require yields above 6.8 t/ha; otherwise, Peruvian rice would not be competitive in international markets.

The government has not shown interest in developing the rice sector while producers do not want or cannot invest money to develop the sector and turn the small self-sufficient farms into bigger producing ones.

Rice environments

Irrigated rice accounts for two-thirds of the rice area and most of the supply, mainly in the forest rim in the regions of Cajamarca and Amazonas, in the higher forest of San Martín, and in the coastal regions of Tumbes, Piura, Lambayeque, La Libertad and Arequipa. Upland rice is grown in the high and low forest, and lowland rice in the low forest in Ucayali and Loreto. Upland and lowland rice are mainly produced for local consumption and supply is unstable, with average yields of 1.5 t/ha and 2.4–2.9 t/ha, respectively.

San Martín is the most favorable rice-growing region because it has water year-round, even though the yield is low compared with that of other Peruvian irrigated rice production regions.

Irrigated rice is sowed by hand using seedlings or using pregerminated seeds; in the lowland system, transplanting is used, whereas, for uplands, rice is sowed by broadcasting seedlings or laying them in rows on dry soil. In the north and south coast, labor for transplanting is expensive and broadcasting seedlings and mechanized transplanting are preferred.

Production constraints

Production constraints in Peru are related not only to rice production but also to the broader agricultural sector, as shown below.

Soil destruction and change in land use. Poor land-use practices and conversion of forest into agricultural areas have caused deforestation, desertification, salinization of soils, depletion of water resources, and degradation of ecosystems. As a consequence, crop yields are low and soon fields become useless, causing poverty.

Production is based on individual small-scale farmers. Peruvian agriculture is based on small farmers with plots of less than 10 ha. In 2011, there were 125,000 rice producers and 26% of rice farms were smaller than 5 ha, 43% had areas of 5–20 ha, and only 31% were bigger than 20 ha. There are very few big producers and they are not organized; the new Peruvian Association of Rice Producers (APEAR) has little negotiating power with the government on matters such as regulating rice production and prices, establishing new rice areas, strengthening international competitiveness of the sector, and protecting small producers against monopsony, oligopsony, and aggressive financial intervention. The result has been economic losses, constant decapitalization, and lack of access to credit, technical assistance, and improved technology.

Uncontrolled prices and markets. Production, harvest, and markets are not organized; many unnecessary intermediaries are involved; wholesale markets do not exist; and poor infrastructure hampers the transport of rice from production centers to consumption areas and hinders the production growth in Peru's noncoastal areas.

No access to regulated long-term credit. Rice production is funded by the rice industry, mainly by loans from the milling industry at high interest rates—7–10% per month. Banks offer only short-term credit and they are concentrated in Lima.

Market price. Recent revaluation of the national currency (nuevo sol peruano) together with the removal of tariffs in January 2011 caused imported rice to become cheaper than domestic rice. In addition, during 2000-10, input costs increased faster (79%) than rice prices (29%).

Limited technical assistance, research, and training. Specialized technical assistance is not readily available and is limited by the fragmentation of the sector and the government's lack of interest. The Ministry of Agriculture does not have a plan for research, technology transfer, and technical assistance to farmers.

Lack of infrastructure. The lack of storage infrastructure is one of the main constraints to rice production regionally.

Water. Rice producers do not have adequate irrigation systems and the establishment of other crops has damaged the soil and caused salinization due to constant flooding.

Rice varieties. The rice varieties now sown have high yield potential and good grain quality but some of them are highly susceptible to pests and diseases, which lowers yield. Additionally, too many varieties are sown, causing difficulties in trade. It is necessary to refocus research on market analysis and not only on production.

Production opportunities

Rice producer associations. The Peruvian Association of Rice Millers (APEAR) strengthens the rice sector to become more competitive. It protects rice producer rights and offers training on professional development and technical assistance. APEAR is also working to strengthen the rice producers' union by offering technical assistance; research; trade and policy analysis services; making agreements with companies providing inputs, machinery, and seeds; and designing programs to make the rice sector competitive.

Added value for Peruvian rice. The lack of added value remains a major constraint to rice commercialization. Rice color classifiers to select rice grains are one way to improve grain quality and production indexes; two units have been installed in the country to date.

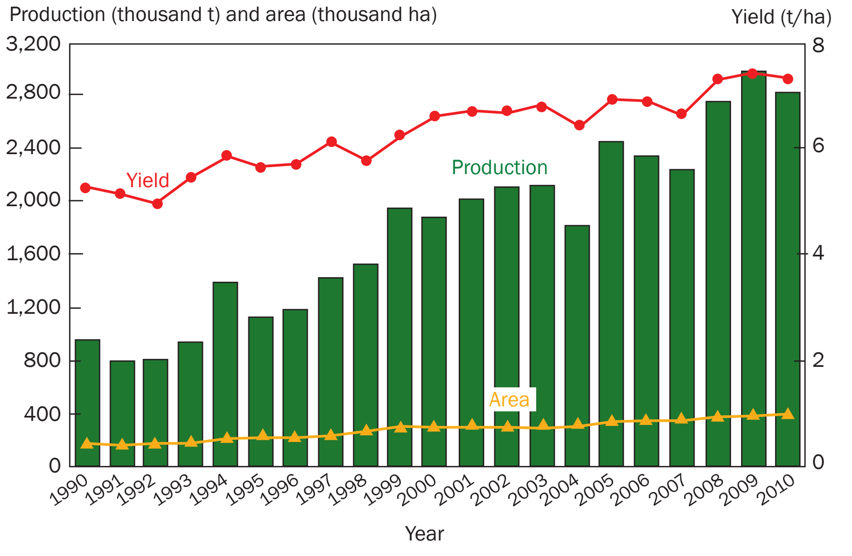
Profitability, sustainability, and competitiveness. The National Institute for Agricultural Innovation (INIA) is developing rice varieties with higher yield, better grain quality, resistance to pests and diseases, and adapted to the Peruvian rice-producing regions; it is also elaborating integrated crop management practices that use less chemicals and reduce production costs.

APEAR is working with the National Institute for the Defense of Competition and Protection of Intellectual Property (INDECOPI) and municipal governments on the formalization of the rice sector. APEAR showed the need for a market for cereals and grains in Lima and asked seed companies for the implementation of sanitary measures and good practices in the production and sale of seeds.

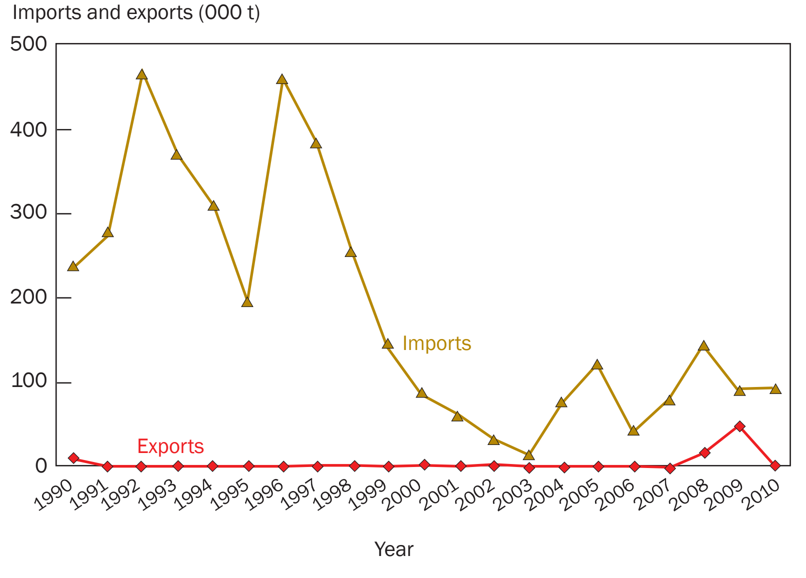
Basic statistics, Peru

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	3,600	3,700	3,650	3,650	3,650	3,650	3,650	
Rice area (×10^3 ha)	203.2	287.1	357.9	343.7	337.6	379.8	404.6	388.7
Share of rice area irrigated (%)								67
Share of rice area under MVs (%)								84
Paddy yield (t/ha)	5.62	6.59	6.90	6.87	6.68	7.31	7.39	7.29
Paddy production (×10^3 t)	1,141.6	1,892.1	2,468.4	2,362.3	2,435.1	2,794.0	2,991.2	2,831.4
Milled production (×10^3 t)	761	1,262	1,646	1,576	1,505	1,851	1,985	1,888
Rice imports (×10^3 t)	196.5	88.0	125.2	44.2	80.0	146.5	91.4	94.7
Rice exports (×10^3 t)	0.0	3.3	0.0	0.1	0.1	17.5	47.9	2.0
Total rice consumption (×10^3 t)	951	1,343	1,749	1,606	1,562	1,968	2,013	
Fertilizer usage of NPK (kg/ha of arable land)	43	69	83	93	110	82	105	

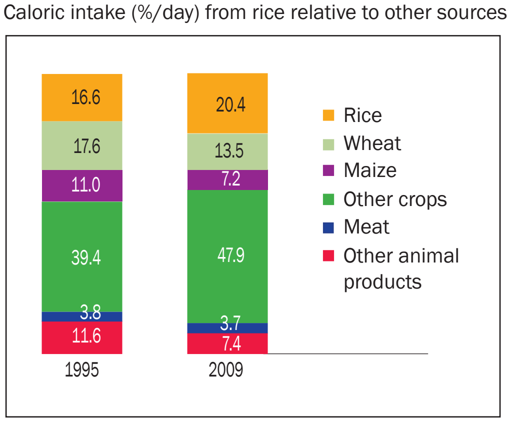
Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.



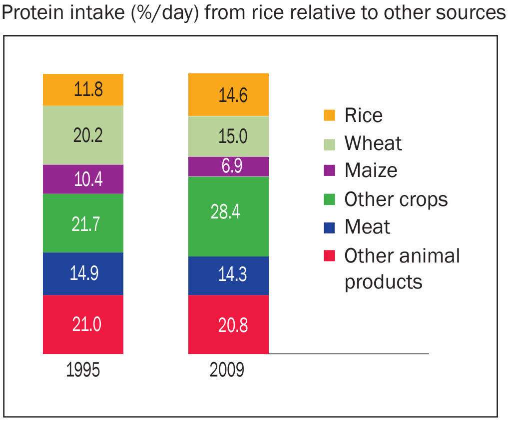
Production (thousand t) and area (thousand ha)
Yield (t/ha)
3,200
2,800
2,400
2,000
1,600
1,200
800
400
0
8
6
4
2
0
Yield
Production
Area
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year



Imports and exports (000 t)
500
400
300
200
100
0
Imports
Exports
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year

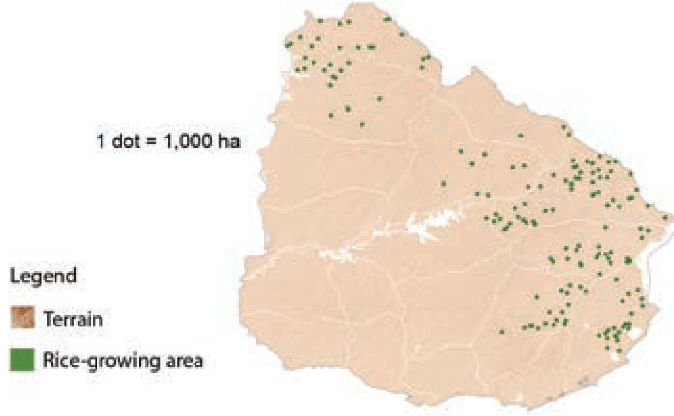


Caloric intake (%/day) from rice relative to other sources
16.6
17.6
11.0
39.4
3.8
11.6
20.4
13.5
7.2
47.9
3.7
7.4
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products



Protein intake (%/day) from rice relative to other sources
11.8
20.2
10.4
21.7
14.9
21.0
14.6
15.0
6.9
28.4
14.3
20.8
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

URUGUAY



General information

- GNI per capita PPP$, 2011: 14,640
- Internal renewable water resources, 2011: 59 km^3/year
- Incoming water flow, 2011: 80 km^3/year
- Main food consumed 2009: milk, wheat, meat, vegetables, starchy roots, soybean oil, maize, rice
- Rice consumption, 2009: 19.2 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Sep-Nov	Feb-Apr

Uruguay is located in South America, bordering Argentina in the west, Brazil in the north and northeast, the Río de Plata in the south, and the Atlantic Ocean in the east. Its national territory totals 17.6 million ha, of which 17.5 million ha are land and the remainder water. Almost 95% of the land area can be used for agriculture and livestock and 4 million ha are available for crops. However, to avoid soil degradation, rotation between pasture and crops is carried out, such that only 1.6 million ha are available at any one time.

The Uruguayan terrain is mostly plains with low hills; there are no high mountains. In the northwest, hills are mixed with valleys and plains. A large part of the country consists of fertile pasture and all the territory is reached by an extensive water network from the rivers Uruguay, La Plata, Merín Lagune, and Negro.

Five geographic regions can be distinguished based on social, economic, and cultural factors: north, center-south, east, south, and west. The northern region covers 13% of Uruguay and includes the departments (provinces) of Rivera and Tacuarembó, with an economy based mainly on livestock and a small amount of agriculture and industry. Crops include rice, soybean, sunflower, maize, sorghum, wheat, potato, and cassava. The northeastern region covers 28% of Uruguay, including the departments of Artigas, Salto, Paysandú, and Río Negro. Intensive livestock and agriculture are common, and there are extensive orange plantations. The center-south includes the departments of Durazno, Flores, Florida, San José, Canelones, and Montevideo. The economy there is based on intensive livestock with forage production mainly in the north and milk production and intensive agriculture in the south. The southwest is characterized by the division of the Cuchilla Grande, which has many divergent ridges separating the headwaters of the rivers Uruguay La Plata, and Merín Lagune. Finally, the eastern region encompasses the departments of Cerro Largo, Treinta y Tres, Lavalleja, Rocha, and Maldonado, where extensive livestock ranching is carried out—mainly sheep in the highlands and cattle in the lowlands. In Treinta y Tres, Cerro Largo, and Rocha, rice is farmed.

Uruguay is characterized by having a small proportion of arable land with a high risk of soil erosion. Maintenance of soil fertility through the integration of traditional crops and livestock production is necessary.

The climate is humid subtropical without large fluctuations in temperature and rainfall during the year. The maximum temperatures vary from 28 to 33 °C and the minimum temperatures from 6 to 9 °C. Rainfall varies from 1,000 mm per year in the south to 1,300 mm in the north. Strong and continuous winds are common most of the year.

The population increased by 0.35% per year, from 3.1 million in 1990 to 3.4 million in 2011. Approximately 93% of the population is urban and increasing while the agricultural population has decreased, from 0.39 million in 1990 to 0.33 million in 2011. The most populated departments are those in the south, southwest, and northwest; the least populated areas are those used for livestock ranching. The highest density is in the capital city, Montevideo, with more than 1,000 persons per km^2. The capital of each department has a relatively high density, ranging from 100 to 500 persons per km^2. Elsewhere, population density is less than 10 persons per km^2.

The economy of Uruguay is characterized by an export-oriented agricultural sector and high levels of social spending, public expenditure, and investment. Since 2004, the economy has shown positive growth despite the global financial crisis. The service sector contributes 70% of GDP, followed by industry with 20.9% and agriculture with 9.1%. The national poverty rate decreased rapidly from 30% in 2007 to 19% in 2010; similarly, unemployment fell from 12% in 2005 to 7% in 2010.

Recent developments in the rice sector

Rice production in Uruguay is based on an extensive system of rotation with pastures and integrated with livestock production. It requires high investments in inputs, certified seed, labor, machinery, and infrastructure, including irrigation systems, storage rooms, silos, and roads. However, it also generates employment not only in the production subsector but also in industry and trade; rice is in third place, after beef and wool, in its contribution to agricultural GDP.

Rice is grown mainly in the north, northeast, and east by small (less than 200 ha), medium (200–500 ha), and large producers (more than 500 ha), with the average farm being 300 ha—bigger in the east region and smaller in the north. Farmers growing other crops as well as rice tend to have larger (400 ha average) farms.

The rice production system is irrigated lowland; direct-seeded or broadcast and then flooded using pumps or gravity irrigation. Usually, the rice crop is grown in fields left fallow or with forage for at least 4 years. This rotation contributes to soil preservation and makes a strong contribution to farmers' economic stability.

Uruguay is 33rd among rice-producing countries and eighth in South America. Rice production has been increasing since 1961 and, since 1990, the growth rate has almost doubled. The highest production occurred in 2008, with 1.33 million t. The most productive regions are the north and the east, especially the departments of Treinta y Tres, Rocha, and Cerro Largo, which account for 77.5% of the rice area.

Yield has also increased significantly, by almost 40% during 1970-95 to 5.5 t/ha due to improved cultural practices and cultivar Bluebelle (from Texas, USA). From 1995 to 2010, national average yield increased by a further 40% to 7.1 t/ha because of improved farming practices, the adoption of local high-yielding cultivars (El Paso 144, INIA Tacuarí, and INIA Olimar) and strengthening of the rice sector through association with FLAR. Recent weather conditions have also contributed to the high rice yields because of the La Niña phenomenon (low humidity and high radiation periods) in at least 5 of the past 7 years.

Rice area doubled from 78,091 ha in 1990 to 161,900 ha in 2010, with 55% of the sown area in the east, 24% in the center-north, and 21% in the north. The potential area for rice is 1 million ha. However, due to crop rotation practices, all the potential area would never be planted simultaneously.

The rice sector in Uruguay is characterized by vertical integration of production, industrialization, and trade. Farmers sell at a price fixed by the Rice Cultivators Association and the National Rice Millers Association, such that farmers, especially on smaller farms, can sow and harvest without concern about price and the rice industry can work at its maximum capacity. This vertical integration also facilitates other common policies related to seed, research, credit, etc.

More than 90% of national rice production is exported. Uruguay was the sixth-largest paddy rice and milled rice exporter in 2009, with most rice going to Brazil. Uruguay's rice production is unique in its relatively low rate of adoption of new cultivars, use of certified seed guaranteeing grain quality and sustainability with low inputs, and, in contrast to other exporting countries such as the US, Uruguayan mills do not mix varieties but keep track of the identity of each variety.

Rice consumption in Uruguay is one of the lowest in South America although caloric and protein intake from rice have risen since 1990. Rice consumption per person per year increased from 9.3 kg in 1995 to 19.2 kg in 2009; daily calorie intake from rice increased from 3.5% to 6.8% and protein from 2.1% to 4.8% in the same period. Contrary to the general situation in other countries where rice consumption is opposite in trend to maize and/or wheat consumption, maize and rice have both increased. At present, rice, wheat, and maize consumption are increasing at the expense of meat consumption.

Rice environments

In the northwest, irrigated rice is grown on slopes in the basins of the Negro, Cuareim, and Uruguay rivers in the departments of Artigas, Salto, Paysandú, Río Negro, and Soriano. In the departments of Durazno, Tacuarembó, Rivera, and west of Cerro Largo (central region), irrigated rice farms are scattered along the basin of the Negro River. More than half the area suitable for rice is in the east region, in the basins of the Cebollati, Olimar, and Tacuarí rivers and Merín Lagune in the departments of Treinta y Tres, Cerro Largo, Lavalleja, and Rocha.

Production constraints

Production costs. The rice crop is the most expensive in Uruguay because of the costs of seed, agrochemicals, fuel, labor, machinery, equipment, irrigation, drainage systems, and construction of water reservoirs. The government does not give subsidies because rice is a business and not a subsistence crop. Rice production has a high fuel requirement; variation in fuel prices affects rice production directly. Production costs increase every year by 10–15%. Rice in Uruguay is not subsidized as it is in other countries, especially the US, the main competitor of Uruguay. Smaller Uruguayan rice producers cannot cover the high production costs; some become indebted and finally drop out of rice production.

Markets. In 1985-2003, Brazil was the main buyer of Uruguayan rice, taking 70–90% of Uruguay's total production. However, since 2003, Brazil has been self-sufficient. Low export prices have affected Uruguayan producers, and rice exports have decreased. Additionally, since 2011, Brazil requires rice exporters to provide a residue analysis, a situation that makes rice trade difficult.

Irrigation systems. Because of constant variation in the levels and volume of the water in the rivers, it is necessary to build reservoirs and dams for irrigation and use pumps to irrigate the rice crop.

Weather. Water availability is the main limitation in rice farming; in dry years, it is sometimes necessary to use additional water pumps, whereas excess rain, especially before the establishment of the crop (September-November), can delay sowing and affect the reproductive phase. Excess rain in January and/or February during grain filling can also reduce production due to a decrease in solar radiation.

Diseases. Abundant rainfall as a consequence of the El Niño phenomenon favors the occurrence of *Pyricularia*, a

Branded Uruguayan rice is loaded at the SAMAN rice mill near Treinta y Tres.

fungus not normally common or important in Uruguay.

Production opportunities

Markets. As a consequence of a drop in exports to Brazil, Uruguay is exploring new markets in Iran, Peru, Central America, and Europe. Uruguay has a great advantage in Europe because of the excellent quality of its rice, none of which is transgenic, unlike some US rice varieties.

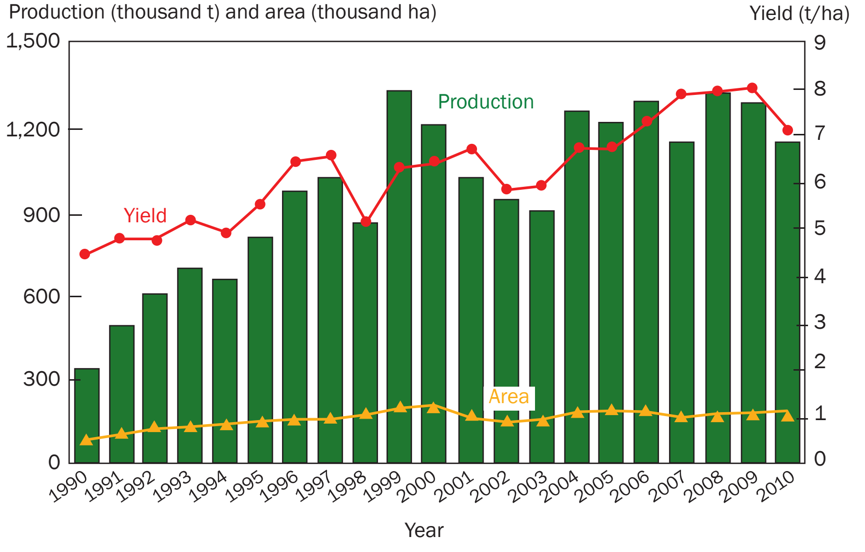
Rice added value. Certified seed is commonly used and the selection process, visual and manual, is very strict. As a result, Uruguay's rice production excels in its grain quality and sustainability; red rice is not a problem.

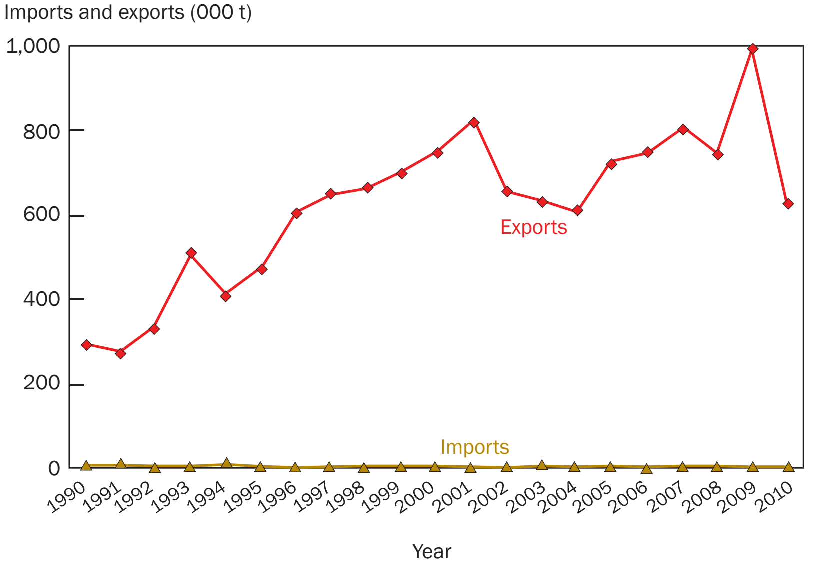
Water availability. The gasoline-based water pumps are being replaced by more efficient electric pumps. All the irrigation systems should be working with electrical energy within a few years. In addition, the Rice Cultivators Association, together with the Ministry of Agriculture and Fisheries and local governments, is building dams to ensure water availability for the entire rice production cycle.

Basic statistics, Uruguay

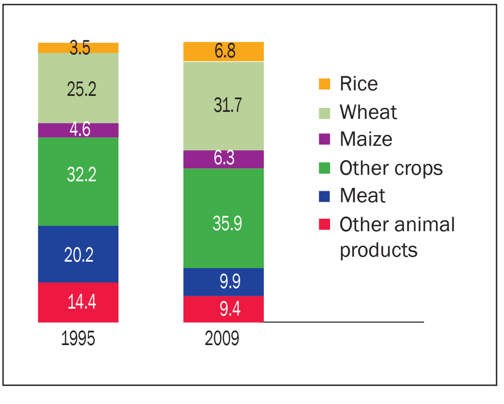
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	1,290	1,373	1,300	1,292	1,340	1,661	1,881	
Rice area (×10^3 ha)	146.3	189.4	184.0	177.3	145.4	168.4	160.7	161.9
Share of rice area irrigated (%)	93	100	100	100	100	100	100	100
Share of rice area under MVs (%)		100	100	100	100	100	100	100
Paddy yield (t/ha)	5.51	6.38	6.60	7.29	7.88	7.90	8.01	7.10
Paddy production (×10^3 t)	806.1	1,209.1	1,214.5	1,292.4	1,145.7	1,330.0	1,287.2	1,148.7
Milled production (×10^3 t)	538	806	810	862	764	887	858	766
Rice imports (×10^3 t)	0.1	0.0	0.1	0.2	0.3	0.1	0.6	1.0
Rice exports (×10^3 t)	462.5	741.4	719.4	744.8	798.7	740.7	994.3	628.2
Total rice consumption (×10^3 t)	55	80	91	91	94	97	97	
Fertilizer usage in NPK (kg/ha of arable land)	51	76	151	161	188	117	131	

Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.
For MV and irrigation coverage: www.aca.com.uy, FAO's Aquastat online database.

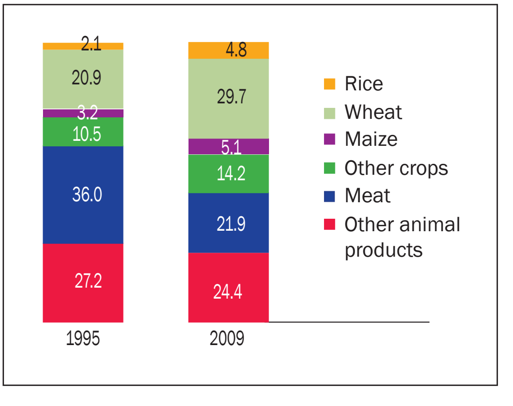




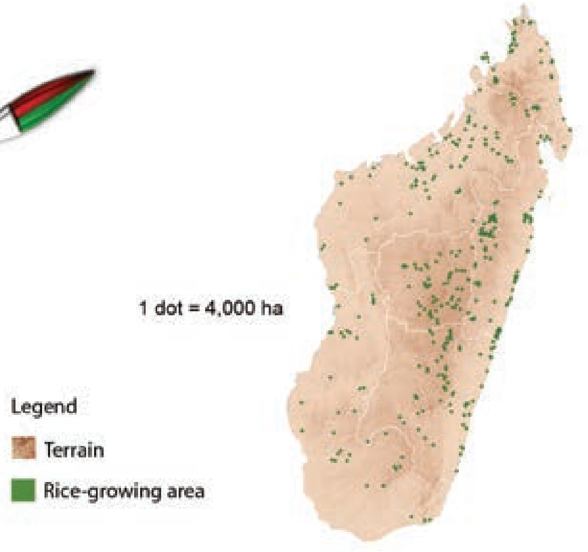
Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



MADAGASCAR



General information

- GNI per capita at PPP$, 2011: 950
- Internal renewable water resources, 2011: 337 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: cassava, rice, fruits, milk, sweet potatoes, maize, meat
- Rice consumption, 2009: 105.5 kg milled rice per person per year

Madagascar is an island nation located in the Indian Ocean. It has a total area of 587,041 km², of which 5.1% (2009) is arable land and contained within a coastline of 4,828 km. The climate is tropical along the coast, temperate inland, and arid in the south. Natural hazards include periodic cyclones, drought, and infestation by locusts. Terrain varies from a narrow coastal plain to high plateaus and mountains in the center. The population in 2011 was 21.3 million, with an estimated annual growth rate of 2.9%. Life expectancy at birth is 64 years. Agriculture, including fishing and forestry, is a mainstay of the economy, accounting for about one-third of GDP and employing 70% of the labor force. Rice is the main subsistence crop in Madagascar and it occupies an important place in the agricultural sector. About 85% of the farmers grow rice. About 2 million farming households and about 10 million people derive at least part of their economic income from the rice sector.

Production seasons

	Planting	Harvesting
Main, plateau	Oct-Nov	Apr-Jun
Vatomandry*, east	Oct-Nov	Jun-Jul
Hosy*, east coast	Apr-Jun	Oct-Nov
Asara*, west coast	Nov	Jan
Atriatry*, west coast	Feb	May
Jeby*, west coast	July	Oct

*Varieties of rice harvested.

Recent developments in the rice sector

The area under rice increased to about 1.81 million ha in 2010 from 1.15 million ha in 1995. Production increased from 2.45 million t in 1995 to about 4.74 million t of paddy rice in 2010. Rice yield increased slightly from 2.1 t/ha in 1995 to 2.6 t/ha in 2010. Enhanced production gradually reduced the need for rice imports. The rice self-sufficiency ratio was about 96.7% in 2009. Caloric intake per day from rice increased from 45.5% in 1995 to 50.7% in 2009. Protein intake from rice over the same period increased from 42.7% to 48.1%. Almost all mineral fertilizer inputs are imported.

The Madagascar Action Plan, which was developed for 2007-12, describes the new strategy and action plan geared toward stimulating economic growth and reducing poverty, and one of the main aspects is increasing rice production. The target for

Farmers make use of a large rock as a threshing tool.

2009 was to move toward doubling paddy production from 2006 in order to reach a volume of 5 million t. This growth is underpinned by an increase in productivity (through the supply of inputs, improvement in crop techniques, improvement of hydro-agricultural techniques, the introduction of agricultural machinery, and regular technical support) as well as an increase in area under cultivation.

Rice environments

There are four principal types of rice growing: irrigated rice, rainfed lowland rice, upland rainfed rice (called *tanety*), and rice as a first crop after slash and burn (called *tavy*). In terms of cultivated area, irrigated rice is the most important, covering 82% of all area under rice in 2008. About 60% of irrigated rice is transplanted. Rice is grown in six zones of Madagascar: the north, northwest, and central-western regions; the central part of the Malagasy highlands; the east; and the central-eastern part, including Lake Alaotra, with its swampy areas, plains, and valleys suited for rice.

Production constraints

Major yield gaps occur between yields obtained in farmers' fields and what would be possible under improved management because of a lack of access to agricultural equipment, good-quality seed, and mineral fertilizers, and a range of biotic and abiotic stresses, including poor soil fertility, drought, and weed infestation. In the dominant irrigated lowland systems, the step-wise introduction of good agricultural practices and principles and improved modern varieties may strongly boost rice productivity. The upland and tavy systems suffer from a multitude of abiotic and biotic stresses; first and foremost are low soil fertility and drought. In the highlands, cold stress and blast disease reduce rice yields.

The major challenge for the rice sector is to ensure a reliable supply to the market of sufficient quantities of quality rice to ensure food security for the growing population, to supply industries down the rice value chain, and eventually to export. Land tenure problems hinder investment by farmers and the private sector. Farmers also lack access to quality agricultural inputs (improved seed, fertilizer, etc.) and have difficulty in obtaining credit because of a lack of collateral and high interest rates. Extension systems are underfunded and understaffed. Rice production systems are too fragmented and heterogeneous to attract private investment. Road infrastructure is often run-down and storage and processing facilities are often sorely lacking or not well maintained.

Production opportunities

Madagascar has an enormous potential for rice production and more than a dozen large rice production basins could be further developed to become veritable “rice baskets” for the country and for the region as a whole. Currently, close to 1 million ha are under irrigation, representing 30% of the agricultural land. The irrigable potential is close to 1.5 million ha. In 2009, the percentage of irrigated rice area represented 78% of the total rice area. Next to rehabilitation and expansion of irrigated rice area, there is clear scope for raising yields and increasing cropping intensity (two or even three crops of rice per year) and diversification.

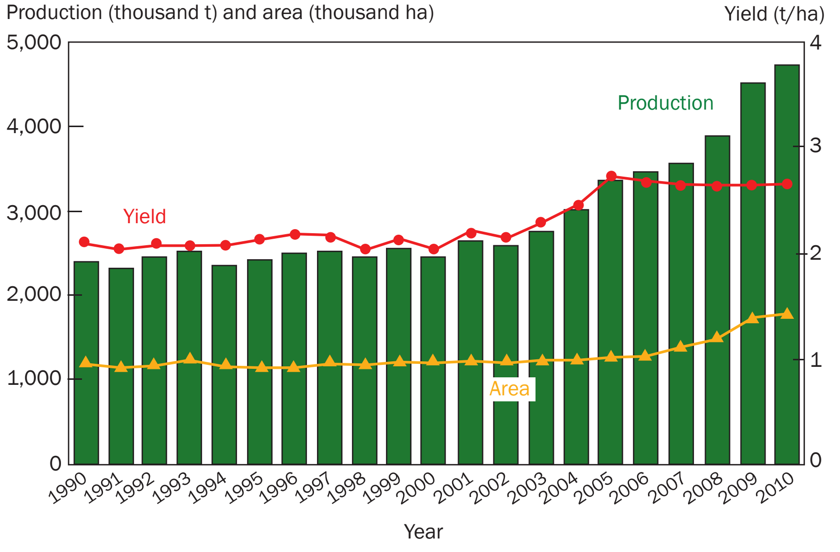
The National Rice Development Strategy (NRDS) for Madagascar developed as part of the Coalition for African Rice Development (CARD) and with clear backing from the government aims to realize that potential by focusing on the following six interventions:

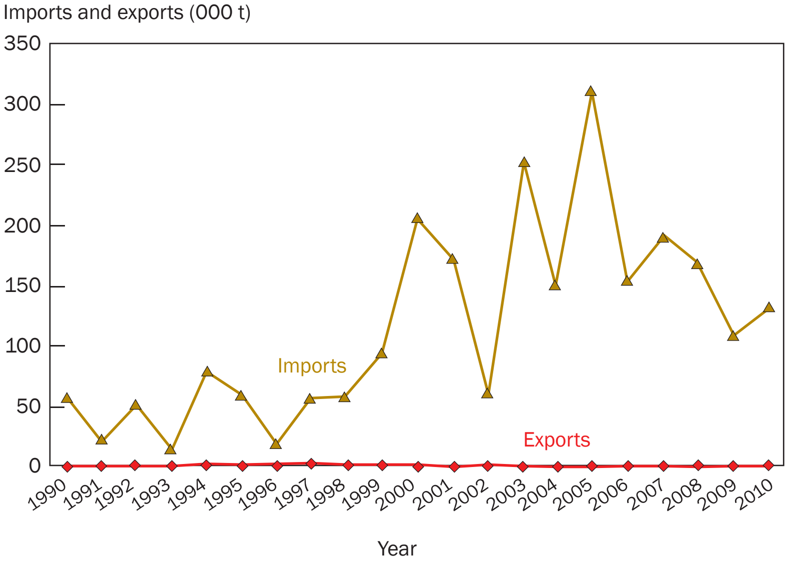
1. Clearly identify rice seed needs and develop the seed sector.
2. Develop a fertilizer market with the private sector as the central actor.
3. Further develop irrigation schemes for rice, rehabilitate and modernize existing schemes, and turn over management of irrigation structures to farmers.
4. Boost agricultural mechanization through capacity building for local artisans, promote cooperatives, build up of sales and distribution networks, and obtain exemption from import taxes.
5. Develop rural credit schemes.
6. Enhance linkages between research and extension and ensure wide-scale diffusion of agricultural technologies and knowledge.

