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INTERNATIONAL RICE COMMISSION NEWSLETTER

BULLETIN DE LA COMMISSION INTERNATIONALE DU RIZ

NOTICIARIO DE LA COMISIÓN INTERNACIONAL DEL ARROZ

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE
ORGANIZACIÓN DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACIÓN
Rome, Roma, 2007

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Ruth Duffy, Rome

The *International Rice Commission* (IRC), which works within the framework of FAO, was established on 4 January 1949 with the object of promoting national and international action in respect of production, conservation, distribution and consumption of rice. Matters relating to trade are outside the purview of the Commission.
Membership of the Commission is open to all FAO Member Nations and Associate Members who accept the constitution of the IRC. The present membership of the Commission is 62 and represents all the rice-growing regions of the world.
The Commission keeps under review the scientific, technical and economic problems relating to rice, encourages and coordinates research, organizes (where necessary) cooperative projects and reports to the member countries and the Director-General of FAO on appropriate action to be taken in furthering its objectives.

La *Commission internationale du riz* (CIR), qui opère dans le cadre de la FAO, a été créée le 4 janvier 1949 afin de promouvoir des actions nationales et internationales en matière de production, de conservation, de distribution et de consommation du riz. Les questions de commerce ne sont pas de son ressort.
La Commission est ouverte à tous les États Membres et Membres associés de la FAO qui acceptent son acte constitutif. Elle compte actuellement 62 membres représentant toutes les régions rizicoles du monde.
La Commission traite des problèmes scientifiques, techniques et économiques relatifs au riz. Elle encourage et coordonne les recherches, organise le cas échéant des projets coopératifs et fait rapport aux États Membres ainsi qu'au Directeur général de la FAO sur les mesures à prendre pour réaliser ses objectifs.

La *Comisión Internacional del Arroz* (CIA) se creó, dentro del marco de la FAO, el 4 de enero de 1949. Su objeto es promover la actividad nacional e internacional en el campo de la producción, la conservación, la distribución y el consumo de arroz. Las cuestiones de comercio quedan fuera de su ámbito de acción.
Pueden ser miembros de ella todos los Estados Miembros y Miembros Asociados de la FAO que acepten la constitución de la Comisión. En la actualidad cuenta 62 miembros, que representan todas las regiones arroceras del mundo.
La Comisión sigue de cerca todos los problemas científicos, técnicos y económicos relativos al arroz, fomenta y coordina las investigaciones, organiza en caso necesario proyectos cooperativos, e informa a los Estados Miembros y al Director General de la FAO sobre las medidas que son necesarias para facilitar el logro de sus objetivos.

Articles are in English with summaries in French and Spanish.
Les articles sont en anglais avec des résumés en français et espagnol.
Los artículos son en inglés con resúmenes en francés y español.

Preface

It is with pleasure that I announce the acceptance of the Constitution of the International Rice Commission by the People's Republic of China as of 31 July 2007, the date of receipt of the instrument of acceptance by the Director-General of the Food and Agriculture Organization of the United Nations. The Constitution of the International Rice Commission (IRC), which was approved in principle by the FAO Council in April 1948, was formally approved by the FAO Conference at its Fourth Session (November 1948). In accordance with Article IX (now XIV), the Constitution of the Commission came into force on 4 January 1949. The Constitution was registered with the Secretariat of the United Nations on 24 January 1952 under No. 1613. Amendments were approved by the Conference at its Eleventh Session (November 1961). At a Special Session (November 1973), the IRC adopted further amendments to its Constitution, which were approved by the FAO Council at its Sixty-second Session (November 1973). The amendments referred to in this paragraph entered into force for all parties to the Constitution; the list of parties may be consulted at: http://www.fao.org/Legal/treaties/002s-e.htm.

The People's Republic of China is both the world's largest rice producer and the world's largest rice consumer. In 2005, it produced about 182 million tonnes of paddy rice (about 29 percent of world rice output), while it consumed about 150 million tonnes of paddy equivalent (about 28 percent of world rice consumption). Before joining the Commission, the People's Republic of China had already contributed a number of technologies – in particular hybrid rice – to support sustainable rice production for world food security. Therefore, the participation of the People's Republic of China in the International Rice Commission is significant and it will strengthen the capacity of the Commission in attaining its objectives, which are *to promote national and international action with respect to production, conservation, distribution and consumption of rice.*

Sustainable rice production for food security faces a number of constraints and challenges. On the one hand, the population continues to grow steadily, while on the other, water and land resources are increasingly limited. In addition, global climate change and the increased demand for bioenergy and livestock feed place new pressures and constraints on global rice production.

In line with the efforts to disseminate information on rice and related topics, Volume 56 of the International Rice Commission Newsletter contains information on the current situation of the world rice market, the performance of rice production and the challenges faced in the 2000–10 decade, and the technical options for enhanced sustainable rice production. It also provides an insight into the orientation and technical development of rice programmes in selected member countries and recent international and regional initiatives to support sustainable rice production.

Shivaji Pandey
Chairperson
FAO Steering Committee
International Rice Commission

Review of the rice market situation in 2007[1]

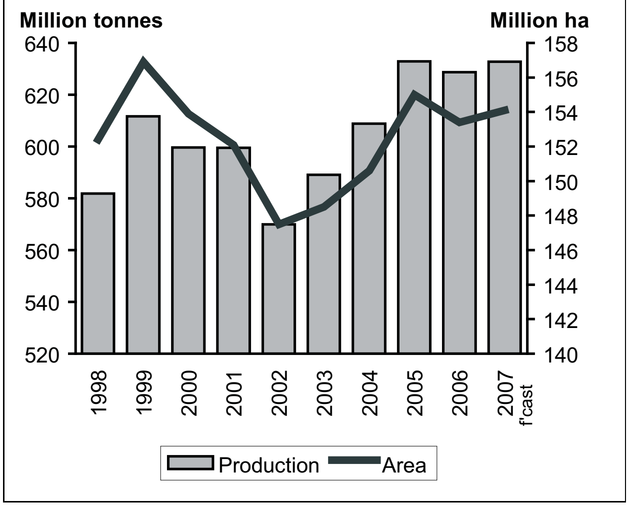
C. Calpe

Senior Economist, Trade and Markets Division, FAO, Rome, Italy

Production

Most recent estimates (Figure 1) show world paddy production to have declined from a record 633 million tonnes in 2005 to 629 million tonnes in 2006: confirmation of the adverse impacts of an erratic monsoon in Asia and the development of an El Niño event in the second half of 2006. Intensive rice cultivation also gave rise to disease and insect attack problems that entailed heavy losses in several Asian countries.

FIGURE 1
Global rice paddy production and area



Asia

In Asia, the 2006 paddy season ended on a low: production fell by 3 million tonnes to 569 million tonnes – a reflection of widespread decline across the region, due mainly to the irregular pattern of the monsoon rains.

In Bangladesh, production in 2006 is anticipated to fall to 39.2 million tonnes, well below the initial government target of 44 million tonnes and 1.5 percent less than the 39.8 million tonnes harvested in 2005. The first aus crop was 14 percent smaller than in the 2005 season, reflecting the lack of rainfall and the competition from higher value crops. The main aman crop, harvested between November and January, also suffered from lack of rainfall, as well as fertilizer shortages and rising fuel costs. Likewise, shortages of basic inputs have marred prospects for the third, irrigated, boro crop. Although the Government distributed high-yielding seeds to farmers, severe fertilizer shortages were reported up to early March 2007, leading to farmer unrest and demonstrations in several parts of the country.

China ended the 2006 paddy season with virtually no growth – a reflection of adverse conditions which reduced the size of the intermediate single rice crop (compensated for by a larger late rice crop). The country's semi-official production estimate is 180.7 million tonnes, marginally above the 180.6 million tonnes harvested in 2005.

The 2006 paddy season ends in Cambodia with the gathering in March of the second (irrigated) crop. The Government predicts a 5 percent increase in production, which would mean a new record of 6.3 million tonnes. A large part of the increase is likely to be destined for the export market. With the harvesting of the second rabi crop in April–May, India completes the 2006 paddy season (Table 1). Preliminary forecasts point to production falling by 1.1 million tonnes in 2006 to 136.6 million tonnes (91.05 million tonnes, milled basis), against an initial target of over 139 million tonnes (92.79 million tonnes, milled basis). The expected year-to-year decline also takes into account the smaller secondary (rabi) crop, which was partly due to the shift from rice to wheat cultivation in the wake of an increase in wheat support prices.

[1] The information contained in this paper is of 30 March 2007.

TABLE 1
India, rice milled production by crop (*million tonnes*)

	1999/2000	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07
Kharif	77.48	72.78	80.52	63.08	78.62	72.23	78.27	78.54
Rabi	12.20	12.20	12.82	8.74	9.91	10.90	13.52	12.51
Total	**89.68**	**84.98**	**93.34**	**71.82**	**88.53**	**83.13**	**91.79**	**91.05**

Source: Department of Agriculture and Cooperation, India.

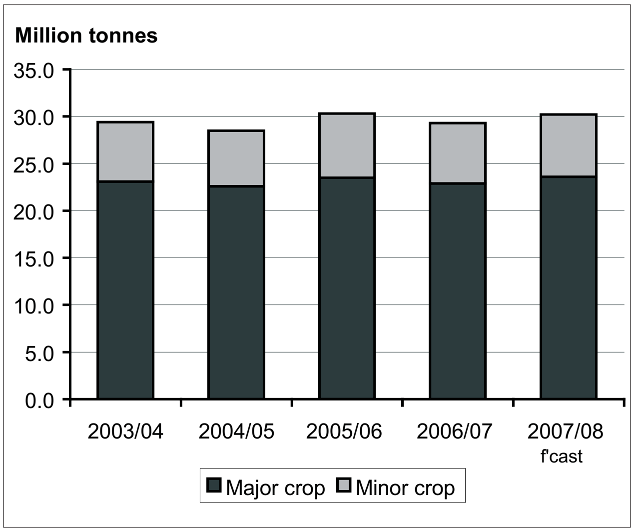
The 2006 season was generally positive for Indonesia, which recorded a small production increase to 54.4 million tonnes – the result of favourable weather conditions, low incidence of pests and diseases, and a marked increase in producer support prices. In Japan, 2006 paddy production dropped by 5 percent to 10.684 million tonnes, due to lack of sunshine and the impact of two typhoons that hit the country in August and September. Official estimates in the Democratic People's Republic of Korea point to a more optimistic outcome for the 2006 season than was previously anticipated, with production at 2 478 521 tonnes and yield at 4.248 tonnes per ha, which would result in a decline of just 100 000 tonnes compared to the relatively buoyant 2005 output. Production in the Republic of Korea fell by 2 percent in 2006, following a reduction in the rice area.

Floods at harvest time contributed to a fall in production in Malaysia. In Myanmar, the 2006 production forecast still stands at 25.2 million tonnes, marginally above the 25.08 million tonnes officially estimated for 2005. Following a downward revision by the Government, paddy production in Pakistan is estimated to have fallen to 8.1 million tonnes in 2006, down from a record 8.3 million tonnes in 2005. The decline mainly reflects the substantial crop losses in the lower Sindh caused by excessive rainfall. Not only was there a reduction in quantity, but the adverse weather conditions impaired the quality of the grain, making it more difficult for exporters to procure suitable supplies to meet contracted sales. There have therefore been strong price increases in the past 3 months, disrupting the normal flow of trade which currently accounts for about 57 percent of production.

In the Philippines, 2006 paddy production (July 2006 – June 2007) has been revised slightly upwards to 15.4 million tonnes, i.e. a 2 percent rise from 2005 and a new record. The increase on the previous season reflects the good main paddy crop grown over the second semester of 2006 (damage from the typhoons that hit the country in the last quarter was limited), as well as positive crop prospects for the period from January to June 2007. Over this period, improved water availability is expected to foster an increase in plantings and yield growth could be sustained by more widespread use of hybrids.

According to the latest official forecast (Figure 2), Thailand harvested 29.4 million tonnes of paddy in 2006 (i.e. 860 000 tonnes less than in 2005). The cut was largely caused by flooding which reduced the area under rice in the northern and central plains over the main crop, but also by unusually dry and cool weather in several north and northeastern provinces which caused problems to the secondary crop harvested in March. The government rice procurement scheme over the main paddy season opened on 1 November 2006 and ended on 28 February 2007. Although the programme made allowances for the purchase of up to 9 million tonnes of paddy from the main 2006 crop, the actual volume pledged by producers amounted to just 1.8 million tonnes, well down on the 5.3 million tonnes procured from the main 2005 paddy crop. This decrease was due for the main part to the high prices that farmers could obtain from private traders and

FIGURE 2
Rice paddy production by crop, Thailand



which rendered the scheme less attractive to them. Procurement for the secondary paddy crop is operational from 16 March to 31 July 2007 and the Government has allocated funds for purchasing up to 2.5 million tonnes at slightly higher prices than those applied over the main season. Indeed, the official prices of the various rice qualities covered by the pledging scheme were all raised by B 100 (baht) per tonne (compared with the main crop), reaching B 6 600 per tonne for 100% white rice, B 6 500 per tonne for 5% broken and B 6 000 per tonne for 25% broken white rice.

In Viet Nam, the latest official estimate of 2006 paddy production was revised downwards from 36.2 to 35.8 million tonnes to take account of the damage caused in the north by a cold spell at the beginning of the season and by the drought in the Red River Delta. Growing regions in the south also incurred losses from drought followed by flooding during the summer/autumn crop-growing period, while severe insect attacks affected 100 000 ha of rice fields in the Mekong River Delta. The sector was also subject to the rising prices of petrol, fertilizers and insecticides. Nevertheless, the level of production (35.8 million tonnes) estimated for 2006 remained virtually unchanged compared with 2005.

Africa

Production in Africa is estimated to have reached 21.6 million tonnes in 2006, i.e. 1.2 million tonnes or 6 percent above the level reached in 2005 and the fifth consecutive year of increases. In the northern part of the region, Egypt officially reported production of 6.528 million tonnes – about 400 000 tonnes more than in 2005 and the highest level on record. This increase reflected the area expansion from 613 300 to 669 100 ha (well above the government ceiling of 420 000 ha), which compensated for a slight drop in yields. Much of the increase in plantings was sustained by strong domestic and export demand which kept producer prices buoyant. In Western Africa, most recent estimates confirm the generally positive outcomes of paddy crops in 2006, consistent with the favourable weather conditions that prevailed over the season and the positive effects of the adoption of NERICA rice varieties, which are spreading in the subregion. Substantial production increases were reported in Burkina Faso, the Gambia, Guinea, Mali, Niger, Nigeria, Senegal and Togo. Gains were spectacular in Burkina Faso, where production rose by 102 percent to 189 175 tonnes. Despite a reduction in plantings, production also increased in Mali, where over 1 million tonnes were harvested in 2006, up from 946 000 tonnes in 2005, as excellent growing conditions boosted yields.

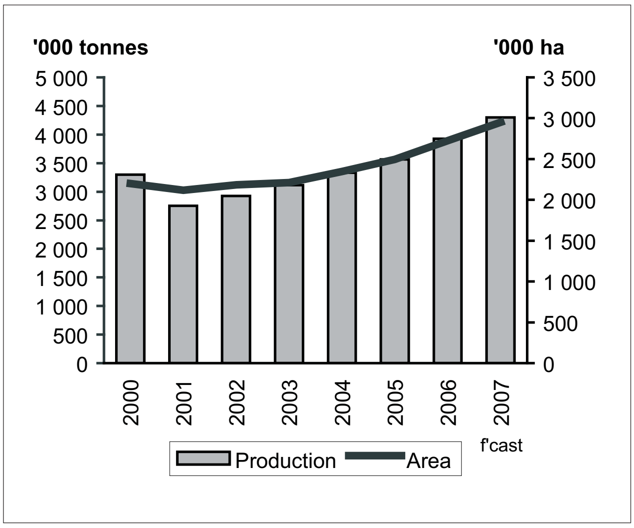
In Nigeria (Figure 3), the tendency for production to rise was confirmed by recently released official figures (with FAO figures even higher). According to the Government, the 2006 harvest was 3.924 million tonnes, i.e. 876 000 tonnes lower than FAO's estimate, but 10 percent above the 2005 official level of 3.567 million tonnes. Growth in 2006 was sustained by favourable weather conditions and by strong institutional support under the "Presidential Initiative on Rice Production, Processing and Export" (in place since 2004).

On the other hand, production in Chad, Côte d'Ivoire and Mauritania is estimated to have fallen in 2006. In southern Africa, good rainfall and improved access to fertilizers and seeds caused production to double in Malawi in 2006. Madagascar also gathered a relatively good crop, now estimated at 3.4 million tonnes, 100 000 tonnes less than the previous forecast and virtually unchanged from 2005. In East Africa, production rose strongly in Tanzania and Uganda, and gains were recorded in Kenya.

Latin America and the Caribbean

Overall, paddy production in Latin America and the Caribbean is estimated to have fallen from 26.4 million tonnes in 2005 to 24.6 million tonnes in 2006, as increases in Central America and the Caribbean failed to compen-

FIGURE 3
Paddy production and area, Nigeria



sate for decreases in South America. In most countries, the paddy season ended positively, thanks to the lower incidence of hurricanes compared with 2005. Overall, production rose from 2.30 (in 2005) to 2.41 million tonnes – a reflection of gains in Cuba, the Dominican Republic, El Salvador, Guatemala and Mexico, which compensated for declines in Costa Rica, Nicaragua and Panama. In the Dominican Republic, production almost achieved self-sufficiency, thanks to the policies designed by the National Rice Committee, representing private and public rice stakeholders, and to the successful national warehouse receipt programme (Programa Nacional de Pignoración), which helps finance storage costs born by rice producers and millers at harvest time.

In South America, production fell from 24.1 million tonnes in 2005 to 22.2 million tonnes in 2006, reflecting cuts in Brazil, Colombia, Ecuador, Peru and Venezuela, which were the consequence of poor prices in 2005 and which depressed rice cultivation. The decline was particularly severe in Brazil and Venezuela, where production is estimated to have fallen by 12 and 20 percent, respectively, reflecting a shift in resources from rice to more remunerative crops. In Peru, the latest government estimates point to a 10 percent drop in production to 2.225 million tonnes. Meanwhile, excellent yields helped propel production in Argentina, Bolivia and Chile. Despite losses to floods in the first crop, paddy production in Guyana rose in 2006 to some 469 000 tonnes (up from 420 000 tonnes in 2005); much of this growth was the result of good yields in the second paddy crop.

Rest of the world

Production in the United States fell by 13 percent in 2006 to 8.788 million tonnes – the lowest level since 2000. This followed a 20 percent cut in rice area, the result of adverse weather conditions and rising costs. Drought problems caused production in the European Union to decline: overall output is currently estimated at 2.613 million tonnes (compared with 2.693 million in 2005). Increases of 19 and 8 percent were recorded in the Russian Federation and Ukraine, respectively. In Australia, the respite from lingering drought problems meant that production reached its highest level since 2002.

INTERNATIONAL TRADE IN RICE

A large part of the crops harvested in the Northern Hemisphere countries in 2006 are destined for trade in 2007, but the outlook for 2006 is not good and a global production decline is forecast. As a result, the world rice supply and demand situation is expected to be tight in 2007. Prospects for the 2007 crops being harvested in Southern Hemisphere countries are also poor, which means that the market situation may worsen during the course of the year.

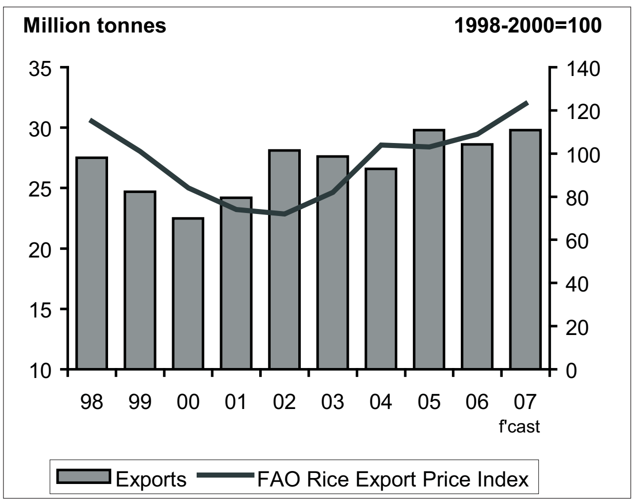
The most recent FAO forecast for global rice trade in 2007 stands at 29.8 million tonnes, about 900 000 tonnes more than previously anticipated and 1.2 million tonnes above the current 2006 trade estimate (Figure 4). The upward revision stems from the increased needs of importing countries facing production shortfalls, rather than from pressure to export, given the limited supplies held in exporting countries. If the current outlook is confirmed, trade in 2007 will virtually match the 2005 record.

Rice imports in 2007

Much of the 1.2-million-tonne increase in imports expected in 2007 is due to larger deliveries to some of the major traditional importing countries – in particular, Bangladesh, Brazil, Indonesia and the European Union – which will more than compensate for smaller shipments to the Islamic Republic of Iran, the Republic of Korea, Guinea, Nigeria, Senegal, Cuba and the Russian Federation.

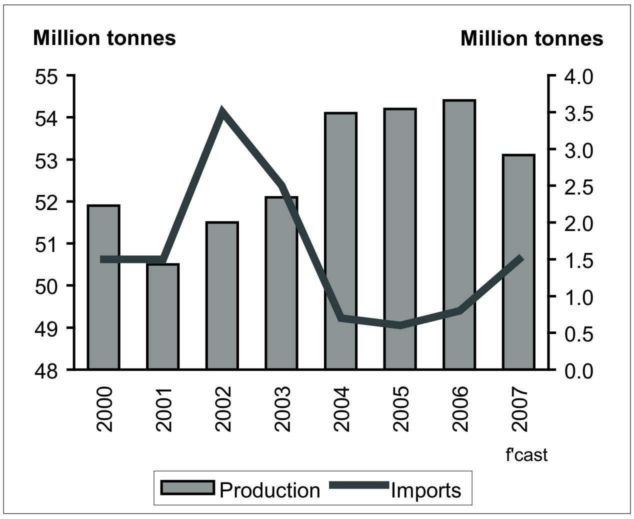
Asian countries are expected to be responsible for much of the increase in world imports in 2007. Imports in the region are expected to rise to 13.8 million tonnes (compared with 12.9 million tonnes in 2006), mostly reflecting larger purchases by Bangladesh, Indonesia, Nepal, the Philippines and Viet Nam, which are all facing

FIGURE 4
Global rice trade and price index



domestic supply constraints. In Bangladesh, pressure from rising retail prices induced the Government to suspend a 5 percent import duty in March 2007: imports may increase from 700 000 tonnes in 2006 to 1 million tonnes in 2007. Imports in Indonesia are forecast to almost double: from 800 000 tonnes in 2006 to 1.5 million tonnes in 2007 (Figure 5). Prevailing regulations state that rice can be imported only if rice stocks held by Bulog, the state food agency, fall below 1 million tonnes or if the retail market price of medium grade rice exceeds Rp 3 550 per kg (US$ 390 per tonne). Market prices in March were in the order of Rp 4 500–5 000 per kg, well above the price threshold. As a result, the country has engaged in both government-to-government and direct imports through Bulog. A reduced number of private firms have also been appointed to import 137 000 tonnes of rice by 31 March; as partners of Bulog, they are committed to distributing locally, subject to official price ceilings. To facilitate the process, the Government agreed to temporarily lower the import duty from Rp 450 to Rp 200 per kg until 31 May. This is the first time since the beginning of 2004 that the private sector has been allowed to engage in rice importation. Shipments to the Democratic People's Republic of Korea in 2007 are forecast to be in the order of 240 000 tonnes, slightly more than the 2006 estimate of 210 000 tonnes, but well below the volumes imported in the early 2000s, mostly as food aid, which ranged from 600 000 to 800 000 tonnes. The country was reported to be purchasing large amounts of rice from China over the first few months of the year. So, unless food aid deliveries resume, overall shipments will be limited to those it can afford to purchase on commercial terms.

FIGURE 5
Rice production and imports, Indonesia



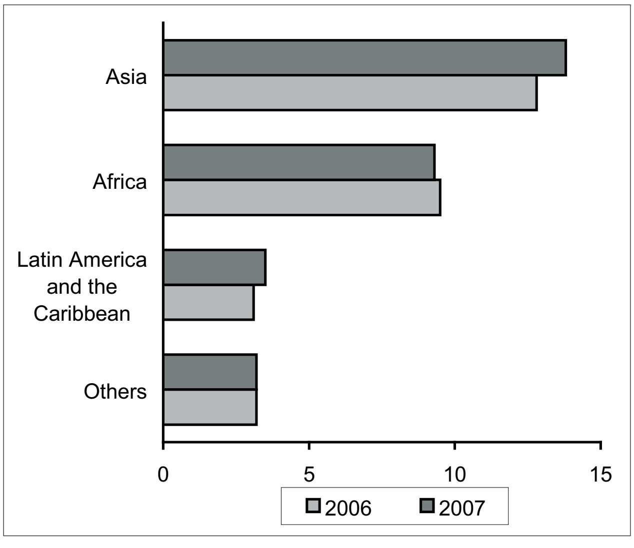
Despite steady gains in rice production in the Philippines, sustained population growth is boosting import demand. As a result, the state trading agency – the National Food Authority (NFA) – announced that the country would increase purchases of foreign rice in 2007 to some 1.65–1.8 million tonnes, 350 000 tonnes for import by private traders (delivered by 31 March) and 163 000 tonnes by producer groups (delivered by 31 May). The FAO forecast has therefore been raised to 1.7 million tonnes, which compares with an official estimate of 1.65 million tonnes for 2006. According to information released in February 2007, the country successfully concluded its negotiations to extend the right, expired in 2005, to retain quantitative restrictions on rice imports until 2012. The negotiation process involved nine WTO (World Trade Organization) countries (Argentina, Australia, Canada, China, Egypt, India, Pakistan, Thailand and the United States). Faced with a very tight rice balance, in January 2007 Viet Nam announced that it would waive tariffs on imports of milled and paddy rice from the Lao People's Democratic Republic until the end of the year (a measure in place for Cambodia since 2006). As a result, Viet Nam, the second largest rice exporter, is expected to import about 300 000 tonnes in the course of the year, up from an estimated 200 000 tonnes for 2006. By contrast, in the Islamic Republic of Iran, imports are forecast to fall to around 950 000 tonnes (150 000 tonnes less than in 2006). Part of the expected decline results from the elimination of special rights granted to people living on the border with Pakistan to import rice at reduced duty rates. Japan is expected to limit its purchases to the 770 000 tonnes in husked rice equivalent pledged under the WTO Agreement (700 000 tonnes on a milled basis). Following the 2005 agreement with interested WTO parties, the Republic of Korea is set to import 266 269 tonnes of milled rice in 2007 under a minimum import quota attracting 5 percent duty. Much of the rice should originate from China, Thailand and the United States, which have all been granted specific country quotas. Imports are unlikely to exceed the volume committed under the minimum import quota, and are therefore below the estimated 330 000 tonnes imported in 2006, when the Republic of Korea also had to provide part of the 2005 quota it had failed to fill. Although the country recently signed a free trade agreement with the United States, this specifically excluded rice.

Current forecasts of imports by African countries (Figure 6) indicate little change for the region as a whole, with overall shipments at around 9.3 million tonnes, down from the current estimate for 2006 of 9.4 million tonnes. While Egypt is predominantly an exporter, it did import about 100 000 tonnes of rice in 2006 (mostly from India) to keep in check rising domestic prices. The move was promoted by the authorities as a means to stabilize domestic supplies which had been drained by large exports; imports in 2007 are expected to reach a similar volume. Shipments to Côte d'Ivoire may also have to be raised to offset the expected production shortfall. By January 2007, Madagascar was already reported to have imported 100 000 tonnes to compensate for flood-related losses. Over the whole year, the country is expected to buy 250 000 tonnes of rice, 50 000 tonnes more than in 2006. By contrast, Nigeria may cut its purchases from 1.8 to 1.7 million tonnes, given the positive 2006 production outcome and restrictions on imports. Similarly, bumper crops for 2006 in Guinea, Mali and Senegal may result in smaller deliveries to those markets in 2007.