Basic statistics, Madagascar

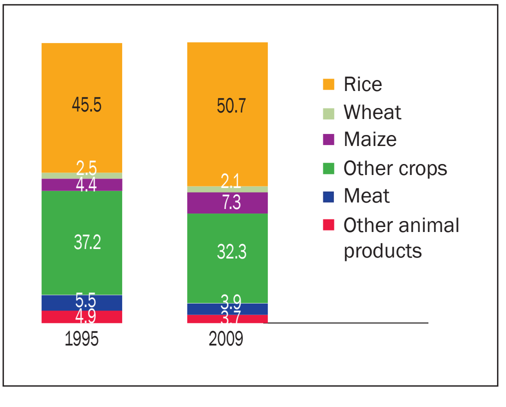
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,900	2,900	2,950	2,950	2,950	2,950	2,950	
Rice area (×10^3 ha)	1,150.0	1,209.3	1,250.0	1,291.0	1,372.0	1,494.0	1,733.0	1,808.0
Share of rice area irrigated (%)		82.0				82.0	78.0	
Share of rice area under MVs (%)	31.0*							
Paddy yield (t/ha)	2.13	2.05	2.71	2.70	2.62	2.62	2.62	2.62
Paddy production (×10^3 t)	2,450.0	2,480.5	3,393.0	3,485.0	3,595.8	3,914.2	4,540.4	4,738.0
Milled production (×10^3 t)	1,634	1,654	2,263	2,324	2,398	2,611	3,028	3,159
Rice imports (×10^3 t)	60.2	207.7	313.0	155.4	190.6	168.6	109.5	132.5
Rice exports (×10^3 t)	0.6	0.3	0.2	0.1	2.0	0.1	0.0	0.0
Total rice consumption (×10^3 t)	1,616	1,887	2,471	2,527	2,612	2,830	3,132	
Fertilizer usage in NPK (kg/ha of arable land)	4.33	3.14	5.54	2.51	3.24	4.33	2.63	

Sources: *WARDA, 1994, ** Madagascar Rice Statistics survey, 2009; FAO’s FAOSTAT database online and AQUASTAT database online, as of September 2012.

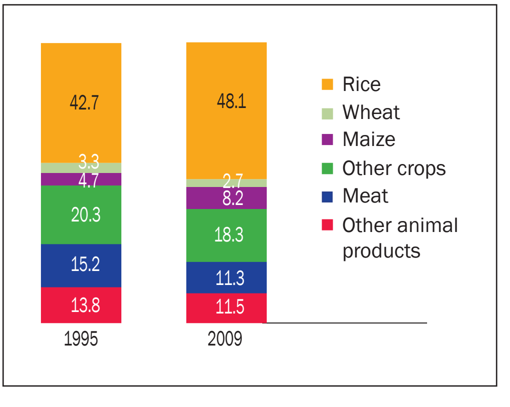




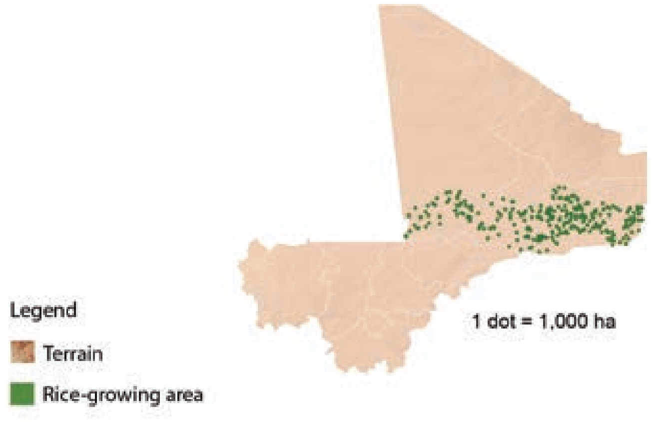
Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



MALI



General information

- GNI per capita at PPP$, 2011: 1,040
- Internal renewable water resources, 2011: 60 km^3/year
- Incoming water flow, 2011: 40 km^3/year
- Main food consumed, 2009: milk, millet, vegetables, rice, sorghum, maize, sugar and sweeteners, meat
- Rice consumption, 2009: 56.0 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Main	May-Jul	Oct-Dec
Off	Jan-Mar	May-Jul
Deepwater rice	Jul-Aug	Dec-Jan

Mali is a landlocked country located in West Africa and it has a total area of 1,240,192 km^2, of which 5.2% (2009) is arable land, contained within a land boundary of 7,243 km. The climate varies from subtropical to arid, being hot and dry (February to June), rainy and humid (June to November), and cool and dry (November to February). Mali covers the southern Sudan savanna zone, the central, semiarid Sahelian zone, and the arid Saharan zone. Terrain varies from flat, sandy plains in the north to southern savanna and rugged hills in the northeast. About 4% of the land area is used for arable crops.

The estimated population in 2011 is 15.8 million, with an estimated annual growth rate of 2.6%. Life expectancy at birth is 53 years.

Mali is among the world's 25 poorest countries, and economic activity is mostly confined to the area irrigated by the Niger River. About 10% of the population is nomadic and about 75% of the labor force is engaged in agriculture. Agriculture accounts for 40% of GDP and contributes close to 30% of export earnings. Rice contributes around 5% of the country's GDP and is deemed having the advantage of enjoying a fast expanding national market.

Recent developments in the rice sector

Rice in Mali is grown in deepwater areas, under irrigation, and under rainfed conditions in both lowland and upland systems. The area under rice doubled in 2009 at 0.66 million ha from area harvested in 1995 at 0.31 million ha but decreased to 0.47 million ha 2010. Production increased from 0.48 million t in 1995 to about 2.31 million t of paddy in 2010. Rice yields across ecosystems have varied widely since 1995 (between 1.6 t/ha and 4.9 t/ha) without a clear increasing or declining trend. Enhanced production gradually reduced the need for rice imports. Caloric intake per day from rice increased from 15.0% in 1995 to 21.2% in 2009. Protein intake from rice over the same period increased from 11.1% to 16.4%.

Almost all mineral fertilizer inputs are imported, representing close to 45% of the total value of agricultural imports. Fertilizer imports have been constantly increasing at an annual rate of 10% since 1971. Rice growing in the Office du Niger alone uses around 20,000 t of diammonium phosphate and urea per year.

Under the CARD (Coalition for African Rice Development) initiative, Mali endorsed a national rice development strategy (NRDS) in 2009 that is fully in line with national policies and international commitments. The vision is to transform Mali into an agricultural powerhouse, to be placed with other emerging countries as an exporter of processed and labeled rice-based products. The strategy aims to intensify high-yielding systems. Emphasis will be placed on

1. Developing new areas with water control (10,000 ha per year).
2. Developing rainfed rice growing with high-yielding varieties such as NERICA4.
3. Intensifying other production systems, especially controlled swamp rice cultivation, and lowland and natural swamp rice cultivation.

Rice environments

The Office du Niger is the rice basket in the country with 90,000 ha of irrigated land, used almost entirely for rice, with potential for 900,000 ha of irrigable land. There are large irrigation schemes in Selingue, Baguinéda, the San Ouest plains, and the small village holdings situated along the Niger and Senegal rivers. Total developed area is 125,000 ha and average yields have reached 5 to 6 t/ha, from an initial low of 2 t/ha in the 1980s through rehabilitation of irrigation schemes and the introduction of modern rice varieties, transplanting, and well-timed and appropriate mineral fertilizer use.

Upland rice cropping is mainly restricted to the southern part of the country. With the introduction of NERICA varieties, upland rice is now also grown near Sikasso, Kayes, and Koulikoro. Yield is about 1 to 2 t/ha, but can reach 3 to 4 t/ha.

Controlled swamp rice farming depends on rainfall for crop establishment and on intake from rivers for flooding. Cultivated area is around 74,000 ha, and is mainly located in Ségou and Mopti. Yields vary between 1.0 and 2.5 t/ha.

For water control, lowland rice farming is characterized by a great diversity from full water control to complete dependence on rainfall. The potential land area for this system is 300,000 ha and around 140,000 ha of rice are grown per year in undeveloped lowlands, mostly by women in the Ségou, Sikasso, and Kayes regions, where yields vary between 0.8 and 2 t/ha.

Traditional floating rice cultivation is practiced in the interior delta of the Niger and along the loop of the river. Varieties used are *Oryza glaberrima* types, which are notable for rapid growth that allows them to keep pace with the rising water levels of the river, which can rise 5 cm per day. Planting takes place during the rainy season before the waters arrive to flood the rice paddies. Water can rise by several meters in some places, and rice grows so that only the panicles show above the water (giving the name floating rice). Harvesting is mostly done using canoes and yields rarely surpass 1 t/ha from a total area of about 300,000 ha.

Production constraints

Suboptimal timing of crop management interventions may still cause considerable yield losses in irrigated systems, for example, because of the late arrival of credit, fertilizer, etc. Insect and disease pressure such as rice yellow mottle virus may further reduce yields. In some years, locust attacks can wipe out production. Certain invasive species such as water hyacinth block irrigation networks, slowing down the water supply to rice fields. Upland systems may suffer from drought, poor soil fertility, competition from weeds (including Striga), and attacks by pests and diseases (blast). Flooding, drought, weeds, and disease attacks cause yield losses in rainfed lowland systems.

In general, inadequate postharvest technologies decrease the quality of locally produced rice. Mainly in the rainfed systems, farm operations are still mostly done manually. Farmers and processors do not have easy access to credit or have to face high interest rates. Storage, processing, and marketing of local rice are not well organized, hampering trade between surplus- and deficit-producing areas and leading to high transaction costs. Land tenure issues may discourage investment in the development of land and water resources to be used for rice cropping.

Production opportunities

Mali has great potential for rice. The government provides strong support to the development of the agricultural sector and rice in particular, through a special Presidential Initiative. The area that could be grown under irrigated rice has been estimated at 2.2 million ha, with only 20% of this potential currently used. Within the framework of the NRDS, eight priority areas have been identified to double or even triple Mali's production by 2018 vis-à-vis 2008:

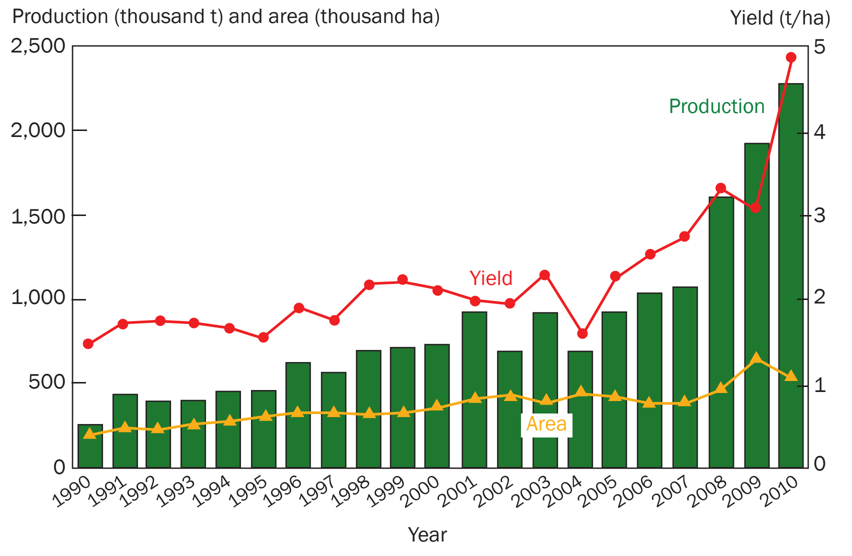
1. Improving farmers' access to quality rice seed
2. Enhancing the preservation and maintenance of rice genetic resources
3. Enhancing the use of organic inputs to improve soil quality and enhance mineral fertilizer uptake
4. Improving farmers' access to mineral fertilizers
5. Improving postharvest operations and marketing of locally produced rice
6. Enhancing investments in water control techniques and irrigation
7. Enhancing rice research and extension capacity
8. Improving access to agricultural loans for rice value chain actors

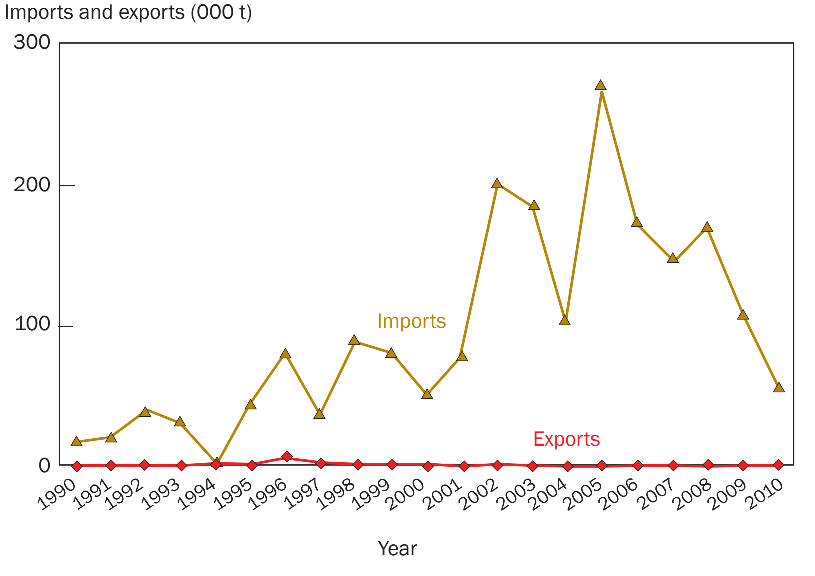
The Millennium Challenge Corporation plans to develop 16,000 ha of irrigated land in the Alatona Irrigation Project. Within the framework of African integration, member states of the West African Economic and Monetary Union are planning to develop about 11,000 ha in the Office du Niger. A joint Malian-Libyan project is developing 100,000 ha in the Office du Niger area. Mali is building national rice stocks for food security. These stocks were expected to rise to 100,000 t by 2012.

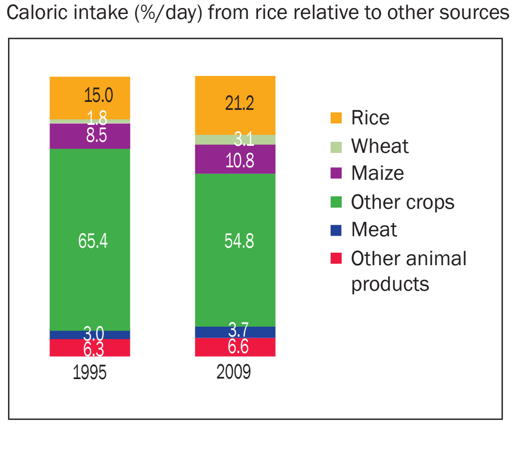
Basic statistics, Mali

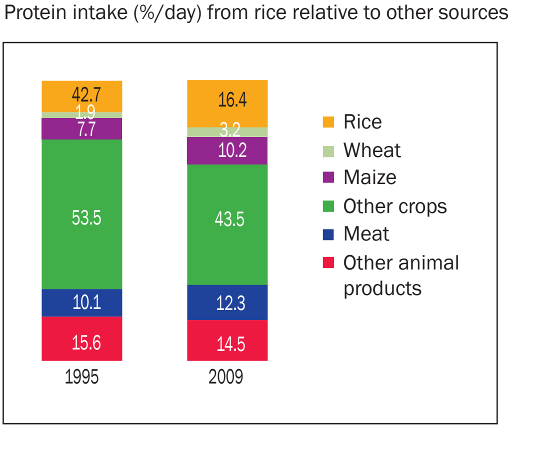
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land ($\times10^3$ ha)	3,339	4,589	5,603	5,677	5,808	5,761	6,361	
Rice area ($\times10^3$ ha)	307.5	352.7	414.0	412.5	391.9	482.6	659.9	471.8
Share of rice area irrigated (%)		41.5**				91.18		
Share of rice area under MVs (%)		50 (1997)						
Paddy yield (t/ha)	1.55	2.11	2.28	2.55	2.76	3.37	2.96	4.89
Paddy production ($\times10^3$3 t)	476.1	742.6	945.8	1,053.2	1,082.4	1,624.3	1,950.8	2,308.2
Milled production ($\times10^3$ t)	318	495	631	703	722	1,083	1,301	1,539
Rice imports ($\times10^3$ t)	45.7	51.9	272.2	174.4	147.4	172.3	109.5	57.7
Rice exports ($\times10^3$ t)	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Total rice consumption ($\times10^3$ t)	359	587	715	744	788	909	967	
Fertilizer usage in NPK (kg/ha of arable land)	8.09	8.68	11.19	12.95	8.17	7.61	3.17	

Sources: * Mali Rice Statistics survey, 2009; **144,514 hectares from AQUASTAT
FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

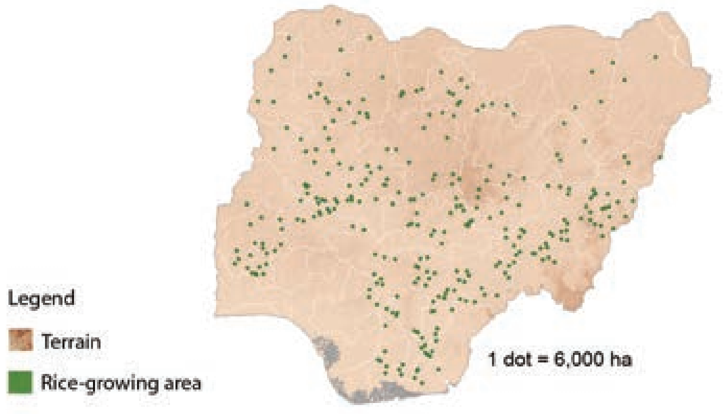

Production (thousand t) and area (thousand ha)
Yield (t/ha)
2,500
2,000
1,500
1,000
500
0
5
4
3
2
1
0
Production
Yield
Area
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year


Imports and exports (000 t)
300
200
100
0
Imports
Exports
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year


Caloric intake (%/day) from rice relative to other sources
15.0
1.8
8.5
65.4
3.0
6.3
1995
21.2
3.1
10.8
54.8
3.7
6.6
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
42.7
1.9
7.7
53.5
10.1
15.6
1995
16.4
3.2
10.2
43.5
12.3
14.5
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

NIGERIA



General information

- GNI per capita at PPP$, 2011: 2,290
- Internal renewable water resources, 2011: 221 km^3/year
- Incoming water flow, 2011: 65.2 km^3/year
- Main food consumed, 2009: starchy roots, sorghum, millet, maize, rice, wheat, vegetables, fruits
- Rice consumption, 2009: 20.9 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Main, south	Apr-May	Aug-Oct
Main, north	Jun-July	Nov-Dec
Off, south	Nov-Dec	Mar-Apr
Off, north	Jan-Feb	May-Jun

Nigeria is located in western Africa between Benin and Cameroon and has a total area of 923,768 km^2, of which 34.6% (2009) is arable land, and is contained within a 4,047 km land boundary and a coastline of 853 km. The climate varies from equatorial in the south to tropical in the center and arid in the north. Terrain varies from southern lowlands, central hills and plateaus, mountains in the southeast and plains in the north. The estimated population in 2011 is 162.5 million, with an estimated annual growth rate of 2.6%. Life expectancy at birth is 52 years. Agriculture contributes about 35% to the GDP and employs about 70% of the total labor force. Exports are dominated by oil and derived products (95%).

Recent developments in the rice sector

Consumers' preferences are shifting from traditional staples (such as cassava, maize, and yams) to rice. Urban consumers currently prefer imported rice to locally produced rice on quality grounds.

The area under rice increased from 1.8 million ha in 1995 to about 2.72 million ha in 2006 but dropped back to about 1.8 million ha in 2010. Production increased from 2.92 million t in 1995 to a high of 4.18 million t of paddy rice in 2008 but went down to about 3.22 million t in 2010. Rice yields across ecosystems over the last 20 years were between 1.3 t/ha and 1.9 t/ha. Rice imports have been increasing steadily, reaching 1.8 million t of milled rice in 2009. Average yearly per capita consumption was 15.8 kg during 1981-90, and by 2009 it was estimated at 20.9 kg. During 1990-2009, self-sufficiency reached a high of 87% but, during 2009, it declined to 64%. Caloric intake per day from rice increased from 7.3% in 1995 to 7.9% in 2009. Protein intake from rice over the same period increased from 6.7% to 6.8%. Fertilizer consumption in Nigeria is at 13 kg/ha, one of the lowest in sub-Saharan Africa. Less than 1% of the arable land is irrigated. Farmers have limited access to credit and extension services. Only about 30,000 tractors are available for all 14 million farming families or groups. Processing capacity is a major bottleneck to increasing the national rice supply. Increasing local rice production means that scarce foreign exchange used to import rice can be used to develop the local rice sector. Imports of rice in 2006 cost Nigeria $695 million, well above the 2001-05 average of US$113 million. The Nigerian government started an Agricultural Transformation Agenda in 2011 with rice as one of the five priority commodity value chains. The objective is to make Nigeria self-sufficient in rice by 2015.

Rice environments

The three rice production environments and their coverage in Nigeria are rainfed lowland (69.0%), irrigated lowland (2.7%), and rainfed upland (28.3%). More than 90% of Nigeria's rice is produced by resource-poor small-scale farmers, while the remaining 10% is produced by corporate/commercial farmers.

About 95% of the processors are small-scale with low-capacity and obsolete mills. Nigeria possesses a huge but largely untapped potential for developing irrigated rice. There are an estimated 3.14 million ha of irrigable land, out of which less than 50,000 ha are growing irrigated rice. Nigeria has large irrigation schemes in Anambra, Kwara, Kogi, Adamawa, Niger, Sokoto, Kebbi, Borno, Bauchi, and Benue states.

Production constraints

In the irrigated rice schemes, production constraints include low nitrogen-use efficiency and iron toxicity, disease and pest pressure (especially birds), and low mechanization. Socioeconomic constraints include a lack of involvement of farmers in the planning and implementation of irrigation schemes, lack of access to inputs (including credit), and a loss of labor and an aging farming population because of migration to cities. Rice yield in these schemes is 3.0–3.5 t/ha compared with the potential of 7–9 t/ha.

In the rainfed lowland environment, rice cultivation is characterized by a low yield range of 1.5–3.0 t/ha vis-à-vis a potential of 3.0–6.0 t/ha, caused by suboptimal water management, inadequate weed management, low adoption of modern varieties, low mechanization, pest and disease pressure, and uncertain land tenure.

In the upland environment, rice cultivation is challenged by drought, low adoption of improved varieties, soil acidity and general soil infertility, poor weed control, limited capital investments and labor shortages, and low mechanization. Yields range from 1.0 to 1.7 t/ha compared with a potential of 2.0–4.0 t/ha.

Farmers and rice value chain actors have difficulty in accessing agro-inputs, particularly quality seed, fertilizer, and credit. Infrastructure development is lagging behind with respect to irrigation facilities, feeder/rural roads, and rice storage and processing capacity. In the past, changes in government policies in the areas of concessions and tariffs have discouraged investors. In general, the rice value chain is characterized by yields that are far below what would be possible with improved management, improved market information and structure, and sufficient and updated rice-processing capacity.

Production opportunities

Imported rice volumes dominate rice trading in Nigeria because of the poor quality of locally produced rice. A huge potential market for locally produced rice exists in urban centers if quality, standards, and grading are addressed. The government plans to put more land under irrigation for rice production and rehabilitate dilapidated irrigation schemes under the Agricultural Transformation Agenda. For upland rice systems, NERICA varieties will be promoted in the north-central and southwest regions of the country. Yield gaps can be reduced substantially across environments through the adoption of good agricultural practices and principles (integrated rice management), and the use of robust and high-yielding varieties.

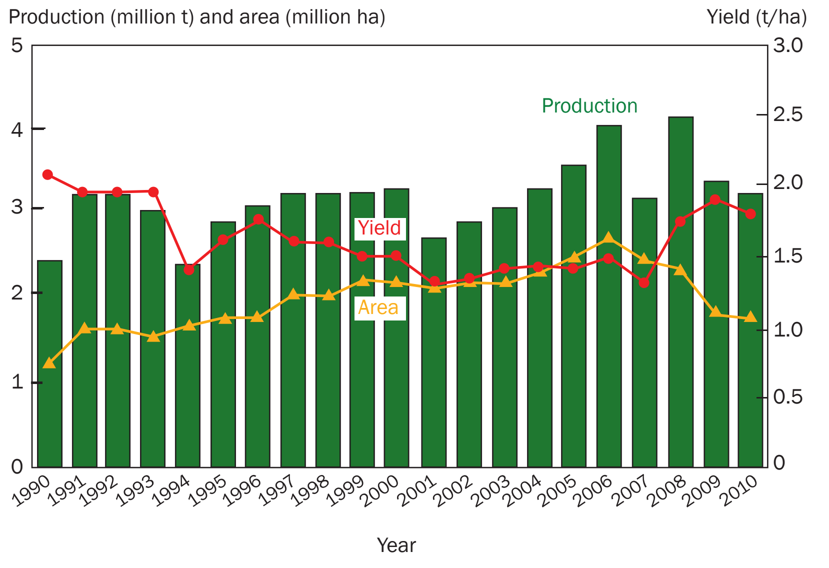
Policies and conditions that offer opportunities for developing the rice sector in the country include zero tariffs on agricultural machinery and equipment, a large domestic market for rice products and by-products, government subsidies on fertilizer, seed, and tractors and implements, and guaranteed minimum price support for farmers. The credit system has also received a boost from the government's establishment of rice-processing credit schemes at 4% interest rate and a 15 years' payback period to increase national rice-processing capacity.

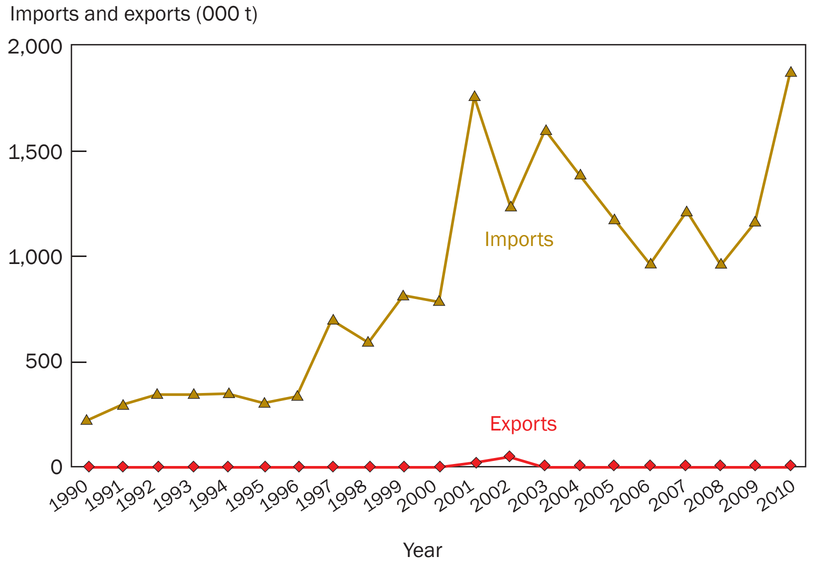
Basic statistics, Nigeria

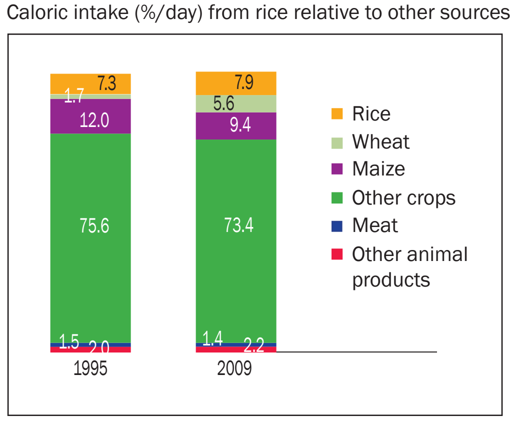
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	30,371	30,000	35,000	37,000	37,500	37,000	3,4000	
Rice area (×10^3 ha)	1,796.0	2,199.0	2,494.0	2,725.0	2,451.0	2,382.0	1,788.2	1,788.2
Share of rice area irrigated (%)	16.00	16.00				2.70	2.70	
Share of rice area under MVs (%)		27 (2001)						
Paddy yield (t/ha)	1.63	1.50	1.43	1.48	1.30	1.75	1.90	1.80
Paddy production (×10^3 t)	2,920.0	3,298.0	3,567.0	4,042.0	3,186.0	4,179.0	3,402.6	3,218.8
Milled production (×10^3 t)	1948	2200	2379	2696	2125	2787	2270	2146
Rice imports (×10^3 t)	300.0	785.7	1,187.8	975.9	1,217.0	971.8	1,164.3	1,885.3
Rice exports (×10^3 t)	0.0	0.0	4.4	2.5	0.3	0.0	0.0	0.1
Total rice consumption (×10^3 t)	2,249	2,993	3,182	3,371	3,601	3,323	3,545	
Fertilizer usage in NPK (kg/ha of arable land)	6.03	6.25	7.40	9.98	4.15	7.66	2.12	

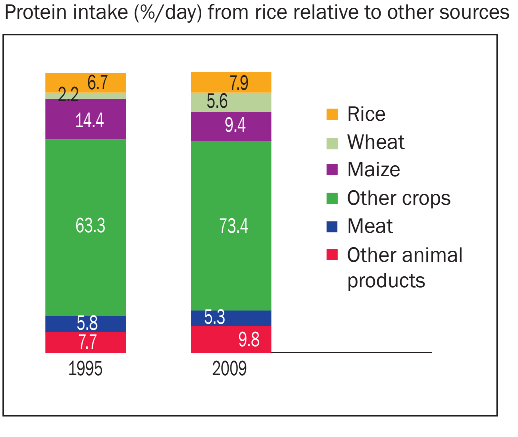
Sources: FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

Nigerian farmers collect every valuable rice grain.

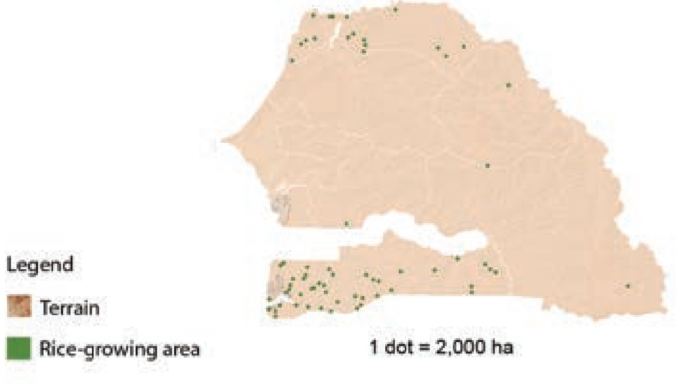

Production (million t) and area (million ha)
Yield (t/ha)
Production
Yield
Area
Year
0
1
2
3
4
5
0
0.5
1.0
1.5
2.0
2.5
3.0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


Imports and exports (000 t)
2,000
1,500
1,000
500
0
Imports
Exports
Year
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


Caloric intake (%/day) from rice relative to other sources
7.3
1.7
12.0
75.6
1.5
2.0
7.9
5.6
9.4
73.4
1.4
2.2
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
6.7
2.2
14.4
63.3
5.8
7.7
7.9
5.6
9.4
73.4
5.3
9.8
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

Senegal



General information

- GNI per capita at PPP$, 2011: 1,940
- Internal renewable water resources, 2011: 25.8 km^3/year
- Incoming water flow, 2011: 13 km^3/year
- Main food consumed, 2009: rice, vegetables, milk, wheat, maize, millet, starchy roots, fish
- Rice consumption, 2009: 71.5 kg milled rice per person per year

Senegal is located in West Africa, bordering the Atlantic Ocean, and has a total area of 192,530 km², of which 20% is arable land, contained within a land boundary of 2,640 km, with 531 km of coastline. The climate is tropical—hot and humid; May to November witnesses a rainy season with strong southeast winds and December to April a dry season with harmattan winds (hot, dry, and dusty trade winds). Natural hazards include drought and seasonal flooding of lowlands. The terrain comprises generally low, rolling plains rising to foothills in the southeast. The estimated population in 2012 was 13 million, with an estimated annual growth rate of 2.7%. Life expectancy at birth is 60 years. Key export industries are phosphate mining, fertilizer production, and commercial fishing. The country's national dish is rice with fish (*thièbou-djène*). Senegal is among the largest consumers of rice in West Africa and one of the largest importers of broken rice.

Production seasons

	Planting	Harvesting
Main	Jun-Jul	Oct-Dec
Off	Feb-Mar	Jun-Jul

Recent developments in the rice sector

The area under rice increased from 69,000 ha in 1995 to about 147,200 ha in 2010. Production increased from 155,200 t in 1995 to about 604,000 t of paddy rice in 2010. Average paddy rice yields across ecosystems varied widely over the last 20 years (between 2.0 and 4.1 t/ha) without a clear increasing or declining trend. Imports had been at less than half a million t in 1995 and reached the million mark in 2007 but decreased in 2010 to 706,700 t. The rice self-sufficiency ratio was almost 25% during 2005-09. Calorie intake per day from rice increased from 27.1% in 1995 to 28.5% in 2009. Protein intake from rice over the same period decreased from 27.1% to 23.1%. Fertilizers are mostly imported, except for phosphate that is mined in the country.

Faced with an increasing population and growing urbanization, the government of Senegal gave priority to increased national agricultural production, and as part of the GOANA initiative (in English, Grand Agricultural Offensive on Food and Abundance). Senegal also developed a National Rice Development Strategy under the Coalition for African Rice Development (CARD).

Rice environments

Rice production systems in Senegal are largely dominated by small and family-held farms. Irrigated rice farming occupied about 53,000 ha during the 2008 crop year (off-season and rainy season) split between the Senegal River Valley (50,000 ha) and the Anambé Basin (3,000 ha). Irrigated rice production represents 70% of national production. Rice yields vary between 4 and 6 t/ha on average.

Double cropping is, in principle, possible in the Senegal River Valley, but difficult because of the risk of cold stress in the wet season and heat stress in the dry season if sowing is delayed. It is hardly practiced because of difficulties with the timing of crop management interventions (late harvesting of the previous crop, late arrival of seed and other inputs). Harvest and postharvest operations remain major bottlenecks in irrigated systems in Senegal.

Rainfed lowland or upland rice farming is found in the southern parts of the country. During the 2009 rainy season, rainfed rice growing occupied 72,000 ha, representing 30% of national production.

Production constraints

Irrigated rice farming faces a number of constraints such as land tenure problems, high development costs, and timely access to quality inputs, in particular seed and mineral fertilizer. Poor timing of crop management interventions because of the late arrival of inputs or delay in harvesting of the previous crop leads to important yield losses. Weed infestation, in particular in direct-seeded fields, and bird damage are major constraints. Late harvesting often leads to both substantial quantitative losses due to shattering and qualitative losses in the final rice product. Yields are generally between 4 and 6 t/ha. Yield potential is much higher, between 8 and 11 t/ha, depending on the growing season and the location along the Senegal River due to highly fertile soils and a generally favorable climate.

Production, harvesting, and processing operations in rainfed systems are done manually and mostly by women. Farmers generally lack access to seed of improved varieties, such as NERICAs. Drought, weed infestation, and low soil fertility are major constraints in rainfed upland systems, with yields usually from 1 to 1.5 t/ha. In rainfed lowland systems, yields are usually clearly higher, up to 3 t/ha, because of more favorable soils and moisture conditions. In both rainfed upland and lowland systems, important yield gains can be obtained with the introduction of improved varieties with greater resistance to biotic and abiotic stresses and the introduction of improved water management and water-harvesting techniques.

Production opportunities

The favorable climate for double cropping of rice, the progressive return of donors ready to invest more and more in rice growing, and the current state of play of the international rice market are in themselves great opportunities to be seized. The huge imports offer a clear opportunity for Senegalese farmers and rice value-chain actors as a whole.

The main objective of the National Rice Development Sector was to lift national rice production to 1,000,000 t of milled rice by 2012. The contribution expected from irrigated rice cultivation to attain this objective is 800,000 t, with rainfed rice contributing 200,000 t. This will consist of homogeneous broken and whole rice fetching competitive prices compared with imported rice and giving a financial return for all the actors in the sector. To achieve these goals, there is a need for

1. Development of the rice seed sector
2. Rehabilitation of irrigation schemes in disuse and building of new schemes and achieving an average cropping intensity of at least 1.5 rice crops per year in these schemes
3. Providing farmers with access to agricultural equipment for harvest and postharvest activities and rice processing plants
4. Increased diffusion of integrated crop management options to reduce yield gaps in both irrigated and rainfed systems

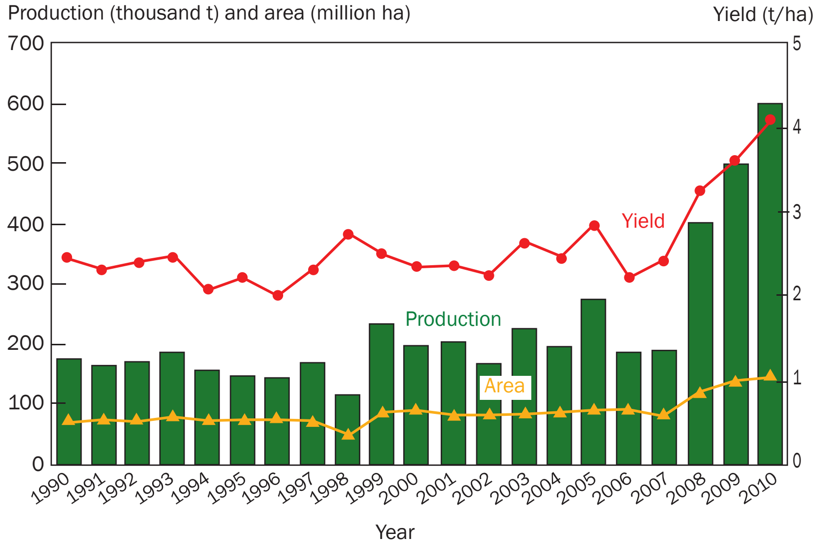
5. Better organization of marketing, and the creation of private professional agencies in charge of buying, processing, and selling milled rice
6. Development of a coherent input subsidy policy
7. Support for promoting by-products of rice for animal feed and energy production
8. Improved access to agricultural credit
9. Better intergovernmental coordination of campaigns against locust attacks

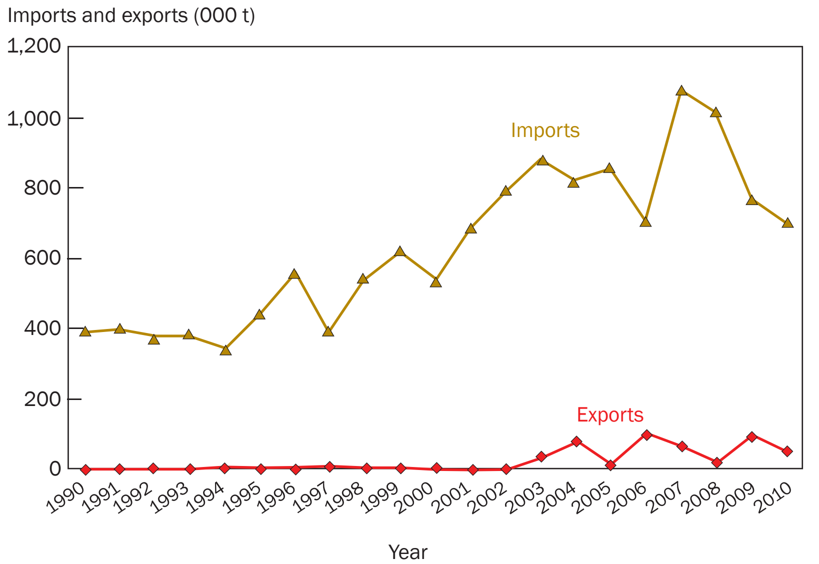
Basic statistics, Senegal

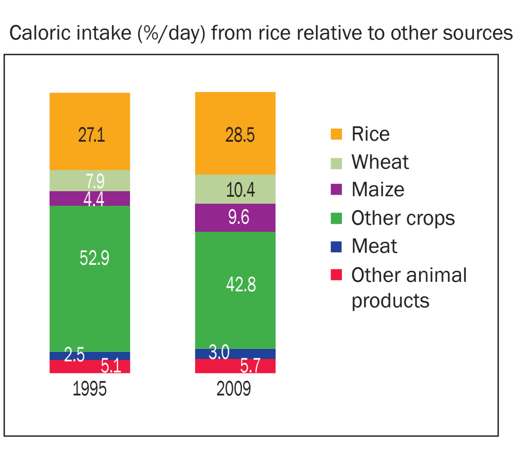
Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (x10^3 ha)	2,942	3,050	3,176	2,986	2,985	3,650	3,850	
Rice area (×10^3 ha)	69.0	86.3	97.8	85.0	80.3	125.3	139.4	147.2
Share of rice area irrigated (%)*						53.5	42.4	70**
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.25	2.35	2.85	2.24	2.41	3.26	3.60	4.10
Paddy production (×10^3 t)	155.2	202.3	279.1	190.5	193.4	408.2	502.1	604.0
Milled production (×10^3 t)	103	135	186	127	129	272	335	403
Rice imports (×10^3 t)	441.2	536.9	855.9	705.9	1,072.7	1,012.4	770.9	706.7
Rice exports (×10^3 t)	0.0	0.0	7.1	100.2	74.1	20.2	94.0	53.7
Total rice consumption (×10^3 t)	543	749	909	877	1024	1052	984	
Fertilizer usage in NPK (kg/ha of arable land)	6	13	10	2	2	2	5	

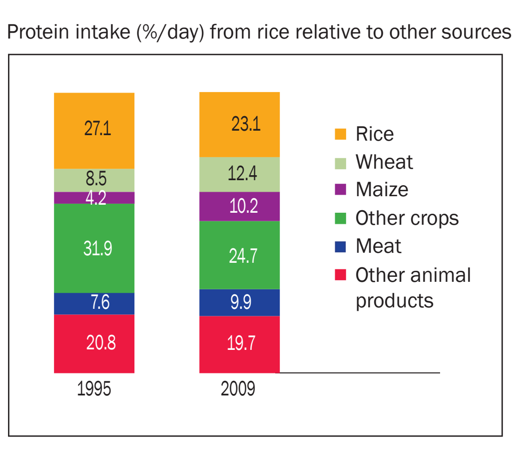
Sources: *Senegal Rice Statistics survey, 2009; **Grain Report of the USDA, 2010; FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

Packaging helps local Senegal rice become competitive in the market.

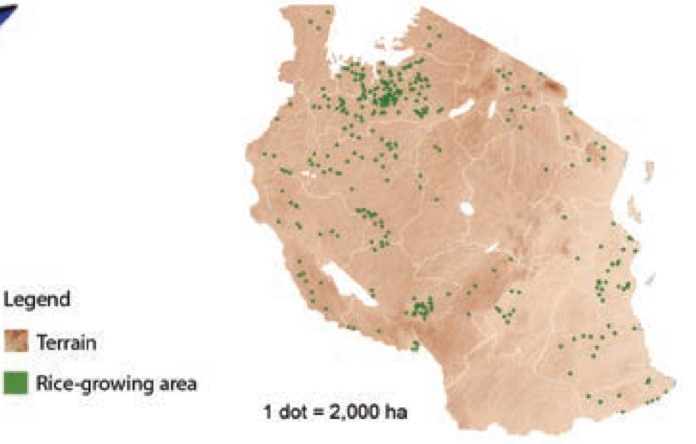

Production (thousand t) and area (million ha)
Yield (t/ha)
700
600
500
400
300
200
100
0
5
4
3
2
1
0
Yield
Production
Area
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year


Imports and exports (000 t)
1,200
1,000
800
600
400
200
0
Imports
Exports
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Year


Caloric intake (%/day) from rice relative to other sources
27.1
7.9
4.4
52.9
2.5
5.1
28.5
10.4
9.6
42.8
3.0
5.7
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products


Protein intake (%/day) from rice relative to other sources
27.1
8.5
4.2
31.9
7.6
20.8
23.1
12.4
10.2
24.7
9.9
19.7
1995
2009
Rice
Wheat
Maize
Other crops
Meat
Other animal products

TANZANIA



General information

- GNI per capita at PPP$, 2011: 1,500
- Internal renewable water resources, 2011: 84 km^3/year
- Incoming water flow, 2011: 12.27 km^3/year
- Main food crops, 2009: starchy roots, bananas, maize, milk, vegetables, rice, wheat, beans
- Rice consumption, 2009: 20.1 kg milled rice per person per year

Tanzania is located in East Africa and has a total area of 945,090 km^2, of which 11.3% (2009) is arable land and is contained within a land boundary of 3,861 km and a 1,424-km coastline. The climate varies from tropical along the coast to temperate in highlands. Natural hazards include drought and flooding on the central plateau in the rainy season. The country's main geographic features are a coastal plain in the west, northern highlands along the border with Kenya, southern highlands near the Zambian border, and the semiarid central plains. Kilimanjaro is the highest mountain in Africa at 5,859 m above sea level.

The estimated population in 2011 is about 46.2 million, with an estimated annual population growth rate of 2%. Life expectancy at birth is 53 years.

Agriculture accounts for more than a quarter of GDP and employs about 76% of the labor force. About 85% of exports are related to agriculture, providing about 22% of foreign exchange earnings.

Production seasons

	Planting	Harvesting
Main	Dec-Feb	May-Jul
Off	Jun-July	Nov-Dec

Recent developments in the rice sector

Rice is grown in three major ecosystems, rainfed lowland, upland, and irrigated systems. The area under rice increased from about 0.39 million ha in 1995 to about 0.72 million ha in 2010. Production increased from about 0.62 million t in 1995 to about 1.33 million t of paddy rice in 2009 but dropped to 1.10 million t in 2010. Average paddy yields across ecosystems have varied widely over the last 20 years (between 1.25 and 2.40 t/ha) without a clear increasing or declining trend. Enhanced production gradually reduced the need for rice imports. The rice self-sufficiency ratio was about 91.8% in 2010. Caloric intake per day from rice increased from 6.9% in 1995 to 9.1% in 2009. Protein intake from rice over the same period increased from 5.2% to 7.0%. Fertilizers are mostly imported, except for rock phosphate that is mined in the country.

Under the CARD (Coalition for African Rice Development) initiative, Tanzania endorsed a national rice development strategy (NRDS) in 2009 that is fully in line with national policies and international commitments. The vision is to transform the existing subsistence-dominated rice subsector progressively into commercially and viable production systems. In implementing the NRDS, Tanzania will focus on eight strategic areas:

1. Increasing availability of and access to agricultural inputs (seeds, fertilizers, pesticides, and appropriate farm machinery)
2. Introducing improved varieties and integrated crop management options to close yield gaps, especially in irrigated rice systems
3. Reducing postharvest losses and enhancing marketing of rice
4. Rehabilitation and development of new irrigation schemes and improving irrigation and water-harvesting technology
5. Enhancing access to and maintenance of agricultural equipment
6. Improving capacity for technology development, training, and dissemination systems
7. Enhancing access to credit and agricultural finance
8. Promotion of medium- and large-scale processing industry

Rice environments

The priority areas for rice production are the irrigated lowland, rainfed lowland, and upland ecosystems. In the irrigated lowlands, improved rice varieties such as IR64 and SARO5 are usually grown. Yields range from 2.5 to 4 t/ha, with great scope for further yield improvement through improved crop management and further intensification. Total potential area for irrigation development is 29.4 million ha, out of which 2.3 million ha are characterized as high potential areas, 4.8 million ha as medium potential, and 22.3 million ha as low potential. In the upland systems, landraces (Supa) are commonly grown. In these systems, NERICA varieties are being introduced. Yields currently range from 0.8 to 1.0 t/ha. In the rainfed lowlands, water is usually adequate. Soils are also relatively fertile as compared to upland soils. Varieties grown are mostly landraces. Yields range from 1.5 to 2.0 t/ha. Crop diversification and intensification have great potential in these rainfed lowland systems.

Production constraints

Farmers grow mainly local and traditional varieties, many of which have low yield potential. Most of the rice grown depends on rainfall and many irrigation schemes need urgent rehabilitation. Upland systems are prone to drought, weed infestation (including Striga), and attacks by pests and diseases (blast). Rainfed lowland systems suffer from floods during heavy rains but can also face drought. Weed infestation, pests (African rice gall midge and stem borers), and diseases (rice yellow mottle virus, blast, bacterial leaf blight) cause low yields. Soil fertility is generally low. Rice competes with other crops such as maize, for land and labor. Inadequate postharvest technologies result in low-quality rice and low prices in the market. Farm operations are mostly (95%) done manually. Farmers and processors do not have easy access to credit. The infrastructure for transportation, storage, and processing is often lacking or in need of rehabilitation.

Production opportunities

Tanzania has large land resources suitable for rice (29 million ha) and abundant water resources (underground, rivers, and lakes) for irrigation. There is also clear political will of the government to enhance rice production and productivity. There is currently a suitable policy environment, with tax exemption measures on the import of agricultural machinery and subsidies provided to farmers on agricultural inputs such as fertilizer and seed. The government is providing an enabling environment for the private sector to participate more strongly in agricultural production, processing, and marketing. The general objective is to double rice production by 2018 vis-à-vis 2008, which would be achieved through the following specific interventions:

1. Improving rice production through better farmer access to improved varieties and improved crop management practices and postharvest technologies

2. Introducing and adopting small-scale labor-saving technologies to improve the timeliness and efficiency of farm operations
3. Strengthening seed systems for delivery of improved varieties to farmers and other end-users (public and private)
4. Strengthening the capacity of public and private institutions responsible for research, extension, and training in rice technology development and dissemination
5. Enhancing agro-processing and value addition
6. Strengthening collaboration and linkages among national, regional, and international institutions involved in rice research and development.

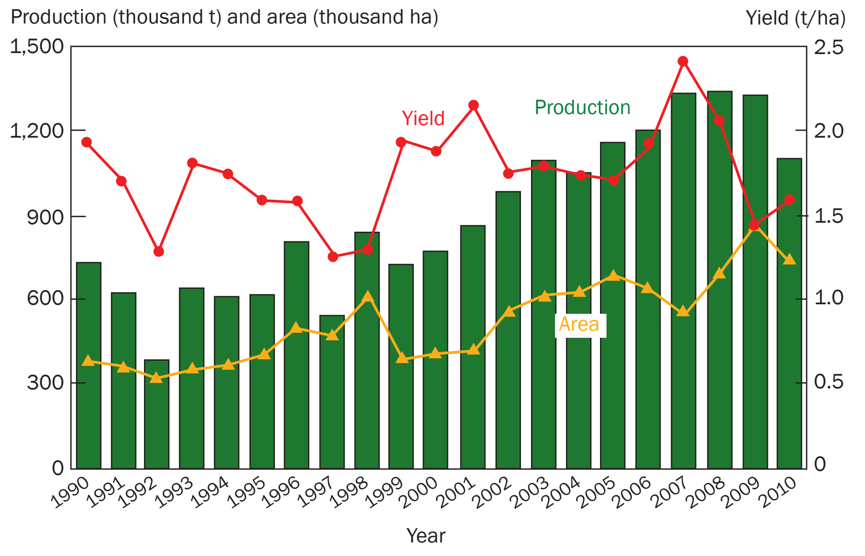
Breeders in Tanzania inspect a rice variety trial.

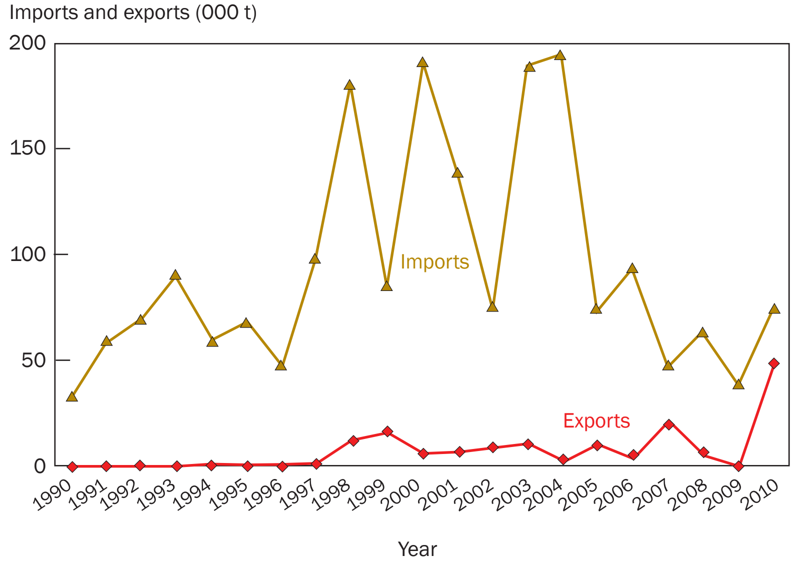
Basic statistics, Tanzania

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	9,000	8,800	9,500	9,500	9,500	9,600	10,000	
Rice area (×10³ ha)	394.0	415.6	702.0	633.8	558.0	664.7	904.5	720.0
Share of rice area irrigated (%)		15.74 *				29.00	29.00	
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.58	1.88	1.66	1.90	2.40	2.03	1.47	1.53
Paddy production (×10³ t)	622.6	781.5	1,167.7	1,206.2	1,341.9	1,346.3	1,334.0	1,104.9
Milled production (×10³ t)	415.0	521.0	779.0	805.0	895.0	898.0	890.0	736.6
Rice imports (×10³ t)	67.7	191.7	75.1	94.2	48.5	64.2	39.6	74.9
Rice exports (×10³ t)	0.0	5.7	9.5	4.4	20.2	5.6	0.8	48.4
Total rice consumption (×10³ t)	474	674	847	892	923	998	970	
Fertilizer usage in NPK (kg/ha of arable land)	3.00	2.55	5.88	5.51	5.34	5.52	8.65	

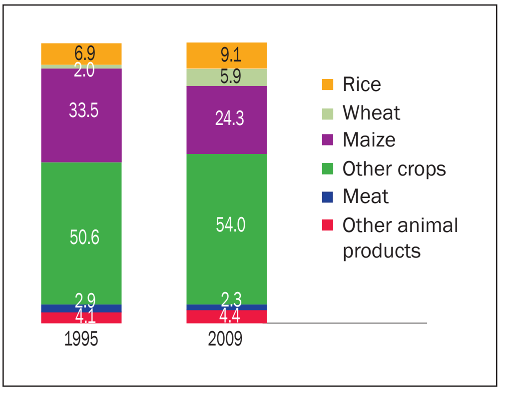
Note: No figures available, but there is low adoption in 2000 (RICEINFO 2002).

Sources: Tanzania Rice Statistics survey, 2009; *2002 data; FAO's FAOSTAT database online and AQUASTAT database online, as of September 2012.

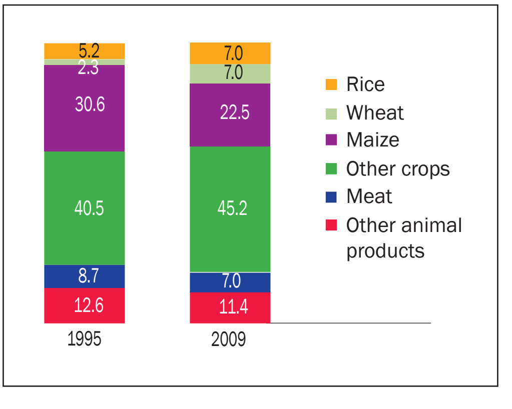




Caloric intake (%/day) from rice relative to other sources



Protein intake (%/day) from rice relative to other sources



Additional rice-producing countries

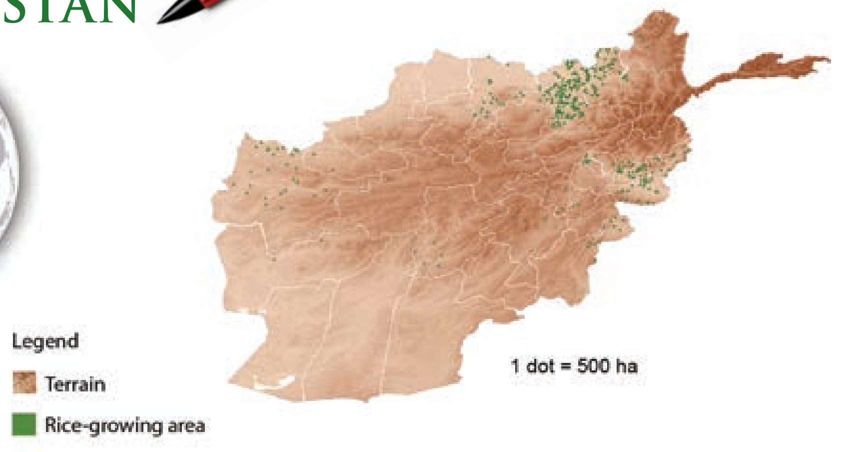
Rice is produced in at least 95 countries apart from the 20 major countries described earlier. Some of the other Asian countries produce more rice than the major countries in LAC and Africa. U.S. rice production is also high, being the 11th top producer in the world in 2010. At the other extreme, at least seven countries produce less than one thousand tons per year, the lowest being Jamaica, which produces only around 2 t of rice annually.

For the purposes of the almanac, summary information on 61 of these rice-producing countries is given in this chapter. The remaining countries produce relatively insignificant quantities of rice. However, rice consumption may be locally important and Fiji, which produced only 7,700 t in 2010, is included in the country descriptions to illustrate that even in the Pacific islands, rice is becoming a staple food.

Notes:

- For all country descriptions: GNI = gross national income, PPP = purchasing power parity.
- In all data tables, *paddy* refers to unmilled rice.

AFGHANISTAN



Afghanistan is a landlocked country surrounded by China, Iran, Pakistan, and the Central Asian Republics with a population of 31.4 million as of 2010. The country sits at an important geostrategic location that connects the Middle East with Central Asia and the Indian subcontinent. It consists of highland plains separated by mountains. Afghanistan is largely dry and rocky, with some fertile lowlands where rice and other grains, as well as cotton and fruits, are grown. Agricultural activities make up 30% of GDP, although about 12% of the country is arable. Deforestation has increased rapidly, leading to desertification; potable water is scarce. The main population centers are in eastern valleys.

General information

- GNI per capita PPP$, 2010: 1,060
- Internal renewable water resources, 2011: 47.15 km^3/year
- Incoming water flow, 2011: 18.18 km^3/year
- Main food consumed, 2009: wheat, maize, rice, barley, pulses, potatoes, fruits, meat
- Rice consumption, 2003: 17 kg milled rice per person per year

Production season

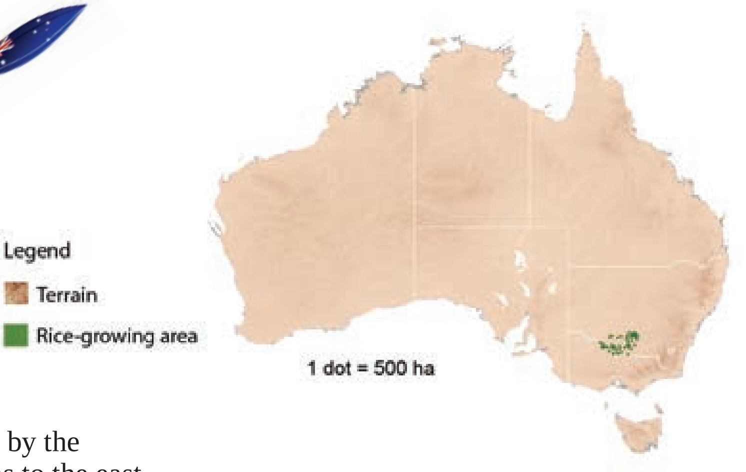
	Planting	Harvesting
Main	May-Jun	Oct-Nov

Basic statistics, Afghanistan

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	7,653	7,683	7,805	7,794	7,794	7,794	7,793	
Rice area (×10^3 ha)	170	130	160	160	170	190	200	208
Share of rice area irrigated (%)	≈100							
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.29	2.00	3.03	3.38	3.25	3.22	3.23	3.23
Paddy production (×10^3 t)	390	260	485	540	552	612	645	672
Milled production (×10^3 t)	260	173	323	360	368	408	430	448
Rice imports (×10^3 t)	90.0	220.0	156.1	223.8	126.0	124.6	313.8	
Fertilizer usage in NPK (kg/ha of arable land)	0	1	4.24	6.29	3.62	2.98	4.52	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

AUSTRALIA



Australia is surrounded by the Tasman and Coral seas to the east, the Arafura and Timor seas to the north, and the Indian Ocean to the west and south. Australia is about the same size as the continental United States, but its population in 2010 of 22.3 million is only about 7% of that of the United States. The western two-thirds of the continent range from hyperarid to semiarid. The majority of the population lives along the relatively well-watered eastern and southeastern coasts. The climate ranges from warm humid tropics to cool subtropics. Agriculture contributes about 2.3% to GDP. The main feature of Australian agriculture is the dominance of large-scale dryland farming and grazing systems. Most irrigated agriculture is found in the Murray-Darling Basin in New South Wales. Irrigated agriculture represents 16% of the value of agricultural production; about 5% of the value of irrigated agriculture is rice. Rice contributes 3.2% to the total food caloric intake. Arable land is 6.1% of the land area.

General information

- GNI per capita at PPP$, 2010: 36,410
- Internal renewable water resources, 2011: 492 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: milk, meat, wheat, fruits, vegetables, potatoes, sugar, oils and fats
- Rice consumption, 2009: 11.5 kg milled rice per person per year

Production seasons

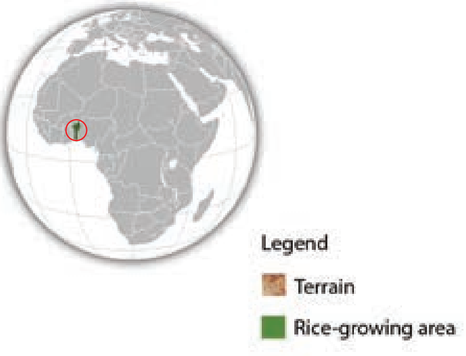
	Planting	Harvesting
Main, New South Wales	Oct	Mar-Apr
Main, Western Australia	Nov	Apr-May

Basic statistics, Australia

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	40,097	47,304	49,402	47,715	44,180	44,024	47,161	
Rice area (×10^3 ha)	129.2	133.3	51.2	99.0	20.0	2.2	8.0	18.9
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	8.80	8.26	6.62	10.13	8.15	8.00	8.15	10.41
Paddy production (×10^3 t)	1,137.0	1,100.7	338.9	1,003.0	163.0	17.6	65.2	196.7
Milled production (×10^3 t)	758	734	226	669	109	12	43	131
Rice imports (×10^3 t)	31.0	52.3	107.0	101.2	124.5	194.7	204.0	192.7
Rice exports (×10^3 t)	541.8	621.7	52.4	320.2	192.3	48.3	17.3	55.9
Total rice consumption (×10^3 t)	199	296	285	278	270	305	292	
Fertilizer usage in NPK (kg/ha of arable land)	46.57	48.09	44.84	43.14	46.14	42.43	34.96	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Benin



Benin, a small West African country facing south in the Atlantic Ocean between Nigeria and Togo, has an area of 112,620 km^2 and is bordered also by Burkina Faso and Niger. The land comprises mainly low plains and nearly a quarter is arable, with agriculture accounting for 32% of GDP. The climate ranges from hot and humid in the coastal south to semiarid in the north. The population in 2011 was estimated at 9.1 million. About 44% of the workforce was engaged in the agricultural sector in 2010.

General information

- GNI per capita at PPP$, 2011: 1,630
- Internal renewable water resources, 2011: 10.3 km^3/year
- Incoming water flow, 2011: 16.09 km^3/year
- Main food consumed, 2009: yam, cassava, maize, rice, meat, pulses, vegetables
- Rice consumption, 2009: 34.4 kg milled rice per person per year

Production seasons

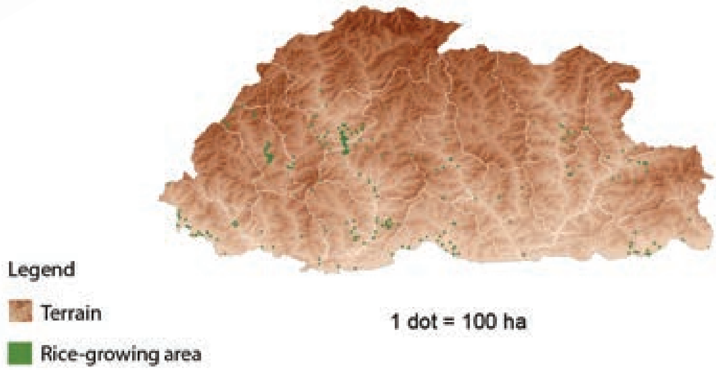
	Planting	Harvesting
Main	Apr-May	Aug-Sep
Irrigated rice	May-Jul	Nov-Jan

Basic statistics, Benin

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	1,790	2,380	2,700	2,500	2,500	2,550	2,450	
Rice area (×10^3 ha)	10.3	23.3	28.9	26.9	27.3	33.3	40.3	39.9
Share of rice area irrigated (%)						8.9		
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.67	2.11	2.71	2.64	2.50	3.28	3.74	4.19
Paddy production (×10^3 t)	17.2	49.2	78.3	71.0	68.2	109.4	150.6	167.0
Milled production (×10^3 t)	11	33	52	47	45	73	100	111
Rice imports (×10^3 t)	182.6	50.0	378.2	732.0	663.7	697.1	674.5	599.4
Rice exports (×10^3 t)	0.0	2.0	5.0	4.9	12.0	28.9	140.3	553.0
Total rice consumption (×10^3 t)	193	81	282	326	311	309	341	
Fertilizer usage in NPK (kg/ha of arable land)	0.20	0.15	0.45	0.01	0.25	0.31	6.48	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

BHUTAN



Bhutan, surrounded by India and China high in the Himalayas, is a tiny nation of 38,394 km^2 with a 2010 population of 725,940. Apart from snow-covered mountains, there are southern tropical plains and central temperate plains. Only 2% of the land is arable, and half of that is on steep mountainsides. Although the share of agriculture in GDP is gradually decreasing (18.7% of GDP in 2009), agriculture provided livelihood to 65.4% of the population in 2009.

The improved communication facilities in the country during the last 10 years increased the trend from a subsistence basis in agriculture toward cash crops. The number of mechanized farms is increasing as a result of the government's sizable investments and subsidy on machinery and other inputs.

General information

- GNI per capita at PPP$, 2011: 5,480
- Internal renewable water resources, 2011: 78 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2010: rice, maize, wheat, meat, oranges, milk, potato
- Rice consumption, 2010: 172 kg milled rice per person per year

Production season

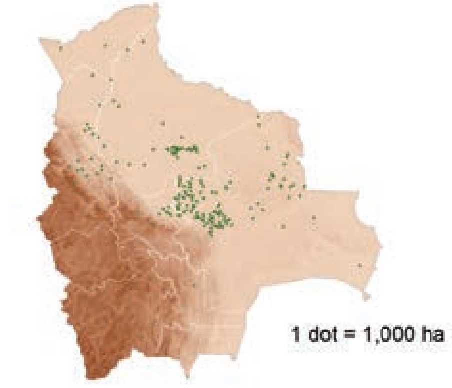
	Planting	Harvesting
Main	Apr-Jun	Aug-Nov

Basic statistics, Bhutan

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	135	130	128	127	127	71	75	
Rice area (×10^3 ha)	30.0	26.0	25.3	26.4	27.5	19.4	23.7	22.8
Share of rice area irrigated (%)	91							100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.67	1.70	2.69	2.75	2.70	4.00	2.80	3.14
Paddy production (×10^3 t)	50.0	44.3	68.0	72.5	74.4	77.4	66.4	71.6
Milled production (×10^3 t)	33	30	45	48	50	52	44	41
Rice imports (×10^3 t)	24.9	33.7	24.7	13.3	7.4	6.2	3.1	52.0
Rice exports (×10^3 t)	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.4
Fertilizer usage in NPK (kg/ha of arable land)	1.67	1.70	2.69	2.75	2.70	4.00	2.80	3.14

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Bolivia



Bolivia is a landlocked country in central South America, divided into three areas: a cold Andean highland plateau where most of the population of 10 million lives, subtropical valleys in the east that contain most of the agricultural production, and tropical plains that are used for livestock and farming of grains, including rice. As of 2009, only 3.4% of the land was arable. Agriculture occupied about two-fifths of the workforce and made up 13% of GDP in 2010.

General information

- GNI per capita at PPP$, 2011: 4,920
- Internal renewable water resources, 2011: 303.5 km^3/year
- Incoming water flow, 2011: 319 km^3/year
- Main food consumed, 2009: wheat, maize, rice, meat, sugar and sweeteners, starchy roots
- Rice consumption, 2009: 25.6 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Oct-Nov	Feb-Mar

Basic statistics, Bolivia

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,500	3,000	3,806	3,491	3,609	3,600	3,735	
Rice area (×10^3 ha)	130.0	156.3	188.4	168.4	170.0	155.4	186.8	193.8
Share of rice area irrigated (%)	1							
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.04	1.91	2.54	2.65	2.07	2.17	2.20	2.32
Paddy production (×10^3 t)	264.6	299.1	479.2	446.5	352.1	337.8	411.0	449.5
Milled production (×10^3 t)	176	199	320	298	235	225	264	300
Rice imports (×10^3 t)	0.3	9.6	3.4	1.6	13.3	43.8	16.1	2.3
Rice exports (×10^3 t)	1.6	0.0	1.1	8.2	5.7	0.1	0.0	3.3
Total rice consumption (×10^3 t)	175	201	294	315	262	265	279	
Fertilizer usage in NPK (kg/ha of arable land)	2.71	2.50	6.47	4.43	6.80	5.58	6.14	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Burkina Faso

Burkina Faso, previously Upper Volta, is a landlocked country bordered by Benin, Côte d'Ivoire, Ghana, Mali, Niger, and Togo. Its 17 million (2011) people live in an area of 274,220 km^2, making it one of the most densely populated countries in the Sahel. The land consists of rolling plains dissected by valleys formed by upper reaches of the Volta River. Agriculture occupies 92% of the working population, contributes about 33% of GDP, and provides more than 85% of export earnings (2011), although only about 21.6% of the land (2009) is arable. Further, substantial desertification has occurred as a result of previous inappropriate farming techniques used for peanuts and cotton for export. Deforestation has also been rampant, resulting in a lack of fuel wood.

General information

- GNI per capita at PPP$, 2011: 1,310
- Internal renewable water resources, 2011: 12.5 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: sorghum, millet, maize, rice, oil crops, groundnuts, vegetables, pulses, meat
- Rice consumption, 2009: 25.5 kg milled rice per person per year

Production seasons

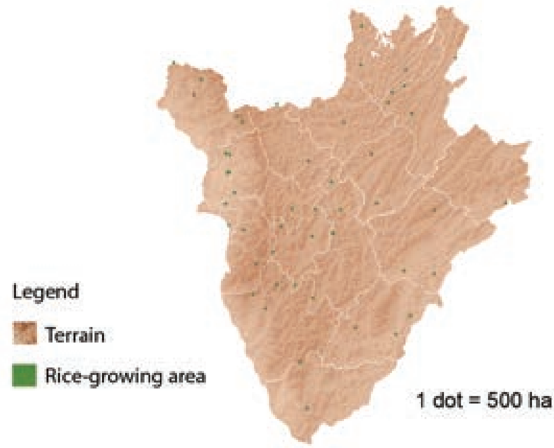
	Planting	Harvesting
Main	May-Jun	Oct-Nov
Off	Jan-Feb	May-Jun

Basic statistics, Burkina Faso

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	3,390	4,040	4,850	5,000	5,200	6,300	5,900	
Rice area (×10³ ha)	43.7	40.2	52.6	44.2	40.5	80.1	92.2	133.7
Share of rice area irrigated (%)							23*	
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.92	2.57	1.78	2.57	1.70	2.44	2.32	2.02
Paddy production (×10³ t)	84.0	103.1	93.5	113.7	68.9	195.1	213.6	270.7
Milled production (×10³ t)	56	69	62	76	46	130	142	180
Rice imports (×10³ t)	108.4	166.6	197.8	191.1	149.6	137.3	264.5	240.3
Rice exports (×10³ t)	0.0	0.3	0.2	0.1	0.1	0.0	0.5	0.6
Total rice consumption (×10³ t)	169	247	274	272	199	271	422	
Fertilizer usage in NPK (kg/ha of arable land)	7.17	8.40	15.40	12.60	9.52	9.08	9.13	

Source: FAOSTAT database as of November 2012. *Irrigated rice occupied on average 23% of the rice area in 1984-2009 and provided nearly 53% of the national production of rice, according to the Direction Générale de la Promotion de l'Economie Rurale.

BURUNDI



Burundi, at the northern end of Lake Tanganyika in Central Africa, is a landlocked country with a land area of 25,680 km^2, most of which is mountainous, with some plains and with a plateau in the east. Burundi borders Tanzania, the Democratic Republic of the Congo, and Rwanda. Although the country is near the equator, the climate is moderate because the average altitude is 1,700 m. Rainfall is characterized by alternating dry and rainy seasons. Unusually, there are two wet seasons (February-May and September-November) and two dry seasons (June-August and December-January). Arable land is 35% of land area. The great majority (89%) of the population of 8.6 million (2011) is rural, occupied in agriculture that accounts for 35% of GDP.

General information

- GNI per capita at PPP$, 2011: 610
- Internal renewable water resources, 2011: 10.06 km^3/year
- Incoming water flow, 2011: 2.48 km^3/year
- Main food consumed, 2009: bananas, starchy roots, vegetables including oils, beans, maize, fermented beverages, fruits
- Rice consumption, 2009: 6.4 kg milled rice per person per year

Production season

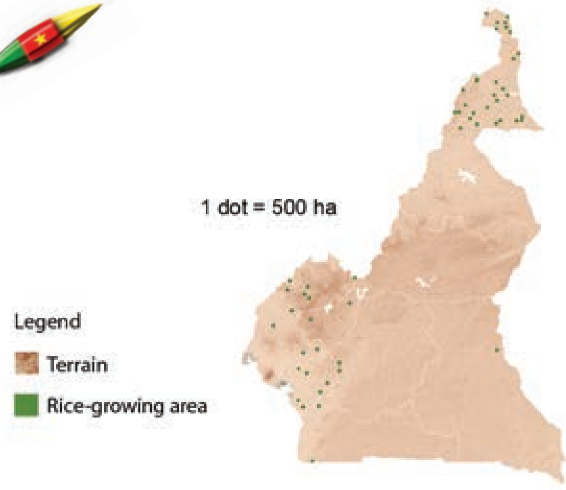
	Planting	Harvesting
Main	Oct-Dec	May-Jun

Basic statistics, Burundi

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	940	960	946	900	900	900	900	
Rice area (×10³ ha)	10.0	17.0	19.9	20.5	21.0	22.0	24.0	21.9
Share of rice area irrigated (%)		25						
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.68	3.04	3.41	3.33	3.38	3.39	3.27	3.79
Paddy production (×10³ t)	26.8	51.7	67.9	68.3	70.9	74.5	78.4	83.0
Milled production (×10³ t)	18	34	45	46	47	50	52	55
Rice imports (×10³ t)	4.0	2.9	2.4	11.5	7.1	3.5	9.8	15.6
Rice exports (×10³ t)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6
Total rice consumption (×10³ t)	22	38	48	57	57	54	61	
Fertilizer usage in NPK (kg/ha of arable land)	3.19	3.65	3.58	3.34	1.91	2.17	1.62	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

CAMEROON



Cameroon is a West African nation bordering the Atlantic Ocean, with an area of 475,440 km^2. Cameroon is one of the best-endowed countries in sub-Saharan Africa in natural resources. About half of the workforce is employed in agriculture, which makes up about 20% of GDP. The country has three regions: northern plains, central grasslands, and rich farmlands in the south, where most of the 20.03 million (2011) population lives. About 12.6% of the land is arable. This area is under threat of drought and desertification.