In principle, 2007 should be a transition year for West African countries. In January 2006, the heads of state of countries belonging to the Economic Community of West African States (ECOWAS)[2] agreed to implement a common external tariff (CET) as of January 2008, allowing for a one-year transition until 31 December 2007. The CET adopted by ECOWAS was that of the West African Economic and Monetary Union (WAEMU),[3] which had already been applied since 1 January 2000 by those ECOWAS countries belonging to WAEMU. Rice imports under the WAEMU CET attract a custom duty rate of 10 percent, a 1 percent statistical fee and a solidarity tax of 0.5 percent if imported from third countries.[4] Application of the WAEMU framework would imply a strong cut in protection for some ECOWAS countries, in particular Nigeria.[5] The impact would be less for the other countries where rice attracts already low rates of duty (the Gambia: 0%; Ghana: 20%; Guinea: 10%; and Sierra Leone: 15%).

Rice imports by countries in Latin America and the Caribbean are set to reach 3.5 million tonnes, about 400 000 tonnes more than in 2006. In Central America and the Caribbean, overall shipments in the subregion are expected to remain in the order of 2.3 million tonnes. Good crops in Cuba will probably result in reduced imports, while deliveries to Mexico may feel the effects of the requirement for all shipments from the United States to be certified to be free from genetically modified material. By contrast, imports by South American countries are forecast to rise from some 800 000 tonnes in 2006 to 1.2 million tonnes in 2007, as a result of larger purchases by Brazil, Chile, Colombia and Peru to make up for production shortfalls. In the case of Colombia, imports will also be facilitated by the strengthening of the local currency. Given that Colombia's most-favoured nation (MFN) tariff on rice is equal to 80 percent,[6] rice is mainly imported under preferential tariff rate quotas allocated to companies buying local rice through spot or futures auctions at the National Agricultural Commodity Exchange. A March 2005 decree granted a preferential 70 percent tariff rate import quota of 75 118 tonnes to non-Andean countries for 2006 and 2007, with over-quota

FIGURE 6
Rice imports by region, 2006 and 2007 (million tonnes, milled equivalent)



[2] Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, the Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, the Niger, Nigeria, Senegal, Sierra Leone and Togo.

[3] Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, the Niger, Senegal and Togo.
[4] WAEMU countries also levy a common value-added tax rate of 18 percent, payable at the port of entry plus a service fee of 6 or 12 percent, depending on the customs classification. Overall, tariffs on imported rice to WAEMU countries range from 35 to 45 percent. Provisions exist for safeguard action.
[5] Nigeria's total tariff approximates 110 percent (50 percent tariff, 50 percent additional levy of dutiable value and a 7 percent surcharge).
[6] Base duty of 15 percent on paddy rice, 20 percent on milled rice, and the rest a variable duty under a price band mechanism.

imports subject to the full 80 percent tariff. Following the signing of a side agreement between the Andean Community (Bolivia, Colombia, Ecuador, Peru and the Bolivarian Republic of Venezuela) and Mercosur, Colombia is to phase out over 15 years the rice base duties on imports from Mercosur countries. In 2007, they will be granted a 27 percent reduction on base duty rates, but will still be subject to variable duty of up to 60 percent. On the other hand, under the FTA signed with the United States, Colombia committed to granting the United States a tariff-rate quota of 79 000 tonnes, which is to increase by 4.5 percent a year. In addition, the 80 percent rice tariff is to be eliminated over 19 years, with a 6-year grace period. Peru also concluded its negotiations for an FTA with the United States. The agreement will result in the opening by Peru of a rice free trade tariff-rate quota of 72 000 tonnes, to be raised by 6 percent every year, until the complete abolition of import tariffs after 17 years. Rice imports from the United States will only attract the 25 percent base duty, but not the variable levy arising from the implementation of the price band mechanism. The parliaments of Colombia, Peru and the United States have not yet ratified the deal.

Imports by the 27 countries of the European Union are foreseen to reach 1.2 million tonnes, compared with 1.0 million tonnes in 2006. Part of the rise reflects the accession of Romania and Bulgaria (which have added some 80 000 tonnes to the EU-25 import estimate), but it also mirrors the prevailing high internal prices, which are likely to boost import demand, notwithstanding the elevation of tariffs on non-Basmati husked rice. This was triggered by large purchases in the first semester of the rice marketing year (1 Sept. – 28 Feb.), when the Union imported 352 809 tonnes of husked, non-Basmati rice. As this exceeded the threshold of 255 115 tonnes, the import duty charged from 1 March to 31 August 2007 is set at 65 euros per tonne, instead of the 42.5 euros per tonne applied from 1 September 2006 to 28 February 2007. However, because imports of milled and semi-milled rice were less than the 182 239 tonne ceiling, the duty applicable on their imports until the end of August remains at 145 euros per tonne. The narrowing of the duty differential between husked and milled rice will have negative effects on the EU’s milling industry (Table 2).

USDA (United States Department of Agriculture) forecasts point to imports by the United States reaching a record 675 000 tonnes in 2007, compared with 633 000 tonnes in 2006 – a reflection of the poor outcome of the 2006 season and high domestic prices. In Australia, the government expects purchases to decline from 101 700 tonnes in 2006 to 96 600 tonnes in 2007 – this may not meet the country’s needs, given the extremely low paddy output expected. Deliveries to the Russian Federation are likely to fall by over 20 percent to 250 000 tonnes, following the application of phytosanitary restrictions on rice from the major exporting countries and the introduction of a seasonal duty of 120 euros per tonne to be applied from 1 March to 31 May and from 1 October to 31 December, replacing the 70 euros per tonne introduced in April 2005.

Rice exports in 2007

Current production estimates and forecasts indicate that several of the major rice-exporting countries may face short supply situations in the coming months, which would impede them from responding fully to the expected

TABLE 2

European Union, applied tariffs on rice imports (*euros/tonne*)

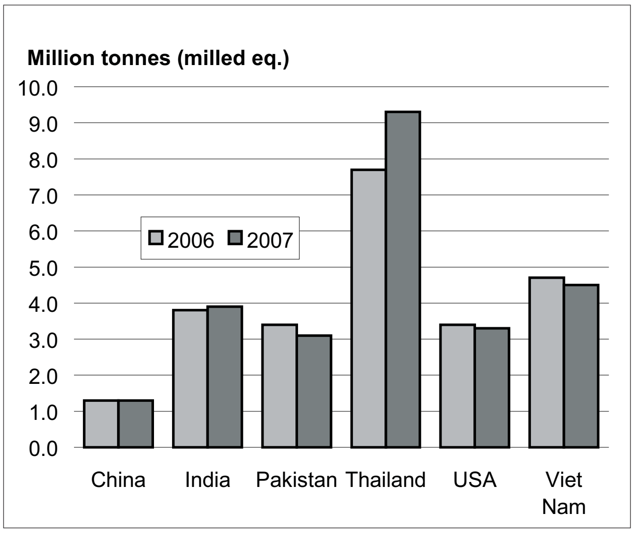
		2001/02	2002/03	2003/04	2004/05[a]		2005/06[a]		2006/07[a]	
					A	B	A	B	A	B
Paddy		211	211	211	211	211.0	211.0	211	211.0	211
Husked	japonica	257	262	228	65	42.5	42.5	65	42.5	65
	indica	264	264	233	65	42.5	42.5	65	42.5	65
Milled	japonica	416	416	416	175	175.0	145.0	145	145.0	145
	indica	416	416	416	175	175.0	145.0	145	145.0	145
Brokens		128	128	128	128	128.0	65.0	65	65.0	65

[a] Figures in column A refer to the period 1 Sept.–28 Feb. Figures in column B refer to the period 1 Mar.–31 Aug.
Source: EU Commission.

growth in import demand. The exception is Thailand – because of the high public stocks accumulated under the high support price policy conducted in 2005 and 2006 – in spite of the 2006 production shortfall. FAO forecasts (Figure 7) that exports by Thailand will increase from 7.7 million tonnes in 2006 to 9.3 million tonnes in 2007, more than 1 million tonnes of which are likely to consist of government-to-government transactions, in particular with Iraq, the Islamic Republic of Iran and Indonesia. The new FAO forecast for exports exceeds the government's March 2007 target of 8.5 million tonnes as well as FAO's previous forecast of 9.0 million tonnes.

The situation is likely to be different for India, where the anticipated 2006 production shortfall, if confirmed, would result in higher domestic prices; this would reduce the competitiveness of Indian rice on world markets and hinder the ability of the Food Corporation of India (FCI) to secure sufficient supplies domestically for its rice distribution programmes. The Government may be under increasing pressure to restrain exports. In March, it reacted to a hike in cereal prices by banning the trading in rice and wheat futures on its commodity exchanges. At present, however, FAO forecasts that the country will export 3.9 million tonnes – a modest increase on the 3.8 million tonnes estimated in 2006 and well below the 5.041 million tonnes officially delivered in 2005.

FIGURE 7
Rice exports by major exporters



Note: 2007 data are forecast.

Given the expected drop in 2006 production, exports by Pakistan could fall to 3.1 million tonnes from last year's 3.35 million tonnes. Part of the drop reflects quality problems resulting from heavy rainfall at harvest time and lack of proper storage. In this connection, the Government is becoming increasingly conscious of the importance of rice as a foreign exchange earner and is launching an awareness campaign to raise the quality of the grain produced, the lack of consistency of which has been a major problem for the sector in terms of gaining a foothold in the most remunerative markets, including the Basmati market. Quality problems have also led to difficulties in traditional markets, the consequence of which has been the mobilization of the Rice Exporters Association of Pakistan (REAP). In February 2007, for example, REAP signed a memorandum of understanding with the Kenya Bureau of Standards to issue rice export certificates based on international standards, in order to prevent the recurring of trade disputes. The memorandum commits REAP to monitor, certify and take responsibility for non-conformity of shipments with certificates. Since 2005, Kenya has been applying the Pre-shipment Verification of Conformity programme.

Exports by China (mainland) are expected to amount to some 1.3 million tonnes (i.e. 5 percent more than last year). The country is therefore predicted to remain a net rice exporter, selling lower quality rice to some Asian and African countries and higher quality rice to the Republic of Korea and Japan, while importing high quality rice, in particular, Hom Mali from Thailand.

In the FAO questionnaire, the Republic of Korea stated that it may suspend all exports of rice in 2007, given the tensions caused by the nuclear tests in the Democratic People's Republic of Korea, which led the Republic of Korea to suspend its food aid deliveries. Official forecasts then pointed to exports by the Republic of Korea falling from 90 000 tonnes in 2006 to nil in 2007. Although it was recently reported that trade between the two countries had resumed, the export forecast is to date unchanged (pending the release of new figures by the Government).

With the current good 2007 crop prospects, Sri Lanka may again have some surplus rice available for export in 2007 and may ship some 40 000 tonnes of rice in 2007, mostly to India (the same volume of exports as estimated in 2006).

In Viet Nam, harvesting of the winter/spring crop is currently under progress, which has eased the supply tightness prevailing since last year and led to the lifting, in February 2007, of the export ban in place since November 2006. Despite that move, the official export target was set at only 4.5 million tonnes for 2007, which might be revised later during the season but which nevertheless is a decrease on the 4.749 million tonnes officially exported by the country in 2006. The decline also reflects the government decision to raise the minimum export price from US$ 290 to US$ 300 per tonne for 5 percent broken rice and from US$ 270 to US$ 280 per tonne for 25 percent broken rice. The minimum export price of all the other grades of rice was also raised by US$ 10 per tonne.

Outside of Asia, exports by Egypt are estimated to rise by 10 percent to 1.1 million tonnes in 2007, in response to buoyant import demand from Near East countries and limited competition from Australia and the United States, the other major suppliers of medium- and short-grain rice to world markets. Growing demand from Near East countries would compensate for the loss of the market in Romania, following the accession of the country to the EU on 1 January 2007.

The latest official export forecast by the United States – 3.30 million tonnes – is slightly lower than the 2006 level of 3.36 million tonnes. The decline would be consistent with the drop in production in 2006, while reflecting the difficulty of selling rice in certain markets requiring US rice consignments to be certified GM-free. Such difficulties could be further exacerbated by the finding in March of GM seeds (Bayer's Liberty Link 604) in long-grain rice planting material (non-biotech Clearfield 131 rice seeds).

Lower production levels in South America are also likely to depress exports in the region. In particular, Brazil is expected to cut sales abroad from an official 290 100 tonnes in 2006 to 200 000 tonnes this year. Likewise, shipments from Argentina, Ecuador and Uruguay may be constrained by the fall in production. By contrast, official forecasts point to a small increase in Guyana's exports, from 204 300 tonnes in 2006 to 213 000 tonnes in 2007. Given the bleak production outlook in Australia, FAO anticipates that shipments will fall from the official estimate of 479 300 tonnes in 2006 to 25 000 tonnes in 2007. This would be well below the current government forecast of 182 100 tonnes.

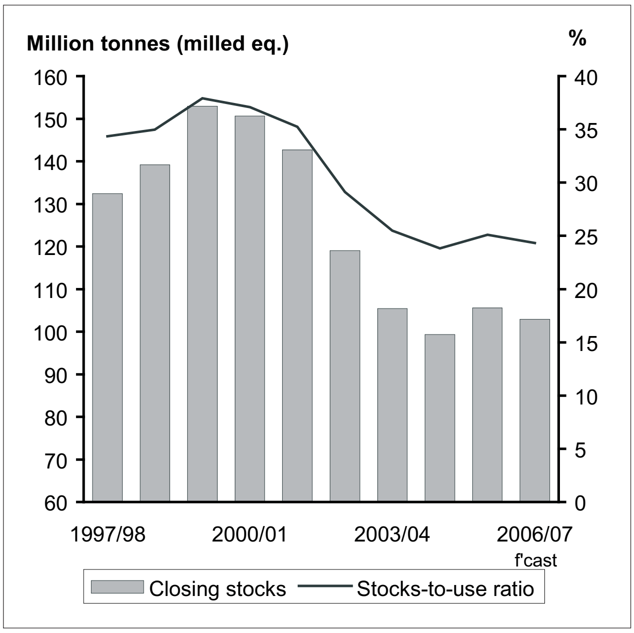
STOCKS

World rice inventories at the end of national crop seasons in 2007 were revised downwards from 105 to 103 million tonnes – a reflection of the worsening 2006 production outlook and a fall of almost 3 million tonnes compared with opening levels. While a significant reduction is expected in Thailand, the leading exporter, it is the importing countries that are expected to account for the bulk of the stock drawdown: closing inventories in Bangladesh, Brazil, Indonesia, the Islamic Republic of Iran, Nepal and Senegal, for example, are all expected to undergo cuts, while increases are forecast in the Philippines and Sri Lanka. Among exporting countries, Cambodia, Thailand, India and the United States may witness a drop, while stocks may increase in Pakistan, Myanmar and, especially, China. Little change is expected in the reserves held by Viet Nam.

The downward revision in the 2007 estimate of world rice carry-overs resulted in a lower rice stocks-to-utilization ratio of 24.3 (compared with the previous estimate of 24.7 and the 2006 figure of 25.1. The ratio is often used as a food security indicator because it measures the extent to which rice reserves can cover rice consumption in the following year (Figure 8).

With regard to stocks at the close of crop seasons ending in 2008, estimates are very preliminary. On the basis of provisional world production, trade and consumption forecasts, closing rice inventories are forecast to rise slightly above the 2007 level.

FIGURE 8
Global rice closing stocks and stocks-to-use ratio



INTERNATIONAL PRICES

Since December last year, export prices of rice from all origins have remained on an upward trend, as indicated by the FAO All Rice Price Index (1998-2000=100), which gained two points in January and February and 1 point in March, passing from 115 in December 2006 to 120 in March 2007. The strength concerned most quotations, with fragrant rice varieties and rice from Pakistan subject to particularly marked increases (Figure 9).

In Thailand, the announcement late last year that state-owned rice would be sold progressively through auctions failed to dampen the tendency for prices to rise, especially since a decision was taken to sell the supplies under government-to-government contracts whenever the prices offered at auctions did not reach the minimum targeted level. Buoyant demand for export and a strong currency contributed to keeping prices on the rise in February, while the opening of government purchases over the second paddy crop in March offered additional support and prevented prices from falling when fresh secondary crop supplies reached the market. Active purchases in India by the domestic procurement agencies under the Levy system made prices leap in December, but little growth was observed after February, as exporters waited for new supplies from the secondary rabi crop, which began to reach the market in March. As prices from other origins kept rising, India became the most competitive source: for example, milled rice with 25 percent brokens averaged US$ 260 per tonne in March, compared with US$ 264 in Pakistan, US$ 288 in Viet Nam and US$ 293 in Thailand (Figure 10). Export prices in Egypt, which supplies the medium- and short-grain rice markets, were stable in March following big rises in January and February. In Pakistan, on the other hand, limited availability of good quality rice led to major price increases, with the quotation of 25 percent brokens surging by 16 percent between December and March. Similarly, large price increases were recorded in Viet Nam, reflecting a combination of limited supplies and new sales, in particular to Indonesia and the Philippines. The pattern of prices in the United States in the first quarter deviated from that in the other major exporting countries: prices tended to fall below the December 2006 level, due to lack of new demand and because of the GM (genetically modified) issue, which led to the introduction of tighter certification requirements on United States rice imports in some major rice markets.

As April and May coincide with the harvesting period of the main 2007 crops in several countries in the Southern Hemisphere and of the secondary 2006 crops in the Northern Hemisphere, the tendency for prices to rise is likely to be tempered until June by the arrival of new supplies to the market. However, prices in the next few months are not expected to weaken much, as import demand is forecast to remain strong, while governments in Thailand, Viet Nam and now Cambodia are adamant about keeping them at remunerative levels. The general price outlook therefore points to continued gains in the coming months (Table 3).

FIGURE 9
FAO price indices for rice

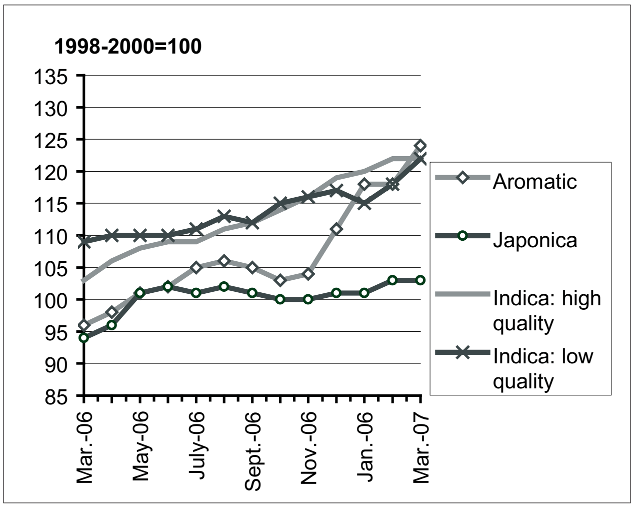


FIGURE 10
Export prices for rice

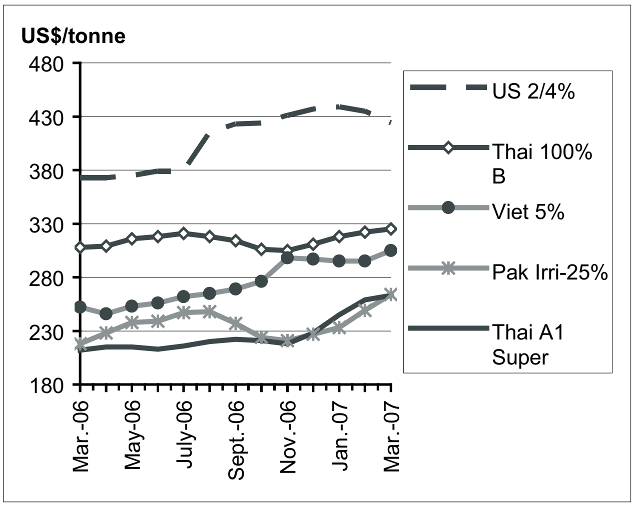


TABLE 3
FAO rice price indices

		All rice	Indica		Japonica	Aromatic
			High quality	Low quality		
		1998–2000 = 100				
2002		72	73	75	67	74
2003		82	79	81	82	91
2004		104	101	110	104	96
2005		103	104	115	92	94
2006		109	114	114	101	102
2006	Mar.	106	109	110	102	96
	Apr.	106	109	111	101	98
	May	108	111	113	102	101
	June	108	112	112	101	102
	July	109	114	115	100	105
	Aug.	110	116	116	100	106
	Sept.	111	119	117	101	105
	Oct.	111	120	115	101	103
	Nov.	113	122	118	103	104
	Dec.	115	122	122	103	111
2007	Jan.	117	123	125	104	118
	Feb	119	124	128	104	118
	Mar.	120	126	131	103	124
2006–07	Jan.–Mar.	105	107	110	100	95
2006–07	Jan.–Mar.	119	124	128	103	120

Note: The FAO rice price index is based on 16 rice export quotations. High quality = < 20% brokens; low quality = ≥ 20% brokens. The sub-index for aromatic rice follows movements in prices of Basmati and fragrant rice.
Source: FAO.

TABLE 4
Export prices for rice

		Thai	Thai	US	Viet Nam	Thai	India	Viet Nam	Pakistan	Thai	US	Egypt	Pakistan	Thai
		White 100% B second grade	Parboiled 100%	Long grain 2.4%	5%	25%	25%	25%	25%	A1 super[a]	California medium grain[b]	Short grain grade 2.6% 178 Camolino	Basmati ordinary	Fragrant 100%
		(*US$/tonne f.o.b.*)												
2002		197	194	207	187	171	140	168	159	151	271	279	366	306
2003		201	196	284	183	176	163	167	175	151	370	291	357	449
2004		244	247	372	224	225	n.a.	212	230	207	493	317	468	443
2005		291	285	319	255	259	236	239	235	219	418	327	473	404
2006		311	300	394	266	269	247	249	230	217	512	353	516	470
2006	Mar.	308	290	373	252	265	238	240	218	212	491	358	500	436
	Apr.	309	290	373	246	267	243	231	228	215	485	361	500	442
	May	316	296	375	253	271	243	237	238	215	498	357	513	467
	June	318	299	379	256	272	243	233	239	213	507	373	525	479
	July	321	311	379	262	274	243	245	247	216	507	-[c]	525	511
	Aug.	318	311	415	265	274	243	250	248	220	507	-[c]	525	520
	Sept.	314	308	423	269	272	252	252	237	222	518	358	525	515
	Oct.	306	307	424	276	267	252	251	224	221	529	326	525	494
	Nov.	305	303	431	298	267	257	283	221	218	529	343	525	454
	Dec.	311	305	437	297	273	270	282	227	228	551	366	525	490
2007	Jan.	318	311	439	295	283	270	280	233	245	551	377	586	529
	Feb	322	315	435	295	291	270	280	249	259	551	392	600	523
	Mar.	325	318	424	305	293	260	288	264	263	551	392	615	537
2006–07	Jan.–Mar.	306	289	361	257	264	238	242	217	212	502	349	500	422
2006–07	Jan.–Mar.	322	315	433	298	289	267	283	249	256	551	387	600	530

[a] White broken rice. [b] Until Aug. 2005, US medium grain no. 2, 4% brokens; since Sept. 2005, no. 1, maximum 4% brokens; sacked, California mill. [c] Not quoted.
Source: Jackson Son & Co. (London) Ltd. and other public sources.

TABLE 5

Supply and utilization of rice in main exporting countries (national crop years)

	China[ab] (Oct.–Sept.)			India[b] (Oct.–Sept.)		
	2004/05	2005/06 (prelim.)	2006/07 (forecast)	2004/05	2005/06 (prelim.)	2006/07 (forecast)
	(‘000 tonnes)			*(‘000 tonnes)*		
Opening stocks	59 200 F	56 000 F	57 085 F	13 000 F	9 000 F	11 600 F
Production[d]	123 723 O	124 774 O	124 865 U	83 130 O	91 790 O	91 050 O
Imports	581 O	828 O	810 F	50 F	82 F	50 F
Total supply	183 504	181 602	182 760	96 180	100 872	102 700
Domestic use	126 806	123 255	123 055	82 139	85 472	87 600
Exports	698 U	1 262 U	1 325 F	5 041 O	3 800 F	3 900 F
Closing stocks	56 000 F	57 085 F	58 380 F	9 000 F	11 600 F	11 200 F

	Pakistan[a] (Nov.–Oct.)			Thailand[a] (Nov.–Oct.)		
	2004/05	2005/06 (prelim.)	2006/07 (forecast)	2004/05	2005/06 (prelim.)	2006/07 (forecast)
	(‘000 tonnes)			*(‘000 tonnes)*		
Opening stocks	650 F	150 F	200 F	3 200 F	3 800 F	5 000 F
Production[d]	5 025 O	5 547 O	5 400 O	18 892 O	20 053 O	19 484 O
Imports	1 F	1 F	1 F	8 O	1 F	1 F
Total supply	5 676	5 698	5 601	22 100	23 854	24 485
Domestic use	2 050	2 148	2 201	10 763	11 149	11 125
Exports	3 475 O	3 350 F	3 100 F	7 537 O	7 705 O	9 300 F
Closing stocks	150 F	200 F	300 F	3 800 F	5 000 F	4 060 F

	United States[c] (Aug.–July)			Viet Nam[a] (Nov.–Oct.)		
	2004/05	2005/06 (prelim.)	2006/07 (forecast)	2004/05	2005/06 (prelim.)	2006/07 (forecast)
	(‘000 tonnes)			*(‘000 tonnes)*		
Opening stocks	761 O	1 211 O	1 370 O	4 900 F	4 700 F	4 700 F
Production[d]	7 463 O	7 113 O	6 195 O	24 112 O	23 873 O	23 896 O
Imports	424 O	545 O	640 O	40 F	200 F	300 F
Total supply	8 648	8 869	8 205	29 052	28 773	28 896
Domestic use	3 943	3 809	3 923	19 152	19 324	19 696
Exports	3 494 O	3 690 O	3 262 O	5 200 O	4 749 O	4 500 F
Closing stocks	1 211 O	1 370 O	1 020 O	4 700 F	4 700 F	4 700 F

O: official figure.
U: unofficial figure.
F: FAO estimate/forecast.

[a] Rice trade data refer to the calendar year of the second year shown.
[b] Including Taiwan Province.
[c] Rice trade data refer to the August/July marketing season.
[d] Milled basis.

TABLE 6

World paddy production

	2005	2006 (estimated)	2007 (forecast)
	(million tonnes)		
World	**632.9**	**628.7**	**632.8**
Developing countries	607.0	604.0	609.6
Developed countries	25.8	24.7	23.2
Asia	**572.2**	**569.2**	**574.3**
Bangladesh	39.8	39.2	40.5
Cambodia	6.0	6.3	6.5
China	182.1	182.2	184.5
(of which Taiwan Prov.)	1.5	1.5	1.5
India	137.7	136.6	137.0
Indonesia	54.2	54.4	53.1
Iran (Islamic Rep. of)	3.3	3.3	3.5
Japan	11.3	10.7	10.4
Korea (Rep. of)	6.4	6.3	6.2
Myanmar	25.1	25.2	25.2
Pakistan	8.3	8.1	8.4
Philippines	15.1	15.4	15.8
Sri Lanka	3.2	3.3	3.2
Thailand	30.3	29.4	30.2
Viet Nam	35.8	35.8	36.0
Africa	**20.4**	**21.6**	**21.7**
North Africa	6.2	6.6	6.6
Egypt	6.1	6.5	6.6
Sub-Saharan Africa	14.2	15.0	15.1
Western Africa	8.8	9.3	9.6
Côte d'Ivoire	1.2	1.1	1.0
Guinea	1.3	1.3	1.4
Mali	0.9	1.0	1.0
Nigeria	3.6	3.9	4.3
Central Africa	0.4	0.4	0.4
Eastern Africa	1.4	1.6	1.6
Tanzania	1.0	1.2	1.2
Southern Africa	3.7	3.7	3.5
Madagascar	3.4	3.4	3.2
Mozambique	0.2	0.2	0.2
Central America	**2.3**	**2.4**	**2.5**
Cuba	0.4	0.5	0.5
Dominican Republic	0.6	0.7	0.7
Mexico	0.3	0.3	0.4
South America	**24.1**	**22.2**	**22.1**
Argentina	1.0	1.2	1.1
Brazil	13.2	11.6	11.3
Colombia	2.5	2.3	2.5
Peru	2.5	2.2	2.4
Uruguay	1.2	1.3	1.1
North America	**10.1**	**8.8**	**8.5**
United States	10.1	8.8	8.5
Europe	**3.4**	**3.4**	**3.5**
EU	2.7	2.6	2.8
Oceania	**0.3**	**1.1**	**0.1**
Australia	0.3	1.0	0.1

Note: Totals computed from unrounded data.