General information

- GNI per capita PPP$, 2011: 2,360
- Internal renewable water resources, 2011: 273 km^3/year
- Incoming water flow, 2011: 12.5 km^3/year
- Main food consumed, 2009: cassava, plantains, maize, bananas, sorghum, vegetables, rice, pulses
- Rice consumption, 2009: 30.3 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Main	May-Jun	Oct-Nov
Off	Jan-Feb	May-Jun

Basic statistics, Cameroon

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	5,960	5,960	5,963	5,963	5,963	5,963	5,963	
Rice area (×10³ ha)	8.8	20.4	45.0	50.0	68.3	72.0	95.0	140.0
Share of rice area irrigated (%)							42	
Share of rice area under MVs (%)								<20
Paddy yield (t/ha)	4.02	3.01	1.30	1.29	1.00	1.00	1.21	1.25
Paddy production (×10³ t)	35.3	61.3	58.4	64.5	68.3	72.0	115.0	174.8
Milled production (×10³ t)	24	41	39	43	46	48	47	117
Rice imports (×10³ t)	124.1	158.2	446.5	436.1	470.9	427.3	469.5	363.8
Rice exports (×10³ t)	0.1	0.2	0.0	0.0	0.0	1.3	0.0	1.5
Total rice consumption (×10³ t)	122	164	408	460	437	474	597	
Fertilizer usage in NPK (kg/ha of arable land)	5.03	7.73	8.00	9.03	8.62	6.56	6.67	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Republic of Chad

The Republic of Chad is a landlocked country of 1,259,200 km^2 in the Sahel region of Africa. The country is divided into three regions: desert (the Sahara) in the north, occupying 40% of the total area; plains in the central part, used mainly for grazing; and fertile lands in the south that are more tropical and on which most of the 11.5 million population lives. Agriculture is a dominant force in the economy at 51% of GDP, with 66% (in 2010) of the population engaged in agricultural activities. Arable land, however, is only 3.4% of its land area.

General information

- GNI per capita PPP$, 2011: 1,370
- Internal renewable water resources, 2011: 15 km^3/year
- Incoming water flow, 2011: 28 km^3/year
- Main food consumed, 2009: sorghum, millet, yams, cassava, nuts, oil crops, meat, maize, wheat
- Rice consumption, 2009: 7.1 kg milled rice per person per year

Production seasons

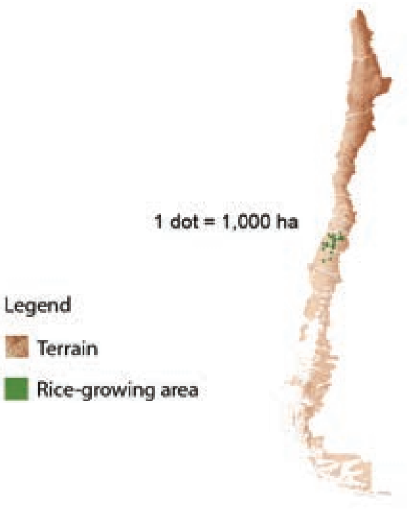
	Planting	Harvesting
Main	Jun-Jul	Oct-Dec
Off	Jan-Feb	May-Jun

Basic statistics, Chad

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	3,420	3,520	4,200	4,300	4,100	4,200	4,300	
Rice area (×10^3 ha)	59.6	89.6	109.8	80.8	80.0	110.9	133.1	130.0
Share of rice area irrigated (%)			10 (2002)					
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.32	1.03	1.35	1.32	1.33	1.53	1.31	1.31
Paddy production (×10^3 t)	79.0	92.6	148.7	106.6	106.4	169.8	175.0	170.0
Milled production (×10^3 t)	53	62	99	71	71	113	87	113
Rice imports (×10^3 t)	5.9	0.0	5.2	1.7	0.5	0.7	0.8	10.9
Rice exports (×10^3 t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10^3 t)	68	82	84	73	71	114	88	
Fertilizer usage in NPK (kg/ha of arable land)	2.50	4.97						

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

CHILE



Chile occupies a 6,435-km-long strip of coastal land and mountains in South America, south of Peru, bordering Argentina and Bolivia in the east. The population of 17.3 million (2011) is unevenly distributed over a total area of 756,090 km^2; only 1.7% is arable, including a fertile central valley. The climate is temperate and variable: arid desert in the north, Mediterranean in the central area, and cool in the southern parts. Agriculture comprises 3.4% of GDP, providing employment for 13% of the workforce in 2010.

General information

- GNI per capita at PPP$, 2011: 16,330
- Internal renewable water resources, 2011: 884 km^3/year
- Incoming water flow, 2011: 38 km^3/year
- Main food consumed, 2009: wheat, milk, vegetables, meat, fruits, beverages (fermented), potatoes, sugar
- Rice consumption, 2009: 9.3 kg milled rice per person per year

Production season

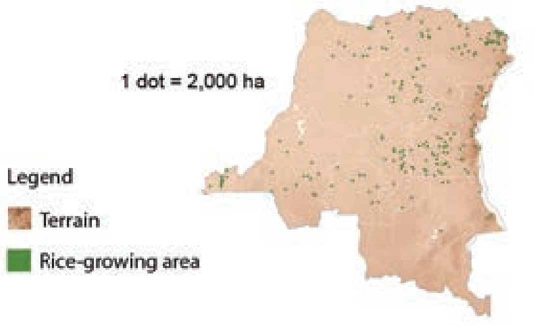
	Planting	Harvesting
Main	Sep-Oct	Feb-Mar

Basic statistics, Chile

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,120	1,750	1,450	1,350	1,266	1,265	1,270	
Rice area (×10^3 ha)	33.9	25.8	25.0	28.0	21.6	21.0	23.7	24.5
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	4.30	5.24	4.67	5.73	5.08	5.79	5.38	3.86
Paddy production (×10^3 t)	145.9	135.1	116.8	160.3	109.6	121.4	127.3	94.7
Milled production (×10^3 t)	97	90	78	107	73	81	85	63
Rice imports (×10^3 t)	50.6	68.0	94.1	102.2	112.2	124.2	119.2	124.1
Rice exports (×10^3 t)	0.1	0.0	0.0	0.1	0.0	0.2	1.3	1.2
Total rice consumption (×10^3 t)	149	132	174	191	198	218	206	
Fertilizer usage in NPK (kg/ha of arable land)	191.04	275.43	434.76	475.81	532.41	712.77	452.22	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

DEMOCRATIC REPUBLIC OF THE CONGO



The Democratic Republic of the Congo, formerly Zaire, is a large central African country with a narrow corridor of land to the Atlantic Ocean with an area of 2,344,860 km^2. Its population was 67.8 million in 2011. The center and the northern parts of the country are covered in rainforest (but which is rapidly disappearing) and are sparsely populated, mainly by subsistence farmers. In the south are extensive grasslands where the bulk of agriculture is carried out. Agriculture constituted 43% of GDP in 2009, occupying some 57% of the workforce.

General information

- GNI per capita at PPP$, 2011: 350
- Internal renewable water resources, 2011: 900 km^3/year
- Incoming water flow, 2011: 383 km^3/year
- Main food consumed, 2007: starchy roots, plantains, maize, nuts, fish, bananas
- Rice consumption, 2007: 7.0 kg milled rice per person per year

Production seasons

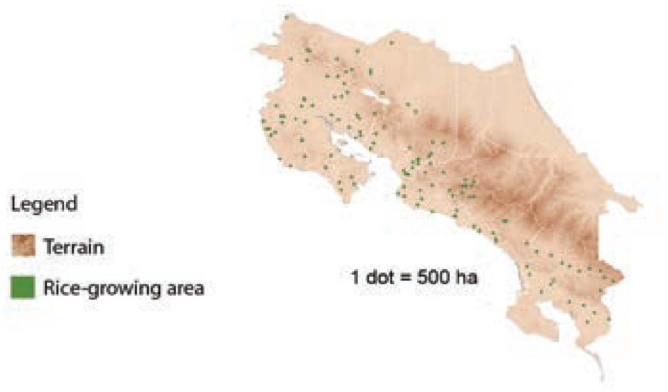
	Planting	Harvesting
Main, north	Jan-Mar	Jun-Jul
Main, south	Sep-Oct	Feb-Mar

Basic statistics, Democratic Republic of the Congo

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	6,700	6,700	6,700	6,700	6,700	6,700	6,700	
Rice area (×10^3 ha)	497.1	447.4	417.9	418.3	418.8	419.2	419.7	420.2
Share of rice area irrigated (%)	1			7				5
Share of rice area under MVs (%)						20		
Paddy yield (t/ha)	0.74	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Paddy production (×10^3 t)	365.8	337.8	315.5	315.8	316.2	316.5	316.9	317.2
Milled production (×10^3 t)	244	225	210	211	211	211	211	211
Rice imports (×10^3 t)	70.8	51.3	209.0	306.1	110.2	98.8	73.0	47.5
Rice exports (×10^3 t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilizer usage in NPK (kg/ha of arable land)	1.34	0.12	0.07	0.45	0.63	0.95	0.51	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Costa Rica



Costa Rica faces both the Pacific Ocean and Caribbean Sea in Central America, between Panama and Nicaragua. It is a tiny country of 51,100 km^2 and 4.7 million inhabitants (2011), and a tropical and subtropical climate with marked wet (May to November) and dry seasons. The land is divided into central mountains with active volcanoes and coastal plains. Only 4.4% of the land is arable and provides agricultural employment for 15% of the workforce, making up 7% of GDP. Rice is a minor commodity but a highly important part of the diet.

General information

- GNI per capita at PPP$, 2011: 11,950
- Internal renewable water resources, 2011: 112.4 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: milk, fruits, sugar, meat, rice, vegetables, wheat, starchy roots
- Rice consumption, 2009: 49.3 kg milled rice per person per year

Production seasons

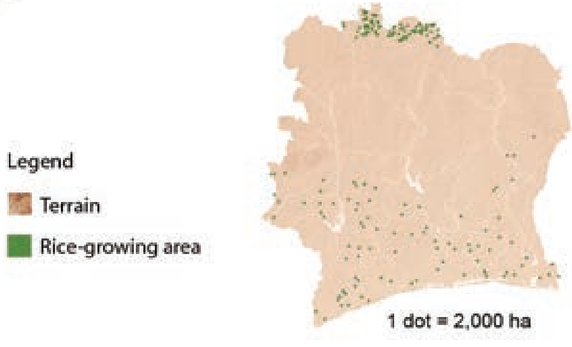
	Planting	Harvesting
Main	May-Jun	Aug-Sep
Second	Aug-Sep	Nov-Jan

Basic statistics, Costa Rica

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	220	210	200	200	200	200	200	
Rice area (×10^3 ha)	41.1	68.4	55.2	48.9	47.3	54.1	63.3	66.4
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	4.45	3.90	3.32	3.97	3.80	4.10	4.10	3.99
Paddy production (×10^3 t)	183.2	266.4	183.3	194.3	179.7	221.5	259.7	264.8
Milled production (×10^3 t)	122	178	122	130	120	148	173	177
Rice imports (×10^3 t)	36.9	43.5	109.3	102.4	123.2	69.8	79.2	66.1
Rice exports (×10^3 t)	4.7	5.1	4.8	1.0	5.0	10.3	6.5	3.6
Total rice consumption (×10^3 t)	176	217	241	224	231	230	237	
Fertilizer usage in NPK (kg/ha of arable land)	554.55	795.24	1,029.92	868.04	790.20	707.48	826.62	

Source: FAOSTAT database as of November 2012.

Côte d'Ivoire



Côte d'Ivoire is centrally located along the southern coast of West Africa. Its borders are formed by Ghana to the east, Burkina Faso and Mali to the north, Guinea and Liberia to the west, and the Gulf of Guinea to the south. The country has two principal zones: the tropical rainforest to the south and the savanna to the north, in a total land area of 318,000 km^2, of which arable land is 8.8% (2009). Toward the middle of the country, the terrain rises to a low plateau covered by a partially wooded savanna. Here, the annual rainfall totals 1,100–1,200 mm during the rainy season from April to October. The Ivorian population was 20.15 million in 2011, of which at least 3 million are immigrants from neighboring countries. Agriculture supports 38% of the population and produces 24% of GDP. Rice is the principal food crop grown in many areas and is one of the most important staple foods for the country's urban population.

General information

- GNI per capita at PPP$, 2011: 1,730
- Internal renewable water resources, 2011: 76.84 km^3/year
- Incoming water flow, 2011: 4.3 km^3/year
- Main food consumed, 2009: rice, cassava, yams, plantains, wheat, maize, vegetables, fermented beverages, sugar, palm oil
- Rice consumption, 2009: 67.3 kg milled rice per person per year

Production seasons

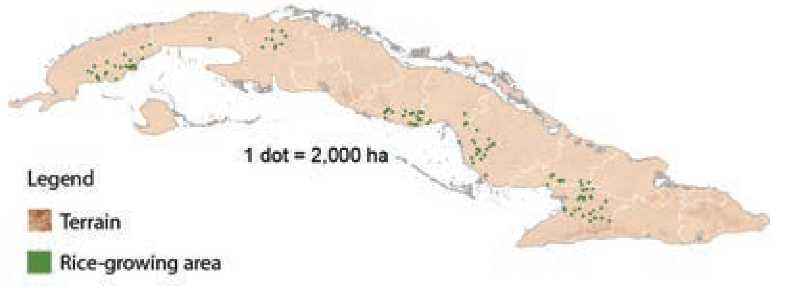
	Planting	Harvesting
Main, north	May-Jun	Oct-Dec
Main, south	Apr-May	Sep-Nov
Off	Dec-Feb	Apr-Jun

Basic statistics, Côte d'Ivoire

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	3,000	2,800	2,800	2,800	2,800	2,800	2,800	
Rice area (×10^3 ha)	650.0	341.5	353.2	370.0	356.4	366.7	377.4	394.9
Share of rice area irrigated (%)						5		
Share of rice area under MVs (%)						3		
Paddy yield (t/ha)	1.06	1.82	1.99	1.93	1.70	1.85	1.82	1.83
Paddy production (×10^3 t)	691.7	621.8	703.9	715.9	606.3	680.0	687.7	722.6
Milled production (×10^3 t)	461	415	470	478	404	454	425	482
Rice imports (×10^3 t)	387.6	440.9	808.2	903.2	808.8	762.2	1121.1	837.9
Rice exports (×10^3 t)	0.1	0.7	11.5	6.3	1.1	21.8	53.4	14.0
Total rice consumption (×10^3 t)	924	975	1,257	1,363	1,479	1,497	1,612	
Fertilizer usage in NPK (kg/ha of arable land)	22.00	23.96	17.78	22.77	24.85	18.86	15.85	

Source: FAOSTAT database online as of November 2012; Revised National Rice Development Strategy for the Côte d'Ivoire Rice Sector (NRDS 2012–2020), Ministry of Agriculture, National Rice Development Office (NRDO), January 2012.

CUBA



Cuba is the main island of the Cuban Archipelago between the Caribbean Sea and the North Atlantic Ocean. The total population was 11.25 million in 2011. The climate is tropical and fertile plains cover much of the island. Arable land makes up 28% of the total land area of 109,820 km^2 and nearly two-thirds are planted to sugarcane, the main crop. Agriculture overall, however, forms only 5% of GDP, while employing a fifth of the workforce.

General information

- Internal renewable water resources, 2011: 38.12 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: vegetables, rice, sugar, wheat, starchy roots, milk, meat, maize, fruits, pulses
- Rice consumption, 2009: 62.3 kg milled rice per person per year

Production seasons

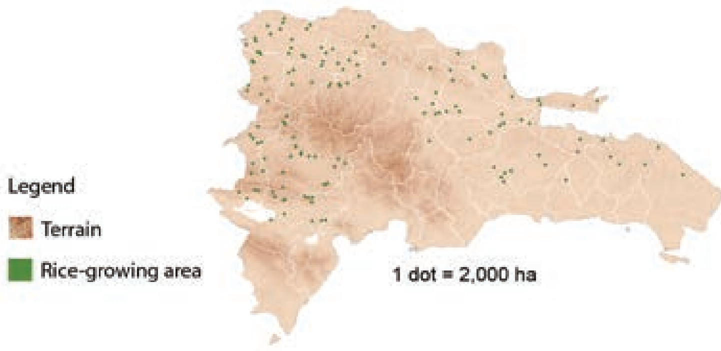
	Planting	Harvesting
Main	Apr-Jul	Jul-Aug
Dry	Dec-Feb	Mar-Jun

Basic statistics, Cuba

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	3,684	3,504	3,672	3,634	3,573	3,500	3,650	
Rice area (×10^3 ha)	154.7	200.1	127.2	142.8	136.1	155.5	215.8	176.4
Share of rice area irrigated (%)	18 (1997)							
Share of rice area under MVs (%)		100						
Paddy yield (t/ha)	2.56	2.76	2.89	3.04	3.23	2.80	2.61	2.58
Paddy production (×10^3 t)	396.1	552.8	367.6	434.2	439.6	436.0	563.6	454.4
Milled production (×10^3 t)	264	369	245	290	293	291	376	303
Rice imports (×10^3 t)	335.9	416.7	723.5	586.5	590.4	575.6	452.5	413.9
Rice exports (×10^3 t)								
Total rice consumption (×10^3 t)	594	799	986	924	927	859	878	
Fertilizer usage in NPK (kg/ha of arable land)	66.23	37.21	22.38	32.12	35.70	43.69	14.16	

Source: FAO's FAOSTAT database online and AQUASTAT database online, as of November 2012.

Dominican Republic



The Dominican Republic occupies an area of 48,670 km^2, the major part of the island of Hispaniola, between the Caribbean Sea and North Atlantic Ocean, with Haiti occupying the smaller, western part of the island. The Dominican Republic had a population of 10 million in 2011, and about 10% of the workforce is engaged in agriculture, which makes up 6% of GDP. It is a tropical country with extensive fertile areas lying between mountain ranges; about 17% is arable land.

General information

- GNI per capita PPP$, 2011: 9,490
- Internal renewable water resources, 2011: 21 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: rice, plantains, meat, milk, wheat, sugar, oils and fats
- Rice consumption, 2009: 53.2 kg milled rice per person per year

Production seasons

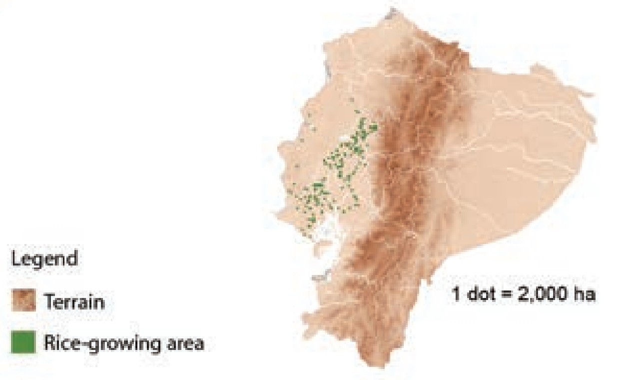
	Planting	Harvesting
Main	Dec-Mar	May-Aug
Off	Jul-Sep	Dec-Jan

Basic statistics, Dominican Republic

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	900	868	820	820	820	800	800	
Rice area (×10³ ha)	102.0	120.1	153.4	152.3	155.7	161.3	182.0	186.3
Share of rice area irrigated (%)								
Share of rice area under MVs (%)		81						
Paddy yield (t/ha)	4.77	4.84	4.20	4.69	4.81	4.83	3.03	3.05
Paddy production (×10³ t)	486.7	581.4	644.9	713.8	749.0	778.5	551.4	567.3
Milled production (×10³ t)	325	388	430	476	500	519	566	378
Rice imports (×10³ t)	47.9	53.6	36.9	31.8	13.2	17.4	11.8	23.1
Rice exports (×10³ t)	0.0	0.0	0.0	0.0	0.0	1.5	0.0	15.0
Total rice consumption (×10³ t)	364	463	468	509	513	536	578	
Fertilizer usage in NPK (kg/ha of arable land)	104.44	105.64	58.24	80.47	94.76	80.40	65.30	

Source: FAOSTAT database online as of November 2012.

ECUADOR



Ecuador, on the tropical Pacific coast of South America, is a small country; the total land area is only 256,370 km^2, extending from coastal plains where most of the population lives and where cash crops, including rice, are grown, to mountainous regions in which agriculture is more at a subsistence level. The population was 14.7 million in 2011, with 28.7% of the workforce employed in agriculture. Arable land constitutes 4.8% of the land area and agriculture accounted for 7.5% of GDP in 2010.

General information

- GNI per capita PPP$, 2011: 8,310
- Internal renewable water resources, 2011: 432 km^3/year
- Incoming water flow, 2011: −7.6 km^3/year
- Main food consumed, 2009: rice, wheat, meat, milk, bananas, meat, plantains, vegetables, sugar and sweeteners
- Rice consumption, 2009: 45.7 kg milled rice per person per year

Production seasons

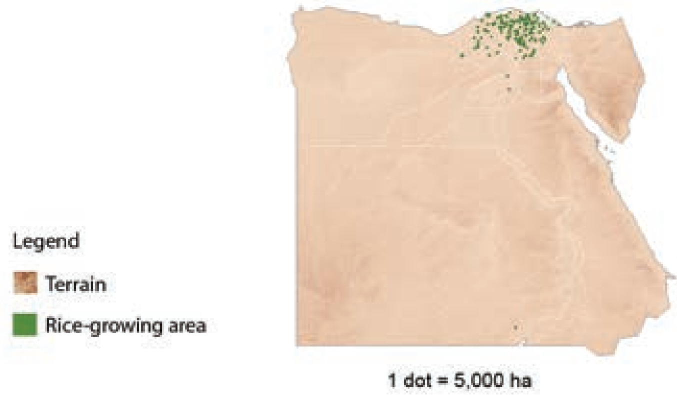
	Planting	Harvesting
Winter	Dec-Feb	Apr-Jun
Summer	May-Jul	Sep-Dec

Basic statistics, Ecuador

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land ($\times10^3$ ha)	1,574	1,616	1,296	1,233	1,195	1,236	1,199	
Rice area ($\times10^3$ ha)	395.6	338.7	377.3	357.6	398.2	354.8	394.8	393.1
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								86
Paddy yield (t/ha)	3.26	3.68	3.90	4.20	4.36	4.06	4.00	4.34
Paddy production ($\times10^3$ t)	1,290.5	1,246.6	1,471.1	1,501.2	1,734.1	1,442.1	1,579.4	1,706.2
Milled production ($\times10^3$ t)	861	832	981	1,001	1,157	962	1,053	1,137
Rice imports ($\times10^3$ t)	0.9	6.4	0.1	0.2	0.1	1.0	0.2	0.2
Rice exports ($\times10^3$ t)	26.2	11.7	31.4	161.0	100.2	5.4	5.1	21.0
Total rice consumption ($\times10^3$ t)	834	811	948	831	1,051	958	1,048	
Fertilizer usage in NPK (kg/ha of arable land)	64.17	101.73	150.83	207.79	199.11	214.12	187.34	

Source: FAOSTAT database online as of November 2012.

EGYPT



Egypt, a large nation of 1 million km^2, mainly consisting of desert, is located in the northeastern corner of Africa. It has a fast-growing population, 82.5 million in 2011, almost all of whom live along the Nile River. The Nile's waters are used extensively to irrigate crops such as rice, which is grown in the summer on about 600,000 ha, mainly in the northern delta. Arable land was 2.9% of the total area in 2009. A quarter of the workforce is involved in agriculture, which makes up 14% (2011) of GDP.

General information

- GNI per capita at PPP$, 2011: 6,120
- Internal renewable water resources, 2011: 1.8 km^3/year
- Incoming water flow, 2011: 55.5 km^3/year
- Main food consumed, 2009: wheat, tomatoes, fruits, maize, milk, rice, sugarcane, potatoes, meat
- Rice consumption, 2009: 38.6 kg milled rice per person per year

Production season

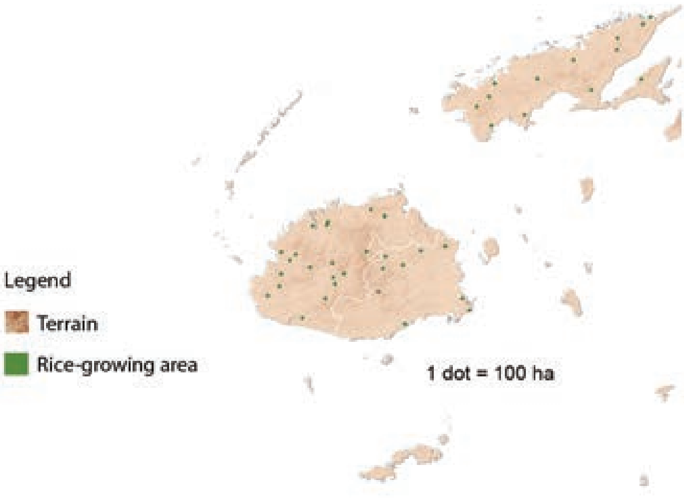
	Planting	Harvesting
Main	May	Oct

Basic statistics, Egypt

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,817	2,801	2,563	2,605	2,564	2,642	2,884	
Rice area (×10^3 ha)	588.5	659.2	613.3	670.5	704.1	745.1	575.5	459.5
Share of rice area irrigated (%)			100 (2002)					
Share of rice area under MVs (%)								
Paddy yield (t/ha)	8.14	9.10	9.99	10.08	9.77	9.73	9.59	9.42
Paddy production (×10^3 t)	4,788.1	6,000.5	6,125.3	6,755.0	6,876.8	7,253.4	5,520.5	4,329.5
Milled production (×10^3 t)	3,194	4,002	4,086	4,506	4,587	4,838	3,682	2,886
Rice imports (×10^3 t)	4.7	1.2	4.5	105.8	118.0	43.5	15.9	13.9
Rice exports (×10^3 t)	156.8	393.1	1,112.0	982.9	1,223.4	306.9	648.8	261.2
Total rice consumption (×10^3 t)	2,970	3,231	3,220	3,486	3,607	3,877	3,607	
Fertilizer usage in NPK (kg/ha of arable land)	399.86	449.74	672.88	492.12	521.79	696.59	502.83	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

FIJI



Fiji, a group of mostly volcanic islands in the South Pacific Ocean totaling 18,274 km^2 in area, has a population of 0.87 million (2011). Arable land constitutes 16% of land area. The climate is hot humid tropical with a dry cooler season (May to October) and warmer wet season (November to April). Agriculture accounts for 9.5% of GDP and 50% of the workforce, mainly in sugarcane production. Rice has been grown for several decades and has become a staple. However, domestic rice production has gradually decreased while demand has grown; more than two-thirds of the rice consumed is now imported.

General information

- GNI per capita at PPP$,2011: 4,590
- Internal renewable water resources, 2011: 28.55 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: rice, starchy roots, kava, oils, vegetables, fruits, meat, milk, seafood
- Rice consumption, 2009: 42.8 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Main	Oct-Nov	Feb-May
Off	Jun-Jul	Sep-Oct

Basic statistics, Fiji

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	180	170	170	170	170	170	160	
Rice area (×10^3 ha)	7.0	5.3	6.4	5.5	5.6	5.1	4.1	2.9
Share of rice area irrigated (%)								20
Share of rice area under MVs (%)								20
Paddy yield (t/ha)	2.66	2.50	2.37	2.31	2.67	2.28	2.87	2.70
Paddy production (×10^3 t)	18.5	13.2	15.2	12.7	14.8	11.6	11.6	7.7
Milled production (×10^3 t)	12	9	10	8	10	8	8	5
Rice imports (×10^3 t)	24.7	24.7	32.6	25.7	32.8	49.8	30.6	50.4
Rice exports (×10^3 t)	0.0	0.1	0.5	0.2	0.2	0.9	0.8	0.8
Total rice consumption (×10^3 t)	33	35	42	38	41	40	40	
Fertilizer usage in NPK (kg/ha of arable land)	100.00	44.12	39.18	25.12	23.80	40.88	22.84	

Source: FAOSTAT database online as of November 2012; Ministry of Primary Industries, Department of Agriculture, Fiji, 2011.

FRANCE

France, in western Europe, consists of the northern plains of the Paris Basin, vast plateaus in the central parts, and mountainous regions in the south. The total area is 549,190 km^2. Only 3% of the workforce in its 2010 population of 63 million was engaged in agriculture, although arable land covers one-third of the country. Agriculture accounts for under 2% of GDP. Extensive rice-growing areas are found in the Camargue region on the Mediterranean coast of France.

General information

- GNI per capita at PPP$, 2011: 35,650
- Internal renewable water resources, 2011: 200 km^3/year
- Incoming water flow, 2011: 11 km^3/year
- Main food consumed, 2009: wheat, meat, milk, fruits, vegetables, oils and fats, starchy roots, sugar and sweeteners, fermented beverages
- Rice consumption, 2009: 4.6 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Apr-May	Sep-Oct

Basic statistics, France

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (× 10³ ha)	18,310	18,440	18,517	18,482	18,433	18,337	18,345.6	
Rice area (×10³ ha)	25.2	19.9	17.9	17.1	17.3	19.4	24.2	23.8
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	4.86	5.84	5.73	5.53	5.08	5.76	5.71	4.98
Paddy production (×10³ t)	122.4	116.0	102.3	94.8	87.7	111.5	138.0	118.5
Milled production (×10³ t)	82	77	68	63	58	74	92	79
Rice imports (×10³ t)	281.0	417.1	462.9	459.6	514.9	505.1	495.0	453.8
Rice exports (×10³ t)	74.4	66.2	97.2	92.5	73.7	76.8	66.6	84.0
Total rice consumption (×10³ t)	277	317	326	308	325	315	313	
Fertilizer usage in NPK (kg/ha of arable land)	268.39	224.77	191.01	188.91	207.67	151.88	148.27	

Source: FAOSTAT database online as of November 2012.

THE GAMBIA

The Gambia is a very small tropical nation of 11,300 km², forming an east-west strip of land along the Gambia River to its mouth in the Atlantic Ocean. Senegal surrounds the country apart from its 80-km coastline. The vegetation is forest and rainforest but large areas have been deforested for firewood and agriculture. About 40% of the land is arable. In 2011, agriculture occupied 76% of the workforce in the population of 1.78 million and contributed 29.9% of GDP.

General information

- GNI per capita at PPP$, 2011: 2,060
- Internal renewable water resources, 2011: 3 km³/year
- Incoming water flow, 2011: 5 km³/year
- Main food consumed, 2009: rice, millet and sorghum, oils and fats, sugar and sweeteners, wheat, maize, milk
- Rice consumption, 2009: 60.6 kg milled rice per person per year

Production seasons

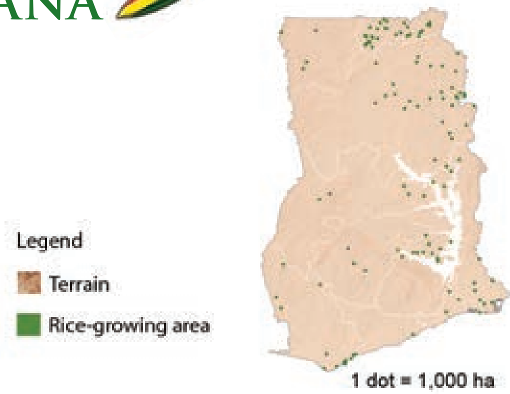
	Planting	Harvesting
Main	May-Jun	Oct-Nov
Off	Jan-Feb	May Jun

Basic statistics, The Gambia

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	180	280	330	345	340	390	400	
Rice area (×10³ ha)	15.4	15.4	17.9	18.3	16.6	34.0	73.0	86.2
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.23	2.21	1.00	1.69	0.69	1.13	1.08	1.16
Paddy production (×10³ t)	19.0	34.1	17.9	31.0	11.4	38.3	79.0	99.9
Milled production (×10³ t)	13	23	12	21	8	26	53	67
Rice imports (×10³ t)	68.2	89.9	111.3	92.4	115.7	118.9	137.0	131.0
Rice exports (×10³ t)	0.0	0.2	0.1	0.1	0.0	0.0	0.9	0.0
Total rice consumption (×10³ t)	84	99	104	108	131	134	208	
Fertilizer usage in NPK (kg/ha of arable land)	5.24	2.86	9.61	9.19	8.00	4.06	6.79	

Source: FAOSTAT database online as of November 2012.

Republic of Ghana



The Republic of Ghana, a small (238,540 km^2) tropical West African country bordering the Gulf of Guinea in the Atlantic Ocean, is predominantly agricultural (25.6% of GDP in 2011), with 55% of the workforce employed in agriculture on wide savannas in the north and cleared rainforest in the south. Arable land is 19.3% of the land area. Deforestation and desertification are of increasing concern. The population in 2011 was 25.0 million.

General information

- GNI per capita at PPP$, 2011: 1,810
- Internal renewable water resources, 2011: 30.3 km^3/year
- Incoming water flow, 2011: 22.9 km^3/year
- Main food consumed, 2009: starchy roots, plantains, vegetables including oils, fish, rice, maize, wheat
- Rice consumption, 2009: 26.9 kg milled rice per person per year

Production seasons

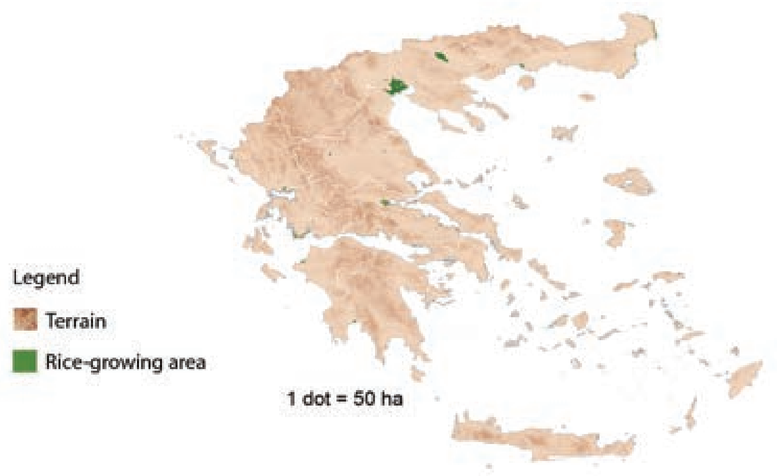
	Planting	Harvesting
Main	May-Jun	Oct-Nov
Off	Jan-Feb	May-Jun

Basic statistics, Ghana

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	3,000	3,950	4,000	4,200	4,400	4,400	4,400	
Rice area (×10³ ha)	99.9	115.2	120.0	125.0	108.9	132.8	162.4	181.2
Share of rice area irrigated (%)		4.3 (2002)						
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.02	2.16	2.39	2.00	1.70	2.27	2.41	2.71
Paddy production (×10³ t)	201.7	248.7	287.0	250.0	185.3	301.9	391.4	491.6
Milled production (×10³ t)	135	166	191	167	124	201	261	328
Rice imports (×10³ t)	104.3	166.8	484.4	390.0	442.1	395.0	383.9	320.1
Rice exports (×10³ t)	0.0	1.4	0.0	2.2	0.0	0.0	0.1	0.0
Total rice consumption (×10³ t)	295	336	526	585	600	647	692	
Fertilizer usage in NPK (kg/ha of arable land)	3.23	3.01	6.00	20.06	17.36	14.88	20.27	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

GREECE



Greece, in the eastern Mediterranean, has a total area of 131,960 km^2. It is mainly mountainous and there are several islands south of the continental mainland. Surprisingly, arable land is 19.8% of the total. The population in 2011 was 11.4 million; 12.5% (2010) of the workforce is engaged in agriculture, which forms 3.3% of GDP.

General information

- GNI per capita at PPP$, 2011: 25,100
- Internal renewable water resources, 2011: 58 km^3/year
- Incoming water flow, 2011: 16.3 km^3/year
- Main food consumed, 2009: milk, vegetables, cereals, fruits, meat, starchy roots, sugar
- Rice consumption, 2009: 7.1 kg milled rice per person per year

Production season

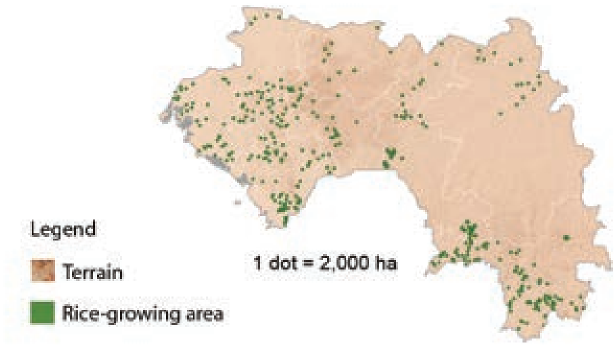
	Planting	Harvesting
Main	Apr-May	Oct-Nov

Basic statistics, Greece

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	2,821	2,741	2,058	2,584	2,118.6	2,571.4	2,550.8	
Rice area (×10³ ha)	26.1	20.0	23.1	23.2	25.6	31.0	29.0	34.0
Share of rice area irrigated (%)*	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)*	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	8.11	7.00	7.24	7.71	7.63	6.74	7.07	6.75
Paddy production (×10³ t)	211.6	140.0	167.2	179.2	195.3	208.8	205.0	229.5
Milled production (×10³ t)	141	93	112	120	130	139	137	153
Rice imports (×10³ t)	6.4	10.5	16.1	25.2	22.5	24.1	20.5	22.9
Rice exports (×10³ t)	49.6	43.7	74.9	95.0	95.4	79.5	82.3	114.1
Total rice consumption (×10³ t)	102	84	101	59	66	108	101	
Fertilizer usage in NPK (kg/ha of arable land)	179.01	166.36	183.42	124.63	117.45	118.35	81.62	

Source: FAOSTAT database online as of November 2012. *www.fao.org/docrep/004/Y0906T/y0906t09.htm

Guinea



Guinea is a populous country (population 10.2 million in 2011) of West Africa, facing the Atlantic Ocean between Guinea-Bissau and Sierra Leone. The majority of the population lives on a hot, humid coastal plain, where rice and other crops are grown. There is a central mountainous region and a drier northeastern area where maize and similar crops are cultivated. Arable land is 11.6% of the land area of 245,720 km^2. Some 80% of the workforce is agricultural, yet agriculture made up only 22.1% of GDP in 2011.

General information

- GNI per capita at PPP$, 2011: 1,020
- Internal renewable water resources, 2011: 226 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: starchy roots, rice, vegetables including oils, plantains, fruits, wheat
- Rice consumption, 2009: 105.8 kg milled rice per person per year

Production seasons

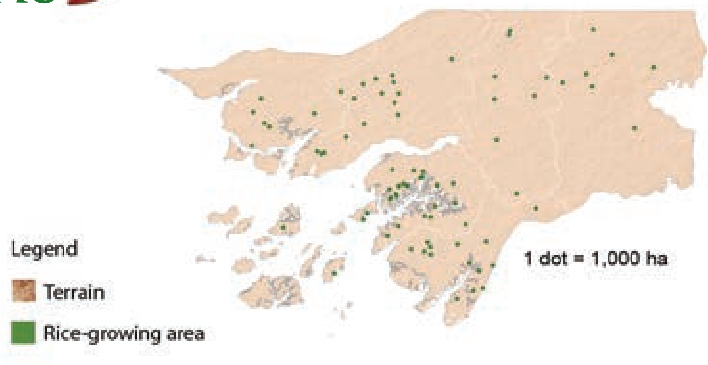
	Planting	Harvesting
Main	Apr-Jun	Sep-Nov
Off	Dec-Feb	Apr-Jun

Basic statistics, Guinea

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,734	2,149	2,741	2,750	2,800	2,850	2,850	
Rice area (×10^3 ha)	536.6	665.6	724.0	758.4	788.8	794.5	871.6	864.3
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.71	1.71	1.76	1.77	1.78	1.93	1.67	1.73
Paddy production (×10^3 t)	918.8	1,140.8	1,272.4	1,340.3	1,401.6	1,534.1	1,455.9	1,499.0
Milled production (×10^3 t)	613	761	849	894	935	1,023	1,000	999
Rice imports (×10^3 t)	291.5	172.4	160.8	251.8	332.6	339.8	237.6	240.9
Rice exports (×10^3 t)	0.0	0.1	1.1	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10^3 t)	894	946	1,022	1,080	1,143	1,206	1,281	
Fertilizer usage in NPK (kg/ha of arable land)	1.87	1.49	0.92	0.88	1.21	1.30	0.63	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

GUINEA-BISSAU



Guinea-Bissau is a tiny tropical West African country of 28,120 km² land area, facing the Atlantic Ocean between Senegal and Guinea. The land is mainly flat, rising to savanna in the east. The population in 2011 was 1.6 million. Rice is grown in both swampy coastal areas and the drier savanna region. About 11% of the land is arable and agriculture, which occupies 79% of the workforce, constitutes 57.3% of GDP (2009).

General information

- GNI per capita at PPP$, 2011: 1,240
- Internal renewable water resources, 2011: 16 km^3/year
- Incoming water flow, 2011: 15 km^3/year
- Main food consumed, 2009: rice, starchy roots, plantains, millet and sorghum, milk, vegetables including oils, meat
- Rice consumption, 2009: 99 kg milled rice per person per year

Production season

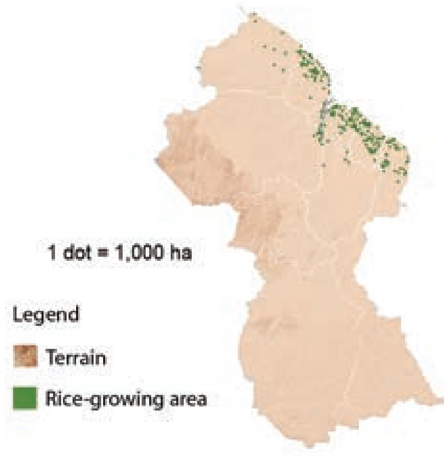
	Planting	Harvesting
Main	May-Aug	Oct-Jan

Basic statistics, Guinea-Bissau

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	280	300	290	300	300	300	300	
Rice area (×10³ ha)	69.9	74.7	65.0	65.0	70.1	82.2	89.3	100.5
Share of rice area irrigated (%)	1*	9*						
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.91	1.42	1.51	1.63	1.82	1.81	2.04	2.08
Paddy production (×10³ t)	133.3	106.1	98.3	106.0	127.3	148.8	181.9	209.2
Milled production (×10³ t)	89	71	66	71	85	99	121	139
Rice imports (×10³ t)	59.0	74.4	79.7	33.2	33.2	19.6	85.1	57.1
Rice exports (×10³ t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10³ t)	138	132	123	116	127	144	161	
Fertilizer usage in NPK (kg/ha of arable land)	1.07	8.00						

Source: FAOSTAT database online and *RICEINFO, as of November 2012.

GUYANA



Guyana, a small country of 214,970 km^2 in area and a population of 756,000 (2011), is located on the northern edge of South America, between Suriname and Venezuela. Nearly all the inhabitants live on a coastal plain, where most agriculture is concentrated. The remainder of the country consists of a rainforest belt backed by an extensive mountain range. Rice and sugarcane are the major crops; only 2.1% of the land is arable. Agriculture formed 21% of GDP and occupied 15% of the workforce in 2010.

General information

- GNI per capita at PPP$, 2010: 3,460
- Internal renewable water resources, 2011: 241 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: milk, rice, vegetables, wheat, starchy roots, meat, sugar, fruits
- Rice consumption, 2009: 81.9 kg milled rice per person per year

Production seasons

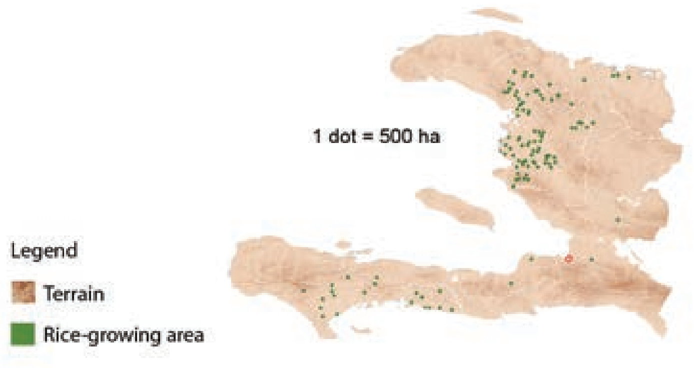
	Planting	Harvesting
Spring	Nov-Dec	Mar-Apr
Autumn	Jun-July	Sep-Oct

Basic statistics, Guyana

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	480	450	420	420	420	420	420	
Rice area (×10^3 ha)	132.9	116.0	106.7	102.1	105.9	119.8	124.8	131.4
Share of rice area irrigated (%)						68*		
Share of rice area under MVs (%)								
Paddy yield (t/ha)	3.97	3.87	3.94	4.59	4.33	4.23	4.44	4.23
Paddy production (×10^3 t)	528.0	449.2	420.4	468.7	458.7	507.0	553.5	556.2
Milled production (×10^3 t)	352	300	280	313	306	338	369	371
Rice imports (×10^3 t)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Rice exports (×10^3 t)	200.5	207.2	232.2	179.1	180.0	196.4	229.1	164.5
Total rice consumption (×10^3 t)	122	110	124	183	126	129	134	
Fertilizer usage in NPK (kg/ha of arable land)	31.25	27.96	22.10	32.58	32.65	56.80	20.25	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012. *Guyana Rice Supply Chain Risk Assessment, February 2011. All ACP Agricultural Commodities Programme, ACP Group of States, European Commission.

HAITI



Tiny Haiti, on the edge of the Caribbean Sea, occupies a third, or 27,750 km^2, of the island of Hispaniola. The Dominican Republic forms the remainder. Most of the country is rugged and mountainous. The climate is tropical and the mountains create semiarid conditions in parts. Haiti had a population of 10.1 million in 2011. Some 38% of the land (2009) is arable. Agriculture, mainly small scale, occupies nearly 59% of the workforce and makes up a quarter of GDP. Rice is the dominant staple but most has to be imported.

General information

- GNI per capita at PPP$, 2011: 1,180
- Internal renewable water resources, 2011: 13.0 km^3/year
- Incoming water flow, 2011: 1.0 km^3/year
- Main food consumed, 2009: starchy roots, rice, wheat, bananas, maize, plantains, sugar, vegetables
- Rice consumption, 2009: 40.4 kg milled rice per person per year

Production seasons

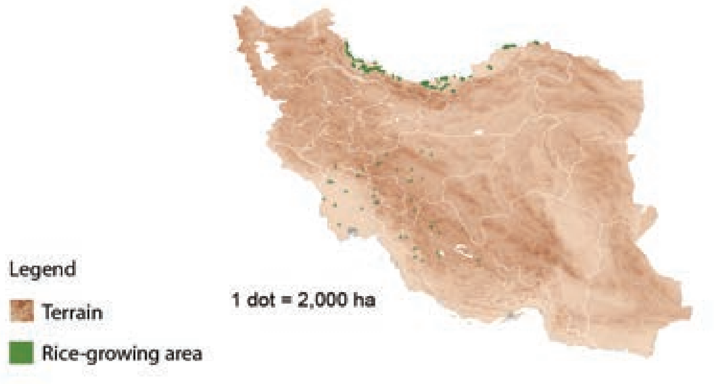
	Planting	Harvesting
Main	Feb-Apr	Jun-Aug
Second	Aug-Sep	Nov-Dec

Basic statistics, Haiti

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	800	900	900	900	1,100	1,000	1,050	
Rice area (×10^3 ha)	50.0	52.0	51.8	53.0	57.8	53.0	57.5	52.4
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.00	2.50	2.03	2.08	2.25	2.08	2.23	2.24
Paddy production (×10^3 t)	100.0	130.0	105.0	110.0	130.0	110.0	128.3	117.6
Milled production (×10^3 t)	67	87	70	73	87	73	86	78
Rice imports (×10^3 t)	208.0	252.6	348.1	412.8	313.2	325.4	335.0	467.0
Rice exports (×10^3 t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10^3 t)	259	329	413	440	416	415	414	
Fertilizer usage in NPK (kg/ha of arable land)	9.25	16.03						

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

IRAN



Iran is a Middle East country bordering the Gulf of Oman, the Persian Gulf, and the Caspian Sea, between Iraq and Pakistan, with a total area of 1.74 million km^2 of mainly deserts and fringing, arid mountainous areas. There are also coastal plains where crops such as rice are grown. About 11% of the land is arable. A quarter of the workforce in the population of 74.8 million in 2011 was occupied in agriculture, which formed 10.2% of GDP.

General information

- GNI per capita at PPP$, 2009: 11,420
- Internal renewable water resources, 2011: 128.5 km^3/year
- Incoming water flow, 2011: 2.7 km^3/year
- Main food consumed, 2009: vegetables including oils, wheat, fruits, milk, potatoes, meat, sugar, grapes, rice
- Rice consumption, 2009: 23 kg milled rice per person per year

Production season

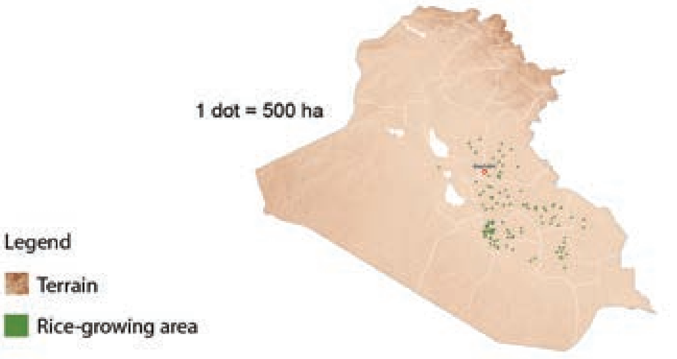
	Planting	Harvesting
Main	May-Jun	Sep-Oct

Basic statistics, Iran

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	17,388	14,924	16,533	16,701	16,869	17,037	17,205	
Rice area (×10^3 ha)	565.6	534.3	628.1	630.6	615.9	526.9	535.8	563.5
Share of rice area irrigated (%)			100					
Share of rice area under MVs (%)								
Paddy yield (t/ha)	4.07	3.69	4.36	4.14	4.33	4.14	4.21	5.35
Paddy production (×10^3 t)	2,300.9	1,971.5	2,736.8	2,612.2	2,664.2	2,184.0	2,253.4	3,012.7
Milled production (×10^3 t)	1,535	1,315	1,825	1,742	1,777	1,457	1,503	2,008
Rice imports (×10^3 t)	1,633.0	1,129.5	1,162.9	1,249.6	1,009.5	1,199.2	803.0	1,132.2
Rice exports (×10^3 t)	0.0	0.4	0.9	0.8	10.6	2.0	0.5	0.2
Total rice consumption (×10^3 t)	2,896	2,256	3,050	2,911	2,782	2,663	2,355	
Fertilizer usage in NPK (kg/ha of arable land)	58.50	93.38	95.05	113.96	90.04	91.10	69.67	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

IRAQ



Iraq, a Middle East country lying between Iran and Kuwait facing the Persian Gulf, has a population of 32.7 million (2011) in an area of 435,240 km² that consists mainly of broad plains with areas of marsh and flooded parts. The climate varies from tropical in the south and southeast to dry in the west. Only 10.4% of the land is arable. Agricultural output accounts for 8.6% of GDP and occupies about 23.4% of the workforce. Rice is the third most important staple after wheat and barley.

General information

- GNI per capita at PPP$, 2011: 3,750
- Internal renewable water resources, 2011: 35.2 km³/year
- Incoming water flow, 2011: 40.4 km³/year
- Main food consumed, 2007-09: wheat, barley, dates, maize, rice, vegetables, meat, yogurt
- Rice consumption, 2007-09: 39.5 kg milled rice per person per year

Production season

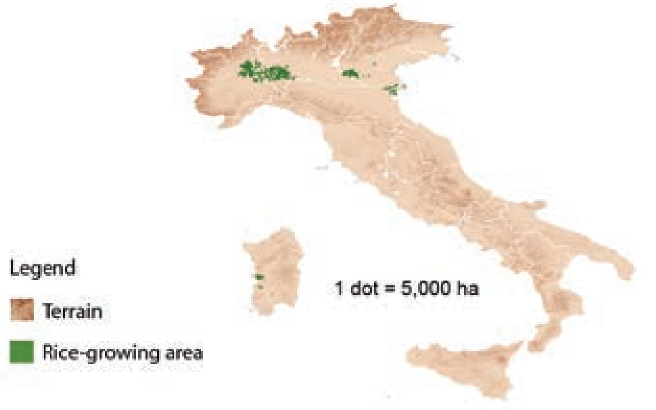
	Planting	Harvesting
Main	Jun-Jul	Sep-Oct

Basic statistics, Iraq

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	5,350	5,000	5,500	5,000	5,200	5,200	4,500	
Rice area (×10³ ha)	175.0	100.0	107.0	125.8	124.3	84.8	54.9	48.0
Paddy yield (t/ha)	1.80	0.60	2.89	2.89	3.16	2.93	3.15	3.25
Paddy production (×10³ t)	315.0	60.0	309.0	363.0	393.0	248.2	173.1	155.8
Milled production (×10³ t)	210	40	206	242	262	165	115	104
Rice imports (×10³ t)	225.0	1,200.0	830.6	1,329.1	735.9	1,051.9	1,099.6	1,123.2
Rice exports (×10³ t)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10³ t)*							1,191	1,225
Fertilizer usage in NPK (kg/ha of arable land)	62.41	74.24	39.34	44.40	35.76	43.80	58.80	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.
*FAO. 2012. Food Outlook, May 2012.

ITALY



Italy is the main rice-producing country in Europe. It forms a large peninsula in the Mediterranean Sea, with 301,340 km² of surface area, supporting a population of 60.8 million (2011). Rice is grown mainly in the northern Po Valley. Arable land makes up 23.4% of the land area. Agriculture as a whole occupies less than 4% of the work-force and contributes only 1.9% to GDP.

General information

- GNI per capita at PPP$, 2011: 32,400
- Internal renewable water resources, 2011: 182.5 km³/year
- Incoming water flow, 2011: 8.8 km³/year
- Main food consumed, 2009: milk, vegetables, fruits, wheat, meat, potatoes, tomatoes, wine
- Rice consumption, 2009: 5.9 kg milled rice per person per year

Production season

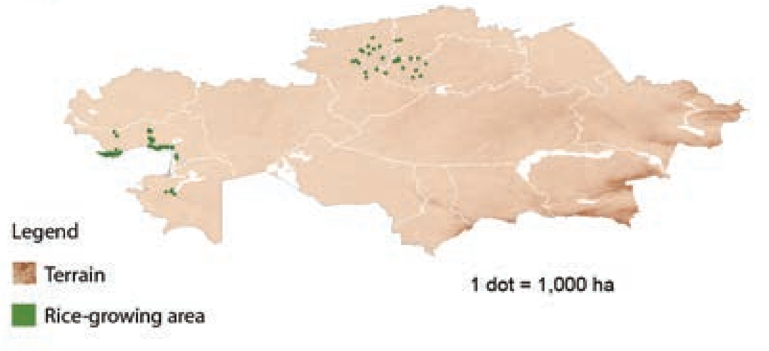
	Planting	Harvesting
Main	Apr-May	Sep-Oct

Basic statistics, Italy

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	8,283	8,479	7,780	7,376	7,171	7,440	6,880	
Rice area (×10³ ha)	239.3	220.3	224.0	226.1	232.5	224.2	238.5	247.7
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	5.52	5.58	6.31	6.28	6.62	6.19	6.79	6.12
Paddy production (×10³ t)	1,320.9	1,229.8	1,413.0	1,419.1	1,540.1	1,388.9	1,620.4	1,516.4
Milled production (×10³ t)	881	820	942	947	1,027	926	1,001	1,011
Rice imports (×10³ t)	58.4	136.7	111.5	186.9	131.9	183.2	126.7	97.8
Rice exports (×10³ t)	523.9	666.3	754.9	738.1	726.9	800.7	724.8	813.0
Total rice consumption (×10³ t)	383	388	425	453	431	418	436	
Fertilizer usage in NPK (kg/ha of arable land)	219.97	204.27	171.75	177.03	190.23	144.59	117.00	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Kazakhstan



Kazakhstan, with an area of 2.7 million km², is the ninth largest country in the world but has a population of only 16.2 million (2011). Positioned between China and Russia, it lies at the top of Central Asia. The land gradually changes from mountains and steppes in the north and northeast to flat deserts. Only 8.7% is arable and most crops are irrigated. The climate is arid and semiarid. Agriculture makes up 5.5% of GDP (2011) and occupies 29.4% of the workforce (2009).

General information

- GNI per capita at PPP$, 2011: 11,250
- Internal renewable water resources, 2011: 64.4 km^3/year
- Incoming water flow, 2011: 44.1 km^3/year
- Main food consumed, 2009: milk, vegetables, wheat, potatoes, meat, fruits, sugar
- Rice consumption, 2009: 8.6 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	May-Jun	Sep-Oct

Basic statistics, Kazakhstan

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	31,742	21,535	22,630	22,710	22,720	22,720	23,400	
Rice area (×10³ ha)	84.1	72.1	84.9	87.6	87.4	75.5	86.7	94.0
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.19	2.97	3.35	3.30	3.37	3.37	3.54	3.97
Paddy production (×10³ t)	184.5	214.3	284.6	288.8	294.4	254.7	307.0	373.2
Milled production (×10³ t)	123	143	190	193	196	170	205	249
Rice imports (×10³ t)	0.7	2.6	4.1	9.0	13.7	20.7	34.5	20.0
Rice exports (×10³ t)	34.8	6.2	33.4	24.1	41.9	26.3	6.4	19.6
Total rice consumption (×10³ t)	88	139	166	177	168	164	170	
Fertilizer usage in NPK (kg/ha of arable land)	2.99	1.72	1.80	1.82	2.59	1.36	2.41	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Democratic People's Republic of Korea

The Democratic People's Republic of Korea (North Korea) occupies the northern part of the Korean Peninsula, with a population of 24.45 million (2011) in an area of 120,540 km^2, bordering China and the Republic of Korea. Much of the country is mountainous, with rice, the main agricultural crop, and other crops being grown on plains. Arable land is 22% (2009) of the total. Agriculture makes up 21% of GDP, occupying a third of the workforce.

General information

- GNI per capita at PPP$, 2011: 1,610**
- Internal renewable water resources, 2011: 67 km^3/year
- Incoming water flow, 2011: 10.2 km^3/year
- Main food consumed, 2009: vegetables, rice, fruits, potatoes, maize, wheat
- Rice consumption, 2009: 76.2 kg milled rice per person per year

Production season

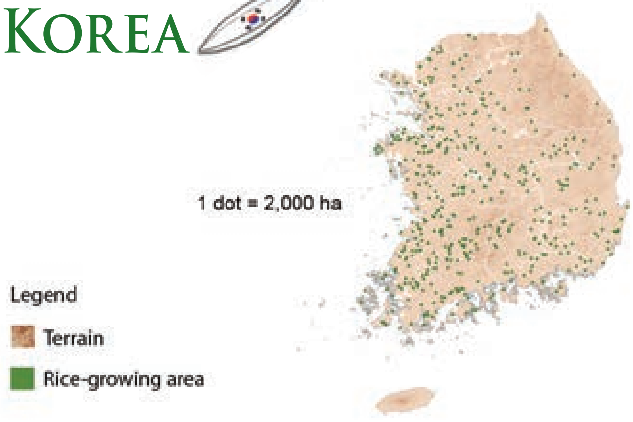
	Planting	Harvesting
Main	May-Jun	Sep-Oct

Basic statistics, Democratic People's Republic of Korea

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	2,400	2,600	2,750	2,700	2,700	2,700	2,650	
Rice area (×10³ ha)	582.0	535.0	583.4	583.4	583.4	570.4	569.0	570.0
Share of rice area irrigated (%)				80				100*
Share of rice area under MVs (%)	80	100	100	100	100	100	100	100
Paddy yield (t/ha)	3.46	3.16	4.43	4.25	3.20	5.02	4.11	4.26
Paddy production (×10³ t)	2,016.0	1,690.0	2,583.4	2,478.5	1,869.5	2,862.0	2,336.0	2,426.0
Milled production (×10³ t)	1,345	1,127	1,723	1,653	1,247	1,909	1,558	1,617
Rice imports (×10³ t)	587.0	778.9	794.0	153.8	784.9	66.9	114.3	96.0
Rice exports (×10³ t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10³ t)	2,214	1,814	2,266	2,324	2,140	2,234	2,106	
Fertilizer usage in NPK (kg/ha of arable land)	43.4	98.5						

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012. *FAO. 2012: CFSAM-Korea, DPRK. **www.nationsonline.org/oneworld/GNI_PPP_of_countries.htm; 2011: The Bank of Korea (www.nkeconwatch.com), approx. 5.3% of South Korea.

Republic of Korea



The Republic of Korea (South Korea) occupies the southern part of the Korean Peninsula, with a population of 48.4 million (2011) in an area of 99,900 km^2. The country has large areas of coastal plains in the west and south used mainly for agriculture. Arable land is about 16.4% of the land area. The country has become mainly industrial and agriculture is only 2.7% (2011) of GDP, supporting 6.6% of the workforce.

General information

- GNI per capita at PPP$, 2011: 30,370
- Internal renewable water resources, 2011: 64.9 km^3/year
- Incoming water flow, 2011: 4.9 km^3/year
- Main food consumed, 2009: vegetables including oils, rice, fruits, fermented beverages, meat, fish, wheat
- Rice consumption, 2009: 81.3 kg milled rice per person per year

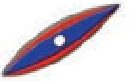
Production season

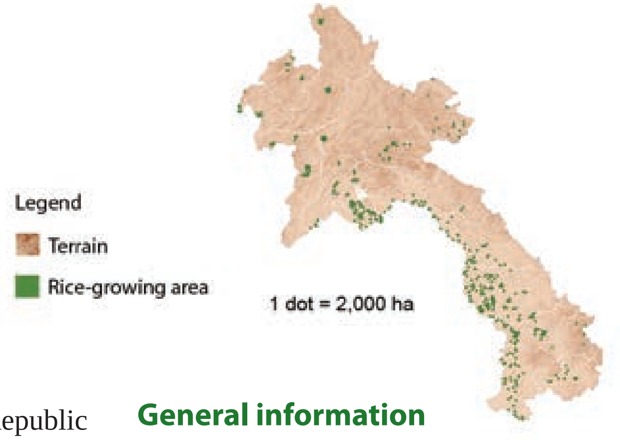
	Planting	Harvesting
Main	May-Jun	Sep-Oct

Basic statistics, Republic of Korea

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	1,783	1,718	1,643	1,619	1,597	1,553	1,595	
Rice area (×10^3 ha)	1,055.3	1,072.4	979.7	955.2	950.3	935.8	924.5	892.1
Share of rice area irrigated (%)				80				
Share of rice area under MVs (%)			100	100	100	100	100	100
Paddy yield (t/ha)	6.05	6.71	6.57	6.71	6.35	7.39	7.60	6.88
Paddy production (×10^3 t)	6,387.3	7,196.6	6,435.0	6,411.0	6,038.0	6,919.3	7,023.0	6,136.3
Milled production (×10^3 t)	4,260	4,800	4,292	4,276	4,027	4,615	4,684	4,091
Rice imports (×10^3 t)	0.7	172.3	133.5	255.0	264.7	308.7	267.3	345.0
Rice exports (×10^3 t)	0.5	0.1	0.0	0.0	0.5	0.4	4.2	3.8
Total rice consumption (×10^3 t)	4,535	4,412	4,107	4,178	4,150	4,174	4,426	
Fertilizer usage in NPK (kg/ha of arable land)	549.09	455.96	643.36	469.85	511.04	479.54	362.08	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Lao People's Democratic Republic 



The Lao People's Democratic Republic (Laos) is an elongated landlocked country between Thailand and Vietnam, also bordering Cambodia in the south and Myanmar and China in the north. With an area of 236,800 km², most of the land is mountainous and covered in rainforest. Logging of the forests is a major environmental problem. About 5.9% of the land area is arable (2009). The Mekong River forms a fertile valley through most of the country, where agriculture, mainly rice farming, is carried out. The population in 2011 was 6.3 million. Agriculture occupied 75% of the workforce and made up 30.8% of the country's GDP in 2011.

General information

- GNI per capita at PPP$, 2011: 2,580
- Internal renewable water resources, 2011: 190.4 km³/year
- Incoming water flow, 2011: 143.1 km³/year
- Main food consumed, 2009: rice, vegetables, fruits, starchy roots, sugar, meat, fish
- Rice consumption, 2009: 165.5 kg milled rice per person per year

Production seasons

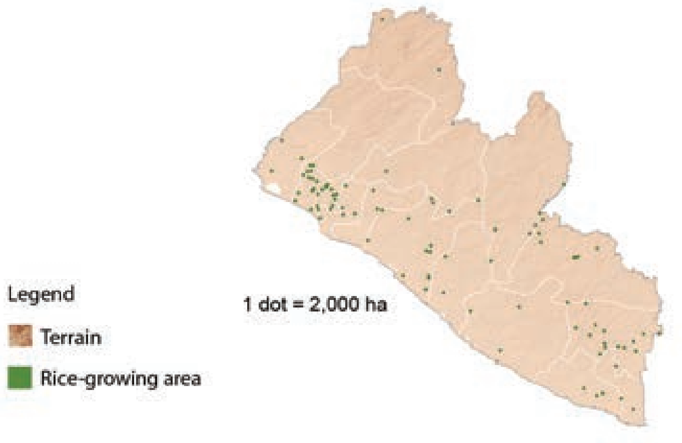
	Planting	Harvesting
Wet	May-Jul	Nov-Dec
Dry	Dec-Jan	Apr-Jun

Basic statistics, Laos

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	828	877	1,050	1,100	1,070	1,300	1,360	
Rice area (×10³ ha)	559.9	719.4	736.0	742.9	727.9	786.3	818.6	855.1
Share of rice area irrigated (%)			42					
Share of rice area under MVs (%)		70						
Paddy yield (t/ha)	2.53	3.06	3.49	3.59	3.72	3.78	3.84	3.59
Paddy production (×10³ t)	1,417.8	2,201.7	2,568.0	2,663.7	2,710.1	2,969.9	3,144.8	3,070.6
Milled production (×10³ t)	946	1,469	1,713	1,777	1,808	1,981	2,098	2,047
Rice imports (×10³ t)	15.9	13.7	22.3	17.3	24.6	23.7	43.0	42.8
Rice exports (×10³ t)								
Total rice consumption (×10³ t)	1,019	1,323	1,553	1,610	1,668	1,783	1,877	
Fertilizer usage in NPK (kg/ha of arable land)	7.47	6.85						

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

LIBERIA



Liberia, whose coast is known as the Grain Coast, faces the Atlantic Ocean in West Africa, occupying 111,370 km^2 between Sierra Leone and Côte d'Ivoire, with a population of 4.1 million (2011). There are low-lying coastal plains where most crops, including rice, are grown, and a mountainous interior with central plateaus. Arable land is less than 5% of the land area, but agriculture contributes 53.1% to the country's GDP and occupies less than two-thirds of the workforce.

General information

- GNI per capita at PPP$, 2011: 540
- Internal renewable water resources, 2011: 200 km^3/year
- Incoming water flow, 2011: 32 km^3/year
- Main food consumed, 2009: cassava, rice, bananas and plantains, vegetables including oils, wheat, sugar, meat
- Rice consumption, 2009: 96.1 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Apr-Jul	Sep-Dec

Basic statistics, Liberia

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	350	380	380	385	385	400	400	
Rice area (×10³ ha)	50.0	143.5	120.0	130.0	160.0	190.0	247.6	251.2
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.12	1.28	1.29	1.26	1.45	1.55	1.18	1.18
Paddy production (×10³ t)	56.2	183.4	154.8	164.0	231.8	295.2	293.0	296.1
Milled production (×10³ t)	37	122	103	109	155	197	195	197
Rice imports (×10³ t)	30.2	81.0	151.9	216.2	148.7	170.5	248.6	294.5
Rice exports (×10³ t)	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10³ t)	68	189	235	302	314	377	433	
Fertilizer usage in NPK (kg/ha of arable land)								

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

MALAWI

Landlocked Malawi in southeastern Africa consists mainly of a plateau beside Lake Nyasa, whose waters make up 24,400 km^2 of the total area of 118,484 km^2. The population of 15.4 million (2011) makes Malawi one of the world's most densely populated countries. Agriculture comprises almost a third of GDP, occupying nearly 80% of the workforce. Arable land is 38.2% of the land area. The climate is subtropical with a rainy season in November to May, the remainder of the year being dry.

General information

- GNI per capita at PPP$, 2011: 870
- Internal renewable water resources, 2011: 16.1 km^3/year
- Incoming water flow, 2011: 1.1 km^3/year
- Main food consumed, 2009: starchy roots, maize, banana and plantains, vegetables including oils, pulses, sugar
- Rice consumption, 2009: 5.9 kg milled rice per person per year

Production season

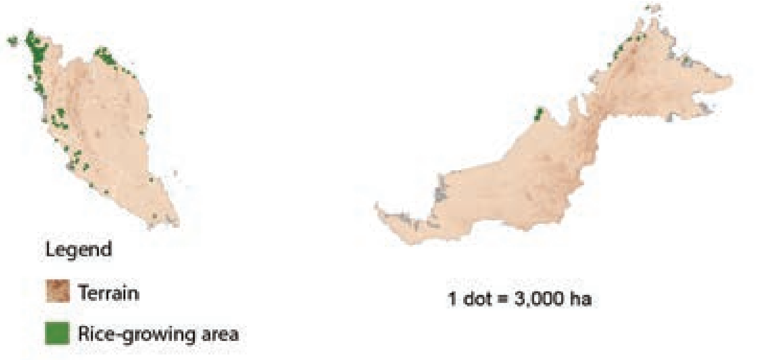
	Planting	Harvesting
Main	Nov-Dec	May-Jul

Basic statistics, Malawi

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	2,300	2,750	3,000	3,000	3,000	3,500	3,600	
Rice area (×10³ ha)	33.3	43.5	49.0	52.0	58.1	63.1	64.0	59.1
Share of rice area irrigated (%)					15*			
Share of rice area under MVs (%)				40*				
Paddy yield (t/ha)	1.56	1.65	0.84	1.76	1.95	1.82	2.13	1.86
Paddy production (×10³ t)	52.1	71.6	41.3	91.5	113.2	114.9	136.0	110.1
Milled production (×10³ t)	35	48	28	61	75	77	91	73
Rice imports (×10³ t)	2.5	3.5	1.3	3.7	3.8	5.3	6.7	0.8
Rice exports (×10³ t)	4.7	0.0	0.0	0.1	5.0	1.5	7.8	1.3
Total rice consumption (×10³ t)	32	51	56	65	70	81	91	
Fertilizer usage in NPK (kg/ha of arable land)	18.92	18.11	32.52	40.51	41.72	31.82	28.51	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012. *Mzengeza T. 2010. Genetic Studies on Grain and Morphological Traits in Early Generation Crosses of Malawi Rice (*Oryza sativa* L.) Landrace and NERICA Varieties. PhD Thesis at African Centre for Crop Improvement, University of Kwazulu, Natal, Republic of South Africa.

Malaysia



Malaysia consists of a peninsula bordering Thailand in the north, and the northwestern side of the island of Borneo, with a total area of 330,800 km^2 and a population of 28.9 million (2011). Most of the peninsula is covered in tropical forest, much of it on a central mountain range. Coastal plains dominate the Borneo states and the interior is mountainous. About 13% of the workforce is engaged in agriculture; 5.5% of the land is arable (2009). Agriculture made up 11.9% of GDP in 2011.

General information

- GNI per capita at PPP$, 2011: 15,650
- Internal renewable water resources, 2011: 580 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: rice, wheat, fish, meat, vegetables, fruits, sugar, milk
- Rice consumption, 2009: 74 kg milled rice per person per year

Production seasons

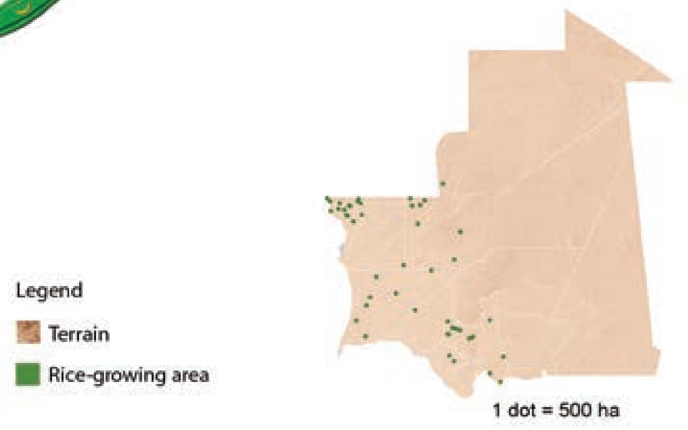
	Planting	Harvesting
Main, Peninsular	Sep-Oct	Nov-Mar
Main, Sabah	Jun-Sep	Dec-Apr
Main, Sarawak	Jan-May	Aug-Sep

Basic statistics, Malaysia

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	1,820	1,820	1,800	1,800	1,800	1,800	1,800	
Rice area (×10^3 ha)	672.8	698.7	676.2	645.0	673.2	656.6	674.9	677.9
Share of rice area irrigated (%)				56.3				
Share of rice area under MVs (%)		90						
Paddy yield (t/ha)	3.16	3.06	3.42	3.39	3.53	3.58	3.72	3.64
Paddy production (×10^3 t)	2,127.3	2,140.8	2,314.0	2,187.0	2,375.0	2,353.0	2,511.0	2,464.8
Milled production (×10^3 t)	1,419	1,428	1,543	1,459	1,584	1,569	1,675	1,643
Rice imports (×10^3 t)	427.6	595.6	584.7	843.3	798.5	1,119.6	1,087.0	931.4
Rice exports (×10^3 t)	2.4	0.1	5.4	4.5	0.2	0.9	0.6	0.4
Total rice consumption (×10^3 t)	1,898	2,072	2,085	2,081	2,156	2,154	2,201	
Fertilizer usage in NPK (kg/ha of arable land)	600.00	652.90	775.31	855.70	954.48	1,036.07	769.79	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Mauritania



Mauritania is a large West African country bordering the Atlantic Ocean. Two-thirds of the land area of 1 million km² is desert. Most of its population of 3.54 million (2011) lives in the southwest, where the Senegal River provides water for irrigation. Agriculture contributes 16.3% (2011) of GDP and occupies 50% of the labor force. Arable land is only 0.4% of the land area, but fishing and livestock are the main agricultural activities.