TABLE 7

World rice imports

	2005	2006 (estimated)	2007 (forecast[a])
	(million tonnes, milled eq.)		
World	**29.8**	**28.6**	**29.8**
Developing countries	25.5	24.0	25.2
Developed countries	4.3	4.5	4.6
Asia	**13.3**	**12.8**	**13.8**
Bangladesh	1.0	0.7	1.0
Cambodia	6.0	6.3	6.5
China	0.9	1.2	1.1
(of which Taiwan Prov.)	0.1	0.1	0.1
Indonesia	0.6	0.8	1.5
Iran (Islamic Rep. of)	1.2	1.1	1.0
Iraq	1.1	1.2	1.2
Japan	0.8	0.6	0.7
Malaysia	0.8	0.8	0.8
Philippines	1.8	1.7	1.7
Saudi Arabia	1.0	1.1	1.1
Sri Lanka	0.1	0.0	0.0
Africa	**10.5**	**9.5**	**9.3**
Côte d'Ivoire	0.9	0.9	0.9
Nigeria	2.3	1.8	1.7
Senegal	0.9	0.8	0.8
South Africa	0.8	0.7	0.7
Central America	**2.4**	**2.3**	**2.3**
Cuba	0.7	0.7	0.7
Mexico	0.5	0.6	0.5
South America	**0.8**	**0.8**	**1.2**
Brazil	0.5	0.6	0.9
Peru	0.1	0.0	0.1
North America	**0.7**	**1.0**	**1.0**
Canada	0.3	0.3	0.3
United States	0.4	0.6	0.7
Europe	**1.6**	**1.8**	**1.7**
EU	0.8	1.0	1.2
Russian Federation	0.4	0.3	0.3
Oceania	**0.4**	**0.4**	**0.4**

[a] Tentative.

TABLE 8
World rice exports

	2005	2006 (estimated)	2007 (forecast[a])
	(million tonnes, milled eq.)		
World	**29.8**	**28.6**	**29.8**
Developing countries	25.5	24.4	26.1
Developed countries	4.3	4.2	3.7
Asia	**22.9**	**21.6**	**23.5**
China	0.7	1.3	1.3
(of which Taiwan Prov.)	0.0	0.0	0.0
India	5.0	3.8	3.9
Myanmar	0.2	0.1	0.2
Pakistan	3.5	3.4	3.1
Thailand	7.5	7.7	9.3
Viet Nam	5.2	4.7	4.5
Africa	**1.1**	**1.0**	**1.1**
Egypt	1.1	1.0	1.1
South America	**1.7**	**2.0**	**1.7**
Argentina	0.3	0.5	0.5
Guyana	0.2	0.2	0.2
Uruguay	0.7	0.8	0.7
North America	**3.9**	**3.4**	**3.3**
United States	3.9	3.4	3.3
Europe	**0.2**	**0.2**	**0.2**
EU	0.2	0.2	0.2
Oceania	**0.1**	**0.5**	**0.0**
Australia	0.1	0.5	0.0

[a] Tentative.

Examen de la situation du marché du riz en 2007[1]

Les estimations de la production mondiale de paddy en 2006 ont été révisées à la baisse de 2 millions de tonnes depuis décembre 2006, le chiffre actuel étant de 629 millions de tonnes. À ce niveau, la campagne 2006 de paddy qui vient de se terminer se solderait par un déficit de 4 millions de tonnes par rapport à la campagne record de 2005. Une bonne partie de cette diminution vient sans doute de la baisse des récoltes qu'ont provoquée en Asie une mousson irrégulière et des attaques d'insectes. La production est également en baisse dans la région Amérique Latine et Caraïbes, mais reste en progression en Afrique pour la cinquième année consécutive. Le reste du monde a connu des résultats variables.

En même temps que les prévisions de production fléchissaient, les prévisions FAO pour le commerce mondial de riz montaient, atteignant à ce jour à un niveau de 29,8 millions de tonnes, soit une hausse de 900 000 tonnes. Cela représenterait une amélioration de 1,2 million de tonnes par rapport à 2006, égalant presque le record commercial de 2005. La hausse des volumes échangés attendue pour 2007 reflète l'accroissement des besoins d'approvisionnement des pays importateurs, face à des déficits de production. Du point de vue des pays exportateurs, il y a moins de pression pour une expansion des volumes mis sur le marché international, en raison des contraintes dont peut également avoir à souffrir l'approvisionnement des principaux pays exportateurs.

L'accroissement des importations mondiales attendu pour 2007 serait largement la conséquence des

[1] Les informations reprises par ce document datent du 30 mars 2007.

livraisons plus importantes en direction des pays d'Asie, plus particulièrement le Bangladesh, l'Indonésie, le Népal, les Philippines et le Viet Nam. Les pays africains, en revanche, grâce à leur bonne campagne 2006 de paddy, seront peut-être en mesure de réduire leurs importations. Les importations des pays de la région Amérique Latine et Caraïbes devraient monter, l'accroissement des importations brésiliennes, colombiennes et péruviennes l'emportant sur la baisse des volumes destinés au Mexique et à Cuba. Dans le reste du monde, les États-Unis et l'Union européenne devraient importer davantage en 2007, tandis que la Fédération de Russie, ayant relevé ses barrières douanières, devrait voir décliner ses propres achats de riz.

Parmi les exportateurs, seule la Thaïlande et le Cambodge semblent capables de réagir à l'accroissement de la demande d'importations par une progression substantielle de leurs exportations. Des prix mondiaux plus rémunérateurs pourraient également entraîner une progression, relativement limitée, des exportations indiennes et égyptiennes, mais le reste des principaux producteurs – y compris l'Australie, le Pakistan, les États-Unis et le Viet Nam – devraient, pour la plupart, restreindre leurs exportations.

Les stocks mondiaux de riz à la fin des campagnes nationales de production de 2007 ont été révisés à la baisse, vers un chiffre de 103 millions de tonnes, par rapport à une estimation initiale de 105 millions de tonnes – ce qui résulte essentiellement des moins bonnes perspectives de production en 2006. À ce niveau, les stocks mondiaux de riz connaîtraient une chute de près de 3 millions de tonnes par rapport au niveau précédent, entraînant une détérioration du ratio « stock sur consommation » qui passerait de 25,1 pour cent en 2006 à 24,3 pour cent en 2007.

Depuis décembre 2006, les prix à l'exportation de toutes les origines ont connu une tendance régulière à la hausse, illustrée par l'Indice FAO des prix du riz (base 100 = 1998-2000), qui est passé de 115 en décembre 2006 à 120 en mars 2007. Cette évolution positive affecte la plupart des origines, en particulier les variétés parfumées de riz et le riz pakistanais.

Du fait qu'avril et mai coïncident avec la récolte des principales campagnes 2007 de l'hémisphère Sud et celle des campagnes secondaires 2006 de l'hémisphère Nord, la tendance à la hausse des prix pourrait s'inverser jusqu'en juin suite à la mise sur le marché de ces nouvelles productions. Cependant, une baisse substantielle des prix est improbable, en raison de la demande d'importation qui devrait demeurer importante, tandis que les Gouvernements de Thaïlande, du Viet Nam et plus récemment du Cambodge restent intransigeants sur le principe d'un niveau rémunérateur des prix. On peut donc s'attendre de façon générale à une hausse soutenue au cours des mois à venir.

Examen de la situación mundial del arroz en 2007[1]

Las estimaciones de la producción mundial de arroz en 2006 se han reducido en 2 millones de toneladas desde diciembre de 2006, situándose ahora en 629 millones de toneladas. Con este volumen, la campaña arrocera de 2006 que acaba de concluirse arrojaría un resultado inferior en 4 millones de toneladas al nivel sin precedentes de 2005. Es probable que tal disminución se deba en gran parte a la obtención de cosechas menores en Asia a causa del comportamiento irregular de los monzones y los ataques de insectos. La producción también descendió en 2006 en América Latina y el Caribe, pero en África creció por quinto año consecutivo. En el resto del mundo, los resultados fueron mixtos.

Al reducirse las perspectivas de la producción ha crecido el volumen de comercio mundial pronosticado por la FAO para 2007, el cual se sitúa actualmente en 29,8 toneladas habiendo sufrido un incremento de 900 000 toneladas. Esto representaría un aumento de 1,2 millones de toneladas con respecto a 2006, con el que casi se alcanzaría el volumen récord de intercambio de 2005. El incremento del comercio previsto para 2007 es consecuencia de las mayores necesidades de suministros de los países importadores, aquejados por déficit productivos. En los países

[1] La información contenida en este documento es la disponible al 30 de marzo de 2007.

exportadores existe menos presión para expandir el comercio, puesto que también dichos países pueden enfrentarse con limitaciones de oferta suministro.

El incremento previsto de las importaciones mundiales en 2007 sería consecuencia en gran parte de las mayores entregas a los países asiáticos, en particular Bangladesh, Filipinas, Indonesia, Nepal y Viet Nam. Por otra parte, los países africanos podrían estar en condiciones de reducir sus importaciones gracias a sus buenas campañas arroceras de 2006. Las importaciones de los países de América Latina y el Caribe están destinadas a crecer por el aumento de las compras del Brasil, Colombia y Perú, que superan los envíos, más reducidos, de México y Cuba. En el resto del mundo, Estados Unidos de América y la Unión Europea están preparados para incrementar sus importaciones en 2007, mientras que un aumento de la protección en las fronteras podría reducir las compras de la Federación de Rusia. Entre los exportadores, sólo Tailandia y Colombia parecen estar en condiciones de responder a la demanda creciente incrementando considerablemente sus entregas. Los precios mundiales atractivos también podrían determinar un ligero incremento de las exportaciones de la India y Egipto, pero se prevé que la mayor parte de los otros grandes proveedores – incluidos Australia, Estados Unidos, Pakistán y Viet Nam – reducirán sus exportaciones. Al finalizar las campañas arroceras nacionales en 2007 el nivel de las existencias mundiales de arroz se revisó a la baja, calculándose en 103 millones de toneladas frente a la estimación anterior de 105 millones. Esto se debió principalmente al empeoramiento de las perspectivas de la producción en 2006. En ese nivel, las existencias mundiales de arroz habrían descendido en casi 3 millones de toneladas con respecto a los niveles de apertura con el consiguiente deterioro de la relación entre reservas y utilización, que descendió de 25,1 % en 2006 a 24,3 % en 2007.

Desde diciembre de 2006 los precios de las exportaciones de arroz de todos los orígenes registran una tendencia constante al alza, como indica el índice de precios de la FAO para todos los tipos de arroz (1998–2000=100) que ascendió de 115 en diciembre de 2006 a 120 en marzo de 2007. Esta solidez refleja la mayor parte de las cotizaciones, en particular las de arroz aromático y las del arroz del Pakistán.

Puesto que abril y mayo coinciden con la cosecha de los cultivos principales de 2007 en el hemisferio sur y con la de los cultivos secundarios de 2006 en el hemisferio norte, la tendencia al alza de los precios puede disminuir hacia junio con la llegada de los nuevos suministros al mercado. Sin embargo, es improbable que los precios se debiliten mucho considerando que se mantiene la fuerte demanda de importación, mientras que los gobiernos de Tailandia, Viet Nam, y ahora también el de Camboya, se muestran inflexibles en cuanto al mantenimiento de los niveles lucrativos. Por consiguiente, la perspectiva general con respecto a los precios apunta al mantenimiento de las ganancias en los próximos meses.

Performance and challenges of global rice production during 2000–10

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INTRODUCTION

In 2004, more than 3 billion people depended on rice as a staple food, and given the steady population growth this number will increase in the near future. Following a gradual decline, global rice production has been increasing since 2002, but in terms of food security, further effort and support is required from all stakeholders. Global climate change may have a large impact on rice production in the second half of the first decade. Although international rice prices improved considerably during the first half of the decade, rice production in the remaining years could be significantly affected by the competition for land and water resources for the production of crops for feed and for fuel. Sustainable rice production in the near future, therefore, will depend greatly on competitiveness. Fortunately, technological options are available for increasing the competitiveness of rice production. This paper provides a summary review of: the performance of global rice production in the first half of the decade; and the rice requirement for food security in the second half. It then discusses the potential challenges that rice could face in the near future and finally the technological options for increasing competitiveness for sustainable production.

RICE PRODUCTION IN THE FIRST DECADE OF THE TWENTY-FIRST CENTURY

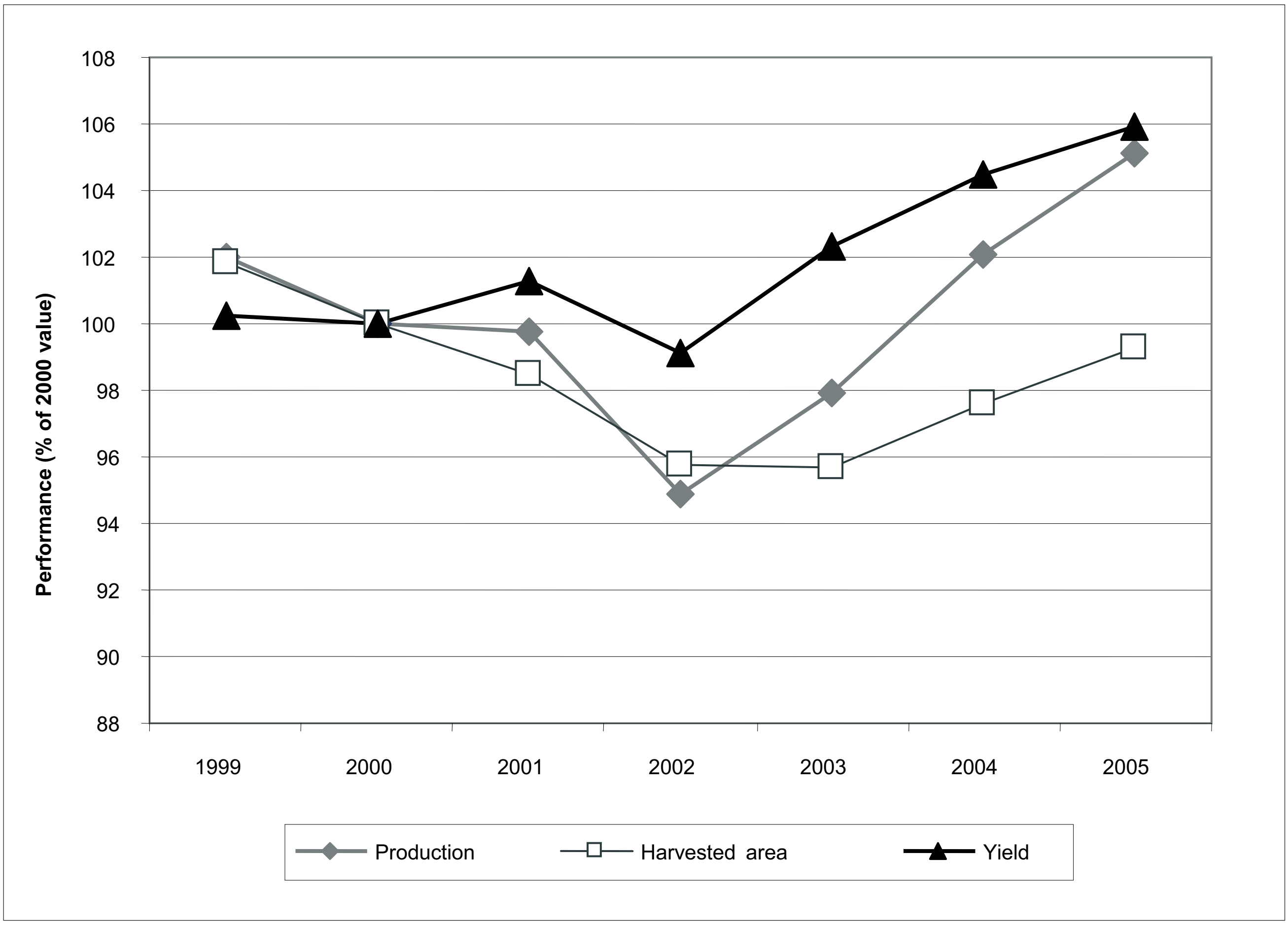
During the first half of the decade, global rice output decreased sharply between 2000 and 2002 and then rebounded strongly back. In spite of the strong recovery in global production, the per capita rice output in 2005 was still substantially less than in 1999. As the population continues to grow, the food security of rice-dependent populations will be at risk unless there is an effort to support an increase in global rice production in the second half of the first decade of the twenty-first century.

Rice production in the first half of the decade, 2000–05

After reaching 610.6 million tonnes in 1999, global rice output began a declining trend. The 31st Session of the FAO Conference met in November 2001 and, noting the degraded situation of global rice production, adopted Resolution 2/2001 recommending the United Nations General Assembly (UNGA) to declare an International Year of Rice. Global rice output continued to decline in 2002 (Figure 1). In December 2002, UNGA declared 2004 the International Year of Rice in order to raise global awareness of the vital role that rice plays in the worldwide effort to reduce hunger and poverty (Millennium Development Goal 1). World rice output began to recover in 2003 and reached 610.9 million tonnes in 2004 and 629.3 million tonnes in 2005 (FAOSTAT). Global rice output since 1999 has been sustained mainly by farmers' efforts to increase productivity or yield. World rice yield in 2005 was 4.11 tonnes/ha (about 6 percent higher than the 1999 figure of 3.88 tonnes/ha), while the global rice harvest area during the period from 2000 to 2005 remained below 156.7 million ha (the level reached in 1999).

During 2000–05, twenty of the 113 rice-producing countries produced about 95 percent of the world's rice: 15 from Asia (Bangladesh, Cambodia, China, India, Indonesia, the Islamic Republic of Iran, Japan, the Republic of Korea, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand and Viet Nam), 3 from Africa (Egypt, Madagascar and Nigeria) and 2 from America (Brazil and the United States). Rice production in the Islamic Republic of Iran, the Philippines, the United States and Viet Nam increased steadily and substantially during 2000–05. The increased production in the Islamic Republic of Iran, the Philippines and the United States was more due to increased rice yield than to increased harvested area; in Viet Nam, on the other hand, it was entirely

FIGURE 1
Trends of global rice production, harvested area, and yield, 1999 to 2005 (2000 value = 100%)



due to yield increase, as the harvested area steadily decreased. In Madagascar, Myanmar and Thailand, the production increase between 2000 and 2002 was modest, becoming substantial after 2002, mainly as a result of yield increase (Table 1, Group 1).

The patterns of change in rice production in Bangladesh, Indonesia, Sri Lanka, Cambodia and Pakistan were similar: stagnated production from 2000 to 2002, followed by a substantial increase between 2002 and 2005. India, Nigeria and Brazil, on the other hand, saw production decrease from 2000 to 2002, followed by a substantial increase. The change in rice production in India was exceptional, with a rapid decrease of about 20 million tonnes from 2000 to 2002, followed by a rapid increase of about 30 million tonnes from 2002 to 2005. The substantial increase in rice production in India and Brazil during 2002–05 was due to increases in both harvested area and yield, while in Nigeria it was due mainly to the expansion of the harvested area (Table 1, Group 2).

Rice production in Egypt and Nepal remained more or less unchanged between 2000 and 2005. In Nepal, both yield and harvested area were constant, while in Egypt yield increased and harvested area decreased during this period. The rice outputs of China, Japan and the Republic of Korea in 2005 were less than in 2000. In China and Japan, rice production showed a sign of recovery after 2002, but in the Republic of Korea rice production steadily decreased during 2000–05 (Table 1, Group 3).

Rice requirement for food security in the second half of the decade, 2006–10

The world population in 2004 was 6.37 billion (6.4 percent higher than the 1999 figure of 5.99 billion) (FAOSTAT). The world rice output in 2005 was 3 percent

TABLE 1

Rice production, harvested area and yield in the top 20 rice-producing countries, 2000, 2002 and 2005

	2000			2002			2005		
	Production (*million tonnes*)	Harvested area (*million ha*)	Yield (*tonnes/ ha*)	Production (*million tonnes*)	Harvested area (*million ha*)	Yield (*tonnes/ ha*)	Production (*million tonnes*)	Harvested area (*million ha*)	Yield (*tonnes/ ha*)
***Group 1:** Rice production increased steadily between 2000 and 2005*									
Iran (Islamic Republic of)	1.9	0.53	3.68	2.8	0.61	4.72	3.5	0.63	5.55
Philippines	12.3	4.03	3.06	13.2	4.04	3.27	14.6	4.20	3.47
Viet Nam	32.5	7.66	4.24	34.4	7.50	4.59	35.7	7.32	4.88
United States of America	8.6	1.23	7.03	9.5	1.29	7.37	10.1	1.36	7.43
Madagascar	2.4	1.21	2.05	2.6	1.21	2.14	3.4	1.25	2.72
Myanmar	21.3	6.30	3.38	21.8	6.38	3.41	25.3	7.00	3.61
Thailand	25.8	9.89	2.61	26.0	9.98	2.60	29.2	9.97	2.92
***Group 2:** Rice production either stagnant or decreased between 2000 and 2002, then increased rapidly between 2002 and 2005*									
Bangladesh	37.6	10.80	3.48	37.5	10.77	3.49	39.7	10.52	3.78
Indonesia	51.8	11.79	4.40	51.4	11.52	4.46	53.9	11.80	4.57
Sri Lanka	2.8	0.83	3.43	2.8	0.82	3.48	3.2	0.91	3.54
Cambodia	4.0	1.90	2.11	3.8	1.99	1.91	5.9	2.41	2.47
Pakistan	7.2	2.37	3.03	6.7	2.22	3.01	8.3	2.62	3.17
India	127.4	44.71	2.84	107.6	41.20	2.61	136.5	43.40	3.14
Nigeria	3.2	2.20	1.50	2.9	2.18	1.34	3.5	2.49	1.43
Brazil	11.0	3.65	3.02	10.4	3.14	3.32	13.1	3.91	3.37
***Group 3:** Rice production either unchanged or decreased between 2000 and 2005*									
Nepal	4.2	1.56	2.70	4.1	1.54	2.67	4.2	1.55	2.71
Egypt	6.0	0.66	9.10	6.1	0.65	9.39	6.1	0.61	9.98
China	189.8	30.30	6.26	176.3	28.50	6.18	182.0	29.08	6.25
Japan	11.8	1.77	6.70	9.7	1.68	6.58	11.3	1.70	6.64
Republic of Korea	7.1	1.07	6.71	6.6	1.05	6.34	6.4	0.98	6.56

Source: FAOSTAT.

higher than in 1999. Consequently, the per capita rice output in 2005 was less than in 1999. Between 1999 and 2004, the world population increased by 385 million; at this rate, it is likely to reach 6.7 billion in 2010. In order to maintain the 2005 level of rice output (97.4 kg/person), global rice output needs to reach about 652.5 million tonnes in 2010 (i.e. 23.2 million tonnes more than in 2005 – scenario I). Similarly, an output of 682.0 million tonnes in 2010 (52.7 million tonnes more than in 2005 – scenario II) will be required to recover the per capita rice output (101.8 kg/person) obtained in 1999 (Table 2). In order to produce the extra quantity of rice, global rice production requires more resources (especially land and water) and support to raise productivity. However, the current increase in rice prices in the global markets may provide an incentive to farmers to grow more rice during the second half of the first decade of the century.

TABLE 2

Global population and global rice output and per capita rice output in the first decade of the twenty-first century

Year	Global population (*billion*)	Global rice output (*million tonnes*)	Per capita rice output (*kg/person*)	
1999	5.99	610.6	101.8	
2000	6.07	598.4	98.5	
2001	6.14	597.3	97.1	
2002	6.22	568.3	91.2	
2003	6.30	585.7	92.9	
2004	6.37	610.9	95.7	
2005	6.45[a]	629.3	97.4[a]	
2010	6.7[a]	652.5	97.4	= 2005 value
2010	6.7[a]	682.0[a]	101.8	= 1999 value

[a] Estimated values.

Source: FAOSTAT.

MAIN CHALLENGES OF RICE PRODUCTION IN THE NEAR FUTURE

During the second half of the twentieth century, dams were built to divert the flow of the river or to store surface water and then channel it onto rice fields. In the late 1960s, farmers in a number of countries turned to underground sources and millions of irrigation wells were drilled to provide water for rice production. In tropical climate areas, especially in Asia, the availability of irrigation together with early-maturing and photoperiod-insensitive rice varieties have allowed farmers to grow two to three rice crops on the same pieces of land in the same year (Tran and Nguyen, 2001) and this had led to the substantial increase in the global rice harvested area from about 125 million ha in 1965 to about 156.7 million ha in 1999 (FAOSTAT). The land and water resources for rice production in the near future may be significantly affected by the global climate change. Also, the recent developments indicate that the land and water resources for rice could be under intense competition from the production of crops for feed and fuel. The recent evolution of rice prices, however, highlights the competitiveness of the crop and the potential for farmers to allocate more land and water resources to rice production in the near future.

Global climate change

The main characteristics of global climate change are: increase in temperature, variation in rainfall and its distribution, and rising sea level. About 40 percent of the world rice area is classified as rainfed lowland and upland, while about 3.5 million ha of riceland are still being classified as deep-water or flood-prone. The variability in rainfall and its distribution under global climate change would cause more droughts and flooding in these rice ecologies. In 1992, it was reported that the core agricultural zone in Zimbabwe would be reduced by 67 percent with a 2 °C temperature increase (Downing, 1992). Recently, Darwin *et al*. (2005) estimated that the amount of land classified as "land class 6" (the primary land class for rice, tropical maize, sugar cane and rubber in tropical areas) would decline by 18.4 to 51 percent in the next century as a result of global warming.

Large areas in the low-lying deltas of the Ganges, the Mekong, the Mississippi, the Nile, the Yangtze, the Yellow and other major river systems with important rice-growing regions, have been affected by tidal waves. For example, it was reported that there were about 650 000 ha of saline soils along the coastal belt in the Mekong River Delta and 350 000 ha in the Red River Delta of Viet Nam (FAO, 1988). Most rice varieties are severely injured in submerged soil culture at an electrical conductivity (ECe) of 8–10 mmho/cm at 25 °C (Ponnamperuma and Bandyopadhya, 1980). Rising seas would result in an expansion of the area affected by tidal waves. Enormous areas of coastal Florida, much of Louisiana, the Nile Delta and Bangladesh would become uninhabitable once seas rise by as much as 88 cm (Kluger and Lemonick, 2001).

Competition for land water resources by the production of crops for feed

Humans consume a variety of foods to provide energy, protein, vitamins and other essential elements for growth, development and maintenance of their bodies, and societies have relied mainly on agricultural production systems to provide these foods. The foods that provide energy are called staple foods, and rice was the staple of more than 3 billion people in 2004. Rice is rich in energy-producing materials, but proteins and other elements are often limited; rice must therefore be supplemented with animal proteins.

The rapid increase in demand for animal proteins during the second half of the twentieth century, however, has outgrown the sustainable yield of the natural ocean and rangeland systems. Therefore, the production of beef and milk, chicken and eggs and pork increasingly takes place in confined feedlots, while fish and shrimps are produced in inland ponds. The animal protein that is produced in these so-called "confined systems" has been supported by feed, which is produced from grain crops such as maize and soybean and to a lesser extent wheat and other crops.

It is estimated that about 7 kg of grain are needed to produce 1 kg of additional weight in beef production, 3.5 kg in pork, 2 kg in poultry, and 1 to 2 kg in fish (Brown, 2005). The world demand for animal protein is expected to increase in the second half of the first decade of the twenty-first century. Consequently, more land and water resources will be used for the production of maize, soybean and other crops for feed production.

Competition for land water resources by the production of crops for fuel

The world is increasingly looking to crops as a source of renewable fuel or biofuels. In Brazil, sugar cane has been a popular biofuel crop, while in the United States maize has recently become the top biofuel crop with 550 to

750 million bushels of maize being used for ethanol production per year (Lyddon, 2006; Donley, 2007). The quantity of maize used for ethanol production in the United States is projected to increase in the near future. Rapeseed and maize have also been grown for biofuel production in Canada. In China, fuel ethanol production increased from 30 000 tonnes in 2002 to 1.02 million tonnes in 2005 (Anon., 2007). The quantity of maize used for production of ethanol and other industrial products in China in 2006 was about 23 million tonnes or an increase of about 84 percent on 2001.