General information

- GNI per capita at PPP$, 2011: 2,400
- Internal renewable water resources, 2011: 0.4 km³/year
- Incoming water flow, 2011: 11 km³/year
- Main food consumed, 2009: milk, wheat, sugar, vegetables, rice, meat, fish
- Rice consumption, 2009: 30.5 kg milled rice per person per year

Production seasons

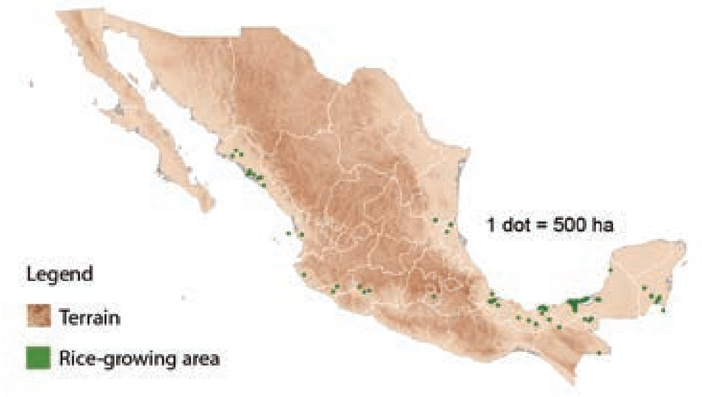
	Planting	Harvesting
Main	Jun-Jul	Oct-Nov
Off	Oct-Dec	Mar-April

Basic statistics, Mauritania

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	498	488	400	400	400	400	390	
Rice area (×10³ ha)	13.4	18.0	18.5	15.7	17.4	17.3	13.4	25.7
Share of rice area irrigated (%)		100	100	100	100	100	100	100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	3.94	4.24	3.89	4.48	4.72	4.76	3.99	5.23
Paddy production (×10³ t)	52.8	76.2	72.0	70.5	82.2	82.2	53.6	134.4
Milled production (×10³ t)	35	51	48	47	55	55	36	90
Rice imports (×10³ t)	70.0	42.1	51.8	56.7	56.0	122.0	133.5	97.5
Rice exports (×10³ t)								
Total rice consumption (×10³ t)	105	135	100	114	107	107	107	
Fertilizer usage in NPK (kg/ha of arable land)	8.03							

Source: FAOSTAT database online and FAO RICE INFORMATION online, as of November 2012.

MEXICO



Mexico, at the southern end of North America, faces the Pacific Ocean and the Gulf of Mexico. Its area of 1.96 million km^2 is mainly mountainous with a climate ranging from desert conditions in the north to rainy tropics in the southeast. Arable land is about 13% of the land area. Agriculture occupies 13% of the workforce in a population of 114.8 million (2011) and constitutes only about 3.8% of GDP.

General information

- GNI per capita at PPP$, 2011: 15,390
- Internal renewable water resources, 2011: 409 km^3/year
- Incoming water flow, 2011: 48.2 km^3/year
- Main food consumed, 2009: maize, milk, fruits, meat, beer, vegetables, sugar, wheat
- Rice consumption, 2009: 5.8 kg milled rice per person per year

Production seasons

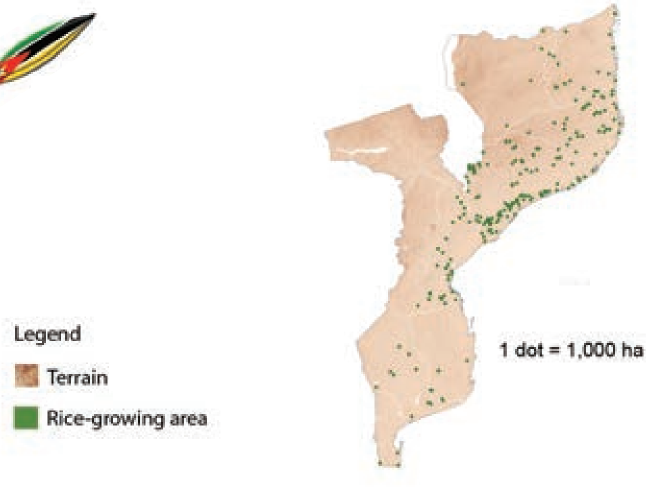
	Planting	Harvesting
Main	Apr-Jul	Sep-Jan
Autumm/winter	Dec-Feb	Aug
Spring/summer	May-Jul	Oct-Dec

Basic statistics, Mexico

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	25,100	25,100	25,000	24,500	24,453	25,202	25,133	
Rice area (×10³ ha)	78.4	84.1	57.5	70.5	70.9	50.3	54.2	41.7
Share of rice area irrigated (%)		82						
Share of rice area under MVs (%)								
Paddy yield (t/ha)	4.68	4.18	5.07	4.79	4.15	4.46	4.85	5.19
Paddy production (×10³ t)	367.0	351.4	291.1	337.3	294.7	224.4	263.0	216.7
Milled production (×10³ t)	245	234	194	225	197	150	175	144
Rice imports (×10³ t)	246.4	426.1	490.3	538.9	558.3	547.3	563.0	572.1
Rice exports (×10³ t)	0.6	0.3	2.8	2.7	14.2	10.5	7.3	5.5
Total rice consumption (×10³ t)	491	671	692	773	752	679	708	
Fertilizer usage in NPK (kg/ha of arable land)	51.24	72.99	73.79	65.83	72.17	49.36	54.52	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

MOZAMBIQUE



Mozambique extends nearly 2,500 km along the southeastern coast of Africa, with an area of 799,380 km². Much of this consists of wide coastal plains, rising to low inland plateaus. Agriculture occupies about 81% of the workforce in a population of 23.9 million (2011). Arable land is 6.4% of the total area; however, agriculture makes up 32% of GDP.

General information

- GNI per capita at PPP$, 2011: 970
- Internal renewable water resources, 2011: 100.3 km^3/year
- Incoming water flow, 2011: 116.8 km^3/year
- Main food consumed, 2009: starchy roots, maize, wheat, rice, fruits, sugar, vegetables including oils
- Rice consumption, 2009: 19 kg milled rice per person per year

Production season

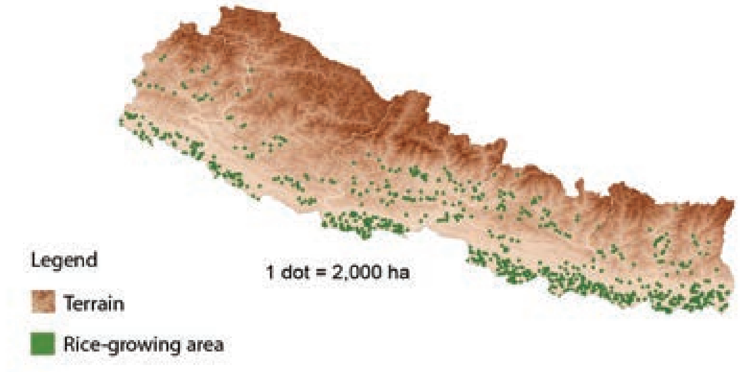
	Planting	Harvesting
Main	Nov-Jan	May-Jun

Basic statistics, Mozambique

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	3,650	3,900	4,500	4,800	4,800	4,800	5,050	
Rice area (×10³ ha)	129.6	184.2	67.0	105.0	105.0	104.0	182.0	185.0
Share of rice area irrigated (%)		2.2			3*			
Share of rice area under MVs (%)								
Paddy yield (t/ha)	0.87	0.98	0.97	0.94	1.00	0.98	0.98	0.97
Paddy production (×10³ t)	113.0	180.8	65.0	99.2	104.7	101.9	179.0	180.0
Milled production (×10³ t)	75	121	43	66	70	68	119	120
Rice imports (×10³ t)	90.9	70.9	344.7	454.9	487.3	367.9	495.4	303.6
Rice exports (×10³ t)	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.1
Total rice consumption (×10³ t)	137	182	309	397	450	431	458	
Fertilizer usage in NPK (kg/ha of arable land)	2.14	3.67	1.59	4.74	2.88	12.84	4.39	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.
*National Rice Development Strategy, Mozambique, Ministry of Agriculture, Republic of Mozambique, 2 September 2009. Draft.

NEPAL



Nepal is a small (147,480 km^2) country in the central Himalayan Mountains between India and China. It consists of low tropical plains and central plateaus that rise up to the world's highest peaks. Arable land covers 16.7% of its land area. The population in 2011 was 30.5 million. According to the Nepal Department of Agriculture, agriculture provides a livelihood for 66% of the economically active population and accounts for 39% of GDP.

General information

- GNI per capita at PPP$, 2011: 1,260
- Internal renewable water resources, 2011: 198.2 km^3/year
- Incoming water flow, 2011: 12 km^3/year
- Main food consumed, 2009: rice, maize, wheat, vegetables, starchy roots, milk, fruits, wheat, sugarcane, vegetables, including oil
- Rice consumption, 2009: 79.7 kg milled rice per person per year

Production season

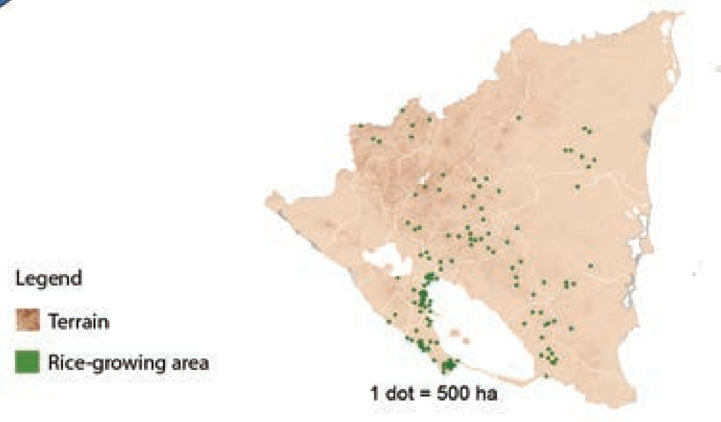
	Planting	Harvesting
Main	May-Aug	Oct-Dec

Basic statistics, Nepal

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,324	2,354	2,357	2,357	2,357	2,357	2,400	
Rice area (×10^3 ha)	1,496.8	1,560.0	1,541.7	1,549.5	1,439.5	1,549.3	1,555.9	1,481.3
Share of rice area irrigated (%)				46				
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.39	2.70	2.78	2.72	2.56	2.78	2.91	2.72
Paddy production (×10^3 t)	3,578.8	4,216.5	4,289.8	4,209.3	3,680.8	4,299.3	4,523.7	4,023.8
Milled production (×10^3 t)	2,387	2,812	2,861	2,808	2,455	2,868	3,017	2,683
Rice imports (×10^3 t)	40.0	195.0	50.3	157.0	226.6	92.6	103.0	98.2
Rice exports (×10^3 t)	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.4
Total rice consumption (×10^3 t)	2,327	2,655	2,816	2,828	2,840	2,884	3,038	
Fertilizer usage in NPK (kg/ha of arable land)	40.32	31.02	3.45	5.41	1.53	1.39	17.70	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

NICARAGUA



Nicaragua, a small country of 130,370 km^2 in Central America, faces the Pacific Ocean and the Caribbean Sea. Much of the interior is mountainous and volcanic. The bulk of the population of 5.87 million (2011) lives on the western side of the country. Arable land is 15.8% of the land area. Agriculture is undertaken by 15% of the workforce and makes up 20% of GDP (2011).

General information

- GNI per capita at PPP$, 2011: 3,730
- Internal renewable water resources, 2011: 189.7 km^3/year
- Incoming water flow, 2011: 7.0 km^3/year
- Main food consumed, 2009: milk, maize, fruits, rice, sugar, wheat, meat, beans
- Rice consumption, 2009: 43.5 kg milled rice per person per year

Production seasons

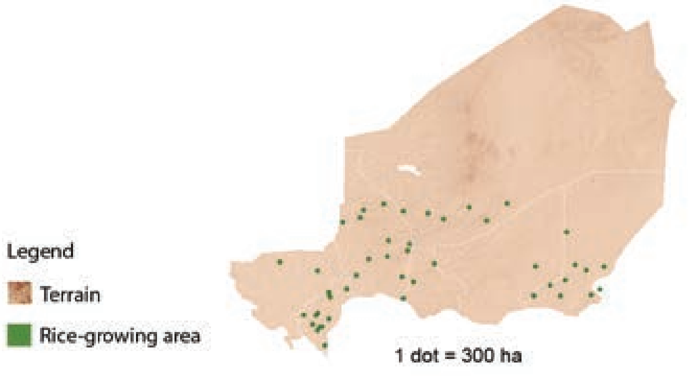
	Planting	Harvesting
Main-Highland	June	Oct-Nov
Main-Irrigated	Jan-Feb	Apr-Nov

Basic statistics, Nicaragua

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	1,650	1,917	2,050	1,970	1,950	1,900	1,900	
Rice area (×10³ ha)	62.7	92.8	95.7	87.8	68.4	71.2	73.8	88.3
Share of rice area irrigated (%)	23	34						
Share of rice area under MVs (%)								
Paddy yield (t/ha)	3.71	3.12	3.31	3.64	3.95	4.01	4.54	5.14
Paddy production (×10³ t)	232.5	289.6	316.7	319.6	269.9	285.1	334.5	454.0
Milled production (×10³ t)	155	193	211	213	180	190	223	303
Rice imports (×10³ t)	52.9	62.3	126.0	64.1	117.8	121.5	85.1	88.1
Rice exports (×10³ t)	1.3	0.2	0.7	0.5	3.0	4.7	4.3	7.1
Total rice consumption (×10³ t)	201	254	288	230	240	255	259	
Fertilizer usage in NPK (kg/ha of arable land)	18.79	15.08	27.43	30.81	29.05	24.25	30.28	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Niger



Niger is one of the larger Central African countries, with an area of 1.27 million km^2. Landlocked, it consists mainly of a plateau. The Sahara Desert occupies the northern parts and there is savanna in the south where crops such as rice are grown. Nearly all (90%) of the workforce in the population of 16.1 million (2011) is rural, engaged in subsistence agriculture, which makes up 39.7% of GDP. Arable land made up 11.8% of total land area in 2009.

General information

- GNI per capita at PPP$, 2011: 720
- Internal renewable water resources, 2011: 3.5 km^3/year
- Incoming water flow, 2011: 30.2 km^3/year
- Main food consumed, 2009: millet and sorghum, milk, vegetables, pulses, meat
- Rice consumption, 2009: 8.3 kg milled rice per person per year

Production seasons

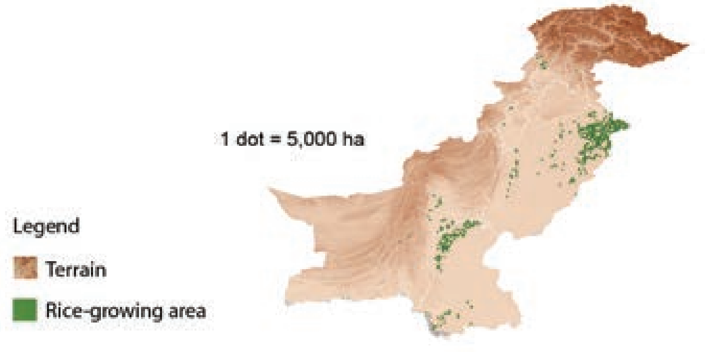
	Planting	Harvesting
Deepwater rice	Jul-Aug	Dec-Jan
Other rice, main	Jun-Jul	Oct-Dec

Basic statistics, Niger

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	13,985	13,980	14,148	14,167	14,958	14,955	14,940	
Rice area (×10^3 ha)	21.0	22.0	15.1	21.1	22.4	17.7	14.1	20.1
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.43	2.75	3.96	3.71	3.12	1.83	1.43	1.49
Paddy production (×10^3 t)	51.0	60.5	59.9	78.4	70.0	32.5	20.1	30.0
Milled production (×10^3 t)	34	40	40	52	47	21	13	20
Rice imports (×10^3 t)	42.9	89.7	291.5	187.0	172.6	269.3	106.1	149.1
Rice exports (×10^3 t)	0.0	0.1	1.0	15.9	16.6	30.1	30.1	39.9
Total rice consumption (×10^3 t)	79	134	311	230	205	198	165	
Fertilizer usage in NPK (kg/ha of arable land)	0.71	0.32	0.39	0.53	0.35	0.15	0.39	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Pakistan



Pakistan, a South Asian country facing the Arabian Sea, with 796,100 km^2 in area and a population of 176.8 million (2011), is largely mountainous and semi-arid. However, on the eastern side, where Pakistan borders India, the Indus River runs nearly the full length of the country. Most agricultural activities are concentrated on its banks, as is most of the population. Arable land is 26.5% of the land area. Agriculture occupies 39% of the workforce and accounts for 21.6% of GDP. The main crops are cotton and wheat.

General information

- GNI per capita at PPP$, 2011: 2,870
- Internal renewable water resources, 2011: 55 km^3/year
- Incoming water flow, 2011: 191.8 km^3/year
- Main food consumed, 2009: wheat, milk, sugar, fruits, vegetables, rice, fruits, meat
- Rice consumption, 2009: 17 kg milled rice per person per year

Production season

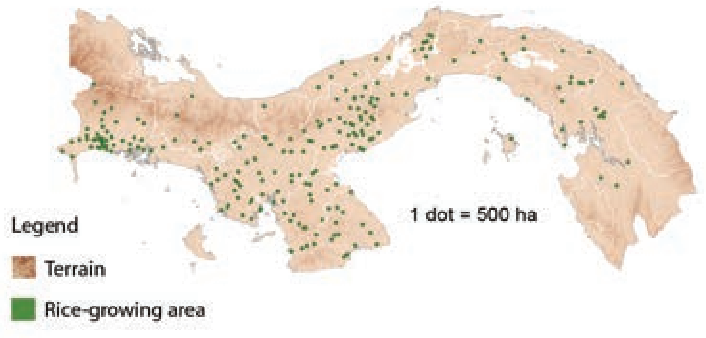
	Planting	Harvesting
Main	May-Jul	Oct-Nov

Basic statistics, Pakistan

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	20,984	21,292	21,265	21,475	21,047	20,427	20,430	
Rice area (×10^3 ha)	2,161.8	2,376.6	2,621.4	2,581.0	2,515.0	2,962.6	2,883.1	2,365.3
Share of rice area irrigated (%)		100	100	100	100	100	100	100
Share of rice area under MVs (%)		42						
Paddy yield (t/ha)	2.75	3.03	3.17	3.16	3.32	3.52	3.58	3.06
Paddy production (×10^3 t)	5,949.8	7,203.9	8,320.8	8,157.6	8,345.1	10,428.0	10,324.5	7,235.2
Milled production (×10^3 t)	3,968	4,805	5,550	5,441	5,566	6,955	6,886	4,823
Rice imports (×10^3 t)	0.1	0.7	0.0	1.9	3.3	3.6	4.2	1.9
Rice exports (×10^3 t)	1,852.3	20,16.3	2,891.4	3,688.7	3,129.3	2,809.5	2,751.5	4,179.8
Total rice consumption (×10^3 t)	2,026	2,234	2,242	2,750	2,816	3,195	3,218	
Fertilizer usage in NPK (kg/ha of arable land)	119.86	139.14	175.19	177.52	169.81	162.52	217.27	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

PANAMA



Panama, facing both the Pacific Ocean and Caribbean Sea in Central America, is bordered by Colombia and Costa Rica. It is a small country of 75,420 km^2, with a population of 3.6 million (2011). Its climate is hot, humid tropical, with most of the land occupied by mountains and upland plains, and coastal plains; only 7.4% is arable. Much of the economy is built around the Panama Canal. Agriculture contributes 4% of GDP, undertaken by 16% of the workforce. Rice is the second largest crop after bananas.

General information

- GNI per capita at PPP$, 2011: 14,510
- Internal renewable water resources, 2011: 147.4 km^3/year
- Incoming water flow, 2011: 0.6 km^3/year
- Main food consumed, 2009: fruits, fermented beverages, milk, meat, rice, wheat, vegetables including oils, sugar, maize
- Rice consumption, 2009: 62.2 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Apr-July	Aug-Oct

Basic statistics, Panama

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	500	548	548	548	548	548	548	
Rice area (×10³ ha)	99.0	85.6	109.5	95.7	99.5	104.6	106.8	102.8
Share of rice area irrigated (%)	16 (1997)		100	100	100	100	100	100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.78	2.42	2.15	2.43	2.38	2.88	2.26	2.67
Paddy production (×10³ t)	176.2	207.4	235.2	232.4	237.0	301.0	241.5	274.0
Milled production (×10³ t)	118	138	157	155	158	201	161	183
Rice imports (×10³ t)	2.3	10.2	43.3	29.0	48.7	63.5	14.8	83.0
Rice exports (×10³ t)	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10³ t)	131	112	210	210	220	222	224	
Fertilizer usage in NPK (kg/ha of arable land)	55.40	56.90	34.42	37.84	33.59	35.29	46.88	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Paraguay

Paraguay, a relatively small landlocked country in central South America, has an area of 406,750 km^2 and a population of 6.6 million (2011). The country consists of fertile irrigated plains in the east and dry savanna in the west. Arable land is 9.6% of the land area. Most crops are grown in the easterly plains, with soybeans being the major export crop. About one-quarter of the workforce is engaged in mainly subsistence agriculture, which constitutes 23.5% of GDP.

General information

- GNI per capita at PPP$, 2011: 5,390
- Internal renewable water resources, 2011: 94 km^3/year
- Incoming water flow, 2011: 242 km^3/year
- Main food consumed, 2009: cassava, fruits, milk, fermented beverages, maize, vegetables, meat, wheat, sugar
- Rice consumption, 2009: 3.4 kg milled rice per person per year

Production season

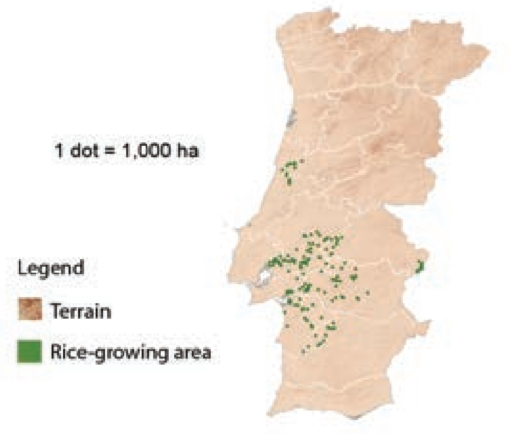
	Planting	Harvesting
Main	Oct-Dec	Mar-May

Basic statistics, Paraguay

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,600	3,020	3,460	3,550	3,640	3,737	3,800	
Rice area (×10^3 ha)	48.0	26.3	33.5	42.0	42.0	33.9	50.0	59.5
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.84	3.85	3.04	3.00	3.10	4.27	4.30	5.30
Paddy production (×10^3 t)	136.3	101.0	102.0	126.0	130.0	144.7	215.0	315.2
Milled production (×10^3 t)	91	67	68	84	87	97	143	210
Rice imports (×10^3 t)	1.3	3.8	0.5	0.8	0.9	1.2	0.7	1.1
Rice exports (×10^3 t)	0.0	14.1	37.1	54.1	71.5	67.6	122.1	137.9
Total rice consumption (×10^3 t)	79	67	48	42	36	32	31	
Fertilizer usage in NPK (kg/ha of arable land)	8.85	21.59	65.76	72.72	94.31	75.10	66.36	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Portugal



Portugal, the westernmost country of Europe, is bordered by Spain and faces the Atlantic Ocean, with an area of 92,090 km^2 that includes the offshore islands of the Azores and Madeira. The northern part of the mainland, which is mountainous and rainy, contains areas of intensive agriculture. The south consists of low plateaus that are mainly very dry. Rice is grown in both areas. Some 10.9% of the population of 10.7 million (2011) is engaged in agriculture. Arable land is 12.3% of the land area, but agriculture forms only 2.4% of GDP.

General information

- GNI per capita at PPP$, 2011: 24,440
- Internal renewable water resources, 2011: 38 km^3/year
- Incoming water flow, 2011: 30.7 km^3/year
- Main food consumed, 2009: milk, vegetables, fruits, wheat, fermented beverages, meat, potatoes, fish, sugar
- Rice consumption, 2009: 14.8 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Apr-May	Sep-Oct

Basic statistics, Portugal

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	2,153	1,632	1,262	1,258.6	1,124	1,175	1,125	
Rice area (×10³ ha)	21.7	23.9	21.9	25.4	26.9	26.3	28.5	29.1
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	5.73	5.98	5.54	5.80	5.81	5.73	5.68	5.85
Paddy production (×10³ t)	124.6	142.6	121.5	147.2	156.2	150.7	161.8	170.2
Milled production (×10³ t)	83	95	81	98	104	101	106	113
Rice imports (×10³ t)	103.2	101.7	132.3	79.6	96.3	120.8	103.6	106.0
Rice exports (×10³ t)	10.4	7.4	14.0	13.5	17.3	5.7	22.4	30.7
Total rice consumption (×10³ t)	148	184	187	167	165	194	164	
Fertilizer usage in NPK (kg/ha of arable land)	113.33	134.19	209.74	135.29	204.22	153.32	167.56	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Russian Federation

The Russian Federation in northern Asia is the world's largest country, occupying an area of 17 million km², from Europe in the west to the North Pacific Ocean in the east. The climate varies from arctic to subtropical and the terrain from mountainous to desert. Overall, 8% of the population of 142.8 million (2011) is engaged in agriculture, which forms 4.3% of GDP. Arable land is 7.4% of the land area.

General information

- GNI per capita at PPP$, 2011: 20,560
- Internal renewable water resources, 2011: 4,313 km^3/year
- Incoming water flow, 2011: 194.6 km^3/year
- Main food consumed, 2009: milk, wheat, vegetables, potatoes, fermented beverages, meat, fruits, fish
- Rice consumption, 2009: 5.1 kg milled rice per person per year

Production season

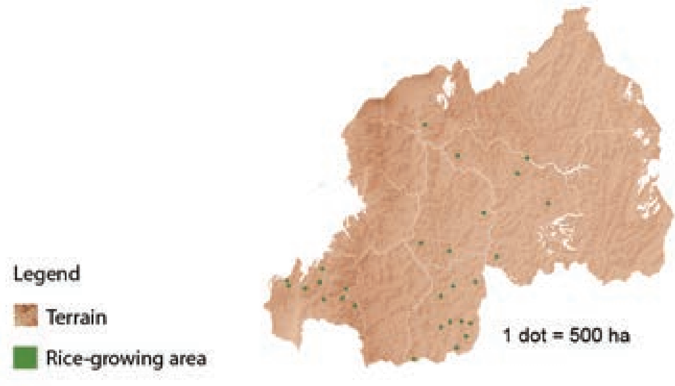
	Planting	Harvesting
Main	May-Jun	Aug-Sep

Basic statistics, Russian Federation

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	127,500	124,374	121,781	121,574	121,574	121,649	121,750	
Rice area (×10³ ha)	144.1	167.6	136.7	156.2	157.0	160.4	177.5	200.9
Share of rice area irrigated (%)		100	100	100	100	100	100	100
Share of rice area under MVs (%)		100	100	100	100	100	100	100
Paddy yield (t/ha)	3.21	3.49	4.20	4.36	4.49	4.60	5.14	5.28
Paddy production (×10³ t)	461.9	585.8	574.6	680.6	704.5	738.3	913.0	1,060.7
Milled production (×10³ t)	308	391	383	454	470	492	609	707
Rice imports (×10³ t)	145.7	351.4	368.3	356.7	232.4	271.1	257.1	225.2
Rice exports (×10³ t)	90.7	21.9	10.8	17.3	11.9	21.2	80.8	147.8
Total rice consumption (×10³ t)	364	760	752	802	697	747	794	
Fertilizer usage in NPK (kg/ha of arable land)	13.73	11.42	11.79	12.48	14.25	15.88	15.61	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Rwanda



Rwanda in Central Africa is the most densely populated country on the continent, with a population of 10.9 million (2011) in an area of 26,338 km^2. Rwanda is landlocked, surrounded by Burundi, Democratic Republic of the Congo, Tanzania, and Uganda, with part of its western border in Lake Kivu. Most of the country is made up of grassy plains and hills, with some mountainous areas, such that more than half is arable (52.7% of the land area). The great majority of the workforce (89%) is engaged in agriculture and contributes 32% to GDP. The climate is temperate and there are two wet seasons, in September-December and March-May. Rice consumption and production are increasing in the country, although much rice consumed is imported.

General information

- GNI per capita at PPP$, 2011: 1,270
- Internal renewable water resources, 2011: 9.5 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: plantains, starchy roots, fermented beverages, vegetables, pulses, milk, maize, sorghum
- Rice consumption, 2009: 9.6 kg milled rice per person per year

Production seasons

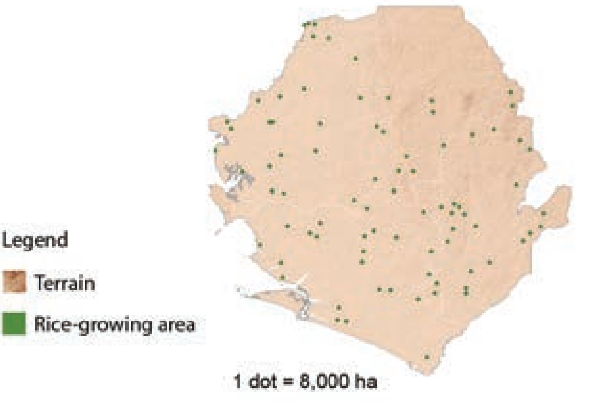
	Planting	Harvesting
First wet	Sep-Oct	Jan-Feb
Second wet	Feb-Mar	May-Jun

Basic statistics, Rwanda

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	700	900	1,150	1,150	1,200	1,290	1,300	
Rice area (×10³ ha)	0.6	4.3	13.9	14.0	15.0	18.5	14.4	13.0
Share of rice area irrigated (%)						38		
Share of rice area under MVs (%)								
Paddy yield (t/ha)	3.65	2.73	4.47	4.48	4.13	4.44	5.62	5.18
Paddy production (×10³ t)	2.3	11.7	62.2	62.9	62.0	82.0	81.1	67.3
Milled production (×10³ t)	2	8	41	42	41	55	74	45
Rice imports (×10³ t)	7.8	1.7	14.5	16.7	18.7	12.7	32.3	44.6
Rice exports (×10³ t)	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.2
Total rice consumption (×10³ t)	10	10	56	59	61	68	107	
Fertilizer usage in NPK (kg/ha of arable land)	0.00	0.33	2.96	3.38	7.35	8.34	1.11	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

SIERRA LEONE



Sierra Leone, between Guinea and Liberia on the West African coast facing the Atlantic Ocean, is a small country, with a population of 6 million (2011) in an area of 71,740 km^2. It consists of a large swampy coastal plain and inner agricultural areas that were previously tropical forest, and an eastern plateau. About 15% of the land was arable in 2009. More than half the workforce (60%) is engaged in agriculture, mainly at the subsistence level, contributing 44.4% to GDP (2011).

General information

- GNI per capita at PPP$, 2011: 840
- Internal renewable water resources, 2011: 160 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: rice, cassava, fermented beverages, vegetables including oils, fruits, fish, pulses, wheat
- Rice consumption, 2009: 92.3 kg milled rice per person per year

Production season

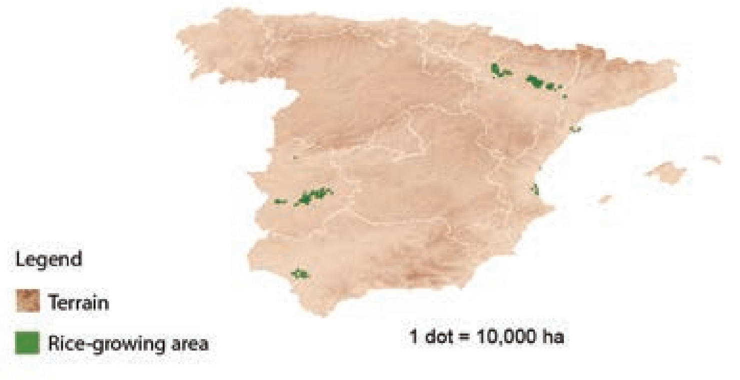
	Planting	Harvesting
Main	Apr-Jul	Sep-Jan

Basic statistics, Sierra Leone

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	485	490	1,295	1,487	1,011	1,084	1,085	
Rice area (×10^3 ha)	274.5	183.2	650.0	742.0	432.4	475.6	499.1	549.0
Share of rice area irrigated (%)	10							
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.30	1.09	1.14	1.43	1.36	1.43	1.78	1.87
Paddy production (×10^3 t)	355.5	199.1	738.0	1,062.3	588.0	680.1	888.4	1,026.7
Milled production (×10^3 t)	237	133	492	709	392	454	523	684
Rice imports (×10^3 t)	243.2	100.0	80.7	112.4	112.3	196.2	106.3	103.5
Rice exports (×10^3 t)								
Total rice consumption (×10^3 t)	407	452	565	606	579	614	638	
Fertilizer usage in NPK (kg/ha of arable land)	6.19	0.31						

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Spain



Spain, in southwestern Europe, has an area of 505,370 km², including the Balearic and Canary islands. The mainland faces both the Atlantic Ocean and Mediterranean Sea. It consists of a central plateau mainly surrounded by mountainous areas. Twenty-five percent of the land is arable, but agriculture now forms less than 3% of GDP and occupies only 4.3% of the workforce in a population of 46.5 million (2011). There are extensive rice-growing areas in the southwest and northeast.

General information

- GNI per capita at PPP$, 2011: 31,400
- Internal renewable water resources, 2011: 111.2 km³/year
- Incoming water flow, 2011: 0.3 km³/year
- Main food consumed, 2009: vegetables including oils, milk, fermented beverages, meat, wheat, fruits, fish, sugar, olives
- Rice consumption, 2009: 11.5 kg milled rice per person per year

Production season

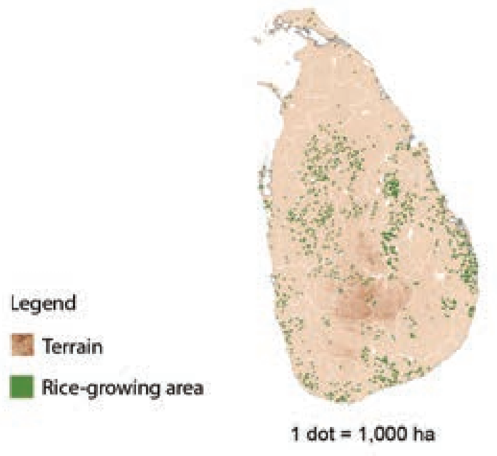
	Planting	Harvesting
Main	Apr-May	Sep-Oct

Basic statistics, Spain

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	14,045	13,400	12,913	12,720	12,586	12,488	12,497	
Rice area (×10³ ha)	54.5	117.0	119.2	106.5	101.6	96.1	119.3	122.5
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	6.05	7.07	6.92	6.80	7.12	6.92	7.54	7.56
Paddy production (×10³ t)	329.5	827.1	824.1	724.4	723.4	665.2	899.4	926.4
Milled production (×10³ t)	220	552	550	483	483	444	600	618
Rice imports (×10³ t)	179.3	104.3	57.5	82.6	161.5	107.3	109.2	60.1
Rice exports (×10³ t)	179.6	299.9	290.6	294.1	235.5	164.2	103.2	288.5
Total rice consumption (×10³ t)	298	346	297	299	381	390	564	
Fertilizer usage in NPK (kg/ha of arable land)	133.05	160.40	142.14	142.33	157.72	106.54	96.93	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Sri Lanka



Sri Lanka, a small island at the southern tip of India, had a population of 21 million in 2011. The country has an area of 65,610 km^2, which is divided into two climate zones, wet in the southwest and dry elsewhere. The land is mainly flat with a central mountain range. Arable land was 19% of the total land area in 2009. Agriculture accounts for 44% of the workforce and 12% of GDP. Rice is the second largest crop after tea.