In the European Union, the "Biofuels Directive" issued in 2003 requires member states to achieve an inclusion rate of 2 percent renewable fuel by 2005 and 5.75 percent by 2010 (Lyddon, 2007). Today, canola or rapeseed oil are the dominant materials used in the production of biodiesel in the European Union where about 3.8 million tonnes of biodiesel were produced in 2005. It is estimated that to achieve the 5.75 percent target in 2010, the European Union would need around 11 million tonnes of biodiesel. Consequently, more land and water resources will be used for the production of biofuel crops, if no alternative source is found.

Evolution of rice prices in the first decade of the twenty-first century

Although rice is the staple food crop of the majority of rice farmers, rice production is an economic activity. The net return or income from rice production (compared to the production of crops for feed and fuel) affects a farmer's decision on whether or not to continue rice production or to shift to the production of feed and/or fuel crops. The income from rice production is defined as follows:

Income = yield × unit price – (production cost)

The export prices for all types of rice have increased steadily since 2002 (see Table 4, p. 11). Consequently, the income from rice production has also improved, especially when the production costs were either kept unchanged or changed minimally. The FAO Rice Price Indices showed that the prices of all types of rice in 2006 were about 9 percent higher than in the 1998–2000 period. A continuation of this positive trend of rice prices would encourage farmers to allocate more land and water resources for rice production and to apply good production practices that minimize production costs.

TECHNOLOGICAL OPTIONS FOR INCREASING THE COMPETITIVENESS OF RICE PRODUCTION

In the near future, sustainable rice production depends greatly on its competitiveness. Generally, the increase in rice yield and higher rice prices have enhanced the economic competitiveness of rice production during the first half of the first decade of the twenty-first century. Below are a number of technological options for further increasing rice yield and economic competitiveness in the second half of the first decade of the twenty-first century as well as for improving the environmental protection and conservation aspects of rice production.

Increasing yield to increase the competitiveness of rice production

The development and adoption of high-yielding and hybrid rice varieties has greatly contributed to the increase in global rice yield from about 2.032 tonnes/ha in 1965 to 4.017 tonnes/ha in 2005. Much of the yield increases, however, occurred in irrigated ecologies. A recent review of rice breeding indicated that, at present, NERICA (New Rice for Africa) and hybrid varieties are still viable for further increasing rice yield in the near future (Nguyen, 2006). The review also revealed that promising results have been obtained by the efforts to create a new generation of rice varieties.

The yield of existing rice varieties could be substantially increased with the integrated application of good management practices (Hill *et al.*, 2004; Lacy and Steel, 2004; Abdulrachman, Las and Yuliardi, 2005; Nguyen and Ferrero, 2005; Kueneman, 2006). Yields of the existing irrigated rice varieties in several developing countries were increased by as much as 4 tonnes/ha on experimental farms (Kueneman, 2006) and more than 1 tonne/ha in large-scale production (Anon., 2006) with integrated application of good management practices, which also enhanced the efficiency of applied inputs, thus reducing production costs (Pham, Trinh and Tran, 2005), and substantially decreased the quantity of applied water in rice production (Lacy and Steel, 2004).

The yield and productivity of rainfed lowland rice systems could be increased with on-farm water-harvesting facilities. Total rainfall during the monsoon season in most tropical areas is more than adequate to guarantee the water supply of a rice crop with a growth duration of up to 5 months. However, due to variation in rainfall distribution, much of the rainwater is lost. Traditionally farmers in Southeast Asia built on-farm water-harvesting facilities, such as ponds, and alternated deep furrows and raised beds to improve water supply and enhance productivity in rainfed lowland ecologies. These systems offered one or a combination of the following possible advantages:

- Provision of supplemental irrigation with water from ponds or deep furrows to minimize the negative effects of drought.
- Planting rice in raised beds to minimize the negative effects of flood.
- Using available water from the ponds or deep furrows, scheduling planting so that the crop can benefit from higher solar radiation following the monsoon season to produce higher yield.
- Cultivation of fish and other aquatic animals in ponds and deep furrows.

Biomass utilization to increase the competitiveness of rice production

Rice crops produce grains and straw at harvest. Varieties with a grain/straw ratio of 1 produce 1 tonne of straw for every tonne of grain. Milling 1 tonne of grain produces an average of 70–100 kg of broken rice, 50–70 kg of rice bran, 190–200 kg of rice husks, and about 640–690 kg of milled rice (or whole rice). Most milled rice is used as food, while broken rice and rice bran have been used as feed for animals and fish. Rice bran is also used for the production of cooking oil, cosmetic materials and other products. However, in many countries straw and husks have not been widely used, although there are technological options for converting them into value-added products. In southern Asian countries (e.g. Bangladesh, India, Nepal and Pakistan), rice straw has been used as feed for cattle and traded for cash in markets (FAO, 1990). The utilization of rice straw and other biomass for milk production is extremely successful in India (Brown, 2005). The major constraints in the utilization of rice straw in many places are its collection, transport and conservation. Bale pressers have been used for the rapid collection of straw and crop residues in a number of countries.

Burning 1 kg of rice husks at 10 percent moisture content yields approximately 11 megajoules (MJ), compared with 29 MJ from 1 kg of anthracite and 36.3 MJ from 1 litre of kerosene (Phan *et al*., 2000). Rice husks have been used in China and Myanmar (FAO, 1990) for electricity generation. Rice husks have been used to generate heat and energy for grain drying (FAO, 1990; Phan *et al*., 2000; Castillo-Nino, 2007). Recently, a cyclonic burner that can generate up to 10 million Btu per hour by consuming over 1 tonne of rice husk (i.e. the equivalent of the energy generated from burning 74 gallons [approx. 300 litres] of diesel) was developed in Thailand (Castillo-Nino, 2007). Rice straw is a particularly attractive feedstock for making liquid fuels. About 70 to 80 gallons [approx. 300–350 litres] of ethanol could be produced from 1 tonne of straw (Clausen, 2007). In December 2006, the foundation stone of a project for the generation of power from rice straw and other farm wastes was laid down in the village of Ghanaur in Patiala District, India (Singh, 2006). The efficient use of rice straw and husks for feed and fuel production would enhance the competitiveness of rice production while minimizing the competition for land and water resources due to the production of crops for feed and fuel.

CONCLUSION

Global rice production has been rising strongly since 2002. However, the food security of more than 3 billion people continues to require substantial effort and support from all stakeholders in rice production for the rest of the decade. In order to maintain the per capita rice output obtained in 2005 (97.4 kg/person), the global rice output should reach about 652.5 million tonnes in 2010 (i.e. 23.2 million tonnes more than 2005). Land and water resources for rice production in the near future may be significantly affected by global climate change. Also, recent developments indicate that the land and water resources for rice production could be under intense competition from the production of crops for feed and fuel. The competitiveness of rice production could be enhanced with the use of NERICA and hybrid varieties to increase yield in the near future. Also, the yield of existing irrigated rice varieties could be substantially increased with the integrated application of good management practices. In rainfed lowland ecologies, yield and productivity could be increased with on-farm water harvesting facilities. Increased conversion of rice straw and husks into feed and energy could minimize the competition for land and water resources due to the production of crops for feed and fuel while enhancing the competitiveness of rice production in general.

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Production globale de riz: résultats et défis 2000–10

La production mondiale de riz a connu un déclin accentué entre 2000 et 2002 avant de rebondir. Malgré cette reprise, la production per capita en 2005 restait inférieure à celle de 1999; de plus, le simple maintien de ce niveau de production à l'horizon 2010 nécessiterait une production annuelle augmentée de 23,2 millions de tonnes au moins. Les changements climatiques globaux pourraient avoir un effet significatif sur la production de riz au cours de la seconde moitié de la première décennie du siècle. Qui plus est, on peut penser, sur la base de l'évolution récente, que les ressources en terre et en eau utilisées pour la production rizicole pourraient bien faire l'objet d'une concurrence intense du fait de la production de biocarburant et d'aliments pour le bétail. Cependant, l'évolution suivie par les prix du riz depuis 2002 a amélioré la compétitivité de la production rizicole. Les variétés NERICA et hybrides restent très prometteuses en termes d'amélioration continue du rendement, tandis que la mise en œuvre intégrée de bonnes pratiques culturales améliore de façon substantielle le rendement des variétés existantes, tout en renforçant l'efficience de l'utilisation d'intrants et en limitant les volumes d'eau nécessaires pour la production rizicole. D'autres possibilités techniques pour améliorer la compétitivité et la durabilité de la production rizicole et sa contribution à la sécurité alimentaire au cours de la seconde moitié de la première décennie du XXI[e] siècle sont le recours à des installations de collecte d'eau au niveau de l'exploitation agricole, et l'utilisation économiquement efficiente des pailles et balles de riz pour la production d'énergie et d'aliments du bétail.

Producción mundial de arroz en 2000–10: resultados y desafíos

La producción mundial de arroz disminuyó bruscamente entre 2000 y 2002, después de lo cual experimentó una recuperación. Sin embargo, el nivel de producción de arroz per cápita en 2005 seguía siendo más bajo que en 1999; además, para mantener este nivel de producción hasta 2010 deberán producirse, como mínimo, 23,2 millones de toneladas más. Los cambios climáticos mundiales pueden tener un efecto importante en la producción arrocera durante la segunda mitad del primer decenio. Además, los acontecimientos recientes indican que los recursos de tierras y aguas para la producción de arroz pueden ser objeto de una competencia intensa entre la producción de cultivos y la de piensos y combustibles. Al mismo tiempo, la evolución de los precios del arroz desde 2002 ha incrementado la competitividad de la producción arrocera. NERICA y las variedades de arroz híbrido siguen ofreciendo posibilidades de obtener rendimientos aún mayores, mientras que la aplicación integrada de buenas prácticas de gestión se traduce en un aumento sustancial del rendimiento de las variedades de arroz existentes, potencia la eficiencia de los insumos utilizados, y reduce la cantidad de agua aplicada en la producción. Las instalaciones de captación de agua en las fincas y el uso eficiente de la paja y los hollejos de arroz para producir piensos y combustible constituyen, por otra parte, otras tantas opciones técnicas útiles para aumentar la competitividad y sostenibilidad de la producción de arroz con miras a la seguridad alimentaria en la primera década del siglo XXI.

Conservation agriculture: synergies of resource-conserving technologies in rice-based systems[1]

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BACKGROUND

In 2000, about 850 million people were suffering from hunger, 815 million of which in developing countries. From a global perspective, hunger is a problem not of food production but of accessibility, since to date world food production has kept pace with demand (FAO, 2006). Although recent predictions point to reduced population growth, a considerable increase in overall production is still required – a major challenge, given the already stretched land and water resources. Future yield increases may be limited compared to past trends (FAO, 2006), but by 2030, food production must double to keep pace with demand.

The production of renewable resources is increasingly important, due both to the growing awareness of sustainability and to rising oil prices. Countries producing a food surplus could in future focus more and more on the production of profitable renewable raw material for industrial products and energy rather than simply on the production of food (FAO, 2002).

There are also regional differences to be taken into account. Sub-Saharan Africa remains a hunger hot spot with a stagnating trend in per capita food production, while other regions are seeing a steady increase (FAO, 2005). Countries with a large population like China and India, and which in the past achieved food self-sufficiency, now face the challenge of maintaining and increasing high yield levels in a scenario of increasing climatic variability.

Over the last few decades the growth in agricultural production has come mainly from yield increase and to a lesser extent from area expansion. Now the agricultural land available per capita is expected to decline (FAO, 2002) while revolutionary technologies for significantly higher production potential do not seem to be in sight. Furthermore, in high intensity agricultural production areas, yield increase seems to have reached a ceiling despite higher input use; in some cases, yields even decline, for example in the grain-producing areas of Punjab in India (Aulakh, 2005).

Water is one of the most precious natural resources for agricultural production and agriculture accounts for 70 percent of water use (FAO, 2002). It is predicted that by 2025 water consumption will exceed “blue water” availability if current trends continue (Ragab and Prudhomme, 2002). In the Indian state of Punjab, characterized by intensive irrigated agriculture, the groundwater table is falling at a rate of 0.7 m per year (Aulakh, 2005). However, the decline of freshwater resources is due not only to increased consumption, but to careless management. Agriculture contributes to the problem by wasting water and by sealing and compacting the soils so that excess water cannot infiltrate and recharge the aquifer – one of the causes of the growing number of flood catastrophes (DBU, 2002). In regions where water is already the limiting factor for agricultural production, this wasteful practice threatens the sustainability of agriculture. Rising temperatures and evapotranspiration rates combined with more erratic rainfall further aggravate the water problems in rainfed agriculture (Met Office, 2005).

Soil affects not only production, but also the management of other natural resources, such as water. Soil structure is strongly correlated with the organic matter content and the soil life. Organic matter stabilizes soil

[1] The views expressed in this paper are the personal opinion of the authors and do not necessarily quote the official policy of FAO.

aggregates, provides feed to soil life and acts as a sponge for soil water. With intensive tillage-based agriculture, the organic matter of soil is steadily decreasing, leading first to a decline in productivity, followed by the visible signs of degradation and finally desertification (Shaxon and Barber, 2003). The lack of yield response to high doses of fertilizer in the Indo-Gangetic Plains can be attributed to poor soil health resulting from over-exploitation (Aulakh, 2005). In the Indian states of Uttaranchal and Haryana, the organic carbon content in soils reaches minimum values of less than 0.1 percent (PDCSR, 2005). While soil degradation is more pronounced in tropical regions, it is also a phenomenon in moderate climatic zones; indeed, the world map of degraded soils indicates that nearly all agricultural lands show some level of soil degradation (FAO, 2000).

RESOURCE-CONSERVING TECHNOLOGIES

Resource-conserving technologies (RCT) have been developed in order to:

- reduce the use of and damage to natural resources through agricultural production; and
- increase the efficiency of resource utilization.

Most of these technologies target the two most crucial natural resources: water and soil, but some also affect the efficiency of other production resources and inputs (e.g. labour, farm power and fertilizer). Some of the more popular RCTs, particularly in irrigated or rice-based cropping systems, are described below.

Laser levelling

For surface irrigated areas it is essential to have a properly levelled surface with the appropriate inclination for the irrigation method adopted. Traditional farmers' methods for levelling by eyesight are not sufficiently accurate (particularly on larger plots), resulting in extended irrigation times, unnecessary water consumption and inefficient water use. The use of laser-guided equipment for the levelling of surface-irrigated fields has become economically feasible and accessible – through hiring services – even to lower-income farmers. Laser levelling reduces the unevenness of the field to about ±2 cm, resulting in better water application and distribution efficiency, improved water productivity, increased fertilizer efficiency and reduced weed pressure. Savings of up to 50 percent in wheat and 68 percent in rice have been reported (Jat *et al*., 2006).

Bed planting

Bed planting refers to a cropping system where the crop is grown on beds and the irrigation water is applied in furrows between the beds. This is common practice for row crops, but not for small grain crops such as wheat and rice. The technique offers a number of advantages, such as improved fertilizer efficiency, better weed control and reduced seed rate. It also saves irrigation water compared to a flat inundated field: the evaporation surface is reduced and water application and distribution efficiency are increased. In addition, the rooting environment is changed and the aeration of the bed zone is better than in flat planting. Reported water savings (compared to flat surfaces) reach 26 percent for wheat and 42 percent for transplanted rice, and yield increases 6.4 percent for wheat and 6.2 percent for rice (RWC-CIMMYT, 2003).

Direct seeding

Direct seeding of rice – compared with transplanting – may be considered an RCT:

- It saves labour and fuel.
- Seeding into dry soil saves water as there is no puddling.
- The total growing period from seed to seed is reduced by about 10 days.
- Yields and water efficiency of the subsequent rotation crops are increased (PDCSR, 2005).

On the other hand, weed management is more difficult in dry direct-seeded rice than in puddled and transplanted rice (RWC-CIMMYT, 2003).

Reduced tillage, zero tillage

Intensive soil tillage is the main cause of reduced soil organic matter and hence of soil degradation. Tillage accelerates the mineralization of organic matter and destroys the habitat of the soil life. On the contrary, when soil tillage is reduced or eliminated, soil life returns and the mineralization of soil organic matter slows down, resulting in better soil structure. Under zero tillage the mineralization of soil organic matter can be reduced to levels inferior to the input, converting the soil into a carbon sink (Reicosky, 2001). Zero tillage also results in water saving and improved water-use efficiency: since the soil is not exposed through tillage, the unproductive evaporation of water is reduced while water infiltration is facilitated (DBU, 2002). The potential water saving through zero tillage varies according to the cropping system and the climatic conditions. On average, water savings of 15 to 20 percent can be expected (PDCSR, 2005). Used in isolation, however, zero tillage can lead to problems with weed control, compaction or surface crusting, depending on the soil type.

Mulching and green manure

The supply of organic matter to the soil through mulching and green manure is important for maintaining and enhancing soil fertility. Mulching material can come from crop residues or green manure crops; it provides feed for the soil life and mineral nutrients for the plants. If legume crops are used as green manure they can supply up to 200 kg/ha of nitrogen to the soil; in the case of rice, this can result in mineral fertilizer savings of 50 to 75 percent (RWC-CIMMYT, 2003). The spreading of mulch on the soil surface reduces evaporation, saves water, protects from wind and water erosion, and suppresses weed growth.

Controlled traffic farming

Controlled traffic farming restricts any traffic in the field to the same tracks. While these tracks become heavily compacted, the rooting zone does not at all, resulting in better soil structure and higher yields. The area lost in the traffic zones is easily compensated for by better growth of plants adjacent to the tracks so that overall yields are usually higher than in conventional systems with random traffic (Kerr, 2001). Controlled traffic farming is the ideal complement to zero tillage or to bed planting systems, but it also provides advantages in conventional agriculture through time and fuel savings, since resistance to soil tillage in the compaction-free rooting zones is significantly lower and traction is more efficient when tyres work on compacted tracks (RWC-CIMMYT, 2003). In the latter case, either GPS (global positioning system) guidance or visible bed and furrow systems must be used to limit the tillage operation to the rooting zones and to not disturb the tracks.

SYNERGIES BETWEEN RESOURCE-CONSERVING TECHNOLOGIES

Resource-conserving technologies provide scope for synergy, for example, between bed planting and controlled traffic or mulching and zero tillage. Used in isolation, any of these technologies may face specific problems (e.g. surface crusting or weeds in direct seeding rice) or have limitations (e.g. zero tillage under irrigated conditions). The combination of resource-conserving technologies working in synergy is commonly referred to as "conservation agriculture" (CA).

Conservation agriculture

Conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits with high and sustained production levels while conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and external inputs – e.g. agrochemicals and nutrients of mineral or organic origin – are applied at an optimum level taking care to not interfere with or disrupt the biological processes. CA is characterized by three interlinked principles:

- minimum mechanical soil disturbance throughout the entire crop rotation;
- permanent organic soil cover; and
- diversified crop rotations in the case of annual crops or plant associations in the case of perennial crops.

During the last decade, CA has been gaining in popularity throughout the world and is now applied on about 95 million ha (Derpsch, 2005). Together with other organizations and stakeholders, FAO has been promoting and introducing CA in several countries in Latin America, Africa and Asia. CA adapts to different climatic conditions from the equatorial tropics to the vicinity of the polar circle and to different crops and cropping systems, including vegetables, root crops and paddy rice.

Zero tillage

When the soil is not tilled, the soil structure changes. A system of continuous macropores is established, facilitating water infiltration and soil aeration as well as root penetration into deeper zones. Soil organic matter content increases, with higher values near the surface, gradually decreasing with depth. Soil macro- and microfauna and flora is re-established resulting in better soil fertility.

Soil cover

The permanent soil cover through crops, mulch or green manure cover crops complements the effects of zero tillage by supplying substrate for soil organic matter build-up and for the soil life which is facilitated by not disturbing the soil. By protecting the soil surface, the mulch reduces evaporation, avoids crusting and suppresses weed growth. Problems experienced in direct seeding or zero tillage (applied in isolation) are thus reduced. It should also be noted that the application of zero tillage and direct seeding facilitates the management of residues which in conventional systems are often considered a problem.

Crop rotation

In addition to the phytosanitary and weed management benefits, crop rotation serves to open different soil horizons with different rooting types. While conventional agriculture "cultivates the land", using science and technology to dominate nature, conservation agriculture tries to "least interfere" with natural processes. Similar thoughts have been developed over the past 50 years in the Far East by Masanobu Fukuoka (1975) and applied in rice-based farming.

Permanent beds

In systems where surface irrigation is applied, bed planting results in water saving. Under CA, the beds are converted into permanent beds and soil tillage is limited to a periodic cleaning and reshaping of the furrows. The same permanent bed system is applicable under conservation agriculture also for crop rotations, which include crops grown on beds (e.g. for drainage purposes). The furrow distances and bed width must be harmonized for all crops in the rotation and for all mechanized traffic operations. In this way a permanent bed system leads also to controlled traffic, another RCT.

Direct seeding

Direct seeding is another complement to CA. Although transplanting of crops, including paddy rice, is possible under zero tillage, direct seeding is preferable for the reasons mentioned above. Direct seeding results in less soil movement than transplanting, which often involves some sort of strip tillage. CA facilitates direct seeding by reducing a number of problems encountered when direct seeding is applied in isolation (e.g. surface crusting or weed control).

Laser levelling

The benefits of laser levelling in conservation agriculture are as for conventional agriculture under surface irrigation conditions. To begin with, significant soil movement is required, and so laser levelling is considered an initial investment before converting to a permanent zero tillage cropping system (i.e. conservation agriculture). The investment in laser levelling lasts much longer than in conventional systems, since under CA no further soil tillage (which could upset the levelling of the field) is applied.

Effects of CA

Under CA the levels of soil erosion are inferior to the build-up of new soil. The soil under CA "grows" at an average rate of 1 mm per year due to the accumulation of soil organic matter. This growth continues until a new point of saturation is reached in the soil which takes 30 to 50 years (Crovetto, 1999). The organic matter levels rise by 0.1–0.2 percent per year due to the residues left on the soil surface, the remaining root biomass and the reduced mineralization. Within a crop rotation, different root systems structure different soil horizons and improve the efficiency of the soil nutrient use. In general the soil structure becomes more stable (Bot and Benites, 2005).

Soils under conservation agriculture also improve water efficiency. The increased amount of continuous vertical macropores facilitate the infiltration of rainwater into the ground and help recharge the aquifer. The increased soil organic matter levels improve the level of water accessibility to plants: 1 percent of organic matter in the soil profile can store water at a rate of 150 m^3/ha. The permanent soil cover and the avoidance of mechanical soil tillage reduce the unproductive evaporation of water, water-use efficiency is increased and a crop's water requirements can be reduced by about 30 percent under both irrigation and rainfed conditions (Bot and Benites, 2005). In addition to the quantitative benefits, reduced leaching of soil nutrients and farm chemicals together with reduced soil erosion lead to a significant improvement in the water quality in watersheds where CA is applied (Bassi, 2000; Saturnino and Landers, 2002).

CA can reduce the overall requirement for farm power and energy for field production by up to 60 percent compared to conventional farming (Doets, Best and Friedrich, 2000). This is due to the fact that the most power-intensive operations, such as tillage, are eliminated and equipment investment, particularly the number and size of tractors, is significantly reduced (Bistayev, 2002). CA produces a decline in the use of agrochemicals due to enhanced natural control processes: natural control of pests and diseases improves over time and experience in weed management through crop rotations also facilitates this long-term decline in agrochemical use (Saturnino and Landers, 2002). The same is true for mineral fertilizer: less fertilizer is lost through leaching and erosion and the different rooting systems recycle more soil nutrients from a larger soil volume, resulting in improved overall efficiency of fertilizer use in the long term with a significant reduction in the fertilizer requirements to maintain the production and soil nutrient levels over the crop rotation (Saturnino and Landers, 2002).

Climate and climate change

Recent decades have seen an increase in the frequency and strength of harsh climatic events, including very high precipitations as well as extended drought periods and extreme temperatures (Met Office, 2005). Agricultural production systems are highly vulnerable to these changes.

Conservation agriculture can assist in the adaptation to climate change, by improving the resilience of agricultural cropping systems and making them less vulnerable to abnormal climatic situations. Better soil structure and higher water infiltration rates reduce the danger of flooding and erosion following high intensity rainstorms (Saturnino and Landers, 2002). Increased soil organic matter levels improve the water-holding capacity and hence the ability to cope with extended drought periods. Yield variations under CA in extreme years (dry or wet) are less pronounced than under conventional agriculture (Shaxon and Barber, 2003; Bot and Benites, 2005).

But CA also helps mitigate the effects of climate change, at least with regard to the emission of greenhouse gases. With the increasing soil organic matter, soils under CA can retain carbon from carbon dioxide and store it safely for long periods of time. This carbon sequestration continues for 25 to 50 years before reaching a new plateau of saturation (Reicosky, 2001). The consumption of fossil fuel for agricultural production is significantly reduced under CA and burning of crop residues is completely eliminated, which also contributes to a reduction in greenhouse gas release. Soils under zero tillage – depending on the type of management – might also emit less nitrous oxide (Izaurralde *et al.*, 2004). With paddy rice in particular, the change to zero tillage systems combined with adequate water management can positively influence the release of other greenhouse gases, such as methane and nitrous oxides (Belder 2005; Gao 2006).

CONSERVATION AGRICULTURE IN RICE-BASED CROPPING SYSTEMS

Irrigated paddy rice has for a long time been considered a stable and sustainable cropping system, although it is far from being conservation agriculture (the puddling results in the destruction of the soil structure). However, irrigated rice is increasingly subject to pressures:

- The high fuel costs of puddling and the reduced availability of labour mean that there is pressure to change from transplanted to direct-seeded rice.
- The water consumption of traditionally puddled rice is too high in many regions – alternatives must be found and rice growing is already restricted in some areas: cultivation of summer rice, grown prior to the monsoon season, is not allowed in parts of northern India; in Karakalpakstan, adjacent to the Aral Sea in Uzbekistan, rice cultivation is restricted because of the scarce water resources and the high evaporation losses; in China, the paddy rice areas around the city of Beijing have been replaced by other crops due to the alarming fall in the ground-water table.
- The release of greenhouse gases such as methane is high in traditionally flooded rice (Gao, 2006).

Rice cultivation has therefore been adapted to conservation agriculture in several countries. Rice can be cultivated without puddling or permanent flooding by adopting resource-conserving technologies. FAO has been working on rice-based CA systems in China and the Democratic People's Republic of Korea, while in the Indo-Gangetic Plains the Rice-Wheat Consortium has been successfully introducing RCTs into rice-based cropping systems. Neither puddling nor zero tillage in rice result in higher yields of the non-rice crops in the crop rotations. The reported water saving through RCTs is usually higher in paddy rice than in other rotation crops (PDCSR, 2005). Cropping systems involving residue retention and zero tillage perform better in terms of profitability, yields and resource conservation, while conventional systems and zero tillage systems without residue retention are inferior. In addition to the resource-conserving effects, the cropping systems involving permanent zero tillage, so-called "double zero tillage"[2]

[2] Term used in rice-wheat cropping in South Asia to describe a system where both, rice and wheat, are cropped under zero tillage.

and residue retention result in significantly increased water infiltration rates (PDCSR, 2005).

The experiences and results obtained in CA in other cropping systems can be confirmed for rice-based cropping systems. This includes options for mitigating climate change by sequestering carbon in the soil and reducing the emission of other greenhouse gases (Gao, 2006). The Rice-Wheat Consortium has developed technologies which allow the application of conservation agriculture in rice-based cropping systems (RWC-CIMMYT, 2003): laser levelling, permanent bed planting and the retention of residues (including rice straw). In rice-wheat systems, the introduction of sesbania as a cover crop to bridge the gap between the wheat harvest and rice seeding is well accepted by the farming community. It helps with weed control and adds additional nitrogen and organic matter to the system. Direct seeding equipment has been developed and introduced to the market to seed different crops into residues and under zero tillage either on flat fields or raised beds (PAU, 2006). The latest model of the "Turbo Happy Seeder" can even cope with seeding into fresh rice straw (Dasmesh, 2006).

CONCLUSIONS

Resource-conserving technologies applied in isolation have advantages and disadvantages; they are not universally applicable as the problems can sometimes outweigh the benefits. However, by combining different resource-conserving technologies, synergies can be created to eliminate the disadvantages of single technologies and accumulate the benefits.

Different RCTs are successfully applied under the concept of conservation agriculture in different cropping systems around the world, allowing stable agricultural production without the known negative environmental impact. The Rice-Wheat Consortium of the Indo-Gangetic plains has been instrumental in adapting the concept of conservation agriculture to rice-based cropping systems, resulting in higher yields, greater profitability, enhanced soil fertility and better water-use efficiency – it represents a possible route towards sustainable agricultural production in rice-based systems. High water consumption is a particular concern. In regions where cropping mainly depends on groundwater for irrigation purposes and where the groundwater tables are falling dramatically, such as in the Punjab of India, water-saving technologies might not be sufficient to guarantee sustainability of the cropping systems. The combination of different RCTs – such as mulching, direct seeding and double zero tillage – results not only in water saving but also in increased infiltration rates (and hence the recharge of the aquifer during the monsoon season).

Combined resource-conserving technologies applied in conservation agriculture produce benefits for the farming sector, the environment and the general public, and it is therefore important to promote and adopt them. FAO and regional partners, such as the Rice-Wheat Consortium, can play an important role in this process.

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Agriculture de conservation: synergies entre technologies de conservation des ressources dans les systèmes de production à base de riz

L'Agriculture de conservation (AC) se définit comme un concept visant à un type de production agricole économe en ressources de base, tout en gardant une rentabilité acceptable et un niveau de production à la fois élevé et durable, le tout dans le respect de l'environnement. L'AC a pour principe de base l'intensification des processus biologiques, tant au dessus de la surface du sol qu'en dessous. Les interventions telles que le labour physique du sol sont maintenues à un minimum absolu, et le recours aux intrants extérieurs tels que produits agrochimiques et nutriments d'origine minérale ou biologique est optimisé, de façon à respecter les processus biologiques sans leur opposer d'obstacle ou de contrainte. L'AC se caractérise par trois principes liés entre eux:

1. Un minimum de bouleversement mécanique du sol tout au long du cycle cultural.
2. La permanence d'un couvert organique du sol.
3. Rotations de cultures diversifiées dans le cas des cultures annuelles, et associations de cultures diversifiées en cas de cultures pérennes.

Les façons culturales traditionnelles en riziculture font appel à un travail du sol intensif à l'occasion de la mise en boue – ce qui n'est pas compatible avec le concept de l'AC. Cependant, la riziculture peut s'adapter aux principes de l'AC tels qu'ils sont mis en œuvre de façon de plus en plus courante. Outre les avantages qu'on lui connaît déjà, l'application de l'AC à la riziculture conduirait également à une économie d'eau (une ressource

de plus en plus rare) et contribuerait à la solution du problème des émissions de gaz d'effet de serre à partir des rizières – sans pour autant compromettre le potentiel de production. Le document explique le concept et les principes de l'AC et examine l'étendue de son expansion actuelle à travers le monde. On y trouvera des exemples factuels d'introduction de l'AC dans des systèmes de production agricole basés sur le riz, et une vue générale de ses avantages, tant déjà démontrés qu'attendus à l'avenir.

Agricultura de conservación: sinergias de las tecnologías de conservación de los recursos en los sistemas basados en el arroz

La agricultura de conservación se define como un concepto de producción agrícola con ahorro de recursos que procura obtener ganancias aceptables y niveles de producción elevados y constantes y asegurar, al mismo tiempo, la conservación del medio ambiente. Este enfoque se basa en la potenciación de los procesos biológicos naturales, tanto por encima como por debajo del suelo. En la agricultura de conservación se reducen lo más posible intervenciones como la labranza mecánica del suelo, mientras que insumos externos tales como agroquímicos y nutrientes de origen mineral u orgánico se aplican en la cantidad óptima para no interferir con los procesos biológicos ni perturbarlos. Tres principios relacionados entre sí caracterizan la agricultura de conservación:

1. Perturbación mecánica del suelo reducida al mínimo en todo el ámbito de la rotación de cultivos.
2. Cubierta orgánica permanente del suelo.
3. Rotación diversificada de cultivos en el caso de los cultivos anuales, o asociación de plantas en el de los perennes.

Las prácticas tradicionales empleadas en los arrozales se basan en la labranza intensiva del suelo durante el enfangado, lo cual no es compatible con los principios de la agricultura de conservación. Sin embargo, es posible adaptar el cultivo de arroz a estos principios, cuya aplicación está cada vez más difundida. Además de sus reconocidas ventajas, en el caso del arroz la agricultura de conservación también permitiría ahorrar agua (un recurso que escasea cada vez más) y ayudaría a hacer frente al problema de las emisiones de gases de invernadero procedentes de los arrozales sin sacrificar su potencial productivo. El documento explica el concepto y los principios de la agricultura de conservación y el alcance de su aplicación actual en todo el mundo, proporciona ejemplos de su introducción en sistemas de cultivo basados en el arroz, y traza un cuadro de sus ventajas probadas y previstas.

Energy generation from rice residues – a review of technological options, opportunities and challenges

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INTRODUCTION

Reliable and adequate supplies of energy are a fundamental necessity for economic growth and development of any community or country. This paper presents technological aspects of the extraction and utilization of energy from rice straw and rice husks. Drawing from case studies of major rice-producing countries in Asia and Africa, it discusses constraints militating against the application of these technologies in rural areas in developing countries and presents possible areas for intervention by various stakeholders.

TECHNOLOGIES FOR ENERGY PRODUCTION FROM RICE RESIDUES

Properties of importance in energy generation

Rice straw and rice husk are lignocellulosic materials with a low bulk density and a relatively high silica content. The main chemical components on a dry basis are cellulose, hemicelluloses, lignin and ash. Lignin is found in the middle lamella and adjacent primary cell walls of the residue tissue, and as such it encapsulates the cellulose and hemicellulose fractions found primarily in the secondary cell walls. Rice straw and husk have relatively high proportions of silica-rich ash. Table 1 presents the main physical properties and chemical composition data that are important in the use of rice straw and rice husks as feedstock for energy generation. Data are also presented on a selection of other biomass fuels for comparison. The implications of these properties for energy generation processes are discussed herein.

Steps in the energy conversion chain

The chain of operations involved in obtaining energy from rice residues comprises the following five steps:

- collection, handling and delivery to a pre-treatment site;
- pre-treatment to prepare the biomass for subsequent conversion;
- conversion of the residue to fuel;
- refining of the fuel; and
- conversion of the fuel into usable energy.

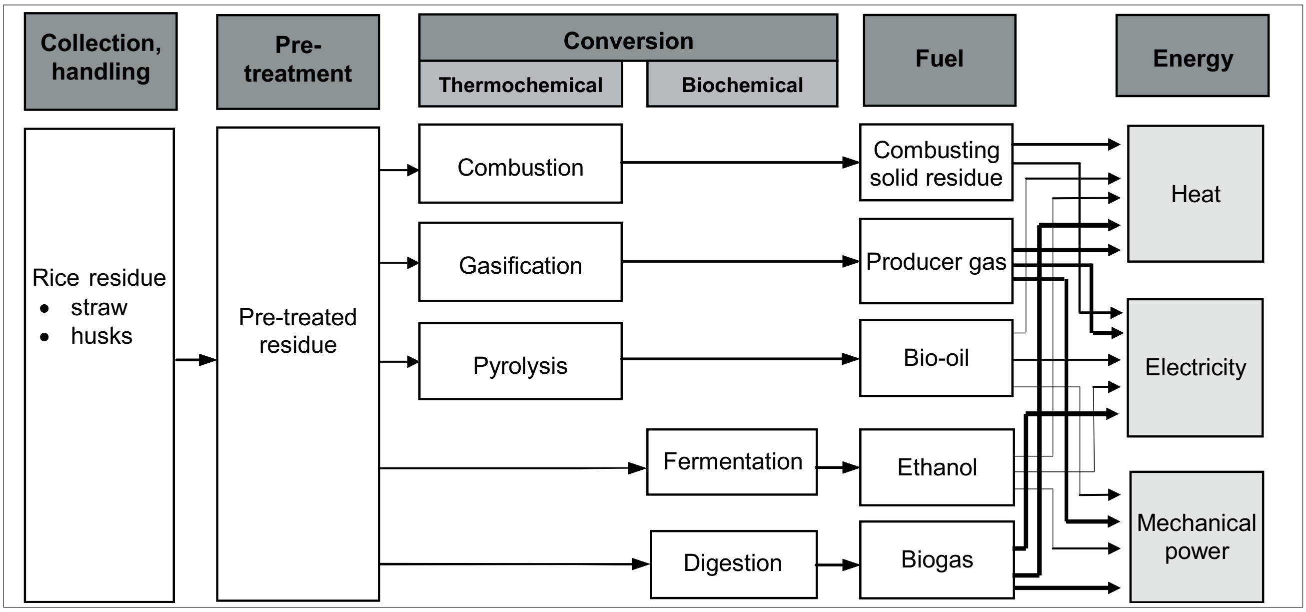
The conversion technology applied dictates the pathway taken to implement each of the five steps in the

TABLE 1
Physical properties and chemical composition of rice residues and other biomass

	Rice straw	Rice husk	Sugar cane bagasse	Eucalyptus wood	Cattle manure
Moisture content (%)	7–13	10–13	48	52	78
Bulk density (*kg/m*^{3})	60	130	160	500	
Chemical composition (%)					
cellulose	35	47	41	43	
hemicellulose	35	18	24	35	
lignin	6	13	18	22	
Carbon-nitrogen ratio	53	102	118	160	18
Ash content (*% of dry matter*)	19	20	2–5	<1	
Silica content of ash (%)	75	91	47		
Residue-to-crop ratio[a] (*kg/kg*)	1.25	0.25	0.29		

[a] For rice straw and rice husk the crop refers to de-husked unpolished grain

FIGURE 1
Pathways for producing energy from rice residues



Source: Bridgwater, 2006 (adapted).

chain (Figure 1). However, irrespective of which pathway is taken, the principal technological challenge that must be faced is to cost-effectively achieve an optimal net positive energy balance for the chain while minimizing the negative effects on the environment and fostering the economic and social development of local communities. As energy – mostly provided by fossil fuels – is required to carry out operations in the chain, an appropriate technology package is required involving minimal energy input (in order to maintain a positive energy balance) and resulting in minimal emission of greenhouse gases and other atmospheric pollutants.

Collection and handling of rice residues

Residues are collected, handled and transported to the site where subsequent operations are carried out. For each kilogram of rice grain, 0.25 kg of husks and 1.25 kg of straw residues are generated (Table 1). Husks are found in high concentrations at the mill where dehusking takes place and can therefore be readily collected and used for energy generation to power various mill operations. In comparison, straw is usually strewn over wide areas in harvested fields and may require substantial inputs of energy – often from fossil fuels – for baling, temporary storage, drying and transportation to the pre-treatment or conversion site.

Pre-treatment

Pre-treatment turns residues into a form that facilitates handling, improves efficiency and limits the adverse environmental impacts of conversion processes. The main pre-treatment steps are described below:

- **Drying** may be done naturally – sun-drying – or by artificial means in an appropriately designed drier.
- **Size reduction** processes (e.g. chopping and maceration) increase the surface area available for, and hence the rate of, biochemical conversion reactions.
- Given the high resistance of lignin to biodegradation, **delignification** is required to expose the cellulose and hemicellulose fractions to biochemical conversion reactions. One method is to steep in an alkali (e.g. sodium hydroxide) and then wash with water (Barreveld, 1989; Marchaim, 1992).
- **Densification** is applied to residues intended for direct combustion and gasification. It improves combustion characteristics, increasing the conversion efficiency and reducing environmental pollutants. It facilitates the handling, transportation and storage of residues. Rice straw can be densified by baling during collection, or by size reduction followed by briquetting; rice husks can be densified by briquetting, after (or without) prior size reduction (Beagle, 1978; Grover and Mishra, 1996; Assureira, 2002).

Conversion

Several technologies exist for converting rice residues into usable energy, including: thermochemical conversion through direct combustion, gasification and fast pyrolysis; and biochemical conversion through anaerobic digestion and fermentation (Figure 1).

Thermochemical conversion processes

Direct combustion. Heat energy is produced during combustion of rice straw or rice husks in stoves, furnaces and kilns. These devices must be properly designed to ensure proper operation, optimal conversion efficiency and heat efficiency. The feeding system must be designed to meter residue at an optimal rate into the combustion chamber. Densification into pellets (see above) improves the handling and combustion characteristics of residues. Rice residues have a high ash content and provision must be made to evacuate ash as fast as it forms in order not to impede the airflow into the combustion area. The design and maintenance plan must take into account the fact that the heat transfer efficiency will be decreased by ash deposits on the combustion chamber walls and that, due to its high silica content, ash is very abrasive and corrosive of metals (FAO, 1993; Robinson, Hollingdale and Reupke,1993; Himpe, 1997; Badger, 1999).

Gasification. Gasification is the thermal conversion of rice straw and rice husk into producer gas (a combustible mixture of carbon monoxide, hydrogen, methane, nitrogen and carbon dioxide). Compared with direct combustion, gasification gives greater flexibility in the use of the fuel and higher conversion efficiency (Stout 1989; FAO, 1999). A residue of ash is formed in the process, and so the design of the combustion chamber is as for direct combustion.

Fast pyrolysis (bio-oil production). Bio-oil is a type of liquid fuel formed through the condensation of gases generated by the decomposition of rice residues by fast pyrolysis. It is a complex mixture of hydrocarbons, phenolic materials and water – the latter acts as a diluent to maintain homogeneity and optimal viscosity. Fast pyrolysis is an advanced process with carefully controlled parameters ensuring high heat transfer rates to the feedstock; a crucial pre-treatment step is size reduction of the residue to very finely divided pieces. Fast pyrolysis for conversion of biomass to organic liquids in high yields became a technical reality 25 years ago (Scott and Legge, 1999; Bridgwater, 2006).

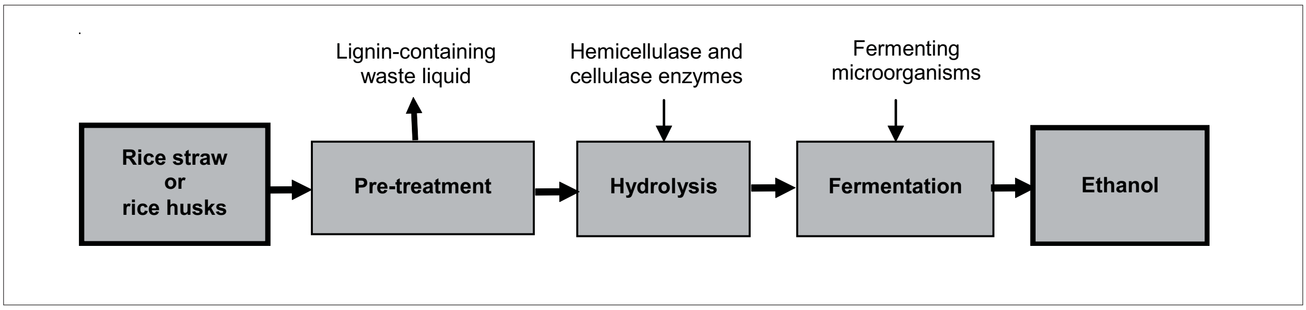
Biochemical conversion processes

Fermentation (ethanol production). Biochemical conversion processes require two main pre-processing operations – size reduction and delignification (see above). Following these operations, the production of ethanol from rice residues involves two main steps: enzymatic hydrolysis of cellulose and hemicellulose into simple hexose and pentose sugars, and fermentation of simple sugars into ethanol (Figure 2).

In recent years there has been a marked acceleration in the development of economically feasible technologies for lignocellulosic ethanol production. These technologies are now commercialized and numerous commercial plants are being developed in the United States, Canada, Brazil, Europe and Japan (Miyamoto, 1997; Solomon, Barnes and Halvorsen, 2007; Yang and Lu, 2007).

Anaerobic digestion. Anaerobic digestion of biomass in semi-continuous digesters is one of the bioenergy generation technologies that have been applied successfully in small-scale operations in rural areas of developing

FIGURE 2
Steps in ethanol production from rice residues



countries. Anaerobic digestion generates biogas, a gaseous mixture of methane, carbon dioxide, hydrogen with small quantities of carbon monoxide, oxygen and hydrogen sulphide. A carbon-to-nitrogen ratio of around 30 is the threshold above which it is considered that the quantity of nitrogen available in the digestion feedstock may be insufficient to support the metabolic processes of the microbiological populations involved. With carbon-to-nitrogen ratios that exceed this value by far (Table 1), rice residues are unsuitable as anaerobic digestion feedstock; however, they may be used if the nitrogen content is raised by mixing with appropriate nitrogen-rich materials (e.g. animal manure, night soil and ammonia). Ammonia also has a delignification effect on ligno-cellulosic materials, and ammoniation may therefore be carried out to achieve both delignification and nitrogen-content adjustment of rice residues. The fibrous nature of rice residues may pose a problem, as residues tend to float and form a hard scum on the surface of digester contents; in this case, special measures must be taken – maceration of the slurry before feeding into the digester and intermittent or continuous mechanical mixing during digestion (Barreveld, 1989; Marchaim, 1992).

Energy utilization

Fuels obtained from rice residues can provide energy in various forms: heat, motive power and electricity (Figure 1). Table 2 shows the energy content of rice residue fuels and data for other comparable fuel products.

Heat

Heat energy produced during direct combustion of rice residues can be used for domestic cooking and heating, as well as for providing process heat in small- and medium-scale industrial operations (e.g. rice parboiling and drying, tobacco curing, bricks and ceramics production, pottery etc.). It is also possible to generate heat by burning liquid fuels (bio-oil and ethanol) and gaseous fuels (producer gas and biogas) derived from residues (Figure 1). Heat generated through direct combustion of residues, or through burning liquid and gaseous derivative fuels, can be used to generate boiler steam to provide heat for use in domestic or industrial operations.

Mechanical power

Gaseous fuels (biogas and producer gas) and liquid fuels (bio-oil and ethanol) obtained from rice residues can be used in internal combustion engines to provide shaft power for pumps, crop processing machinery (e.g. dryer fans and grain threshers), refrigeration systems and other devices in rural areas.

Liquid fuels offer the advantage of easy storage and transportation, and are therefore more suitable than gaseous fuels for powering vehicles and mobile equipment. Unlike ethanol, bio-oil does not mix easily with conventional fossil fuels and has to substitute, rather than be blended with, gasoline or diesel fuel in engines.

Producer gas and biogas are cleaned by bubbling through scrubbers and filters before being used in engines. Both gases contain high proportions of carbon dioxide which is incombustible. Biogas also contains hydrogen sulphide – a corrosive substance that increases engine wear and burns to form sulphur dioxide, itself corrosive and a contributor to acid rain. During gasification, tars and particulates (ash and char) get entrained in the resulting producer gas. They cause damage to engines and lead to environmental pollution (FAO, 1990; Marchaim, 1992; Jenkins, 1999; FAO, 1999; Wheeler, 2000).

Electricity

There are three ways of obtaining electrical power using rice residues as energy feedstock:

TABLE 2
Heating value of rice residue fuels and other comparable fuels

Solid fuels	Heating value (*MJ/kg dry matter*)	Liquid fuels	Heating value (*MJ/kg*)	Gaseous fuels	Heating value (MJ/m^3)
Rice straw	15.32	Bio-oil	17.00	Producer gas	5.90
Rice husk	15.25	Ethanol	26.80	Biogas	20–29
Eucalyptus wood	18.00	Gasoline	44.37	Methane	38.00
Sugar cane bagasse	16.22				
Coal	30.20				

- Gaseous or liquid fuel derivates can be used to run an internal combustion engine providing shaft power to an electricity generator.
- Gaseous fuel derivatives can be used in a gas turbine running an electricity generator.
- Steam generated in a boiler (see above) can be used to operate a turbine that in turn runs an electricity generator.

Electricity generated using any of these three methods can be used in decentralized or grid-connected systems for domestic or industrial applications.

Combined heat and power (CHP)

Rice residues can be used in CHP (cogeneration) systems to simultaneously generate heat and electricity by using either flue gases from electricity-generating gas turbines or waste steam from electricity-generating steam turbines to provide heat for industrial or domestic use. Cogeneration systems are in wide use in rice processing plants, where rice husk from milling is used in boiler furnaces for raising steam which is in turn used for generating electricity to power milling operations. The steam which exits the steam turbine is used to provide process heat for drying and parboiling operations.

Utilization of by-products

The commercial utilization of by-products formed in the bioenergy chain increases the economic feasibility and commercial viability of systems for generating energy from rice residues.

Direct combustion and gasification

A substantial quantity of ash is generated as a by-product during direct combustion and gasification. The ash is rich in silica (Table 1), is highly porous and has a very high surface area. It is a good heat insulator and is therefore suitable for incorporation in refractory bricks and for ensuring uniform cooling and solidification of steel. It can also be used as a fertilizer, oil absorbent, anti-caking agent, filter medium, filler in rubber components, additive in cement and as a source of silica for industrial operations such as glass making (Beagle, 1978; Robinson, Hollingdale and Reupke, 1993).

Anaerobic digestion

The effluent from semi-continuous anaerobic digesters can be used in soil fertility improvement and conditioning, as well as in animal feed and fishmeal (Marchaim, 1992; Wheeler; 2000).

Cellulosic ethanol production

The main by-product from ethanol production is lignin from delignification (Figure 2). With a heating value of 26.63 MJ/kg, lignin is a bona fide fuel material that can be used to provide industrial process heat. Lignin can also be used as raw material for producing a variety of high-value chemicals such as phenols (Scott and Legge, 1999; Bridgwater, 2006).

Bio-oil production

Non-condensable gases and the char residue formed during the fast pyrolysis of rice residues can be used as stand-alone fuels to provide heat in various industrial operations (Scott and Legge, 1999; Bridgwater, 2006).

OVERCOMING CONSTRAINTS IN THE USE OF RICE RESIDUES

The various constraints to the adoption and use of technologies for converting rice residues and other agricultural biomass into energy in rural areas in developing countries are outlined below and the action to be taken by various stakeholders is highlighted (Woods and Hall, 1994; FAO, 1997; Kartha and Larson, 2000; Leung, Yin and Wu, 2004; FAO, 2005; von Braun and Pachauri, 2006; Ahiduzzaman, 2007). Case examples from Asia and Africa are then presented.

Constraints and possible interventions

Policies and institutional framework

In many countries there are no policies providing an environment conducive to the successful development and operation of energy technologies based on biomass in general and rice residues in particular.

Governments must formulate policies and programmes for the bio-energy sector, as part of wider strategic plans for economic development and improvement of living standards in rural areas. Such policies should take into account the multifaceted nature of residue energy production and utilization, with consideration for the technical, economic and socials aspects.

A framework of relevant institutions is required to support residue energy systems. The framework should involve all government ministries and public institutions dealing with the relevant sectors (i.e. agriculture, energy, rural development, environment, planning, industrial development, public works, infrastructure etc.). It should also have links with relevant private sector partner institutions, including financial institutions, advisory services, NGOs, community organizations and utility companies. The policy and institutional framework must develop and enforce rules and regulations for: guiding production, marketing and utilization of energy; providing criteria for quality grades and standards; minimizing negative environmental and health impacts; and applying various pricing instruments and incentives such as subsidies and taxes. International organizations have an important role in providing financial and technical assistance in the development of institutional frameworks, strategies, policies and programmes.

Infrastructure

Many countries lack the infrastructure base required to support the development and utilization of bioenergy technologies.

Governments (local and national) are responsible for providing the infrastructure and infrastructure services that are public goods, and they must also provide the necessary environment and incentives for private sector investment in other infrastructures (residue storage structures, fuel storage structures, pipelines etc.).

Where feasible, local communities should be involved in the construction and maintenance of infrastructure, for example, laying pipe networks to distribute biogas from community digesters to homes. Assistance from international agencies is required to undertake the analysis of infrastructure needs, identify suitable infrastructure and operational models, mobilize required financial resources, develop and implement guidelines and standards at international level, and provide technical and financial assistance in infrastructure development programmes.

Awareness, data and information

There is a lack of awareness of the various aspects of energy generation from rice residues among feedstock producers, technical support personnel, researchers, private sector individuals, policy-makers and energy users. They are not familiar with the technical options for energy generation or the advantages compared to conventional fuels, and they are unaware of the opportunities for job creation and income generation, as well as the social and environmental implications. When people are aware, they are nevertheless without reliable and accurate information concerning critical elements such as potential resources, energy demand, energy utilization and related socio-economic factors.

Governments and private sector stakeholders should carry out awareness-raising campaigns and pilot demonstration projects; they should take appropriate action to generate the data necessary for technology selection and design, policy formulation and development planning. In addition, they should disseminate information dealing with residue utilization, using the available media (printed bulletins and newsletters, radio, television, Internet etc.) and targeting specific interest groups or the public at large.

Through normative (and other) studies, international organizations need to generate relevant data and information; they should also carry out activities within programmes and projects to facilitate access to information and strengthen information exchange networks.

Capital

A very important factor inhibiting the widespread adoption of residue transformation and utilization technologies in rural areas is the lack of capital to cover investment and operations costs.

Measures are required to improve the access of rural dwellers, community groups, potential business people and micro-enterprises to credit and finance schemes that are suitable for local conditions. Governments need to set up an institutional framework and incentives (e.g. low interest or subsidized loans) in order to encourage investment by the private sector. International organizations should provide assistance in developing appropriate institutional frameworks and microcredit schemes.

Skills

The adoption and application of technologies required is hindered by the low level of technical and business management skills and lack of organizational capacities in rural areas. The people who plan the development of bioenergy systems and those that provide technical support for operating these systems often lack the necessary technical and managerial skills.

Training programmes should be organized by governments and the private sector to impart the required skills to policy-makers and planners, and to develop a critical mass of technical personnel familiar with the technologies. Training programmes are required to target relevant rural dwellers, community groups and micro-enterprises and to cover the basic technical aspects, small business management and marketing. International organizations can provide financial and technical assistance in projects with components related to training and demonstration.

Technology

Affordable, easy-to-operate, economically viable, socially acceptable and environmentally friendly technologies adapted to local conditions are required for the production and utilization of energy from rice residues. Basic and applied research is needed to develop new technologies or adapt existing ones to local conditions. Research is required with regard to the technical aspects (e.g. improving conversion efficiency), environmental impacts and socio-economic implications of technology packages, and an appropriate institutional framework must be put in place to support the research, development and demonstration of technologies. The private sector is central to technology development: it carries out its own investigations, provides grants for research and collaborates with research and teaching institutions in their activities. International agencies can provide technical and financial assistance to facilitate technology and knowledge transfer and to strengthen national capacity in assessing, developing and adapting technologies.

Case example 1: Improved rice husk furnace for rice parboiling in Bangladesh

Biomass is by far the dominant energy source in Bangladesh, accounting for approximately 67 percent of the country's total energy consumption. A survey of rice mills revealed that an average 187 kg of husks are produced per tonne of paddy and 70 percent of husks are consumed by the mills themselves for energy generation. Traditionally, mills use poorly designed furnaces to power boilers, leading to poor thermal efficiency and high pollution. Carbon monoxide levels in exhaust gases are double the threshold established by the Ministry of Environment and Forestry.

Collaboration between the Bangladesh Rice Research Institute and the Natural Resources Institute (United Kingdom) led to the design of an improved system featuring: better thermal efficiency, improved fuel conversion efficiency, shorter parboiling time, and a level of carbon monoxide in the flue gas well within legally permitted limits. Studies carried out by a national research organization and technical assistance provided by a development agency were instrumental in the development of an economically viable and environmentally sustainable rice residue conversion technology (Ahiduzzaman, 2007 – based on).

Case example 2: Setting policy in Viet Nam

In 2003, Viet Nam passed a decree (Prime Minister's Decree No.102/2003/ND-CP) to guide the rational exploitation of energy resources in meeting the growing energy demands of the national economy while protecting the environment and achieving sustainable socio-economic development. The decree outlined the legal instruments (e.g. tax preferences) for the importation of energy-saving technologies, and directed ministries and other public sector agencies to allocate funding for scientific, technological and environment research targeting the efficient use of energy. The decree also required these agencies to disseminate relevant information using the mass media and to carry out awareness-raising activities (The National Legal Database, 2003).