General information

- GNI per capita at PPP$, 2011: 5,520
- Internal renewable water resources, 2011: 52.8 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: rice, oilcrops, wheat, vegetables, milk, fruits, sugar, fish
- Rice consumption, 2009: 103.8 kg milled rice per person per year

Production seasons

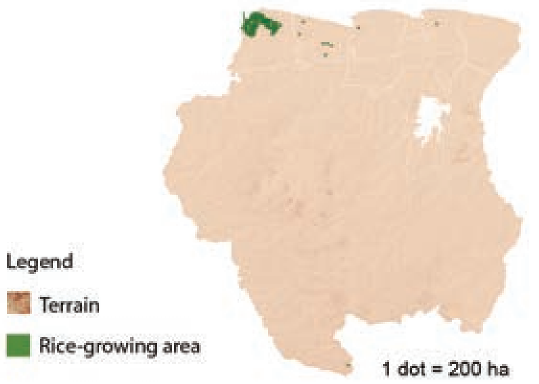
	Planting	Harvesting
Major (Maha)	Oct-Nov	Feb-Mar
Minor (Yaha)	Apr-May	Aug-Sep

Basic statistics, Sri Lanka

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	886	915	1,100	1,050	1,000	1,250	1,200	
Rice area (×10^3 ha)	889.6	832.0	915.3	910.5	816.7	1,053.0	977.1	1,060.4
Share of rice area irrigated (%)				74				
Share of rice area under MVs (%)			99					
Paddy yield (t/ha)	3.16	3.44	3.55	3.67	3.83	3.68	3.74	4.06
Paddy production (×10^3 t)	2,809.9	2,859.9	3,246.0	3,342.0	3,131.0	3,875.0	3,652.0	4,300.6
Milled production (×10^3 t)	1,874	1,908	2,165	2,229	2,088	2,585	2,436	2,867
Rice imports (×10^3 t)	9.1	14.9	51.7	17.1	129.7	83.8	69.6	148.7
Rice exports (×10^3 t)	43.8	2.0	4.1	2.7	5.6	3.9	4.6	10.7
Total rice consumption (×10^3 t)	1,787	1,913	2,114	2,145	2,172	2,290	2,361	
Fertilizer usage in NPK (kg/ha of arable land)	232.55	269.91	255.29	291.32	288.53	299.24	257.93	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

SURINAME



Suriname is a small Latin American country bordering the North Atlantic Ocean, between French Guiana and Guyana, with an area of 163,820 km². It consists of swampy coastal plains where rice, sugarcane, and other crops are grown and tropical forest on inland hills. The population in 2011 was 0.53 million. There is little arable land; bauxite mining dominates the economy. However, agriculture accounted for 10.9% of GDP in 2010 and occupied 17% of the workforce.

General information

- GNI per capita at PPP$, 2010: 7,710
- Internal renewable water resources, 2011: 88 km³/year
- Incoming water flow, 2011: 34 km³/year
- Main food consumed, 2009: fruits (bananas and plantains), rice, wheat, fermented beverages, sugar, meat, vegetables including oils, starchy roots, milk
- Rice consumption, 2009: 67.8 kg milled rice per person per year

Production season

	Planting	Harvesting
Main	Jan-Feb	Apr-May

Basic statistics, Suriname

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	57	57	49	49	46	47	58	
Rice area (×10³ ha)	60.0	42.0	45.6	44.2	42.1	43.7	54.5	53.6
Share of rice area irrigated (%)		98.4 (1998)						
Share of rice area under MVs (%)								
Paddy yield (t/ha)	4.03	3.90	3.60	4.13	4.25	4.19	4.21	4.23
Paddy production (×10³ t)	242.0	163.7	164.0	182.7	179.0	182.9	229.4	226.7
Milled production (×10³ t)	161	109	109	122	119	122	126	151
Rice imports (×10³ t)	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.5
Rice exports (×10³ t)	79.3	40.7	32.8	17.7	21.9	24.7	22.8	77.2
Total rice consumption (×10³ t)	87	76	79	85	86	102	109	
Fertilizer usage in NPK (kg/ha of arable land)	75.44	101.75	106.37	183.33	149.43	548.66	158.29	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

TIMOR-LESTE

Timor-Leste is a tiny (14,874 km^2) new country (independence in 2002) at the eastern end of Indonesia, where it occupies two parts of the island of Timor and two small islands between the Timor Sea to the south and the Banda Sea to the north. Eleven percent of the land area is arable. The land is mountainous, some parts rugged, and the climate is hot humid tropical, with marked wet (December-March) and dry (June-September) seasons. Although the country receives substantial oil revenue, the population of 1.15 million is still largely rural, with agriculture making up 25.6% of GDP and occupying 80% of the workforce. Maize and rice are the main crops.

General information

- GNI per capita at PPP$, 2010: 5,210
- Internal renewable water resources, 2011: 8.2 km^3/year
- Incoming water flow, 2011: 0 km^3/year
- Main food consumed, 2009: maize, rice, starchy roots, meat, vegetables including oils, fruits, wheat, milk
- Rice consumption, 2009: 67.3 kg milled rice per person per year

Production seasons

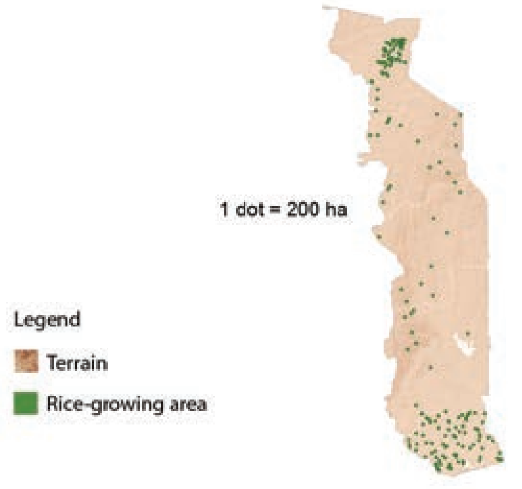
	Planting	Harvesting
Main	Dec-Jan	May-July
Off	Apr-Jun	Aug-Dec

Basic statistics, Timor-Leste

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	130	120	170	170	160	175	165	
Rice area (×10^3 ha)	18.1	17.0	40.0	45.0	40.0	45.6	39.0	36.5
Share of rice area irrigated (%)								93
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.58	3.00	1.47	1.23	1.51	1.76	3.10	3.09
Paddy production (×10^3 t)	46.7	51.0	58.9	55.4	60.4	80.3	120.8	112.9
Milled production (×10^3 t)	31	34	39	37	40	54	81	75
Rice imports (×10^3 t)	22.0	29.0	24.0	27.0	26.5	8.7	3.8	1.3
Rice exports (×10^3 t)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10^3 t)	56	63	88	86	86	68	83	
Fertilizer usage in NPK (kg/ha of arable land)								

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

TOGO



Togo forms a thin strip facing the Atlantic Ocean in West Africa, covering 56,785 km^2 between Benin and Ghana; inland, it borders Burkina Faso. The land consists of a coastal plain with extensive wetlands rising to hilly in the center and to gently rolling savanna in the north. Nearly half (40%) of the land is arable. The climate ranges from hot humid tropical in the coastal south to semiarid in the inland north. The population is 6.1 million (2011) and largely rural. Agriculture accounts for 53% of the workforce and 31.9% of GDP. Demand for rice has been increasing and, although domestic production is increasing, much rice is still imported.

General information

- GNI per capita at PPP$, 2011: 1,040
- Internal renewable water resources, 2011: 11.5 km^3/year
- Incoming water flow, 2011: 3.2 km^3/year
- Main food consumed, 2009: starchy roots, maize, sorghum, vegetables including oils, rice, fermented beverages, meat, pulses, wheat
- Rice consumption, 2009: 21 kg milled rice per person per year

Production season

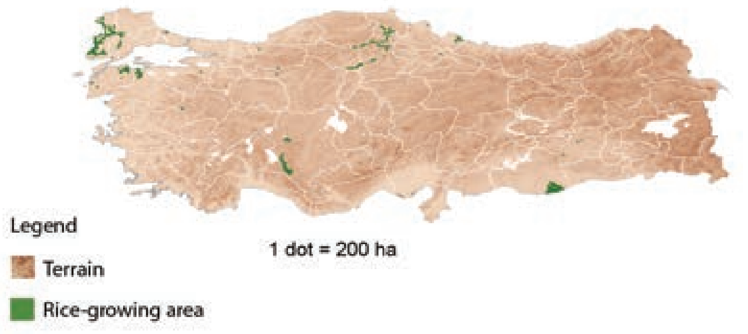
	Planting	Harvesting
Main	May	Oct-Nov

Basic statistics, Togo

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,200	2,510	2,300	2,275	2,250	2,225	2,200	
Rice area (×10^3 ha)	41.9	32.4	33.0	30.7	32.8	36.5	45.7	47.4
Share of rice area irrigated (%)						30*		
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.22	1.92	2.21	2.48	2.28	2.34	2.65	2.32
Paddy production (×10^3 t)	51.2	62.3	72.9	76.3	74.8	85.5	121.3	110.1
Milled production (×10^3 t)	34	42	49	51	50	57	81	73
Rice imports (×10^3 t)	12.0	36.3	80.5	75.3	78.5	246.8	85.3	74.8
Rice exports (×10^3 t)	0.0	2.4	0.1	0.0	1.6	4.1	0.4	0.1
Total rice consumption (×10^3 t)	47	117	152	129	136	130	135	
Fertilizer usage in NPK (kg/ha of arable land)	7.47	7.90	8.84	5.06	6.45	5.37	3.26	

Source: FAOSTAT database online and *National Rice Development Strategy Togo, October 2010.

TURKEY



Turkey, a diverse land of 783,560 km^2 in area, faces the Black Sea and Mediterranean Sea. Its western border marks the traditional separation of Europe and Asia. Turkey is mainly mountainous, with a coastal plain and high central plateau. The proportion of arable land is quite high, 27.7%, and agriculture occupies 32% of the workforce, making up 9.1% of GDP. The population in 2011 was 73.6 million.

General information

- GNI per capita at PPP$, 2011: 16,940
- Internal renewable water resources, 2011: 227 km^3/year
- Incoming water flow, 2011: –16.6 km^3/year
- Main food consumed, 2009: wheat, milk, fruits, vegetables including oils, starchy roots, sugar, meat
- Rice consumption, 2009: 9.3 kg milled rice per person per year

Production season

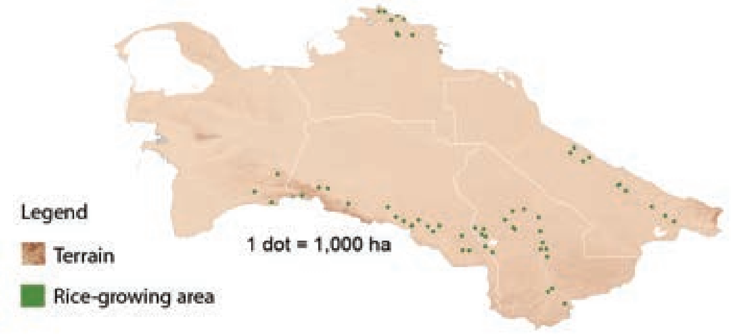
	Planting	Harvesting
Main	Apr-Jun	Sep-Oct

Basic statistics, Turkey

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	24,654	23,826	23,830	22,981	21,979	21,555	21,351	
Rice area (×10^3 ha)	50.0	58.0	85.0	99.1	93.8	99.5	96.4	99.0
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	4.00	6.03	7.06	7.02	6.91	7.57	7.78	8.69
Paddy production (×10^3 t)	200.0	350.0	600.0	696.0	648.0	753.3	750.0	860.0
Milled production (×10^3 t)	133	233	400	464	432	502	500	573
Rice imports (×10^3 t)	300.1	341.7	267.0	235.9	193.7	224.1	204.5	391.9
Rice exports (×10^3 t)	0.9	5.7	0.7	5.6	1.1	8.0	19.3	51.5
Total rice consumption (×10^3 t)	465	590	679	699	645	736	702	
Fertilizer usage in NPK (kg/ha of arable land)	68.97	87.67	86.76	91.84	90.34	71.97	96.50	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Turkmenistan



Turkmenistan in Central Asia lies between Uzbekistan and Kazakhstan to the north and Iran and Afghanistan to the south; the Caspian Sea forms its western side. About 80% is desert with a tropical arid climate. Arable land, 3.9% of the country's area of 488,100 km^2, is along river valleys and almost all irrigated. Agriculture accounts for 14.6% of GDP and employs 30% of the population of 5.1 million (2011). Cotton and wheat are the major commodities; rice is a minor crop.

General information

- GNI per capita at PPP$, 2011: 8,690
- Internal renewable water resources, 2011: 1.4 km^3/year
- Incoming water flow, 2011: 23.4 km^3/year
- Main food consumed, 2009: wheat, milk, vegetables including oils , meat, potatoes, grapes, onions
- Rice consumption, 2009: 13 kg milled rice per person per year

Production season

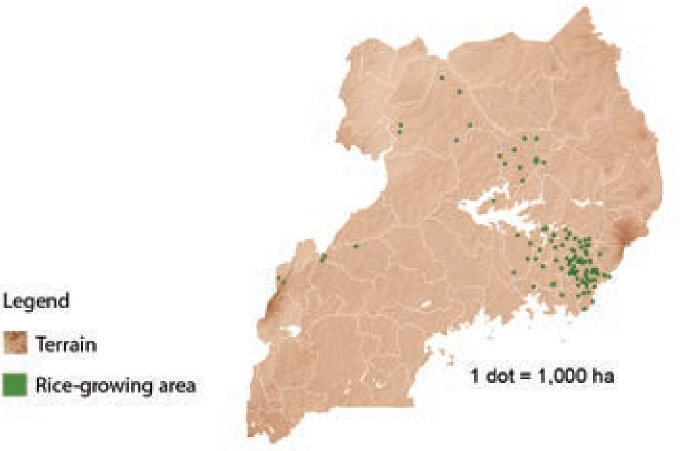
	Planting	Harvesting
Main	Apr-May	Aug-Sep

Basic statistics, Turkmenistan

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	1,622	1,620	1,850	1,890	1,850	1,850	1,850	
Rice area (×10^3 ha)	29.0	70.0	55.0	56.0	49.0	50.0	56.2	59.6
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	2.71	0.39	2.18	2.41	2.26	2.20	1.96	2.43
Paddy production (×10^3 t)	78.6	27.3	120.0	135.0	110.9	110.0	110.0	144.6
Milled production (×10^3 t)	52	18	80	90	74	73	73	96
Rice imports (×10^3 t)	0.2	1.2	0.0	0.2	0.1	0.2	0.2	0.2
Rice exports (×10^3 t)								
Total rice consumption (×10^3 t)	53	19	75	75	74	74	74	
Fertilizer usage in NPK (kg/ha of arable land)	80.76	65.19						

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.
www.waterfootprint.org/Reports/Report41-WaterFootprintCentralAsia.pdf.

UGANDA



Uganda, 241,550 km^2 in area, is a highland plateau country in East-Central Africa, the lowest point being 621 m above sea level. Landlocked and surrounded by five other nations, it has a long border with Lake Victoria and has many other large water bodies. The climate is tropical, with two dry seasons (December-February and June-August). Some 33% of the land is arable; agriculture makes up 23.4% of GDP and occupies 75% of the workforce in a population of 34.5 million (2011). Rice is a relatively new crop and much consumption is from imported rice.

General information

- GNI per capita at PPP$, 2011: 1,310
- Internal renewable water resources, 2011: 39 km^3/year
- Incoming water flow, 2011: 27 km^3/year
- Main food consumed, 2009: starchy roots, plantains, fermented beverages, milk, vegetables including oils, maize, millet
- Rice consumption, 2009: 4.6 kg milled rice per person per year

Production seasons

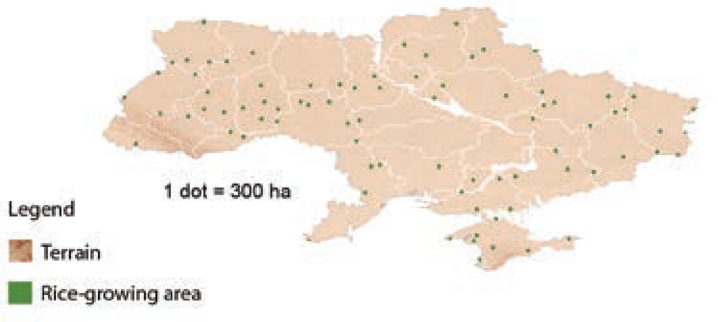
	Planting	Harvesting
First	Feb	Jun
Second	Aug	Dec

Basic statistics, Uganda

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	5,060	5,300	5,950	6,050	6,200	6,400	6,600	
Rice area (×10³ ha)	55.0	72.0	102.0	113.0	119.0	128.0	86.0	87.0
Share of rice area irrigated (%)		2.6 (1998)				3.9		
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.40	1.51	1.50	1.36	1.36	1.39	2.39	2.51
Paddy production (×10³ t)	77.0	109.0	153.0	154.0	162.0	177.9	205.8	218.1
Milled production (×10³ t)	51	73	102	103	108	119	137	145
Rice imports (×10³ t)	8.8	51.3	66.5	50.9	74.7	63.4	80.1	77.2
Rice exports (×10³ t)	0.5	1.6	13.3	15.0	24.6	25.3	38.1	40.0
Total rice consumption (×10³ t)	60	123	155	138	158	153	163	
Fertilizer usage in NPK (kg/ha of arable land)	0.26	1.25	0.97	1.26	1.21	2.97	2.08	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Ukraine



Ukraine, on the Black Sea in Eastern Europe, is a moderately large country with a population of 45.2 million (2011). Ukraine is surrounded by eight other countries, its border with Russia in the east being by far the longest. Land area is 603,550 km^2, of which arable land makes up more than half (56%), as most of the country is fertile steppes and plateaus. However, agriculture makes up only 9.6% of GDP and occupies only 10% of the workforce. The climate is temperate continental, with winters varying from mild on the southern coast to cold inland. Rainfall is highest in the west and north. Rice is grown in the southern regions but much is imported. The area under rice, now around 32,500 ha, is only half that before the breakup of the Soviet Union in 1991.

General information

- GNI per capita at PPP$, 2011: 7,040
- Internal renewable water resources, 2011: 53.1 km^3/year
- Incoming water flow, 2011: 86.5 km^3/year
- Main food consumed, 2009: wheat, milk, vegetables including oils, starchy roots, fermented beverages, fruits, meat, sugar, tomatoes, onions
- Rice consumption, 2009: 3.5 kg milled rice per person per year

Production season

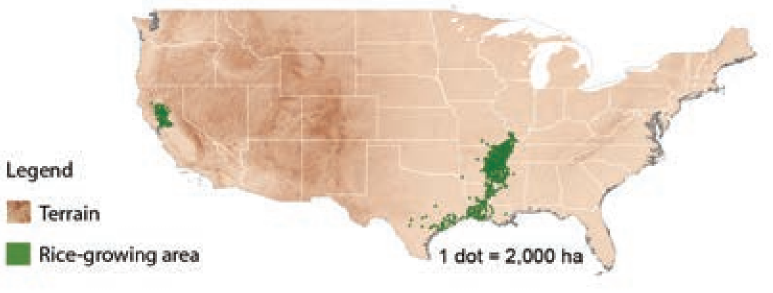
	Planting	Harvesting
Main	Apr-May	Sep-Oct

Basic statistics, Ukraine

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	33,286	32,564	32,452	32,446	32,434	32,474	32,478	
Rice area (×10³ ha)	22.0	25.2	21.4	21.6	20.0	19.8	24.5	29.3
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	3.64	3.56	4.35	4.61	5.40	5.09	5.83	5.05
Paddy production (×10³ t)	80.1	89.7	93.0	99.5	108.0	100.7	142.9	148.0
Milled production (×10³ t)	53	60	62	66	72	67	95	99
Rice imports (×10³ t)	30.9	56.8	123.4	111.2	121.1	73.5	76.4	47.2
Rice exports (×10³ t)	1.1	0.1	0.7	2.5	6.7	3.4	1.9	3.1
Total rice consumption (×10³ t)	84	118	188	178	189	139	172	
Fertilizer usage in NPK (kg/ha of arable land)	26.74	13.51	17.19	21.55	27.64	32.79	29.70	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

United States



The United States, occupying the central part of North America, faces both the Atlantic and Pacific oceans. Its 50 states have an area of 9.6 million km^2. The population in 2010 was 310.4 million. The country has a wide range of climates; the terrain varies from huge plains to river valleys and mountain ranges. Arable land in 2009 was 17.8% of the total land area. Agriculture is a minor sector, only 1% of GDP and employing 1.6% of the workforce. The Rice Belt of the United States comprises Arkansas, Louisiana, Mississippi, and Texas, four southern states that grow a significant portion of the nation's rice crop.

General information

- GNI per capita PPP$, 2011: 48,890
- Internal renewable water resources, 2011: 2,818 km^3/year
- Incoming water flow, 2011: 251 km^3/year
- Main food consumed, 2009: milk, vegetables, meat, fruits, wheat, potatoes, sugar, oils and fats
- Rice consumption, 2009: 8.3 kg milled rice per person per year

Production seasons

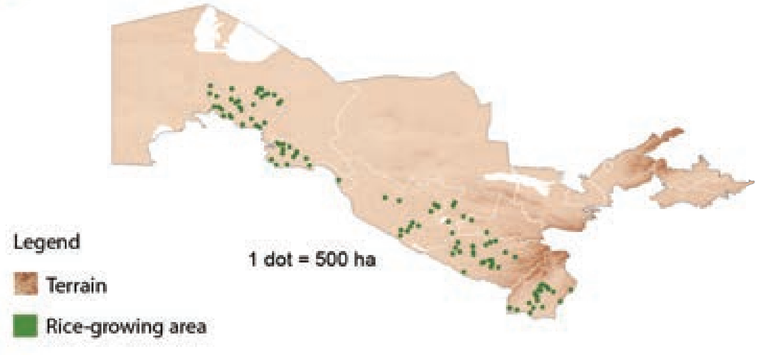
	Planting	Harvesting
Main, Gulf	Apr-Jun	Aug-Oct
Main, California	Sep-Nov	Apr-Jun

Basic statistics, United States

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10³ ha)	181,839	175,368	165,115	160,341	161,780	163,661	162,751	
Rice area (×10³ ha)	1,251.7	1,229.9	1,361.4	1,141.6	1,112.1	1,204.4	1,255.8	1,463.0
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)	100	100	100	100	100	100	100	100
Paddy yield (t/ha)	6.30	7.04	7.42	7.73	8.09	7.67	7.94	7.54
Paddy production (×10³ t)	7,887.0	8,657.8	10,107.5	8,826.2	8,998.7	9,241.2	9,972.2	11,027.0
Milled production (×10³ t)	5,261	5,775	6,753	5,888	6,002	6,164	6,652	7,355
Rice imports (×10³ t)	224.3	304.5	407.6	622.2	683.1	632.5	664.1	542.6
Rice exports (×10³ t)	3,083.6	2,736.5	3,821.6	3,303.2	2,986.6	3,316.1	2,946.6	3,782.5
Total rice consumption (×10³ t)	3,447	3,659	3,867	3,541	3,649	3,414	4,248	
Fertilizer usage in NPK (kg/ha of arable land)	110	107	119	126	123	106	109	

Source: FAOSTAT database online and AQUASTAT database online, as of December 2012.

UZBEKISTAN



Uzbekistan, between Kazakhstan and Turkmenistan in Central Asia, has a population of 27.8 million (2011) in an area of 447,400 km^2 that is mostly desert in an arid climate. The country also has borders with Afghanistan, Kyrgyzstan, and Tajikistan. In the west, it borders the Aral Sea, which has been drying up due to over-use of inflowing river water for irrigation of crops in river valleys. Agriculture, mainly of cotton, occupies 10% of the land, occupies a fifth of the workforce, and contributes 18.9% to GDP. Rice, however, is an important part of the Uzbek diet. Rice is grown in summer under flood irrigation mostly in rotation with winter wheat.

General information

- GNI per capita at PPP$, 2011: 3,420
- Internal renewable water resources, 2011: 16.3 km^3/year
- Incoming water flow, 2011: 32.5 km^3/year
- Main food consumed, 2009: vegetables including oils, wheat, milk, fruits, potatoes, meat
- Rice consumption, 2009: 4.9 kg milled rice per person per year

Production season

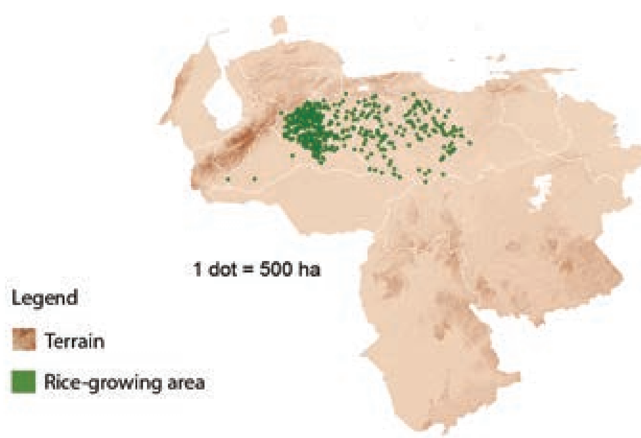
	Planting	Harvesting
Main	Apr-May	Aug-Sep

Basic statistics, Uzbekistan

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	4,475	4,475	4,400	4,350	4,300	4,300	4,301	
Rice area (×10^3 ha)	165.9	131.8	52.5	60.7	55.0	35.0	35.0	61.0
Share of rice area irrigated (%)	100	100	100	100	100	100	100	100
Share of rice area under MVs (%)								
Paddy yield (t/ha)	1.97	1.17	3.27	3.63	3.59	3.15	5.55	3.40
Paddy production (×10^3 t)	327.6	154.8	171.7	220.3	197.7	110.4	194.4	207.4
Milled production (×10^3 t)	219	103	115	147	132	74	130	138
Rice imports (×10^3 t)	0.5	142.2	0.4	8.5	1.2	8.2	15.7	3.5
Rice exports (×10^3 t)	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total rice consumption (×10^3 t)	347	250	161	156	154	82	146	
Fertilizer usage in NPK (kg/ha of arable land)	105.92	163.40		164.37	168.62	173.82	193.29	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

VENEZUELA



Venezuela forms part of the northern edge of South America, facing the Caribbean Sea. The country is bordered by Colombia, Brazil, and Guyana. It has an area of 912,050 km^2 and a population of 29.4 million (2011). There are three main regions: mountainous areas in the north, west, and south; coastal lowlands; and central plains. Arable land is 3.1% of the total; agriculture occupies 5% of the workforce and forms 5.8% of GDP.

General information

- GNI per capita at PPP$, 2011: 12,430
- Internal renewable water resources, 2011: 722.4 km^3/year
- Incoming water flow, 2011: 510.7 km^3/year
- Main food consumed, 2009: milk, fermented beverages, meat, fruits, maize, vegetables, wheat, sugar, starchy roots, rice
- Rice consumption, 2009: 32.1 kg milled rice per person per year

Production seasons

	Planting	Harvesting
Wet	Jul-Aug	Nov-Dec
Dry	Nov-Dec	May-Jun

Basic statistics, Venezuela

Element	1995	2000	2005	2006	2007	2008	2009	2010
Arable land (×10^3 ha)	2,581	2,595	2,650	2,650	2,650	2,700	2,750	
Rice area (×10^3 ha)	177.4	138.2	216.0	226.8	208.8	263.0	240.0	250.0
Share of rice area irrigated (%)								
Share of rice area under MVs (%)								
Paddy yield (t/ha)	4.27	4.90	4.65	4.95	5.05	5.19	4.97	5.00
Paddy production (×10^3 t)	757.0	676.8	1,004.5	1,122.9	1,054.9	1,364.5	1,194.0	1,250.0
Milled production (×10^3 t)	505	451	670	749	704	910	796	138
Rice imports (×10^3 t)	68.1	0.3	0.4	0.7	0.5	67.7	186.3	206.8
Rice exports (×10^3 t)	76.9	60.2	12.0	20.8	18.1	0.0	0.4	4.4
Total rice consumption (×10^3 t)	458	395	711	778	714	852	1,084	
Fertilizer usage in NPK (kg/ha of arable land)	115	109	167.07	122.95	135.96	177.97	157.11	

Source: FAOSTAT database online and AQUASTAT database online, as of November 2012.

Rice facts

Selected rice-consuming and -producing countries	GENERAL INFORMATION							
	Population (million)				Infant mortality (per 1,000 live births)	Life expectancy at birth (years)	GNI[a] per capita	
							PPP ($)	Ave. annual growth[b] (%)
	2010	2011	2035	2050	2010	2010	2011	2000-10
ASIA	4,164.25	4,207.45	4,978.24	5,142.22	-[c]	-	-	-
Afghanistan	31.41	32.36	59.01	58.09	75	48.3	1,060.00 (2010)	8.16
Bangladesh	148.69	150.49	187.10	194.35	39	68.6	1,940.00	4.82
Bhutan	0.73	0.74	0.92	0.96	44	66.9	5,480.00	4.91
Cambodia	14.14	14.31	17.91	18.96	39	62.5	2,230.00	6.42
China	1,341.34	1,347.57	1,381.59	1,295.60	14	73.3	8,390.00	9.78
India	1,224.61	1,241.49	1,579.80	1,692.01	49	65.1	3,590.00	5.51
Indonesia	239.87	242.33	285.84	293.46	26	68.9	4,500.00	4.47
Iran	73.97	74.80	85.31	85.34	22	72.8	11,420.00 (2009)	4.32
Iraq	31.67	32.66	61.98	83.36	31	68.5	3,750.00	-
Japan	126.54	126.50	117.35	108.55	2	82.9	35,330.00	0.95
Kazakhstan	16.03	16.21	19.42	21.21	26	68.3	11,250.00	6.58
Korea, Dem. Rep.	24.35	24.45	26.38	26.38	26	68.5	1,609.61	-
Korea, Rep.	48.18	48.39	50.05	47.05	4	80.8	30,370.00[d]	4.14
Laos	6.20	6.29	8.00	8.38	35	67.1	2,580.00	4.87
Malaysia	28.40	28.86	39.15	43.45	6	74.0	15,650.00	3.31
Myanmar	47.96	48.34	55.05	55.30	49	64.7	1,950.00 (2010)	12.14
Nepal	29.96	30.49	41.98	46.50	41	68.4	1,260.00	1.80
Pakistan	173.59	176.75	246.79	274.88	60	65.2	2,870.00	3.06
Philippines	93.26	94.85	134.23	154.94	21	68.5	4,140.00	2.91
Sri Lanka	20.86	21.05	23.32	23.19	11	74.7	5,520.00	4.52
Thailand	69.12	69.52	73.38	71.04	11	73.9	8,360.00	3.31
Timor-Leste	1.12	1.15	2.24	3.01	49	62.0	5,210.00 (2010)	-
Turkey	72.75	73.64	88.77	91.62	13	73.7	16,940.00	2.91
Turkmenistan	5.04	5.11	6.34	6.64	46	64.9	8,690.00	14.00
Uzbekistan	27.44	27.76	34.21	35.44	42	68.0	3,420.00	4.01
Vietnam	87.85	88.79	103.03	103.96	18	74.8	3,250.00	5.69
AMERICAS	934.61	944.19	1,134.25	1,197.82	-	-	-	-
Argentina	40.10	40.76	47.97	50.56	13	75.6	17,130.00	3.23
Bolivia	9.93	10.09	14.29	16.77	41	66.3	4,920.00	1.64
Brazil	194.95	196.66	223.20	222.84	15	73.1	11,420.00	2.66

Selected rice-consuming and -producing countries	GENERAL INFORMATION							
	Population (million)				Infant mortality (per 1,000 live births)	Life expectancy at birth (years)	GNI[a] per capita	
							PPP ($)	Ave. annual growth[b] (%)
	2010	2011	2035	2050	2010	2010	2011	2000-2010
Chile	17.11	17.27	19.84	20.06	8	78.9	16,330.00	2.41
Colombia	46.29	46.93	58.65	61.76	16	73.4	9,560.00	2.28
Costa Rica	4.66	4.73	5.83	6.00	9	79.2	11,950.00	3.25
Cuba	11.26	11.25	10.80	9.90	5	79.0	4,500.00 (2007)	5.17
Dominican Republic	9.93	10.06	12.41	12.94	22	73.2	9,490.00	4.02
Ecuador	14.46	14.67	18.49	19.55	20	75.5	8,310.00	3.37
Guyana	0.75	0.76	0.80	0.77	30	69.5	3,460.00 (2010)	-
Haiti	9.99	10.12	13.05	14.18	68	61.8	1,180.00	0.63
Mexico	113.42	114.79	138.92	143.92	14	76.7	15,390.00	1.09
Nicaragua	5.79	5.87	7.48	7.85	23	73.7	3,730.00	1.82
Panama	3.52	3.57	4.70	5.13	17	76.0	14,51[illegible]0	4.15
Paraguay	6.45	6.57	9.15	10.32	20	72.3	5,390.00	1.27
Peru	29.08	29.40	36.70	38.83	15	73.8	9,440.00	4.24
Suriname	0.52	0.53	0.61	0.61	26	70.3	7,710.00 (2010)	-
United States	310.38	313.09	372.89	403.10	7	78.2	48,890.00	0.89
Uruguay	3.37	3.38	3.64	3.66	9	76.2	14,640.00	2.13
Venezuela	28.98	29.44	38.58	41.82	13	74.1	12,430.00	1.76
AFRICA	1,022.23	1,045.92	1,713.09	2,191.60	-	-	-	-
Benin	8.85	9.10	16.32	21.73	70	55.6	1,630.00	0.99
Burkina Faso	16.47	16.97	33.08	46.72	82	54.9	1,310.00	2.22
Burundi	8.38	8.58	12.05	13.70	88	49.9	610.00	1.27
Cameroon	19.60	20.03	31.24	38.47	80	51.1	2,360.00	1.45
Chad	11.23	11.53	20.58	27.25	98	49.2	1,370.00	4.64
Côte d'Ivoire	19.74	20.15	32.56	40.67	82	54.7	1,730.00	-0.87
Congo, Dem. Rep.	65.97	67.76	116.69	148.52	112	48.1	35[illegible]0	1.08
Egypt	81.12	82.54	111.62	123.45	19	73.0	6,120.00	2.75
Gambia	1.73	1.78	3.12	4.04	58	58.2	2,060.00	1.70
Ghana	24.39	24.97	39.73	49.11	53	63.8	1,810.00	7.98
Guinea	9.98	10.22	17.65	23.01	81	53.6	1,020.00	3.35
Guinea-Bissau	1.52	1.55	2.48	3.19	99	47.7	1,240.00	-

Continued.

Selected rice-consuming and -producing countries	GENERAL INFORMATION							
	Population (million)				Infant mortality (per 1,000 live births)	Life expectancy at birth (years)	GNI[a] per capita	
							PPP ($)	Ave. annual growth[b] (%)
	2010	2011	2035	2050	2010	2010	2011	2000-2010
Liberia	4.0	4.1	7.3	9.7	61	56.1	540.00	17.21
Madagascar	20.7	21.3	39.6	53.6	44	66.5	950.00	0.12
Malawi	14.9	15.4	32.7	49.7	56	53.5	870.00	-
Mali	15.4	15.8	30.3	42.1	100	51.0	1,040.00	2.02
Mauritania	3.5	3.5	5.7	7.1	76	58.2	2,400.00	1.44
Mozambique	23.4	23.9	39.5	50.2	76	49.7	970.00	5.01
Niger	15.5	16.1	36.1	55.4	69	54.3	720.00	-
Nigeria	158.4	162.5	288.0	389.6	81	51.4	2,290.00	-
Rwanda	10.6	10.9	19.5	26.0	42	55.1	1,270.00	-
Senegal	12.4	12.8	22.1	28.6	48	59.0	1,940.00	1.33
Sierra Leone	5.9	6.0	9.2	11.1	121	47.4	840.00	-
Tanzania	44.8	46.2	94.1	138.3	48	57.4	1,500.00	3.94
Togo	6.0	6.2	9.3	11.1	73	56.6	1,040.00	-0.33
Uganda	33.4	34.5	67.9	94.3	60	53.6	1,310.00	3.53
EUROPE	738.2	739.3	736.9	719.3	-	-	-	-
France	62.8	63.1	69.6	72.4	4	81.4	35,650.00	0.71
Greece	11.4	11.4	11.6	11.6	4	80.4	25,100.00	1.69
Italy	60.6	60.8	60.5	59.2	3	81.7	32,400.00	0.14
Portugal	10.7	10.7	10.1	9.4	3	79.0	24,440.00	0.32
Russian Federation	143.0	142.8	133.8	126.2	10	68.8	20,560.00	5.62
Spain	46.1	46.5	50.5	51.4	4	81.6	31,400.00	0.98
Ukraine	45.4	45.2	39.2	36.1	9	70.3	7,040.00	5.59
Fiji	0.9	0.9	1.0	1.0	15	69.2	4,590.00	-
Australia	22.3	22.6	28.8	31.4	4	81.7	36,410.00 (2010)	1.56
WORLD	6,895.89	6,974.04	8,611.87	9,306.13	38	69.6	11,573.91	1.45

Selected rice-consuming and -producing countries	INFORMATION ABOUT AGRICULTURE							
	Arable land per capita[e] (hectare per person)	Annual renewable freshwater resources per capita (m^3)	Fresh water withdrawals for agriculture (%)	Agriculture share (%)		Average annual growth rate[h] (%)		
				Labor force[f]	GDP[g]	GDP	Agriculture value added	Rice production
	2009	2011	2011	2010	2011	2000-10	2000-10	2000-10
ASIA	-	-	-	-	-	-	-	1.90
Afghanistan	0.23	1,334.92	98.6	60.0	29.92 (2010)	11.3	6.3	9.70
Bangladesh	0.05	697.70	87.8	45	18.43	5.9	3.5	3.21
Bhutan	0.11	105,652.83	94.1	65.4 (2009)	18.75 (2009)	8.6[a]	2.4[a]	7.19
Cambodia	0.28	8,430.51	94.0	66.0	36.68	8.7	5.6	8.23
China	0.08	2,092.80	64.6	39.6 (2008)	10.04	10.8	4.4	1.04
India	0.13	1,164.73	90.4	51.1	17.22	8.0	3.0	1.52
Indonesia	0.10	8,331.76	81.9	38.3	14.72	5.3	3.5	2.61
Iran	0.24	1,717.95	92.2	22.0	10.22 (2009)	5.4	5.9	0.22
Iraq	0.14	1,067.90	78.8	23.4 (2008)	8.57 (2003)	0.4	-5.6[a]	8.43
Japan	0.03	3,364.18	63.1	3.7	1.20 (2010)	0.9	-0.8	-0.59
Kazakhstan	1.45	3,886.23	66.2	29.4 (2009)	5.54	8.3	3.8	4.95
Korea, Dem. Rep.	0.11	2,740.14	76.4	23.0	21.00	-	-	2.54
Korea, Rep.	0.03	1,302.76	62.0	6.6	2.70	4.1	2.0	-0.86
Laos	0.22	30,279.72	93.0	75.0	30.80	7.2	3.4	3.44
Malaysia	0.06	20,097.61	34.2	13	11.87	5.0	3.3	1.70
Myanmar	0.23	20,750.25	89.0	67	36.00	12.9[a]	10.7[a]	5.31
Nepal	0.08	6,501.39	98.2	66.0	39.00	3.8	3.2	-0.07
Pakistan	0.12	311.18	94.0	39	21.63	5.1	3.4	3.62
Philippines	0.06	5,049.97	82.2	31.0	13.04	4.9	3.2	2.96
Sri Lanka	0.06	2,530.07	87.3	42	12.09	5.6	3.1	4.04
Thailand	0.22	3,229.35	90.4	41.5 (2009)	12.37	4.5	2.2	1.93
Timor-Leste	0.15	6,986.26	91.4	80	25.60	3.4	-	7.92
Turkey	0.30	3,082.58	73.8	32.0	9.14	4.7	1.6	10.10

Continued.