Case example 3: Incentives for cellulosic alcohol in China

China imports close to 43 percent of its petroleum requirements and in 2005 petroleum imports increased to about 865 million barrels. In order to reduce dependence on imports, the Government is taking measures to promote the use of ethanol as a petroleum substitute. Given the food security implications of obtaining ethanol from corn, cellulosic ethanol was identified as a more viable substitute for petroleum than corn alcohol.

In 2005, cellulosic ethanol was selected as one of the key environmental protection and energy development technologies to receive priority support under the national strategic high-technology research and development programme. In order to attract foreign technology and capital, the Government recently announced plans to invest US$ 5 billion over the next 10 years in ethanol capacity expansion with a focus on cellulosic ethanol (Yang and Lu, 2007 – based on).

Case example 4: Technical assistance by FAO in Egypt

Through imaginative agronomic programmes and technical assistance to growers, Egypt's rice production systems have become some of the highest-yielding in the world. While high yields have secured the availability of rice grain for feeding the population and earning foreign exchange, large quantities of residue are generated, constituting a major disposal problem. Almost 2 million tonnes of rice straw are burned on-farm resulting in greenhouse gas emissions, aerial pollution and the loss of potential revenue that could be generated from processes using straw as raw material.

In December 2006, FAO started a 20-month pilot technical cooperation project (TCP) in the Nile Delta; one of the key specific objectives is to analyse the technical and economic feasibility of using rice straw as feedstock for energy generation, and findings will be used to design strategies within a proposal for a follow-up project. This is an example of how an international organization can successfully provide technical and financial assistance to support studies, information generation and the design of future interventions in a national programme.

CONCLUSION

Rice residues have immense potential as an energy source in rural areas of developing countries. Technologies applied in the conversion and utilization chain should result in favourable carbon and energy balances and in minimal particulate and greenhouse gas emissions. To overcome the constraints to the adoption and use of these technologies in rural areas, action is required by the public sector, the private sector, local communities, development agencies and international organizations. An appropriate policy, institutional and regulatory framework is needed to create an environment that is conducive to the development and operation of these technologies. Awareness needs to be raised about energy generation from rice residues, while access to capital and relevant information needs to be facilitated. The technical and managerial capacity of various stakeholders needs to be strengthened, and support has to be provided for research, development and demonstration of low-cost technologies appropriate for the particular locality.

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Production d’énergie à partir des résidus de la riziculture – un inventaire des options technologiques, des opportunités et des obstacles à surmonter

Un approvisionnement fiable et suffisant en énergie est une condition fondamentale de la croissance économique et du développement d’un pays ou d’une communauté. L’utilisation domestique de l’énergie couvre la cuisine, l’éclairage et le chauffage; l’agriculture quant à elle en a besoin pour actionner les machines agricoles; tandis que la totalité des secteurs industriels qui traitent des matières premières jusqu’au stade du produit fini utilisent de l’énergie sous une forme ou sous une autre. La disponibilité d’énergie est un facteur important de la création d’emplois et de services dans le domaine de la santé, de l’éducation et de l’assainissement, et constitue en conséquence un facteur clé de l’amélioration du niveau de vie.

Le recours aux carburants d’origine fossile pour la production d’énergie constitue un problème pour la durabilité du développement rural dans les pays en voie de développement. Le plus souvent, ces carburants sont importés et leur utilisation compromet la sécurité énergétique du pays. Les prix des carburants pétroliers sont liés à la conjoncture géopolitique et tendent en conséquence à être imprévisibles, outre leur niveau trop élevé pour une grande partie de la population. La combustion des carburants fossiles relâche dans l’atmosphère du dioxyde de carbone et autres gaz d’effet de serre, sans compter les produits polluants à l’origine de smog, d’intoxications au plomb, de pluies acides et de divers autres problèmes localisés de qualité de l’air.

La production d’énergie à partir de résidus végétaux est une option économiquement viable dans les pays en voie de développement, où les résidus végétaux sont généralement abondants tant en raison de la production agricole que des activités de transformation de ses produits. Les résidus végétaux sont renouvelables à un horizon temporel relativement rapproché, et leur influence sur le cycle du carbone tend à être moins marquée que celle des carburants fossiles. De plus, l’utilisation de résidus végétaux pour la production d’énergie limite la déforestation induite par la production non durable de charbon de bois et de bois de feu. Contrairement à la mise en culture de plantes destinées à la production d’énergie, l’utilisation énergétique de résidus végétaux ne conduit pas à des

conflits sur l’utilisation des ressources foncières, et le risque est moindre – par comparaison avec la production de bioéthanol à partir de canne à sucre ou de maïs, et de biodiesel à partir d’oléagineux – d’assister à un impact négatif sur la disponibilité de nourriture. Les industries basées sur la valorisation énergétique des résidus végétaux sont une source potentielle d’emploi rural.

Les options technologiques retenues pour la production d’énergie à partir de résidus végétaux doivent être concurrentielles en termes économiques, mais également rester compatibles avec la durabilité environnementale et apporter un plus au développement économique et social des communautés locales. Les carburants produits doivent, pour se faire accepter et utiliser à grande échelle, avoir un prix abordable et une qualité irréprochable, tout en présentant une souplesse d’utilisation convenable.

Le présent document examine les aspects technologiques de l’extraction et de l’utilisation d’énergie à partir des pailles et des balles de riz. Sur la base d’études de cas portant sur les principaux pays producteurs d’Asie et d’Afrique, les contraintes qui s’opposent à l’adoption de ces techniques sont passées en revue, et des possibilités d’intervention par diverses parties prenantes sont développées.

Generar energía a partir de residuos de arroz Un examen de las opciones tecnológicas y de las oportunidades y desafíos que se plantean

Un suministro fiable y adecuado de energía es fundamental para el crecimiento económico y para el desarrollo de toda comunidad o país. Los usos domésticos de la energía comprenden su empleo para cocinar así como para calefacción e iluminación; en el campo se necesita energía para accionar la maquinaria agrícola; por último, todas las actividades industriales requieren una u otra forma de energía para convertir la materia prima en su producto final. La disponibilidad de energía es un factor importante para proporcionar empleo, asistencia médica, educación y saneamiento; se trata, pues, de un elemento esencial para la mejora de los medios de vida.

El suministro de energía a partir de combustibles fósiles entraña problemas para el desarrollo sostenible de las zonas rurales en los países en desarrollo. Esos combustibles muy a menudo son importados, lo cual compromete la seguridad energética del país. Los precios de los combustibles derivados del petróleo están vinculados a los acontecimientos políticos mundiales y, por consiguiente, son difíciles de predecir, además de no ser asequibles para una parte considerable de la población. Por otra parte, su combustión libera dióxido de carbono y otros gases de efecto invernadero, así como sustancias que forman nieblas contaminantes y provocan fenómenos de toxicidad, depósitos de ácidos y varios otros problemas locales relacionados con la calidad del aire.

La producción de energía a partir de residuos vegetales representa una opción viable en las zonas rurales de los países en desarrollo, donde habitualmente es posible encontrar gran cantidad de residuos de la producción de cultivos y las actividades de elaboración agrícola. Los residuos vegetales son renovables en un tiempo relativamente breve y tienden, en comparación con los combustibles fósiles, a tener un efecto más neutro respecto de las emisiones de carbono. Además, el uso de residuos vegetales para generar energía reduce la práctica no sostenible de la deforestación con miras a producir leña y carbón vegetal. A diferencia de la producción de cultivos energéticos, el suministro de energía a partir de residuos evita el conflicto con otras formas de uso de la tierra. Además, con respecto a la obtención de bioalcohol del maíz y la caña de azúcar, o a la producción de biodiésel a partir de oleaginosas, tiene menos probabilidades de influir negativamente en la disponibilidad de alimentos. Las industrias que se basan en la producción de energía a partir de residuos vegetales constituyen una posible fuente de generación de empleo en las zonas rurales.

Las opciones tecnológicas que se elijan para esta producción energética deben ser competitivas desde el punto de vista económico, pero a la vez compatibles con la sostenibilidad ambiental; deben, además, fomentar el desarrollo económico y social de las comunidades locales. Para ganarse una aceptabilidad y una utilización amplias los combustibles deben tener precios abordables y ser de calidad óptima, y deben dar lugar a una utilización flexible.

En este documento se examinan los aspectos tecnológicos de la extracción de energía de la paja y los hollejos de arroz, así como el uso de dicha energía. Sobre la base de estudios de caso relativos a importantes países productores de arroz de Asia y África se examinan los obstáculos que se oponen a la aplicación de estas tecnologías, y se presentan las posibles esferas de intervención de los distintos grupos interesados.

Weed management in European rice fields

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INTRODUCTION

Rice is cultivated in the European Union on submerged land in the coastal plains, deltas and river basins, covering a total area of about 400 000 ha, all in the Mediterranean countries. The average crop yields are between 4.80 and 7.25 tonnes/ha, depending on the environmental conditions and water availability. Milled rice consumption ranges from about 6.0–7.0 kg/caput (17 kg/caput in Portugal) in the Mediterranean areas, where the crop is traditionally grown, to 3.5–5.3 kg/caput in non-rice-producing countries (Ferrero, 2005). In Europe's rice-producing countries, most of the rice consumed is from *japonica* varieties, while in northern countries mostly *indica* varieties are consumed.

The ecological conditions of rice cultivation vary with climates ranging from temperate to subtropical (Nguyen and Ferrero, 2006). At higher latitudes (Italy, northern Spain, France) rainfall is concentrated during the first stages of the crop (April–June) and during the harvesting period. Average temperatures in these areas range from 10°–12°C during crop germination to 20°–25°C at flowering time.

Rice is mostly grown on fine-textured, poorly drained soils, where the pH is between 4 and 8 and organic matter between 0.5 and 10 percent. In coastal areas, soils are frequently saline or very saline. Most of the irrigation water is obtained from rivers (Po in Italy, Ebro and Guadalquivir in Spain, Tejo in Portugal, Axios in Greece etc.) and lakes. In European areas, rice is mostly cultivated under permanent flooding, adopting mainly the "flow-through" system, with short periods during which the soil is dried to favour rice rooting (in the early stages) or weed control treatments. Water is kept at a level ranging from 5 cm (in the early stages) to 12 cm (from tillering to flowering).

Rice is mostly cultivated as a monocrop in the same field for many years. Seedbeds are usually prepared by ploughing in autumn or spring at a depth of 20 cm, incorporating residues of the previous crop into the soil. Rice is mainly directly seeded, broadcasting seeds in flooded fields with fertilizer spreaders or by airplane (in Spain).

Fertilizer rates are typically:

- N: 80–120 kg/ha (50% in pre-planting and 50% in post-planting, using urea or other ammoniac fertilizers)
- P: 60–80 kg/ha (pre-seeding)
- K: 100–150 kg/ha (pre-seeding)

WEED SCENARIOS

Weeds are considered the worst noxious organisms affecting rice production in Europe. It is estimated that without weed control, at a yield level of 7 to 8 tonnes/ha, yield loss can be as high as 90 percent (Oerke *et al.*, 1994; Ferrero, Tabacchi and Vidotto, 2002). Weed problems are mainly related to competition with rice plants for light and nutrients, resulting in yield and quality reduction and an increase in the cost of harvesting and drying. Herbicides account for more than 80 percent of the total consumption of pesticides used in crop protection, with a total spending of about 110 million euros per year.

The important changes that occurred in most of the Western European countries during the 1960s in rice management – such as the change from transplanting to direct seeding, the expansion of mechanization and the introduction of chemical weed control – brought about a significant modification in the composition of the weed flora in rice fields.

The rice-field ecosystem is notably complex and the numerous weed species (both C_3 and C_4) present are characterized by particular morphophysiological traits. C_4 plants are mainly found in dry-seeded fields, while C_3 species tend to dominate in submerged rice crops (Bayer, 1991). Depending on the specific ecological conditions and anthropic pressure, some species may appear while others can disappear over time. The major weeds growing in European rice fields are aquatic (Batalla, 1989); they may be grouped on the basis of the practices adopted to control them (Ferrero, Tabacchi and Vidotto, 2002), as follows:

- *Echinochloa* species: *E. crus-galli, E. crus-pavonis, E. oryzoides, E. erecta* and *E. phyllopogon.* Major weeds in rice-cropping systems worldwide, in both water and dry-seeded rice (Holm *et al*., 1977; Ferrero *et al*., 2002), they have high variability in morphological and competition-related traits (e.g. plant size, tillering ability, seed dimensions and germination behaviour) (Barret and Wilson, 1983; Tabacchi *et al.*, 2006), which makes field identification of different species difficult and uncertain.
- *Heteranthera* species: *H. reniformis, H. rotundifolia* and *H. limosa*. Exotic plants first reported in Italy in 1962 (Pirola, 1968), in some areas they have become widespread in recent years and can compete severely with rice from its early stages (Ferrero, 1995).
- Alisma sedges and the sedges group (cyperaceae weeds) *Alisma plantago-aquatica, A. lanceolatum, Cyperus difformis*, *Bolboschoenus maritimus*, *Schoenoplectus mucronatus* and *Butomus umbellatus.* They are grouped together, as they are normally subject to common control programmes and are often sensitive to the same herbicides.
- Weeds in drill-seeded fields from two different floristic groups related to the different ecological conditions present on dry and flooded soil. Dry soil: *Echinochloa* spp, *Panicum dichotomiflorum, Bidens* spp, *Digitaria sanguinalis, Polygonum* spp, *Chenopodium album* and *Amaranthus retroflexus*. Flooded soil: weed species reported in fields flooded since rice planting. In these cultural conditions specific programmes of control are required for both groups of weeds.
- Weedy rice biotypes of cultivated rice (*Oryza sativa* L.). Diffused in much of the world, it is estimated that weedy rice infestations cover between 40 and 75 percent of European rice fields (Ferrero, 2003) and in Italy, France and Spain weedy rice infestations have been reported on 60 to 75 percent of the rice cultivated area.

At the seedling stage, weedy rice plants are difficult to distinguish from the crop, while after tillering the identification of the weed is possible thanks to many distinct morphological differences from the rice varieties: more numerous, longer and more slender tillers; leaves which are often hispid on both surfaces; tall plants; pigmentation of several plant parts; and easy seed dispersal after formation in the panicle (Kwon, Smith and Talbert, 1992). Weedy rice grains frequently have a red pigmented pericarp and the term "red rice" is commonly adopted in international literature to identify these spontaneous plants. This is not very appropriate, however, as red coat grains are also present in some cultivated varieties and absent in various weedy forms (FAO, 1999).

When the seeds break off and onto the soil prior to crop harvesting, the weeds disseminate and feed the soil seedbank (Ferrero and Vidotto, 1998). Following the shift from rice transplanting to direct seeding, red rice spread; the last 15 years have seen the problem worsen in Europe with the cultivation of weak, semi-dwarf *indica*-type rice varieties (Ferrero, 2003). The current spread is mainly related to the planting of commercial rice seeds containing grains of the weed.

WEED MANAGEMENT

All crop management practices may determine the competitive ability of rice and the weeds infesting rice fields. The shift in the early 1950s from transplanting to direct seeding and the abandoning of manual weeding resulted in greater infestations of weeds, including *Echinochloa* spp, *Alisma* spp, sedges and weedy rice plants. Weed management was complicated further following the introduction of short-stature rice varieties and the practice of shallow water in the fields during the early stages which created an ecological environment more favourable to their growth.

A sustainable programme of weed management must be based on a combination of cultural and chemical means: neither chemicals nor cultural practices alone can give satisfactory weed control (Bayer and Hill, 1993).

Cultural management

The main cultural operations that can have a significant direct or indirect impact on weed management are described below.

Soil tillage

Land preparation is an important component of rice weed control programmes: it helps the establishment and growth of rice while suppressing or delaying the development of weeds.

Tillage carried out in the autumn or winter increases soil aeration, favours straw decomposition and reduces algae infestations the following year. Established perennial weeds can then be partially devitalized if the soil dries out before field flooding for seeding the crop. Where perennial weeds are present, equipment fitted with rotary organs of tillage must not be used.

With soil tillage, fertilizers can be incorporated at a depth of 5 to 10 cm, reducing their availability to weeds which can germinate at the soil surface, and limiting nitrification and losses of nitrogen. With minimum tillage, weed seeds remain in the upper layers of the soil; they are spread uniformly and control is therefore more effective – both in pre-seeding (adopting the stale seed bed technique) and in early post-emergence.

Land levelling

Precision land levelling, obtained with laser-directed equipment, has made an important contribution to weedy rice management in European rice production. Level or regularly sloping fields enable appropriate water management, which limits weed growth and guarantees uniform emergence of weeds, which in turn makes herbicides more effective. With good soil levelling, the basin is larger and there are fewer ditches and levees from which weeds can spread into the fields.

Water management

Water management is central to weed control in water seeded rice. The water depth in rice fields has changed quite remarkably over the years, depending on the different growth features of the new varieties introduced in time (different vegetative vigour during the early stages, tall or short size of the plants, tillering degree etc.) and on the specific requirements of the herbicides applied.

In levelled fields, water is maintained at a depth of 5 to 7 cm until tillering and then at 12 to 15 cm until a few days before ripening. Rice fields are commonly drained 2 or 3 times during the crop cycle, in order to:

- hasten rooting of the rice seedlings;
- oxygenate the soil to avoid risks of unfavourable fermentation in the first few days after seed germination (7–15 days after seeding);
- destroy the algal scum;
- apply herbicides requiring drained soil conditions; or
- spread nitrogen fertilizers.

Most herbicides introduced into the market in recent years are characterized by foliar absorption and the plant surface must be well exposed to the herbicide spray. Dry conditions stimulate weed germination; therefore draining should be short to avoid the creation of different-aged weeds which are difficult to control with herbicides.

Rotation

Rotating rice with dry crops is an effective means of managing weeds that cannot be successfully controlled in rice. Where there are high infestations of weedy rice, the rotation of rice with non-flooded crops is the best solution to get a significant reduction of the seed-bank of this weed.

System of rice planting

On a small percentage of the cultivation area, rice is planted in dry soil and only flooded from the beginning of tillering until ripening; the rice fields are then infested by two different floristic groups related to the different ecological conditions of dry and flooded soil. While planting in dry soil reduces or delays the growth of those weed species requiring an aquatic environment (e.g. *Heteranthera* spp), it increases the development of non-aquatic weeds (e.g. *Panicum dichotomiflorum*, *Digitaria sanguinalis* and *Polygonum* spp). Weeds can be partially removed from dry fields with one or two passes of the tine harrow.

Varieties

The cultivation of *indica*-type and early-maturing varieties has significantly increased over recent years in European countries. Most *indica*-type varieties are short, have low growth and are only moderately competitive with weeds – all features which contribute to the spread of weedy rice infestations.

Early varieties usually have a cycle of 130–145 days (about 20–30 days shorter than regular varieties); they are popular because they escape the negative effects of the low temperatures in April and August when the delicate phases of emergence and flowering occur. High-yielding varieties planted in mid-May and which begin to flower before August are favoured. Where short-cycle varieties are selected, weedy rice control is carried out before rice planting.

Herbicide management

Herbicides are a fundamental element in sustainable weed management programmes. Numerous herbicides are available to control major rice weeds (Table 1) (Ferrero, Tabacchi and Vidotto, 2002). In recent years much effort has gone into developing herbicide programmes that maximize the use of commercial products while reducing the number of treatments.

Herbicide strategies are established mainly on the basis of the composition of the infestations. The key factors to be considered when deciding the weed control programme are the seeding conditions and the presence of weedy rice; the latter may influence the organization of the cultural practices or the choice of the herbicides.

Water seeding: infestations of* Echinochloa *spp,* Heteranthera *spp,* Alisma *spp, sedges and others

When weedy rice is absent and infestations are characterized by the presence of most common weeds (e.g. *Echinochloa* spp, *Heteranthera* spp and ciperaceae), two or three treatments are commonly required: one in pre-emergence (mainly against *Heteranthera* spp) and one or two 10–40 days after crop emergence.

TABLE 1

Rate and application timing of herbicides applied in Italy against main weeds of rice

Target weeds and active ingredients	Rates (*kg a.i./ha*)	Application timing
Echinochloa spp:		
Molinate	3.0–4.5	pre-seeding
	3.0–4.5	post-emergence
Thiobencarb	3.0–4.0	pre-seeding
	3.0–4.0	early post-emergence
Quinclorac	0.5–0.6	post-emergence
Propanil	3.5–4.0 + 3.5–4.0	late post-emergence
Bispyribac-sodium	0.02	early post-emergence
Profoxydim	0.1	early post-emergence
Azimsulfuron	0.02	early post-emergence
Cyhalofop-butyl	0.2–0.3	early post-emergence
Penoxsulam	0.04	early post-emergence
Imazamox	0.05	post-emergence (in combination with tolerant rice varieties)
Alismataceae and Cyperaceae:		
Bensulfuron-methyl	0.06	post-emergence
Cinosulfuron	0.06–0.08	post-emergence
Ethoxysulfuron	0.06	post-emergence
Bensulfuron-methyl + metsulfuron-methyl	0.05 + 0.002	late post-emergence
Metosulam	0.06–0.08	post-emergence
Azimsulfuron	0.02	post-emergence
MCPA	0.4–0.6	post-emergence
Triclopyr	0.3–0.4	late post-emergence
Bentazone	1.2–1.6	post-emergence
Penoxsulam	0.04	early post-emergence
Imazamox	0.05	post-emergence (in combination with tolerant rice varieties)
Heteranthera spp:		
Oxadiazon	0.2–0.4	pre-seeding
Pretilachlor	1.0–1.1	early post-emergence
Triclopyr	0.3–0.4	late post-emergence
Imazamox	0.05	post-emergence (in combination with tolerant rice varieties)
Weedy rice:		
Flufenacet	0.4	pre-seeding (30 days before seeding)
Pretilachlor	1.0	pre-seeding (30 days before seeding)
	1.0	post-emergence
Dalapon	12.0–15.0	pre-seeding (after stale seed bed)
Glufosinate-ammonium	1.0	pre-seeding (after stale seed bed)
Glyphosate	1.0–1.2	pre-seeding (after stale seed bed) crop post-emergence (wick bars)
Pretilachlor	1.2	pre-seeding (after stale seed bed)
Imazamox	0.05	post-emergence (in combination with tolerant rice varieties)

The first treatment is normally: oxadiazon (300–380 $g_{a.i.}$/ha) (to control *Heteranthera* species); combined with a graminicide (against *Echinochloa* plants, e.g. thiobencarb or molinate); and sometimes with an ALS inhibitor applied at one-half or one-third the normal rate (against sedges and other weeds). They are applied 3–4 days before planting and soil flooding, or 5–6 days before planting on flooded soil.

Second and sometimes third treatments are frequently necessary to control late emergences of *Echinochloa* spp, sedges, alismataceae and other species.

Water seeding: infestations with weedy rice,* Echinochloa *spp,* Heteranthera *spp,* Alisma *spp, sedges and others

Weed control programmes are principally aimed at weedy rice control and are carried out prior to seeding:

- with an antigerminative herbicide (e.g. flufenacet or pretilachlor) applied about 1 month before rice planting; or
- by mechanical means (harrows or a tractor fitted with cage wheels) or with systemic graminicides (e.g. dalapon, cycloxydim, clethodim or glyfosate) to destroy weedy rice seedlings grown after stale seedbed application (Table 1).

In both cases, a second treatment is usually required to control *Heteranthera* spp in rice pre-planting, and at least a third treatment with a mixture of specific herbicides, to control *Echinochloa* spp, sedges and other weeds, 25–40 days after rice planting.

When pre-planting treatments against weedy rice are not carried out or are unsatisfactory, there is often an intervention at rice flowering time. This can be manual when there are only a few weedy rice plants per ha, but with high infestations, the weed is devitalized by applying systemic herbicides (glyphosate) with wiping bars, provided that the weed plants are taller than those of the crop. The Clearfield® technology is particularly promising: it is based on the planting of a rice variety tolerant to imazamox, an imidazolinone herbicide with a wide spectrum of activity that also includes weedy rice plants.

Drill seeding: infestations with* Echinochloa *spp,* Panicum dichotomiflorum*,* Digitaria *spp,* Polygonun *spp,* Alisma *spp, sedges and others

When rice is seeded in dry soil, two or three treatments are generally required (Table 1):

- First, in rice pre-emergence: pendimethalin (1 000–1 300 $g_{a.i.}$/ha) or clomazone (200–230 $g_{a.i.}$/ha) to control *Echinochloa* spp and other weed grasses; when *Heteranthera* spp is present, oxadiazon is usually added.
- Second, 10–30 days after rice emergence: propanil in combination with an ALS inhibitor to control sedges, *B. umbellatus*, *A. plantago-aquatica* and *Echinochloa* spp plants which escaped the pre-emergence treatment.
- Third, if necessary, just before flooding: against weeds which escaped previous treatments or emerged late, this intervention is sometimes performed after field flooding, applying the same products used in flooded rice fields.

Technological advances in the equipment mean that herbicides are sprayed with low water volume and at low pressure; this improves the efficiency of the products and limits the risk of environmental pollution. Furthermore, thanks to the increased width of the boom sprayers, fewer passes are made in the basins by tractors equipped with toothed wheels, thus diminishing both the cost of spraying and the frequency of late weed germinations which can occur along the wheel tracks.

When using herbicides, particular attention must be paid to water movement and depth in the rice field. Most ALS inhibitors require static water for a few days in order to avoid chemical removal and allow uniform soil absorption. Foliar herbicides (propanil, MCPA etc.) should be applied on drained fields for maximum exposure of the weed foliage to the spray. The improper use of herbicides can result in the appearance of resistant species, cause environmental pollution and risk disrupting the precarious balance of natural pest enemies.

The principal resistant weeds belong to *S. mucronatus*, *A. plantago-aquatica*, *C. difformis* and *Echinochloa* spp (Busi *et al.*, 2002). Studies of *C. difformis* and *S. mucronatus* have shown that there is a generalized cross resistance among several sulfonylureas (azimsulfuron, bensulfuron-methyl, cinosulfuron, imazamox and byspiribac-sodium) (Busi *et al.*, 2006). Some resistant populations are also insensitive to triazolopyrimidine herbicide (metosulam) at three times the recommended field dose (Sattin *et al*., 1999).

The main techniques currently adopted by European rice growers to tackle herbicide resistance are the rotation of herbicides and the application of mixtures of herbicides with different modes of action. For the successful control of ALS-resistant *Alisma* and sedges, farmers are increasingly using hormonic herbicides, such as MCPA which was widely used before the introduction of ALS inhibitors. Crop rotation – probably the best preventive and curative method for dealing with herbicide resistance – is unlikely to be adopted by farmers, for technical (soil suitability for other crops), economic and organizational reasons.

Environmental contamination from herbicide use is an important issue requiring attention (Ferrero *et al*., 2001), with particular regard to the choice of active ingredients having low solubility in water, low volatilization and low persistence.

CONCLUSIONS

Weed management is a major concern for rice growers, as unsuccessful weed control can result in a severe reduction in yield and quality.

The dramatic technological advances of recent decades have influenced rice management: the development of mechanization; the introduction and diffusion of chemical weed control; the change from transplanting to direct seeding; and the introduction of late, dwarf and less competitive rice varieties. All these changes determined important modifications in the composition of the weed flora in rice fields. Weeds such as *Echinochloa* spp, *Alisma* spp, cyperaceae species and weedy rice – previously well controlled by hand-picking or limited in their growth by transplanting – became increasingly competitive. The introduction of rice seed from other countries favoured the diffusion of exotic weeds such as *Heteranthera* spp. The numerous herbicides now available, and which are suited to every floristic situation, help limit yield losses but often do not prevent weed spread and pressure. The improper use of herbicides may lead to the development of resistance in some weeds or to environmental pollution. The main issues in rice weed management can be addressed by integrated strategies based on an appropriate combination of herbicides with good agronomic practices.

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Lutte anti-adventices dans les champs de riz d'Europe

Les adventices sont les organismes les plus nuisibles à la culture du riz en Europe. Les principales infestations d'adventices peuvent actuellement être regroupées de la façon suivante:

1. Espèces du genre *Echinochloa*
2. Espèces du genre *Heteranthera*
3. Espèces du genre *Alisma* et adventices de la famille des Cypéracées (laîches)
4. Mauvaises herbes des champs ensemencés en ligne
5. Biotypes de riz propices à l'infestation par les adventices

Les principales pratiques culturales actuellement en usage dans la culture du riz – labour et préparation du sol, nivellement du sol, gestion de l'eau, rotations, semis, variété choisie – peuvent avoir un impact significatif, direct ou non, sur la lutte anti-adventices. Plus de 80 pour cent des produits phytosanitaires utilisés pour la culture du riz sont des herbicides. Les principaux herbicides utilisés visent *Echinochloa* spp. (Molinate, Propanil, Thiocarbazil, Dimepiperate, Quinclorac, Cyalofop-butyl, Penoxulam, Azimsulfuron et Bispyribac-sodium), *Heteranthera* spp. (Oxadiazon) et les espèces de la famille des Alismatacées et des Cypéracées (Bensulfuron-methyl, Cinosulfuron, Ethoxysulfuron, Azimsulfuron, Bispyribac-sodium, Metosulam, MCPA et Bentazone). L'utilisation inconsidérée des herbicides aboutit occasionnellement à une pollution de l'eau ou du sol, ou à la sélection d'adventices résistantes. À la suite de l'application d'herbicides inhibiteurs d'ALS, il a été rapporté des pertes de maîtrise de la lutte contre *Alisma plantago-aquatica*, *Schoenoplectus mucronatus* et *Cyperus difformis,* ainsi que pour *Echinochloa* spp. à la suite d'application de Propanil.

Les approches les plus couronnées de succès en matière de lutte anti-adventices dans les champs de riz sont actuellement celles qui reposent sur des pratiques de conduite intégrée des cultures, associant des herbicides spécifiques et des pratiques agronomiques appropriées.

El control de malezas en los arrozales de Europa

Las malezas son los organismos nocivos que más daños causan a los arrozales europeos. En la actualidad, las malezas principales pueden agruparse como sigue:

1. Especie *Echinochloa*
2. Especie *Heteranthera*
3. Especie *Alisma* y malezas ciperáceas
4. Malezas de los campos sembrados con sembradoras en línea
5. Biotipos de arroz maleza

Las principales operaciones aplicadas actualmente en el cultivo de arroz –labranza y preparación de la tierra, nivelación del terreno, regulación de aguas, rotación, plantación, elección de la variedad– pueden tener un efecto directo o indirecto importante en el control de malezas. Los herbicidas representan más del 80 % del consumo total de plaguicidas destinado a la protección de los cultivos. Los principales herbicidas aplicados en el control de malezas se emplean en la lucha contra *Echinochloa* spp. (molinate, propanil, tiocarbacilo, dimepiperato, quinclorac, cihalofop-butilo, penoxulam, azimsulfurona y bispiribaco de sodio), *Heteranthera* spp. (oxadiazona) y las especies *Alismataceae* y *Cyperaceae* (bensulfuron-metilo, cinosulfuron, etoxisulfuron, azimsulfurona, bispiribaco de sodio, metosulam, MCPA y bentazona). El uso impropio de herbicidas provoca ocasionalmente la contaminación del suelo y el agua, o el desarrollo de resistencia en las malezas. Existen informes de falta de control de *Alisma plantago-aquatica*, *Schoenoplectus mucronatus* y *Cyperus difformis* tras la aplicación de herbicidas inhibidores de la enzima ALS, y de *Echinochloa* spp. después de la aplicación de propanilo.

Actualmente, los métodos más eficaces para el control de malezas de los arrozales se basan en la aplicación de prácticas integradas de gestión de cultivos que emplean una combinación de herbicidas con prácticas agronómicas apropiadas.

Rice genetic potential and its application in rice breeding for stress tolerance

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INTRODUCTION

Using the vast genetic potential of the rice collection and modern methods of creation and evaluation of the breeding material, the All-Russia Rice Research Institute (ARRRI) has released a number of varieties resistant to environmental stress factors, well adapted to local conditions and widely used. ARRRI also provides a valuable source of basic material for breeding new generation rice varieties. An analysis of rice production in the Russian Federation reveals the negative effect of the permanent increase in fuel prices: the self-cost of the grain rises and its competitive ability declines. The solution is seen in the development and introduction of energy-saving, ecologically safe rice-growing and harvesting methods, as well as in the breeding of new varieties. Varieties need to combine low energy requirements with adequate productivity, resistance to diseases and environment stress factors, and growth ability without the application of herbicides. The last 20 years of research at ARRRI have been dedicated to the release of such rice varieties.

SAMPLE ASSESSMENT: THE FOUNDATION OF RICE BREEDING

The success of breeding activities largely depends on the availability of diverse initial material and the bank of crop genetic resources. Principal activities include the collection, safe-keeping, study, description and provision to rice breeders of samples. Rice collection in the Russian Federation was initiated in the 1920s by the specialists of the All-Union Institute of Plant Industry (VIR) under the guidance and with the direct participation of Mr N.I. Vavilov. The collection currently contains over 5 000 samples belonging to varieties and types that reach maturity under the climatic conditions in the Russian Federation. Special nomenclature of the *Oryza* L. genus has been established for rice evaluation using uniform assessment methods. The best rice samples in the world are included in the ARRRI working collection comprising over 3 000 viable samples of various pedigrees, including: mutants and polyploids; varieties that have been rejected or that did not pass the tests; selections from hybrid populations of senior generations; the best varieties in the world collection; and varieties commercially grown in Russia.

ARRRI and breeding centres in other rice-growing countries exchange material so as to have access to the latest achievements in world rice breeding for the creation of new varieties. Quarantine and introductory nurseries prevent the introduction of quarantine pests and diseases with rice seeds received from other countries.

The majority of varieties coming to Russia from other countries are late-maturing and – being as a rule native of the tropical zone – they are photosensitive and react to a 16-hour photoperiod (under conditions in Krasnodar) with an increased vegetation period of 150–160 days or more. The majority of samples do not reach heading and many of them are used only for hybridization under conditions of climatic chamber.

Foreign samples are often used as sources of traits such as short stem, long grain, high milling qualities, and resistance to pests, diseases and environmental stress factors; in return, ARRRI sends collection samples in response to the requests of foreign colleagues. Rice breeders in other countries evaluate the ARRRI samples and report back on the behaviour of the material under local conditions, providing interesting data, in particular with regard to the degree of resistance to pests and diseases under other ecological conditions.

EVALUATION OF COLLECTION MATERIAL

Every sample in the ARRRI working collection undergoes complex evaluation of 40 traits to identify potential donors of economically valuable features. The samples are studied under field and vegetative conditions and in laboratory tests, with the participation of numerous specialists: plant breeders, specialists in genetics, plant physiology, biochemistry and phytopathology from ARRRI and other research institutes.

In standard field experiments, the samples are evaluated and described according to their morphological traits, and their resistance to logging and shedding, and to pests and diseases is defined. In special experiments under provocation settings, the resistance to salinity, low temperatures, blast, aphids and rice leaf nematode is evaluated; the reaction to high nitrogen rates is also determined. Under laboratory conditions, the rice grain is assessed for its milling qualities: total milled rice and white rice, vitreousity, filminess, fracturing, grain size and form, and weight of 1 000 grains. The protein and amylose content is also defined.

Sources of early maturity, high-yielding ability, high grain quality, increased protein and amylose content, salt and cold tolerance, and resistance to pests and diseases are selected. An important feature is high yield, which is obtained by individual productivity of plants under optimal plant density. The working collection is constantly replenished with high production samples created in the course of breeding research. As productivity depends on the duration of the vegetation period, most sources of high productivity are medium- and late-maturing. Russian rice growing is one of the northernmost in the world; therefore special attention is paid to breeding rice with a short vegetation period (Table 1). ARRRI breeders use early-maturing (up to 100 days of vegetation) and fast-maturing (100–110 days) rice samples to obtain early-maturing primary material. The collection includes over 250 samples.

Rice breeding for cold tolerance is based on valuable samples which combine tolerance to low temperatures with other economically valuable traits. Each year ARRRI plant physiologists evaluate 100–150 collection samples for cold tolerance and the best are recommended for hybridization. The samples obtained though breeding for cold tolerance are added to the germplasm bank (Table 2).

Large areas of rice systems are subject to increased salinity; breeding programmes for salt tolerance were therefore initiated. To define the sources of salt tolerance, as many as 400 samples from working and world collections are assessed each year. The best samples – combining high salt tolerance with other positive traits – are recommended for further breeding programmes (Table 3).

Under Russian Federation conditions the most noxious disease in rice fields is blast, caused by fungus *Pyricularia oryzae* Cav. All collection samples are therefore evaluated for resistance to this disease and the best are used in hybridization (Table 4).

In addition to high productivity and resistance to diseases and environmental stress factors, varieties should have vitreous grain and resistance to crushing – able to give maximum total milled rice and more economically efficient. Russian rice breeders aim to release high-quality varieties meeting modern market demand: Table 5 lists samples combining high quality of milled rice with maximum number of economically valuable traits.

Protein content is an important indicator of rice alimentary quality. Protein is 98 percent assimilated by the human organism, and low protein rice varieties contain 7.33 percent protein (dry matter) while high-quality varieties up to 11.9 percent. ARRRI biochemists have selected samples combining increased protein content with maximum content of amylose (Table 6).

Under Russian Federation conditions, the selected collection samples accumulate more protein and amylose than Krasnodarsky 424; they provide basic material for these traits and are recommended for breeding. The data obtained for each sample are registered in a special logbook and on catalogue cards and any hybridization

TABLE 1
Collection samples as sources of early maturity

ARRRI catalogue number	No. days from flooding to flowering	Plant height (*cm*)	Resistance to lodging (*points*)
03455	59	78.8	9
03456	59	69.8	9
03527	59	76.0	5
03530	66	82.1	7
03534	62	79.9	9
03537	60	74.8	5
03540	50	84.6	9
01317 – standard	67	82.4	7

TABLE 2
Collection samples as sources of cold tolerance

ARRRI catalogue number	No. days from flooding to flowering	Plant height (*cm*)	Cold tolerance (*points*)
0856	77	101.2	9
02990	62	86.1	9
03054	63	90.7	9
03305	77	94.8	9
03333	74	115.2	9
03339	68	85.6	9
03584	72	86.4	9
01310 – standard	75	101.0	9

TABLE 3
Collection samples as sources of salt tolerance

ARRRI catalogue number	No. days from flooding to flowering	Plant height (*cm*)	Salt tolerance (*points*)
0812	73	73.5	7
02231	77	82.7	7
02432	65	69.0	7
02625	73	69.9	7
02712	63	70.7	7
03064	61	91.5	7
03225	73	97.6	7
01318 – standard	82	85.0	7

includes data analysis for parent selection. ARRRI created the Rice Genetic Resources Database for: storing and processing of information on rice collection; automatic searches for sources of required traits; and the development of breeding programmes. Information about the collection is obtained rapidly and sample use is improved, in particular when there is a rare combination of individual traits.

METHODS OF CREATION OF BASIC MATERIAL FOR BREEDING NEW RICE VARIETIES

The principal method used at ARRRI for breeding basic material is intraspecific hybridization. Mutagenesis and biotechnological methods are widely adopted for production of new forms. Modern methods of hybridization include castration and flower pollination. The most efficient – while simple – method is pneumatic castration, for which a special device has been developed: the panicles are pollinated on the castration day and the parents are grown in climatic chambers under optimal thermal and photoperiod conditions. Hybridization programmes are carried out all year round.

The application of pneumatic castration and pollination are responsible for the considerable increase in hybrid grains: every year the ARRRI hybridization centre receives for 120–130 combinations (i.e. 40 000–50 000 flowers) as many as 20 000 hybrid grains. The average grain setting is 50–60 percent and for some combinations it reaches 90 percent; there is a high output of true first generation hybrids from 93.1 to 98.0 percent.

TABLE 4
Collection samples as sources of blast resistance

ARRRI catalogue number	No. days from flooding to flowering	Plant height (*cm*)	Plant susceptibility (*points*)	
			Leaf	Panicle
010	84	60.0	0	0
020	83	100.0	0	0
01089	94	89.5	0	0
01179	93	94.1	0	0
01970	88	86.0	0	0
02056	87	99.2	0	0
02344	86	86.8	0	0
02384 – standard	119	118.0	5	7

TABLE 5
Collection samples used as sources of high grain quality

ARRRI catalogue number	No. days from flooding to flowering	Plant height (*cm*)	Total (*%*)	
			Milled rice	Head rice
0252	111	91	72.6	99.7
01458	112	107	72.0	95.6
01746	107	50	71.8	98.5
02313	106	113	72.3	91.6
02898	111	107	71.1	98.2
12901	118	83	71.6	98.4
03060	114	124	72.5	92.5
03198	102	101	72.5	97.8
02384 – standard	119	118	71.6	91.7

TABLE 6
Rice samples with high content of protein and amylose

ARRRI catalogue number	Sample designation	Content (%)	
		Protein	Amylose
01202	Mutant 68	10.5	19.0
01730	Mutant 4207	12.0	18.8
01841	VNIIR 6955	11.0	19.6
02231	VNIIR 9199	11.0	18.4
02687	Line 84-1-25-2-1	11.3	19.0
03463	VNIIR 751	9.5	19.2
03486	DZ-192	10.7	17.8
03636	KP-108-87	10.7	18.8
02384 – standard	Krasnodarsky 424	9.5	15.4

F_1 hybrids are grown in vegetation vessels: in winter in climatic chambers and in summer on vegetation plots. To overcome the problem of newly harvested seed germinating, the dormancy period is interrupted: F_1 hybrid grains are warmed in hot water (70 °C) for 7–10 minutes, then thermostat-controlled at 40 °C for 24 hours. Further germination then takes place at 28–30 °C (thermostat-controlled), reaching 95–98 percent. Hybrids of second and subsequent generations are evaluated and multiplied under field conditions. Rice breeders select elite plants with pre-planned parameters for the development of a breeding nursery.

Over the ensuing years the material obtained is studied according to generally accepted breeding methods. The evaluation process is performed by various scientists and specialists in phytopathology, entomology, plant physiology, biochemistry and rice grain milling quality. Before varieties are handed over for state evaluation, farming methods are developed and primary seed production is started. Every year ARRRI specialists issue two or three different varieties for state evaluation, including ones tolerant to environmental stress factors. The state register includes varieties with various characteristics: Sprint, Slavyanets and Leader (adapted for herbicide-free management systems); Kurchanka (salt tolerant); Viola (glutinose); and Snezhinka (long-grain) – see Table 7. While they share high grain milling quality and tolerance to stress factors, they have very different morphological traits and biological properties, outlined below:

- Sprint (fast-maturing) and Leader (medium-late-maturing) are characterized by low requirements in terms of growing conditions and their fast growth during emergence when the shoots easily overcome a water layer of 20 cm; they are therefore recommended for cultivation without application of herbicides. Resistance to blast means that fungicide treatments are not necessary.
- Slavyanets (medium-maturing) is increasingly widely grown and belongs to universal varieties; it can be grown using any farming methods accepted in the farm.
- Kurchanka (salt-tolerant) is suitable for cultivation in rice fields with increased soil salinity, where it has achieved yields 500–600 kg/ha higher than other varieties. This variety is salt tolerant at both emergence and flowering, when other varieties are especially susceptible to salinity.
- Snezhinka (long-grain, *indica*) produces high-quality milled rice. Following state tests and production verification, the variety was included in the state register and admitted for commercial production. It requires no special methods during growth; it possesses effective blast resistance genes and therefore needs no chemical treatments. Processing the long grains remains a problem, however: the equipment in factories is adapted to milling short-grain varieties and so efforts are still required in this area.
- Viola (glutinous) was state commissioned for use in baby and diet food. The variety has been tested and patented in the Russian Federation.

TABLE 7
Performance of rice varieties resistant to environment stress factors

Variety	Vegetation period (*days*)	Plant height (*cm*)	Emerging rice growth rate (*points*)	Grain type (*l/b*)	Total milled rice (*%*)	Blast resistance
Sprint	87–90	90–95	9	1.8	72	Resistant
Slavyanets	112–117	85–95	8	1.7	71	Resistant
Leader	120–122	90–95	9	1.7	71	Resistant
Kurchanka	120–122	80–85	8	2.4	71	Average resistance
Snezhinka	120–122	90–95	7	4.0	68	Resistant
Viola	112–116	75–80	9	1.7	68	Resistant

CONCLUSION

Using the vast genetic potential of the rice collection and applying modern methods of creation and evaluation of the breeding material, ARRRI has released varieties with resistance to environmental stress factors, well adapted to local conditions and widely used. In addition to these varieties, there are valuable sources of basic material for breeding rice varieties of new generations.

Le potentiel génétique du riz et ses applications à la sélection de variétés résistantes au stress

En raison de la hausse continuelle des prix de l'énergie et des coûts internes de la production céréalière, il est nécessaire de mettre au point des pratiques culturales économes en énergie et non nocives pour l'environnement, ainsi que de sélectionner des variétés nouvelles. La réussite des activités de sélection dépend en grande partie de la disponibilité de matériel génétique de base diversifié et d'une banque de ressources génétiques agricoles confirmée. Les meilleures obtentions de riz à l'échelle mondiale sont contenues dans la collection de travail de l'Institut de Recherche rizicole de toutes les Russies (ARRRI). Il est donc possible de disposer de sources de caractéristiques telles que maturité précoce, capacité de haut rendement, bonne qualité du grain, teneur en protéines et en amylose améliorées, tolérance au froid et à la salinité, et résistance aux parasites et aux maladies. La maladie la plus destructrice présente dans les champs de riz de la Fédération de Russie est la nielle du riz, causée par la moisissure *Pyricularia oryzae* Cav. La principale méthode de sélection à partir de nouveaux matériels génétiques de base utilisée à l'ARRRI est l'hybridation intraspécifique. La mutagenèse et d'autres méthodes de biotechnologie sont couramment utilisées pour produire des variétés nouvelles. Les méthodes modernes d'hybridation comprennent la castration et la pollinisation des fleurs. Le document présente les résultats obtenus par l'ARRRI dans l'utilisation de ressources génétiques rizicoles pour la sélection de variétés améliorées au cours des 20 dernières années.

El potencial genético del arroz y su aplicación en el mejoramiento para obtener tolerancia al estrés

A causa del constante aumento de los precios del combustible, y el costo unitario creciente de la producción de cereales, se hace necesario desarrollar métodos de cultivo y recolección del arroz que permitan ahorrar energía y sean seguros desde el punto de vista ecológico. Es preciso, además, seleccionar nuevas variedades. El éxito de las actividades de mejoramiento depende en gran medida de que se pueda contar con material inicial diverso y con un banco establecido de recursos fitogenéticos. Las mejores muestras de arroz disponibles en todo el mundo se encuentran en la colección de trabajo del Instituto ruso de investigación sobre el arroz (ARRRI). Gracias a ello es posible seleccionar fuentes de maduración rápida, con capacidad de proporcionar altos rendimientos, granos de alta calidad, un contenido más elevado de proteínas y amilasa, más sal y tolerancia al frío, y que ofrezcan resistencia a las plagas y enfermedades. La enfermedad más nociva que ataca los arrozales de la Federación de Rusia es el añublo del arroz, provocado por el hongo *Pyricularia oryzae* Cav. El principal método de mejoramiento que se emplea para el nuevo material básico del ARRRI es la hibridación intraespecífica. Existe un amplio uso de la mutagénesis y los métodos biotecnológicos para producir nuevas formas. Los métodos modernos de hibridación incluyen la castración y la polinización de las flores. Este informe presenta los resultados de la aplicación de los recursos genéticos del arroz en la actividad de mejoramiento destinada a obtener variedades mejoradas del cereal que se ha llevado a cabo en el ARRRI durante los últimos 20 años.

Crop management research and recommendations for rainfed lowland rice production in Cambodia

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INTRODUCTION

Rainfed lowland rice dominates the farm cropping systems in Cambodia. More than 80 percent of the cultivated area sown to rice is rainfed lowland culture: the systems are traditional and ancient in origin and rice is monocropped year after year on the same land; shortages of water and inadequate irrigation infrastructure are typical of rural areas.

In areas where supplementary water is available, other crops are also grown, providing a measure of diversification, crop rotation, change of diet and opportunities for off-farm sales and trading – all positive factors. Supplementary water also enables rice production to be intensified with two – or even three – crops grown annually. Where supplementary water is insufficient for a second rice crop, growers will typically sow a second short-duration cash or food crop. Mung beans, black gram and vegetables are popular, and frequently precede or follow a wet season rice crop. Rainfed lowland rice is grown in a variety of environments, even where production resources are poor: it is not uncommon, for example, for no fertilizer to be used despite the low level of nutrients, particularly N and P (White, Oberthur and Sovuthy, 1997).

The risks inherent in intensification can be minimized with the choice of suitable varieties. For example, early-maturing varieties that flower to coincide with the peak of the rain season risk damage to spikelets and this reduces pollination levels; furthermore, spikelets at this time are more likely to be damaged by rodents. An understanding of crop scheduling is essential for double or multiple cropping, in order that growers can select varieties, stagger planting to suit the season and space crops on their small areas of land (Sarom, 2001).

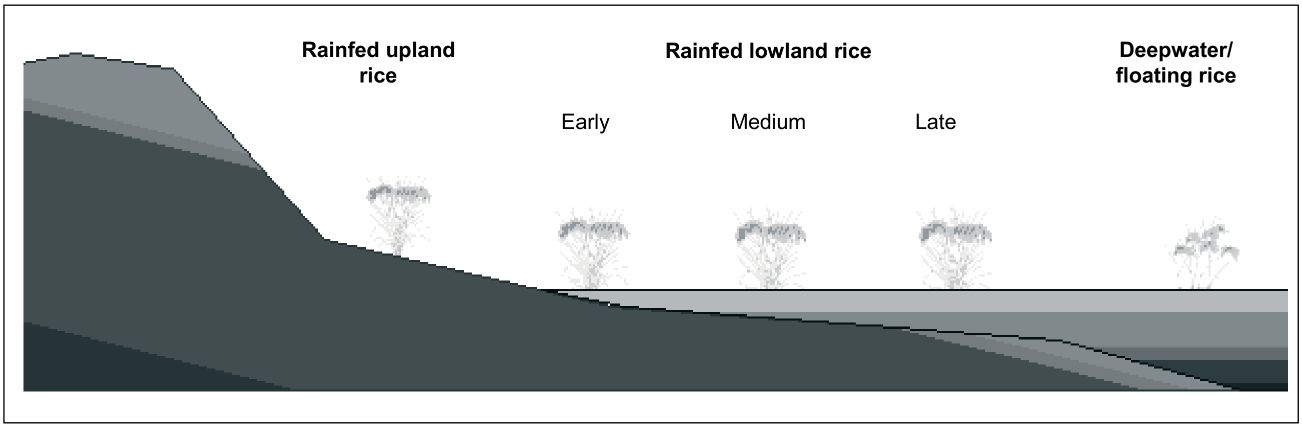
RICE GROWING IN CAMBODIA

Cambodia enjoys a monsoon climate with two distinct main seasons: wet and dry. Rice is grown throughout the year, with wet-season rice accounting for 88 percent of national production and dry-season rice the remainder. Wet-season rice depends mainly on rainfall from May to October. Dry-season rice is cultivated in the main cropping period with full or supplementary irrigation or in receding floodwaters. On the basis of rainfall, flooding patterns and topography, wet-season rice can be categorized further into rainfed upland, rainfed lowland and deepwater production (Figure 1).

- Rainfed upland rice is grown in small areas and mainly in the hill regions of northern and north-eastern Cambodia, where annual rainfall is higher than in the central plain. This is small sector production and accounts for around 2 percent of total production.
- Rainfed lowland rice accounts for about 93 percent of the total production area of wet-season rice. In Cambodia, rainfed lowland rice is found in all provinces, but mainly in the central plain around the great lake (Tonle Sap), and on the lower streams of the Mekong and Bassac rivers. Annual rainfall in the region is between 1 200 and 2 000 mm.
- Deepwater/floating rice is cultivated in the same areas as rainfed lowland rice, but is found mainly on the edges of lakes where the water is deep (Figure 1); it occupies about 5 percent of national ricelands.

In Cambodia each year, rice is cultivated on an estimated 2.2 million ha (Table 1). Therefore, rainfed lowland rice, as the major category of rice produced in

FIGURE 1
Rice agro-ecosystems in Cambodia



the country, has contributed significantly to the growth of the Cambodian economy. With this rice ecosystem, farmers have cultivated thousands of varieties for many hundreds of years. While subject to environmental pressures – flooding, drought, adverse soils and insect pests – throughout a diverse history of cultivation, these traditional varieties provide not only grain for farmers, but also highly valuable genetic stocks for plant breeders. Variations in time to flowering mean that varieties from different groups are grown at different water levels in the fields. Normally, early varieties are grown near villages where the water level is shallow and where the crop can be given supplementary irrigation. Intermediate-maturing varieties are often grown on middle field terraces, and late-maturing varieties are grown in the lowest part of the fields where water is likely to be deeper and where submergence may frequently occur. Low rainfall can, however, result in drought for all three groups. Most rainfed lowland rice varieties have traits (such as time to flowering) that are adapted to local environments; they also satisfy the taste preferences of the local people. Although only a few varieties are actually resistant to drought, a large proportion of traditional varieties are able to recover once the drought is over. The highly variable levels of recovery exemplify the different levels of drought tolerance.

CONSTRAINTS OF RAINFED LOWLAND RICE PRODUCTION

Rainfed lowland rice occupies 88 percent of the rice area. Crop losses caused by natural disasters such as floods and drought can be high. During 2000–03, the area

TABLE 1
Production loss in rice farming in Cambodia

Year	Area planted (*'000 ha*)	Area harvested (*'000 ha*)	Area damage (*'000 ha*)	% loss	Total production (*'000 tonnes*)	Yield (*tonnes/ha*)	Production loss (*'000 tonnes*)
2000	2 318	1 903	415	17.9	4 026	2.12	879
2001	2 186	1 980	206	9.4	4 099	2.07	426
2002	2 113	1 995	119	5.6	3 823	1.92	227
2003	2 314	2 242	72	3.1	4 711	2.10	152
Mean	**2 233**	**2 030**	**203**	**9.1**	**4 165**	**2.05**	**421**

Note: Figures are based on the following assumptions (based on MAFF calculations):
Milling recovery is 64%
Consumption rate is 143 kg/capita/annum
$421 \times 0.64 \times 10^6/143 = 188\ 341$ persons
Approximately 188 341 people could be fed with the production loss caused by the reduction in total rice harvested areas against total planted.

Source: MAFF reports, 2000–03.

planted to rice each year was in the order of 2.23 million ha. During the same period, however, an estimated 200 000 ha of croplands were lost each year resulting in annual crop losses of more than 420 000 tonnes (Table 2). The major constraints of rainfed lowland rice production are outlined below.

Water availability

Rainfall is highly variable from year to year, season to season and location to location. Frequency and distribution vary, with a significant effect on productivity. Excessive rains can cause floods, while droughts can follow a shortage of rain; sometimes the unfortunate rice grower is subject to both floods and droughts during the growing season. Irregular rainfall at the beginning of the wet season may delay planting, encourage weed growth and encourage build-up of insect pests, resulting in yield loss. Excessive rain at crop maturation not only reduces productivity, but affects grain fertility. Excess water encourages the growth of fungal diseases (which lowers yields), gives poor grain appearance and reduces grain-milling recovery. Drought during flowering reduces yield and – if the drought comes later in the growing cycle – the crop may face an outbreak of grasshopper pests.

Soil fertility

Rainfed lowland rice areas typically have sandy soils with low fertility. These are soils that respond poorly to fertilizer application. Nitrogen and phosphorus deficiencies and iron toxicity are common in most rice soils (White, Oberthur and Sovuthy, 1997); some soils are also deficient in potassium and micro-elements. Low organic matter and poor water-holding capacity are also common. The productivity of rainfed lowland rice can be increased if the appropriate fertilizer is applied to overcome deficiencies in soil fertility (often associated with toxicities). In general, however, fertilizer use in Cambodia is neglected and compares poorly with other countries in the region (Table 2).

Pests and diseases

There are a large number of weeds, insects and diseases that typically attack rainfed lowland rice. Productivity suffers and, depending on the severity of the attack, crop losses can be high.

- Broadleaf weeds, grasses and sedges are a greater problem if weeding is poor at the time of crop establishment.