Selected rice-consuming and -producing countries	INFORMATION ABOUT AGRICULTURE							
	Arable land per capita[e] (hectare per person)	Annual renewable freshwater resources per capita (m^3)	Freshwater withdrawals for agriculture (%)	Agriculture share (%)		Average annual growth rate[h] (%)		
				Labor force[f]	GDP[g]	GDP	Agriculture value added	Rice Production
	2009	2011	2011	2010	2011	2000-2010	2000-2010	2000-2010
Turkmenistan	0.37	275.20	94.3	30.0	14.55	13.6	12.3	12.43
Uzbekistan	0.15	556.90	90.0	21.0	18.90	7.1	6.4	3.13
Vietnam	0.07	4,091.53	94.8	51.7 (2006)	19.66	7.5	3.7	2.02
AMERICAS	-	-	-	-	-	-	-	1.56
Argentina	0.77	6,770.59	66.1	1.2 (2009)	9.09	5.6	2.9	5.37
Bolivia	0.38	30,084.93	57.2	41.0	12.85 (2010)	4.1	2.9	3.28
Brazil	0.32	27,550.78	54.6	17.0 (2009)	5.46	3.7	3.6	1.23
Chile	0.07	51,188.44	70.3	13	3.40	4.0	4.2	-2.66
Colombia	0.04	45,005.95	38.9	17.9	6.77	4.5	2.2	-0.04
Costa Rica	0.04	23,780.43	53.4	15	7.02	4.9	3.3	1.00
Cuba	0.32	3,387.34	74.7	18.6 (2008)	4.99 (2010)	6.7	-0.9	-3.38
Dominican Republic	0.08	2,088.27	64.3	10	6.10	5.6	3.4	-0.35
Ecuador	0.08	29,455.77	91.5	28.7 (2009)	7.48	4.8	4.4	2.53
Guyana	0.56	318,766.20	97.6	15.0	21.35	2.2[a]	-1.6[a]	1.36
Haiti	0.11	1,285.09	77.5	59.0	25.00	0.6	-0.6[a]	1.05
Mexico	0.22	3,562.92	76.7	13.1	3.78	2.1	1.7	-1.38
Nicaragua	0.33	32,317.64	83.9	15.0	19.95	3.6	2.9	3.09
Panama	0.16	41,274.81	50.9	16	4.00	6.8	2.9	0.47
Paraguay	0.60	14,311.18	71.4	25	23.49	3.8	5.2	8.92
Peru	0.13	54,966.33	84.9	24	7.82	6.1	4.1	4.31
Suriname	0.11	166,219.95	92.5	17	10.91 (2010)	4.4[a]	4.7[a]	2.45
United States	0.53	9,043.88	40.2	1.6	1.18 (2010)	1.8	1.9	0.91
Uruguay	0.56	17,514.72	86.6	11	10.08	3.6	2.1	1.97
Venezuela	0.10	24,673.82	43.8	5	5.79	4.7	2.5	7.30

Continued.

Selected rice-consuming and -producing countries	INFORMATION ABOUT AGRICULTURE							
	Arable land per capita[e] (hectare per person)	Annual renewable freshwater resources per capita (m^3)	Fresh water withdra-wals for agriculture (%)	Agriculture share (%)		Average annual growth rate[h] (%)		
				Labor force[f]	GDP[g]	GDP	Agriculture value added	Rice produc-tion
	2009	2011	2011	2010	2011	2000-10	2000-10	2000-10
AFRICA	-	-	-	-	-	5.0	3.2	3.71
Benin	0.28	1,131.88	45.4	44	32.20 (2005)	4.0	4.6	11.09
Burkina Faso	0.37	736.69	70.1	92	33.28 (2009)	5.5	6.2	8.73
Burundi	0.11	1,173.15	77.1	89	35.18	3.2	-1.5	3.86
Cameroon	0.31	13,629.31	76.1	48	19.47 (2007)	3.2	3.4	9.23
Chad	0.39	1,301.46	51.8	66	51.00	9.0	1.3[a]	4.84
Côte d'Ivoire	0.14	3,812.85	42.6	38	24.31	1.1	1.6	1.00
Democratic Republic of the Congo	0.10	13,282.65	17.7	57	43.00 (2010)	5.3	1.7	-0.36
Egypt	0.04	21.81	86.4	25	13.95	5.1	3.3	-0.56
Gambia	0.24	1,689.09	28.1	76	29.91	3.7	3.2	8.70
Ghana	0.18	1,213.66	66.4	55	25.60	5.9	4.5[a]	4.16
Guinea	0.29	22,109.59	84.0	80	22.09	2.9	5.0	3.88
Guinea-Bissau	0.20	10,342.19	82.3	79	57.28 (2009)	1.5	-	7.35
Liberia	0.10	48,442.90	33.6	62	53.10	0.9	-	9.32
Madagascar	0.15	15,810.36	97.5	70	-	3.4	2.4	6.58
Malawi	0.25	1,049.35	83.6	79	30.17	5.2	2.9	4.94
Mali	0.43	3,787.99	90.1	75	40.00 (2009)	5.2	4.8	10.68
Mauritania	0.12	112.95	93.7	50	16.26	4.4	1.3	2.30
Mozambique	0.22	4,191.44	73.9	81	31.96	7.8	8.3	0.34
Niger	1.00	217.81	88.0	83	39.65 (2009)	4.2	3.2[a]	-10.12

Continued.

Selected rice-consuming and -producing countries	INFORMATION ABOUT AGRICULTURE							
	Arable land per capita[e] (hectare per person)	Annual renewable freshwater resources per capita (m^3)	Freshwater withdrawals for agriculture (%)	Agriculture share (%)		Average annual growth rate[h] (%)		
				Labor force[f]	GDP[g]	GDP	Agriculture value added	Rice Production
	2009	2011	2011	2010	2011	2000-2010	2000-2010	2000-2010
Nigeria	0.22	1,360.24	53.4	70 (2009)	40.0 (2009)	6.7	7.0[a]	1.85
Rwanda	0.13	868.14	68.0	89	31.95	7.6	5.8[a]	19.41
Senegal	0.32	2,020.75	93.0	70	17.84	4.2	2.5	10.16
Sierra Leone	0.19	26,677.84	71.0	60	44.38	8.8	5.2[a]	13.82
Tanzania	0.23	1,817.45	89.4	76	27.11	7.1	4.4	4.48
Togo	0.37	1,868.46	45.0	53	31.92	2.7	2.8	6.04
Uganda	0.20	1,130.13	37.8	75	23.42	7.7	2.2	6.97
EUROPE	-	-	-	-	-	-	-	2.85
France	0.28	3,056.40	12.4	2.9 (2010)	1.80 (2010)	1.3	0.3	0.79
Greece	0.23	5,130.93	89.3	12.5	3.30	2.6	-	4.29
Italy	0.11	3,003.13	44.1	3.8	1.89 (2010)	0.5	-0.1	1.97
Portugal	0.11	3,572.44	73.0	10.9	2.44 (2010)	0.7	-0.2	1.36
Russian Federation	0.86	30,388.22	19.9	8	4.25	5.4	1.5	7.17
Spain	0.27	2,405.10	60.5	4.3	2.72 (2010)	2.4	-0.1	-0.44
Ukraine	0.71	1,161.77	51.2	10.0	9.58	4.8	2.9	6.37
Fiji	0.19	32,876.33	61.2	50.00	9.50 (2010)	1.0[a]	-1.2[a]	-3.75
Australia	2.15	21,750.09	73.8	3.3 (2009)	2.28 (2010)	3.2	1.7	-32.31
WORLD	0.20	6,115.64	70.0	35.0 (2005)	2.81 (2010)	2.7	2.5	1.93

Selected rice-consuming and -producing countries	RICE CONSUMPTION									
	Total rice consumption (000 t)				Rice consumption (kg/capita/yr)		Daily calorie supply (kcal/capita/day)		Rice in total calorie supply (%)	
	Paddy equivalent		Milled equivalent							
	2000	2009	2000	2009	2000	2009	2000	2009	2000	2009
ASIA	528,363	595,992	352,418	397,527	78.9	77.2	2,591	2,706	30.6	28.7
Afghanistan	-	-	480 (2003)	-	17 (2003)	-	-	2,477	-	6.8
Bangladesh	35,407	46,213	23,616	30,824	165.9	173.3	2,309	2,481	71.6	69.6
Cambodia	3,819	7,245	2,547	4,833	171.4	160.3	2,129	2,382	74.4	64.2
China	192,933	196,674	128,686	131,182	78.6	76.3	2,867	3,036	28.4	26.2
India	123,656	133,490	82,478	89,038	71.8	68.2	2,264	2,321	31.4	29.1
Indonesia	54,088	63,243	36,076	42,183	126.8	127.4	2,431	2,646	51.6	47.6
Iran	3,382	3,531	2,256	2,355	30.3	23	3,137	3,143	10.3	7.0
Iraq	1,191	1,191	-	1,191	-	39.5	-	-	-	-
Japan	12,386	11,127	8,262	7,421	60	54	2,902	2,723	22.2	21.3
Kazakhstan	209	255	139	170	8.3	8.6	2,396	3,284	3.3	2.6
Korea, Dem. Rep.	2,719	3,158	1,814	2,106	70.7	76.2	2,135	2,078	32.4	35.8
Korea, Rep.	6,614	6,636	4,412	4,426	87.9	81.3	3,090	3,200	30.9	27.6
Laos	1,983	2,814	1,323	1,877	161.6	165.5	2,146	2,377	66.6	61.6
Malaysia	3,107	3,300	2,072	2,201	84.2	74	2,864	2,902	28.7	25.2
Myanmar	19,589	31,954	13,066	21,313	162.4	140.8	2,174	2,493	63.9	48.3
Nepal	3,980	4,555	2,655	3,038	84.8	79.7	2,257	2,443	35.8	31.1
Pakistan	3,349	4,825	2,234	3,218	13.8	17	2,374	2,423	5.9	7.2
Philippines	13,183	18,189	8,793	12,132	104.2	123.3	2,412	2,580	42.5	47.0
Sri Lanka	2,868	3,540	1,913	2,361	92.7	103.8	2,332	2,426	38.5	41.4
Thailand	15,648	19,438	10,437	12,965	114.6	133	2,650	2,862	43.1	46.2
Timor-Leste	94	125	63	83	61.3	67.3	1,902	2,076	29.1	29.2
Turkey	885	1,052	590	702	9	9.3	3,636	3,666	2.3	2.3
Turkmenistan	29	110	19	74	3.2	13	2,608	2,878	1.2	4.5

Continued.

Selected rice-consuming and -producing countries	RICE CONSUMPTION									
	Total rice consumption (000 t)				Rice consumption (kg/ capita/yr)		Daily calorie supply (kcal/capita/day)		Rice in total calorie supply (%)	
	Paddy equivalent		Milled equivalent							
	2000	2009	2000	2009	2000	2009	2000	2009	2000	2009
Uzbekistan	375	218	250	146	9.6	4.9	2,376	2,618	3.9	1.8
Vietnam	24,958	29,886	16,647	19,934	145.6	141.2	2,269	2,690	63.2	51.7
AMERICAS	30,589	36,403	20,403	24,281	19.7	20	3,173	3,205	6.3	6.3
Argentina	375	586	250	391	5.3	7.9	3,268	2,918	1.7	2.8
Bolivia	302	418	201	279	22.2	25.6	2,121	2,172	10.7	12.9
Brazil	11,964	12,679	7,980	8,457	38.3	34.6	2,882	3,173	13.5	11.1
Chile	198	309	132	206	6.8	9.3	2,808	2,908	2.4	3.1
Colombia	2,775	3,138	1,851	2,093	35.9	35.2	2,662	2,717	13.7	13.2
Costa Rica	326	356	217	237	53	49.3	2,825	2,886	17.6	16.0
Cuba	1,198	1,316	799	878	59.7	62.3	3,046	3,258	19.4	18.9
Dominican Republic	695	866	463	578	45	53.2	2,322	2,491	18.8	20.8
Ecuador	1,216	1,572	811	1,048	56.3	45.7	2,221	2,267	23.9	19.0
Guyana	164	201	110	134	81.2	81.9	2,814	2,718	28.0	29.3
Haiti	493	620	329	414	36.4	40.4	1,931	1,979	18.8	20.5
Mexico	1,006	1,061	671	708	5.7	5.8	3,158	3,146	1.9	1.9
Nicaragua	381	388	254	259	47.2	43.5	2,148	2,517	20.4	16.1
Panama	168	335	112	224	34.6	62.2	2,195	2,606	15.4	23.9
Paraguay	100	47	67	31	11.6	3.4	2,596	2,518	4.5	1.4
Peru	2,013	3,017	1,343	2,013	42.1	48.7	2,379	2,563	19.2	20.4
Suriname	114	163	76	109	75.7	67.8	2,457	2,548	28.6	24.7
United States	5,486	6,368	3,659	4,248	8.8	8.3	3,804	3,688	2.4	2.4
Uruguay	121	146	80	97	15	19.2	2,844	2,808	5.3	6.8
Venezuela	592	1,625	395	1,084	11.6	32.1	2,484	3,014	4.5	10.2

Continued.

Selected rice-consuming and -producing countries	RICE CONSUMPTION									
	Total rice consumption (000 t)				Rice consumption (kg/ capita/yr)		Daily calorie supply (kcal/capita/day)		Rice in total calorie supply (%)	
	Paddy equivalent		Milled equivalent							
	2000	2009	2000	2009	2000	2009	2000	2009	2000	2009
AFRICA	24,115	34,661	16,084	23,119	18.4	21.1	2,421	2,560	7.6	8.2
Benin	121	512	81	341	10.1	34.4	2,395	2,592	4.2	13.3
Burkina Faso	370	633	247	422	19.4	25.5	2,371	2,647	7.8	9.3
Burundi	57	92	38	61	4.8	6.4	1,674	1,604	2.6	3.7
Cameroon	246	895	164	597	10.1	30.3	2,133	2,457	4.8	12.4
Chad	122	132	82	88	9	7.1	1,954	2,074	4.6	3.4
Côte d'Ivoire	1,462	2,417	975	1,612	49.3	67.3	2,550	2,670	17.6	22.8
Democratic Republic of the Congo	-	-	-	-	-	-	-	7 (2007)	-	-
Egypt	4,845	5,408	3,231	3,607	39.7	38.6	3,318	3,349	12.6	12.1
Gambia	149	312	99	208	41.2	60.6	2,350	2,643	16.9	22.7
Ghana	504	1,038	336	692	15.7	26.9	2,472	2,934	5.9	8.8
Guinea	1,418	1,921	946	1,281	91	105.8	2,490	2,652	36.6	40.3
Guinea-Bissau	198	241	132	161	99.2	99	2,372	2,476	41.8	40.0
Liberia	283	649	189	433	57.1	96.1	2,191	2,261	26.3	42.8
Madagascar	2,829	4,696	1,887	3,132	98.1	105.5	2,073	2,117	48.1	50.7
Malawi	77	136	51	91	4.3	5.9	2,209	2,318	1.9	2.5
Mali	879	1,449	587	967	46.1	56	2,217	2,624	20.7	21.2
Mauritania	202	161	135	107	48.4	30.5	2,713	2,856	17.3	10.5
Mozambique	273	687	182	458	9.1	19	1,979	2,112	4.6	8.8
Niger	200	248	134	165	11.5	8.3	2,171	2,489	5.1	3.2
Nigeria	4,488	5,315	2,993	3,545	21.8	20.9	2,611	2,711	8.5	7.9
Rwanda	14	161	10	107	1.1	9.6	1,867	2,188	0.5	4.2
Senegal	1,123	1,476	749	984	76	71.5	2,243	2,479	33.2	28.5
Sierra Leone	678	956	452	638	98.3	92.3	1,989	2,162	48.0	41.5
Tanzania	1,010	1,455	674	970	18.1	20.1	1,999	2,137	9.3	9.1

Continued.

Selected rice-consuming and -producing countries	RICE CONSUMPTION									
	Total rice consumption (000 t)				Rice consumption (kg/capita/yr)		Daily calorie supply (kcal/capita/day)		Rice in total calorie supply (%)	
	Paddy equivalent		Milled equivalent							
	2000	2009	2000	2009	2000	2009	2000	2009	2000	2009
Togo	176	202	117	135	23	21	2,208	2,363	10.1	8.8
Uganda	184	244	123	163	4.7	4.6	2,270	2,260	2.0	1.9
EUROPE	5,447	6,570	3,633	4,382	4.5	5.2	3,248	3,362	1.4	1.6
France	476	470	317	313	4.9	4.6	3,608	3,531	1.5	1.4
Greece	127	152	84	101	6.7	7.1	3,608	3,661	1.7	1.8
Italy	581	653	388	436	5.7	5.9	3,720	3,627	1.6	1.7
Portugal	276	246	184	164	17.1	14.8	3,534	3,617	5.0	4.2
Russian Federation	1,140	1,190	760	794	4.9	5.1	2,889	3,172	1.6	1.5
Spain	519	845	346	564	7.9	11.5	3,375	3,239	2.4	3.8
Ukraine	177	258	118	172	2.3	3.5	2,896	3,198	0.8	1.1
Fiji	52	60	35	40	40.9	42.8	2,847	2,996	15.5	15.7
Australia	443	438	296	292	8.8	11.5	3,014	3,261	2.7	3.2
WORLD	589,022	674,110	392,878	449,631	53.9	53.3	2,732	2,831	19.8	18.9

Selected rice-consuming and -producing countries	RICE PRODUCTION						RICE TRADE					
	Production (000 t)		Area (000 ha)		Yield (t/ha)		Exports (000 t)			Imports (000 t)		
	2000	2010	2000	2010	2000	2010	2010	2001-05	2006-10	2010	2001-05	2006-10
ASIA	545,546.46	633,745.53	138,145.01	143,234.20	3.95	4.42	23,826.23	20,846.97	22,995.28	14,010.84	11,621.62	13,436.69
Afghanistan	260.00	672.00	130.00	208.00	2.00	3.23	-	-	-	-	199.06	157.65
Bangladesh	37,627.50	50,061.20	10,801.20	11,700.00	3.48	4.28	3.93	1.47	10.60	656.85	809.49	673.70
Bhutan	44.30	71.64	26.00	22.82	1.70	3.14	0.38	0.73	0.16	52.00	20.49	16.38
Cambodia	4,026.09	8,245.32	1,903.16	2,776.51	2.12	2.97	51.18	4.14	16.55	67.24	58.58	39.29
China	189,814.06	197,212.01	30,301.50	30,117.26	6.26	6.55	615.90	1,654.39	994.67	486.10	859.69	904.37
India	127,465.00	143,963.00	44,712.00	36,950.00	2.85	3.38	2,225.39	3,901.20	3,609.53	0.10	0.31	0.11
Indonesia	51,898.00	66,469.40	11,793.00	13,253.50	4.40	5.02	0.35	10.40	1.35	686.11	929.24	617.06
Iran	1,971.46	3,012.70	534.33	563.52	3.69	5.35	0.24	0.38	2.82	1,132.22	948.09	1,078.67
Iraq	60.00	155.83	100.00	47.97	0.60	3.25	0.05	4.93	0.01	1,123.17	871.19	1,067.93
Japan	11,863.00	10,600.00	1,770.00	1,628.00	6.70	6.51	38.24	133.54	27.37	664.40	690.37	636.39
Kazakhstan	214.30	373.15	72.10	94.00	2.97	3.97	19.65	24.75	23.65	20.04	11.23	19.58
Korea, Dem. Rep.	1,690.00	2,426.00	535.00	570.00	3.16	4.26	-	0.01	-	95.97	774.95	243.18
Korea, Rep.	7,196.58	6,136.30	1,072.36	892.07	6.71	6.88	3.76	0.08	1.76	345.00	146.17	288.14
Laos	2,201.70	3,070.64	719.37	855.11	3.06	3.59	-	-	-	42.77	25.42	30.29
Malaysia	2,140.80	2,464.83	698.70	677.88	3.06	3.64	0.42	5.06	1.32	931.44	499.64	955.98
Myanmar	21,323.90	33,204.50	6,302.49	8,051.70	3.38	4.12	121.87	496.61	204.82	1.59	11.62	23.85
Nepal	4,216.47	4,023.82	1,560.04	1,481.29	2.70	2.72	0.36	1.47	0.48	98.22	39.93	135.47
Pakistan	7,203.90	7,235.00	2,376.60	2,365.30	3.03	3.06	4,179.79	2,128.46	3,311.77	1.93	6.50	2.97
Philippines	12,389.40	15,771.70	4,038.08	4,354.16	3.07	3.62	0.17	0.09	0.37	2,378.05	1,152.90	2,021.45
Sri Lanka	2,859.90	4,300.62	832.00	1,060.36	3.44	4.06	10.66	2.52	5.46	148.72	94.76	89.79
Thailand	25,843.90	31,597.20	9,891.20	10,990.10	2.61	2.88	8,939.63	8,188.89	8,880.94	5.27	2.53	8.92
Timor-Leste	51.00	112.93	17.00	36.55	3.00	3.09	-	-	-	1.30	29.30	13.47
Turkey	350.00	860.00	58.00	98.97	6.03	8.69	51.54	2.42	17.11	391.91	271.40	250.02
Turkmenistan	27.30	144.60	70.00	59.56	0.39	2.43	-	-	-	0.20	0.41	0.19
Uzbekistan	154.80	207.40	131.80	61.00	1.17	3.40	-	-	-	3.48	62.44	7.42
Vietnam	32,529.50	39,988.90	7,666.30	7,513.70	4.24	5.32	6,886.18	4,019.28	5,358.02	0.98	9.05	1.03

Continued.

Selected rice-consuming and -producing countries	RICE PRODUCTION						RICE TRADE					
	Production (000 t)		Area (000 ha)		Yield (t/ha)		Exports (000 t)			Imports (000 t)		
	2000	2010	2000	2010	2000	2010	2010	2001-05	2006-10	2010	2001-05	2006-10
AMERICAS	32,032	36,975	7,607	7,270	4.21	5.09	5,769	4,688	5,389	4,193	3,630	4,130
Argentina	904	1,241	189	215	4.78	5.77	473	279	494	8	12	8
Bolivia	299	449	156	194	1.91	2.32	3	1	3	2	5	15
Brazil	11,090	11,236	3,655	2,722	3.03	4.13	423	76	404	763	739	637
Chile	135	95	26	25	5.24	3.86	1	0	1	124	96	116
Colombia	2,694	2,412	470	465	5.74	5.19	0	0	0	6	80	94
Costa Rica	266	265	68	66	3.90	3.99	4	6	5	66	88	88
Cuba	553	454	200	176	2.76	2.58	0	0	0	414	536	524
Dominican Republic	581	567	120	186	4.84	3.05	15	1	3	23	36	19
Ecuador	1,247	1,706	339	393	3.68	4.34	21	35	59	0	0	0
Guyana	449	556	116	131	3.87	4.23	164	211	190	0	0	0
Haiti	130	118	52	52	2.50	2.24	0	0	0	467	294	371
Mexico	351	217	84	42	4.18	5.19	6	1	8	572	478	556
Nicaragua	290	454	93	88	3.12	5.14	7	1	4	88	99	95
Panama	207	274	86	103	2.42	2.67	0	0	0	83	16	48
Paraguay	101	315	26	59	3.85	5.30	138	13	91	1	3	1
Peru	1,892	2,831	287	389	6.59	7.29	2	0	14	95	64	91
Suriname	164	227	42	54	3.90	4.23	77	32	33	1	0	0
United States	8,658	11,027	1,230	1,463	7.04	7.54	3,783	3,312	3,267	543	427	629
Uruguay	1,209	1,149	189	162	6.38	7.10	628	683	781	1	1	0
Venezuela	677	1,250	138	250	4.90	5.00	4	19	9	207	19	92

Continued.

Selected rice-consuming and -producing countries	RICE PRODUCTION						RICE TRADE					
	Production (000 t)		Area (000 ha)		Yield (t/ha)		Exports (000 t)			Imports (000 t)		
	2000	2010	2000	2010	2000	2010	2010	2001-05	2006-10	2010	2001-05	2006-10
AFRICA	17,477	25,878	7,562	10,517	2.31	2.46	1,051	759	1,031	9,019	7,389	9,136
Benin	49	167	23	40	2.11	4.19	553	1	148	599	200	673
Burkina Faso	103	271	40	134	2.57	2.02	1	1	0	240	186	197
Burundi	52	83	17	22	3.04	3.79	1	0	0	16	2	9
Cameroon	61	175	20	140	3.01	1.25	1	0	1	364	314	434
Chad	93	170	90	130	1.03	1.31	0	0	0	11	2	3
Côte d'Ivoire	622	723	341	395	1.82	1.83	14	8	19	838	724	887
Democratic Republic of the Congo	338	317	447	420	0.76	0.76	0	0	0	47	139	127
Egypt	6,000	4,330	659	460	9.10	9.42	261	731	685	14	22	59
Gambia	34	100	15	86	2.21	1.16	0	0	0	131	69	119
Ghana	249	492	115	181	2.16	2.71	0	1	0	320	543	386
Guinea	1,141	1,499	666	864	1.71	1.73	0	0	0	241	230	281
Guinea-Bissau	106	209	75	101	1.42	2.08	0	0	0	57	79	46
Liberia	183	296	144	251	1.28	1.18	0	1	0	295	110	216
Madagascar	2,480	4,738	1,209	1,808	2.05	2.62	0	0	0	133	191	151
Malawi	72	110	44	59	1.65	1.86	1	1	3	1	4	4
Mali	743	2,308	353	472	2.11	4.89	0	0	0	58	169	132
Mauritania	76	134	18	26	4.24	5.23	0	0	0	97	36	93
Mozambique	181	180	184	185	0.98	0.97	0	0	0	304	175	422
Niger	60	30	22	20	2.75	1.49	40	1	27	149	201	177
Nigeria	3,298	3,219	2,199	1,788	1.50	1.80	0	14	1	1,885	1,439	1,243
Rwanda	12	67	4	13	2.73	5.18	0	0	0	45	14	25
Senegal	202	604	86	147	2.35	4.10	54	24	68	707	809	854
Sierra Leone	199	1,027	183	549	1.09	1.87	0	0	0	103	147	126
Tanzania	782	1,105	416	720	1.88	1.53	-	8	16	75	135	64
Togo	62	110	32	47	1.92	2.32	0	5	1	75	78	112
Uganda	109	218	72	87	1.51	2.51	40	5	29	77	49	69

Continued.

Selected rice-consuming and -producing countries	RICE PRODUCTION						RICE TRADE					
	Production (000 t)		Area (000 ha)		Yield (t/ha)		Exports (000 t)			Imports (000 t)		
	2000	2010	2000	2010	2000	2010	2010	2001-05	2006-10	2010	2001-05	2006-10
EUROPE	3,181	4,319	606	718	5.25	6.02	2,065	1,479	1,756	3,408	3,297	3,562
France	116	119	20	24	5.84	4.98	84	95	79	454	452	486
Greece	140	230	20	34	7.00	6.75	114	40	93	23	16	23
Italy	1,230	1,516	220	248	5.58	6.12	813	630	761	98	100	145
Portugal	143	170	24	29	5.98	5.85	31	12	18	106	101	101
Russian Federation	586	1,061	168	201	3.49	5.28	148	8	56	225	421	268
Spain	827	926	117	123	7.07	7.56	288	328	217	60	88	104
Ukraine	90	148	25	29	3.56	5.05	3	0	4	47	93	86
Fiji	13	8	5	3	2.50	2.70	1	1	1	50	30	38
Australia	1,101	197	133	19	8.26	10.41	56	241	127	193	79	163
WORLD	599,355	696,324	154,060	159,417	3.89	4.37	32,768	28,081	31,299	31,189	26,803	30,773

Note: Regional totals include countries not shown. When data are not available for countries such as North Korea and Afghanistan, Bhutan, by-country statistical yearbooks are used as source of data.
[a]Gross national income in PPP (purchasing power parity). [b]In per capita GNI PPP dollars computed using the annual growth rate data available from WDI. [c]=Data not available. [d]Bank of Korea. [e]Excluding permanent crops. [f]Sourced from SOFA2012 and WDI online. [g]Gross domestic product. [h]Computed in cases where data are not available using annual data available from source.

Sources: World Bank Development Indicators (WDI) online database; FAOSTAT online database, 2013. IRRI World Rice Statistics; State of Food and Agriculture (SOFA) 2012; United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision, CD-ROM Edition; CIA World Factbook online; FAO Food Outlook; and various statistical yearbooks for Fiji, Afghanistan, Bhutan, Timor-leste and FAO Commission reports for countries such as Korea DPR, Iran, and Iraq.

Important conversion factors, by country

Country	Conversion factors
Asia	
Bangladesh	1 bushel = 0.73 maund = 29.17 seer = 60 lb
	1 maund = 82.29 lb = 37.32 kg
	1 seer = 2.05 lb = 0.93 kg
	1 kg = 2.20462 lb = 1.07 seer
	1 bushel per acre = 67.253 kg per ha
	1 ha = 2.47109 acres
	1 acre = 0.40468 ha
	1 lakh = 100,000
	1 crore = 10,000,000
Cambodia	
	1 picul = 68 kg
	1 mt = 14.7059 picul
China	
	1 mu = 0.067 ha
	15 mu = 1.0 ha
	1 sheng milled rice = 1 liter milled rice = 0.5 kg
	1 dou milled rice = 10 liters milled rice = 5 kg
	1 dan (picu) milled rice = 100 liters milled rice = 50 kg
	20 dan (picul) = 1 mt
	1 dun = 1 mt = 2204.6 lb
	1 dan (picul) = 100 jin
	1 jin (catty) = 0.5 kg = 1.1023 lb
	1 jin/mu = 7.5 kg/ha
Taiwan, China	
	1 kg rough rice = 0.76366 kg brown rice
	1 kg ponlai brown rice = 0.93 kg milled rice
	1 kg chailai brown rice = 0.94 kg milled rice
	1 ha = 1.03 chia1 chia = 0.9699 ha
	1 old catty = 0.5968 kg
	1 shih catty = 0.5 kg
India	
	1 quintal = 100 kg
	1 maund = 37.3 kg = 82.29 lb
	1 Madras measure rice = 54 oz = 3.375 lb
	Bigha is a land measure in rural areas; its definition varies from state to state.
	In Gujarat, 4/7 bigha = 1 acre
	In Rajasthan, 21/2 bighas = 1 acre
	In West Bengal, 3 bighas = 1 acre

Indonesia

1 liter rice = 0.8 kg
1 gantang rice = 8.58 liters = 0.00686 mt
1 mt rice = 145.69 gantang
Dry stalk rough rice (padi) to milled rice (beras) = 52%
Gabah kering (dry rough rice) to milled rice (beras) = 68%
Dry stalk rough rice (padi) to rough rice = 76.47%

Japan

Brown rice x 1.25 = rough rice
Milled rice x 1.37 = rough rice
Brown rice x 0.91 = milled rice
Rough rice x 0.728 = milled rice
1 koku rough rice = 187.5 kg
1 koku brown rice = 150 kg
1 koku milled rice = 136.5 kg
1 sho milled rice = 1.425 kg
1 kan = 3.75 kg
1 kin = 0.6 kg
1 picul = 50 kg
1 cho = 10 tan = 2.45072 acres = 0.99174 ha
1 ha = 10.0833 tan = 1.00833 cho
1 tan = 0.1 cho = 0.9917 ha

Korea, Rep. of

1 danbo = 0.1 jeongbo = 0.099174 ha
1 ha = 1.0083 jeongbo
1 seok milled rice = 144 kg
1 seok brown rice = 155 kg
1 seok rough rice = 100 kg
100 liters milled rice = 79.8264 kg

Malaysia

1 picul brown rice = 133.33 lb = 60.48 kg
1 gantang rough rice = 5.60 lb = 2.54 kg
1 kati = 0.60478 kg

Myanmar

100 measures rough rice = 1 basket
1 basket rough rice = 46 lb = 20.86 kg
1 basket milled rice = 75 lb = 34.02 kg
1 bag milled rice = 225 lb = 102.06 kg
1 pyi milled rice = 4.69 lb = 2.13 kg
1 maund = 0.037 mt
1 mt = 26.792 maunds

Nepal

1 khet = 1.3 ha
1 bigha = 0.67 ha (Terai)
1 matomuri = 0.13 ha = 0.25 ropani
1 ropani = 0.05 ha (Hills) = 4 muris
1 muri = 0.013 ha1 seer = 0.80 kg (Hills)
1 seer = 0.93 kg (Terai)

1 mana = 0.3 kg rough rice
1 mana = 0.454 kg rice
1 maund = 37.32 kg rough rice (Terai)

Pakistan

1 kg = 2.2046 lb = 1.0716 seer
1 quintal = 100 kg = 1.96841 cwt = 2.679 maunds
1 metric ton = 1,000 kg = 0.9842
1 long ton = 26.79 maunds
100 kg per ha = 1.4869 bushels per acre = 1.09 maunds per acre
1 bushel = 0.73 maunds = 29.17 seers = 60 lb
Before 1980, 1 maund = 37.324 kg
After 1980, 1 maund = 40 kg

Philippines

1 cavan rough rice = 50 kg
1 cavan milled rice = 50 kg
1 ganta milled rice = 2.24 kg
Before 1973
1 ganta = 3 liters
1 cavan rough rice = 44 kg
1 cavan milled rice = 56 kg

Sri Lanka

1 bushel rough rice = 46 lb = 20.86 kg
1 bushel rough rice = 30.69 milled rice = 14 kg milled rice
1 bushel milled rice = 64 lb = 32 measures of rice
1 measure milled rice = 2 lb = 0.907 kg

Thailand

1 picul = 60 kg
1 catty = 600 g = 6 kg
1 kwein = 2,000 liters
1 ban = 1,000 liters
1 sat = 20 liters
1 thanan = 1 liter
1 kwein rough rice = 1 mt rough rice
1 rai = 0.16 ha = 0.395 acre

Other countries

Australia

1 bushel rough rice = 42 lb = 19.05 kg

Brazil

1 bushel rough rice = 45 lb = 20.41 kg
1 sack (bag) rough rice = 110.23 lb = 50 kg
1 sack (bag) milled rice = 88.18 lb = 40 k

Egypt

1 sack (bag) milled rice = 220.11 lb = 99.84 kg

Ghana

1 sack (bag) milled rice = 240 lb = 108.86 kg

Guyana

1 sack (bag) rough rice = 140 lb = 63.50 kg
1 sack (bag) milled rice = 180 lb = 81.65 kg

Malawi

1 sack (bag) rough rice = 150 lb = 68.04 kg
1 sack (bag) milled rice = 200 lb = 90.72 kg

Mexico

1 carga rough rice = 304.24 lb = 138 kg
1 carga milled rice = 352.74 lb = 160 kg

Panama

1 lata milled rice = 24.99 lb = 11.33 kg
1 lata rough rice = 35.99 lb = 16.32 kg

Sierra Leone

1 bushel rough rice = 60 lb = 27.21 kg
1 bushel milled rice = 84 lb = 38.10 kg

Swaziland

1 pocket milled rice = 2 lb = 0.91 kg

United States

1 bushel rough rice = 45 lb = 20.41 kg
1 sack (bag) rough rice = 100 lb = 45.36 kg
1 sack (bag) milled rice = 100 lb = 45.36 kg
1 barrel rough rice = 162 lb = 73.48 kg

Uruguay

1 bolsa brown rice = 110.23 lb = 50 kg

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(Complete list that includes online sources at http://irri.org/almanac-references)

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Fig. 2.2. Methane emissions map

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