TABLE 2
Fertilizer use in some countries in Asia

	Agricultural area	Fertilizer use	
	(*million ha*)	(*tonnes*)	(*kg/ha*)
Cambodia	5 307	12 716	23.96
Australia	472 000	2 110 000	44.70
Lao People's Democratic Republic	1 678	10 166	60.58
Myanmar	10 505	171 805	163.55
Philippines	11 280	627 930	556.68
China	535 566	35 077 600	654.96
Indonesia	42 164	2 772 900	657.65
Thailand	21 175	1 660 863	784.35
India	180 600	16 797 500	930.09
Malaysia	7 890	1 406 111	1 782.14
Viet Nam	7 892	1 947 400	2 467.56

Source: Maclean *et al*., 2002 (adapted).

- Insect pests in rice are numerous: brown plant-hopper, armyworm, caseworm, leaf-folder, stem borer and gall midge are the main predators; Cambodian rice is particularly sensitive to hopper attack, which causes the plant leaf to turn brown – a phenomenon known as "hopper burn" and which results in serious crop losses. Rats and crabs are other major pests. Control depends mainly on community involvement with mass trapping and killing. In recent years, golden apple snails have also become pests of rainfed lowland rice (Jahn *et al*., 1997).
- Diseases occur frequently, but their effect varies depending on the variety grown, the management practices adopted and the climate. Major disease incidences are rare, but most crops are susceptible to minor attacks of, for example, blast, brown spot, sheath rot and sheath blight (fungal), bacterial leaf streak, bacterial blight and tungro.

Variety and seed

The cultivation of improved varieties is strictly limited in rainfed lowland rice production. Traditional rice varieties are still grown and are only being slowly replaced. The traditional varieties are generally low-yielding, but are well adapted to local growing conditions and have acceptable grain quality. It is common practice for growers to cultivate several different varieties of rice on a small block of land, planting one variety adjacent to the next with no isolating distance between them. Where flowering times are similar, cross-pollination occurs and varietal purity can be adversely affected. Harvesting, threshing and storing of seeds of the different varieties take place together or in close proximity, leading to varietal mixing, which in turn leads to yield reduction (Sarom, 2002).

CROP MANAGEMENT RESEARCH AND RECOMMENDATIONS FOR RAINFED LOWLAND RICE PRODUCTION

Investments in research and development (R&D) quickly filter through to the national economy. Where funding is limited, it is important to target those sectors where cost-efficiency is more certain. However, given the traditional nature of much of rice production in Cambodia, it tends to be existing and well-proven technologies that are disseminated in preference to new innovation. There is scope for both approaches, and the industry has done much to promote the use of improved technologies, crop care and information exchange.

Variety

To overcome low productivity, one major strategy applied has been the replacement of existing low-yielding varieties with newer higher-yielding varieties, taking into account taste preferences and market requirements. The CARDI (Cambodian Agricultural Research and Development Institute) breeding programme has developed and released more than 30 new varieties of rice to growers (Sarom, 2001 and 2002). Different varieties are recommended for the different sub-ecosystems, ranging from favourable to unfavourable. A 2002 study showed not only that newly recommended varieties gave yield advantages of 17 percent or more over traditional varieties, but that they were preferred by consumers for their taste.

Double cropping system

Rice-based cropping systems have been developed and adapted to farmers' fields. Double cropping (i.e. rice and rice, rice and cash crops) has been widely tested and recommended to farmers. The development of small-scale deep-well systems has contributed significantly to the adoption of double cropping techniques, as small-scale irrigation can be guaranteed. The introduction of legumes (e.g. mung bean, soybean and sesbania) has led to improved soil structure and nutrition, providing the basis for increased rice yield. Major limitations in double cropping systems include: lack of reliable rainfall for early season rice; risk of soil water saturation for early season mung bean; and lack of water for the establishment and subsequent growth of mung bean following wet season rice.

Current practice is to minimize risk and maximize yield in the wet season rice crop, resulting in limited flexibility when growing other crops. For example, early season mung bean should be planted early on to reduce the risk of soil water saturation, whereas dry season mung bean should be planted as soon as possible after harvesting the wet season rice. Another option is to shift the planting dates: grow wet-season rice earlier to accommodate dry-season mung bean, or later to accommodate early-season rice. A systems approach is required to maximize the use of the limited water available and to minimize the risk of crop failure. Characterization of rainfall patterns will assist with the evaluation of risks inherent in the different cropping systems. The availability of supplementary irrigation – even for limited strategic irrigation – reduces the risk of crop loss and increases the value of double cropping.

Land levelling

Uneven (i.e. non-level) fields require more water to wet the soil for ploughing, and to maintain complete water cover for weed control. The unevenness (i.e. the difference in height between the highest and lowest part of the field) of Cambodian rice fields ranges from 70 to 330 mm, with an average of 160 mm. Research by CARDI has shown that land levelling alone can increase rice yields by 15 percent, and reduce weed burden by 40 percent and weeding time by 5–21 labour-days/ha. Land levelling is therefore a technology with the potential to improve the performance of rice-based farming systems in Cambodia, and it has been widely promoted and practised in recent years.

Fertilizer recommendations

Soil classification systems for rice have been developed linking recommended fertilizer rates to different soil types (White, Oberthur and Sovuthy, 1997) on the basis of "fertility capability". Both advisor and farmer are thus able to predetermine the rates of fertilizer applications that may apply to a given soil type. Rice soils in Cambodia have been divided into 11 groups with names relating to the most popular location in which they predominate.

Rat control

Rats cause serious damage in both rice fields and rice stores. There are two main types of field rat that attack rice, namely *Bandicota indica* (“big rat”) and *Rattus argentiventer* (“small rat”). Control is difficult, requiring the full involvement of the community. Every grower suffers from rat infestation and in recent years, the trap-barrier system (TBS) has been tested and recommended for use by rice farmers for all ecosystems including rainfed lowland rice. Following the introduction and adoption of TBS, a significant number of rats have been caught, the threat of rats has declined and productivity has been enhanced. Vigilance, however, is required to prevent the build-up of rat populations.

Farmer knowledge

Significant increases in national rice yield have been noted over the last 10 years thanks to CARDI’s R&D work and the distribution of technical packages to farmers. Such progress must be supported by human resource development, and programmes to boost the capability of farmers and others have been undertaken. Participants from the provincial agricultural offices, agricultural extension offices, technical departments of the Ministry of Agriculture, Forestry and Fisheries (MAFF), international organizations, non-governmental organizations and others have been trained in various technologies and activities. Farmers have been trained to identify and distinguish rice pests from friendly insects and shown recommended pest control measures; they have also been trained to follow appropriate planting times and to grow pest-tolerant or disease-resistant varieties of rice, resulting in rapid increases in rice yields.

CONCLUSIONS

Traditional varieties of rice grown in a traditional manner remain a valuable resource, but yields can be low, which lowers crop productivity. Growers must keep up with research and development and adopt new technologies as they become commercially available. Two general conclusions can be made:

- Agricultural R&D is the basis for national development in Cambodia; it is the focal point for innovation and for the introduction of agricultural technologies to help promote economic growth and alleviate poverty. More than 80 percent of the population live in rural areas and Cambodia is dependent on the productivity of the rural economy. However, rural poverty is more common than urban poverty; investments in agricultural productivity will help reduce rural poverty.
- New technologies are required in order to improve crop productivity. Core research policies centre on the development of appropriate technologies that take into account the socio-economic reality of people living in harmony with their environment. Such technologies should aim to enhance the natural resource base within sustainable production systems.

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Recherche en gestion des cultures et recommandations pour la production de riz pluvial de bas-fonds au Cambodge

Les systèmes de production à base de riz au Cambodge consistent essentiellement en systèmes de production pluviaux de bas-fonds. L'accroissement de production qui s'est récemment fait sentir (tant pour le riz que pour d'autres cultures) a permis au pays d'accéder dans une certaine mesure à l'autosuffisance alimentaire. L'amélioration des rendements a eu pour origine l'élaboration, l'introduction et la mise en œuvre de nouvelles technologies sélectionnées, plus particulièrement adaptées à une utilisation à petite échelle.

Parmi celles-ci, la diffusion de variétés améliorées de riz a revêtu une importance significative. Le principe de la double récolte (riz et riz, riz et culture de rente) a été largement essayé et adopté par les producteurs. Le nivellement des terres, l'utilisation d'engrais et une lutte plus efficace contre les infestations de rats ont également contribué à l'amélioration des rendements. Ceux-ci restent néanmoins faibles en ce qui concerne le riz; la diffusion de l'information et des technologies est appelée à s'étendre de plus en plus dans un avenir proche.

Investigaciones sobre gestión agraria y recomendaciones para la producción de arroz de regadío en las tierras bajas de Camboya

En Camboya, la agricultura basada en el arroz tiene lugar sobre todo en sistemas productivos de tierras bajas que emplean riego. El considerable incremento de la producción registrado recientemente (con arroz y otros cultivos) ha permitido al país alcanzar un cierto grado de autosuficiencia. Los mayores rendimientos se deben al desarrollo, la introducción y el empleo de ciertas tecnologías nuevas particularmente idóneas para las explotaciones en pequeña escala, entre las cuales ha tenido particular importancia la entrega de variedades mejoradas de arroz.

El doble cultivo (arroz y arroz, o bien arroz y cultivos comerciales) ha sido ampliamente experimentado y adoptado por los agricultores. La nivelación del terreno, el empleo de fertilizantes y un control más eficiente de la infestación por ratas también han contribuido al aumento de la producción. Sin embargo, la productividad del arroz sigue siendo baja, por lo que se ha previsto seguir ampliando la difusión de información y tecnologías en el futuro próximo.

Rice production in Japan

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INTRODUCTION

Rice has always been important in Japan. It is the basic staple and was at one time also used as currency. Until the Edo era (c. 1870), local feudal lords were rated on the basis of the quantity of rice produced in their territories. The salaries of their liegemen were paid in rice: the unit was the *koku* and one *koku* was the equivalent of 150 kg of rice (sufficient to feed one subordinate soldier for 1 year). The amount of rice produced did not meet demand – it was never sufficient after tax (farmers and others living in the countryside were "owned" by the feudal lords, and they taxed the farmers half of all the rice produced on their land). Land holdings were small – usually less than 0.5 ha. In an effort to minimize taxes and to provide for their families, farmers made every effort to boost yields, an approach which lives on today.

TECHNOLOGIES CONTRIBUTE TO YIELD INCREASES

About 2 tonnes/ha of brown rice was a typical yield during the mid-nineteenth century (i.e. 150 years ago). The twentieth century saw a steady increase in yields, thanks to numerous technological advances, better use of farm resources, application of fertilizers and improved crop care – resulting in the current average yield of 5 tonnes/ha of brown rice. Technological achievements include:

- Greater water-use efficiency (e.g. improved timeliness of application), thanks to the construction of dams, canals, reservoirs and other water management structures.
- Improved soil performance, following the understanding of the role of plant nutrients, organic manures, improved water-holding capacity etc.
- Chemical fertilizer use, which boosts yields (ammonium sulphate-nitrogen fertilizer was first applied in 1913 and soon became commonplace).
- Variety development, taking advantage of technical innovation, with cross-breeding mainstream practice since 1904.

Rapid yield increase was seen in the mid-twentieth century, but has slowed down since the 1970s (Figure 1).

Rising labour costs saw Japanese rice farmers quick to mechanize, supported by an innovative and dynamic manufacturing sector. Power threshers were developed in the 1930s, power cultivators in the 1950s, binders (i.e. simple harvesters) in the 1960s, and transplanting machines and combine harvesters in the 1970s. There has been similar technical innovation in the post-harvest sector for handling and processing rice and Japan is a world leader in this field.

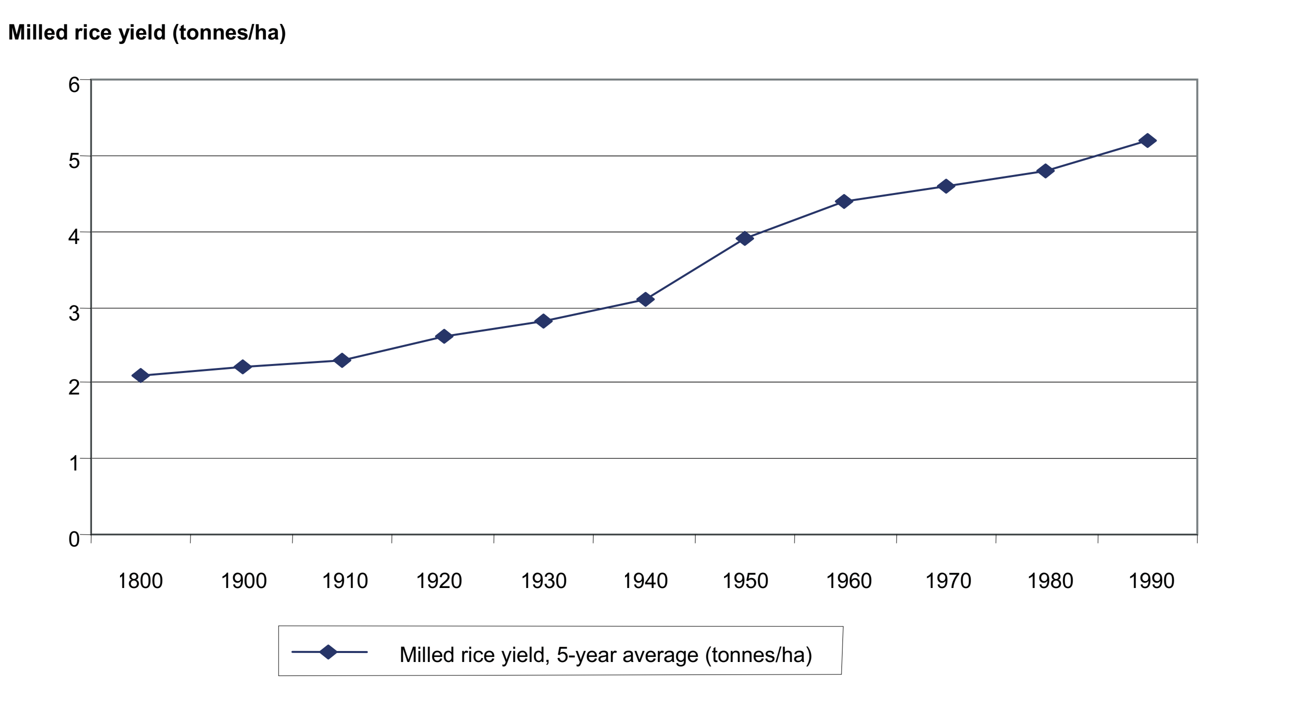
RESPONDING TO CHANGES IN DIETARY LIFESTYLE

Population increase and rice consumption have generally kept pace with yield increase. Consumption reached a peak of 120 kg/year/caput in 1963 and has since been decreasing; by 2003, it was around 60 kg/caput.

Lifestyle changes have driven dietary change: industrialization has led to imports of large quantities of different foods and cereals; people have adopted foods from other countries and large quantities of meat, eggs, fish, bread and oil are now eaten. Rice is thus being replaced in the diet and the shift from country to town, combined with the demand for convenience and novel foods has exacerbated the change. The rural population was down to 5 million in 1970 and has since decreased further.

The change in dietary lifestyle and increases in yield had a profound effect upon the rice industry: over-production became an issue. The trigger was the bountiful harvest of 1968, when an estimated 7.5 million tonnes of surplus was produced at a time when national consumption was 11 million tonnes. The export of surplus rice was impractical given the high costs of production sustained by the public sector. Instead, government policies reduced the area given over to rice while encouraging the production of alternative crops such as wheat and soybean. There were problems: growers lacked experience with alternative crops and paddy fields were used for growing crops that were not adapted to poorly-drained soils, but it

FIGURE 1
National rice yield (5-year average), 1800 to 1990



had nevertheless been decided to shift the emphasis to alternative crops.

Research and development (R&D) programmes emphasized the importance of alternative cropping and also directed the rice industry towards varieties that were more disease resistant, had lower water, fertilizer and pesticide requirements, and which produced grains that were easier to cook. Taste became important, yield less so. Yield nevertheless retained some importance because lower quality grains could be used for animal feed. Japan currently imports more than 20 million tonnes of feed grains a year for use in industrial chicken, pig and cattle production.

Development of rice with good cooking quality

Koshihakari – introduced in 1956 (i.e. 50 years ago) – is still the preferred variety of rice grown in the country. The variety dominates the industry with 560 000 ha sown annually (i.e. an estimated 37 percent of the national crop in 2004). A shift from yield to lifestyle parameters during the 1960s emphasized the importance of the cooking quality of this variety (Figure 2), unmatched by the other varieties grown. The ten leading varieties are all descendents of this original variety (Table 1) and share over 80 percent of the total cropping area.

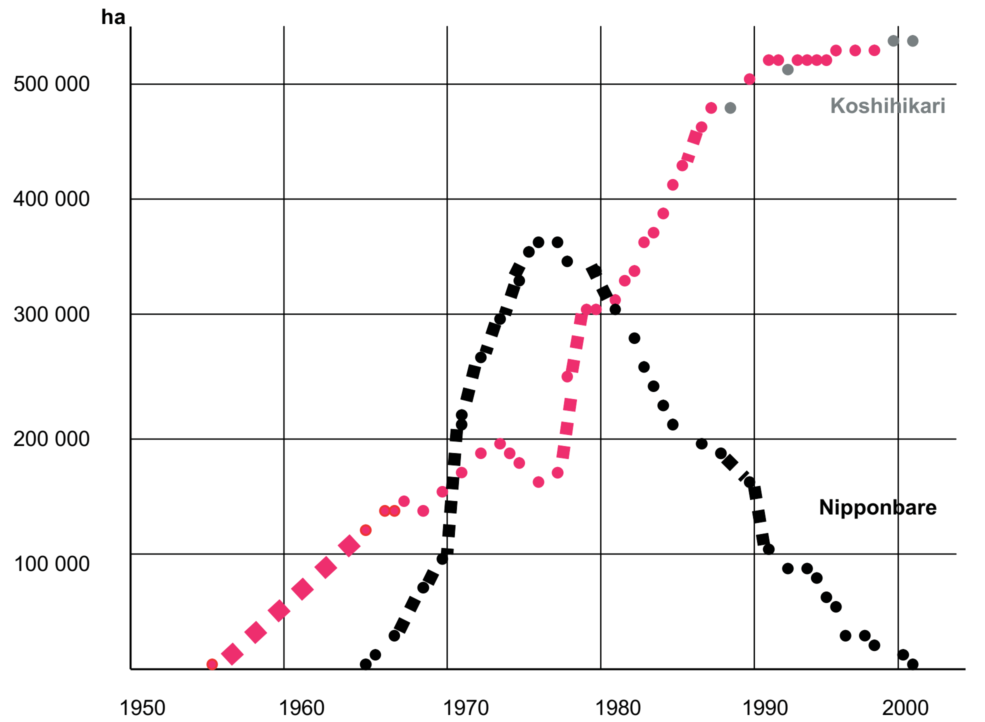
Amylose content and protein content in rice grains

R&D programmes have been introduced to boost the value of rice when cooked. Most Japanese people typically eat rice from a small bowl using a pair of chopsticks. Stickiness and softness (besides taste) are therefore important and the Koshihikari variety dominates, as people want to be able to pick up the rice grains easily. The physical properties of the rice and its chemical content are interlinked. R&D has shown that amylose content in starch and protein content in grain are strongly correlated to cooking quality (Table 2).

The characteristics of rice starch depend on the variety. The typical *indica* variety contains 25–30 percent amylose, *japonica* 18–23 percent and glutinous varieties no amylose. Low amylose mutant varieties containing 5–15 percent have been developed and in 2004, more than 3 000 ha of the milky queen variety were planted.

The higher the protein content, the harder the cooked grain becomes; consumer interest is high and people will check the protein content on the packet before buying, with manufacturers ensuring that protein quantity is prominently displayed. Contracts are placed for low-protein grains with growers who therefore apply less N fertilizer (N increases yield but lowers cooking and eating quality).

FIGURE 2
Harvested areas of Koshihikari and Nipponbare from 1950 to 2000



Development of varieties with different grain characteristics

Between 1989 and 1994, R&D programmes focused on targeting different traits, cooking qualities and tastes to meet consumer demand. Low-gluten rice was produced for people with kidney illnesses; then other varieties suited to particular dietary requirements – low-allergen rice, polyphenol-rich rice and big-embryo rice. The latter contains more gamma-amino-butyric acid (GABA – producing an angiotensine-like effect) than ordinary rice varieties (Table 3).

NEW TREND IN CROP MANAGEMENT

Excessive application of agricultural chemicals and chemical fertilizers can result in groundwater pollution with adverse effects on the natural ecosystem around rice paddies. There is growing concern about the potential ill-effects of agricultural production systems (Figure 3); while chemicals that are obviously damaging to the natural ecosystem are quickly banned, the effects on consumers can be far-reaching. People are beginning to demand non-chemical ("organic") foods to control their health – they are no longer prepared to tolerate the perceived risks of agricultural chemicals. Legislation is an effective tool for controlling chemical use.

TABLE 1
Ten most popular non-glutinous varieties planted in 2004

Variety name	Area planted (*ha*)	Total harvested rice area (*%*)
Koshihikari	552 000	37.2
Hitomebore	149 200	10.1
Hinohokari	146 700	9.9
Akitakomach	128 400	8.7
Kinuhikari	53 400	3.6
Kirari397	49 800	3.4
Haenuki	43 900	3.0
Hosinoyome	38 300	2.6
Tugaruromanroman	23 500	1.6
Nanatsubosi	17 500	1.2

TABLE 2
Relationship between grain characteristics and cooking quality of Japanese rice varieties

Grain characteristics	Cooking quality
High amylose (25–30%)	Hard
Medium amylose (18–23%)	Medium hard
Low amylose (5–15%)	Soft
Amylose free (0%)	Sticky
High protein	Hard
Low protein	Soft

Reducing agricultural chemical use

Growers are obliged to follow market trends: if consumers demand less use of chemicals, growers must comply. There are several ways of doing this:

- Predictions of pest attacks (weeds, insects etc.) prevent over-application of chemicals.
- Adoption of cropping methods to naturally disrupt pest development, e.g. application of pheromone compounds which naturally disrupt the supply of nutrients to pests or introduction of natural enemies which provide a measure of biological control.
- Adoption of mechanical weed-control methods.

Many of these alternatives to chemical control are less efficient and require experience and knowledge; they can also be more costly (Table 4).

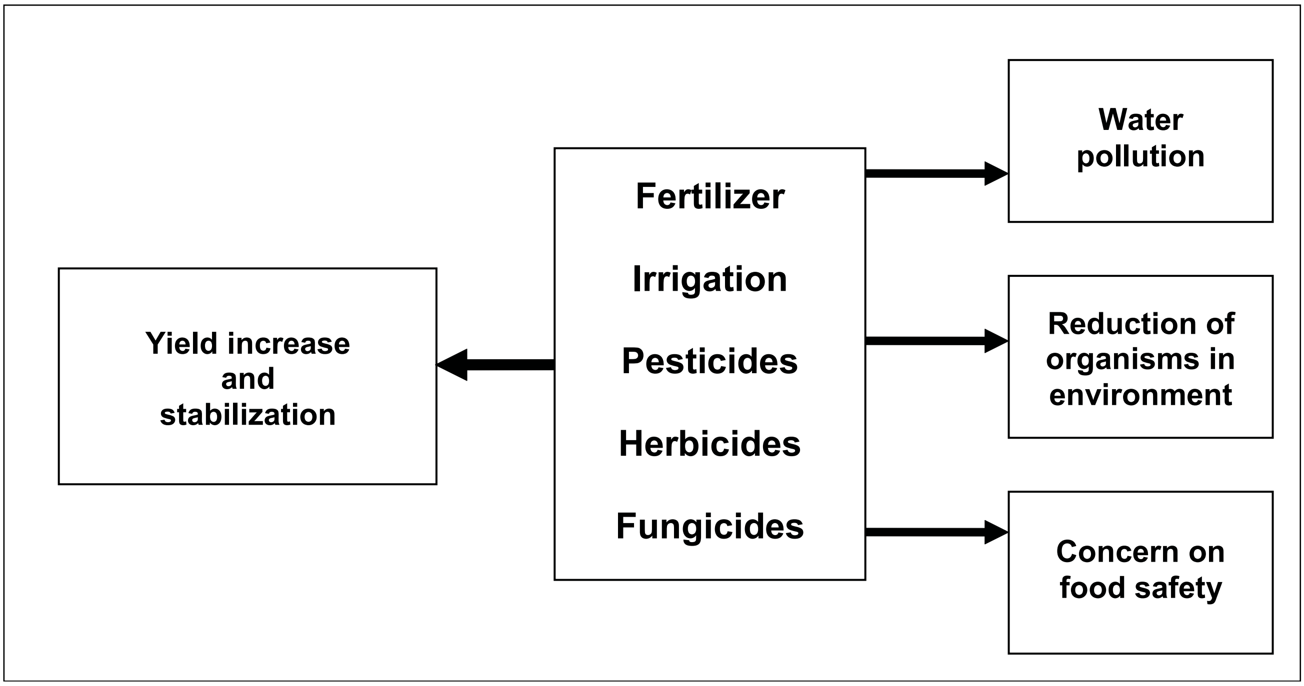
TABLE 3

Rice varieties bred for specialized markets and use

Grain characteristics	Breeding objectives	Name of variety
Low amylose	For ordinary steamed rice	Oborozuki (14% amylose) Yawarakomach (12% amylose) Milky queen (10% amylose)
Low allergen	For patients	LA-1
Low glutelin	For patients with kidney problems	LGC-1 Shunyo LGC Soft LGC Jun LGC Katsu
Low protein	For making sake (alcoholic drink)	Kuranohana
Large embryo	For making brown rice with high GABA	Haiminori
Pigmented rice	Polyphenol-rich rice	Asmurasaki Okunomurasaki Beni Roman
Scented rice	For special occasions	Sari queen Haginokaori Kitakaori
Biomass rice	For animal feed through whole crop silage	Kusahonami Kusayutaka Kusanohoshi

FIGURE 3

Schematic expression of the relationship between input application and the outcomes of such application



If the trend is to move away from chemical use – whether in crop production or crop protection – the R&D industry is obliged to follow the trend and advise the grower accordingly. R&D must meet the challenge of maintaining high yield and high grain quality and plant breeding offers the possibility of producing varietal resistance to all kinds of pests and diseases. When accumulating resistant genes, the selection of DNA marker aids is a valuable approach. Then there are genetically modified (GM) technologies which – linked to environmentally friendly agriculture – are on the brink of a revolution in plant breeding. In this context, the complete analysis of rice genomes was completed in 2004, providing a platform for fundamental work by future scientists and technologists.

Direct seeding

Direct seeding has always been an important technique for sowing rice in Japan. Nevertheless, in 1970 less than 50 000 ha of rice were direct seeded, and when transplanting machines were developed direct seeding became less popular and only 7 000 ha were direct seeded in 1993. With the development of direct-seeding machines, by 2004 this area had crept back up to 10 000 ha – still less than 1 percent of rice production in the country. Direct-seeding technologies are, generally speaking, not compatible with the Japanese climate (temperate and cool), the resulting slow germination and the short elongation that characterizes Japanese rice varieties. Japanese plant breeders are currently developing high-value cooking rice varieties suitable for direct seeding.

CONCLUSION

Despite its long history of rice production, Japan's rice production industry differs from most other Asian countries, mostly because of the climate (the land is subject to a cold temperate winter), but also because of socio-economic factors, as modern Japan is heavily industrialized, affecting the cost of production. The development of appropriate rice production systems in the near future depends on four main issues concerning: farmers, consumers, the environment and population increase.

TABLE 4
Choices: activities and end result

Activity/tactic	Result
Prediction of occurrence of pests, weeds and pathogens	Reduction in rate of pesticide and herbicide use
Transplant at low density	Reduction in rate of pesticide use
Use sex pheromone to jam communication amongst insects	Reduction in insect density
Apply low rate N fertilizers	Reduction in blast infection
Use natural enemies/biological control	Reduction in insect density

Farmers

Rice farmers are faced with trying to make a living in an increasingly competitive world where:

Income = Quantity of production x selling unit price – (production cost + alpha)

and:

- quantity of production is equal to planted area × yield;
- selling unit price is affected by the quality of rice;
- production cost is based on inputs (manures, agrochemicals, fuels etc.) + water supplies + machinery + labour + etc.
- alpha is the cost attributable by society at large for the use of the paddy field and its effects upon the environment and the landscape.

The equation makes no reference to the quality of the rice produced. It is not sufficient to simply target yields. Traders will pay according to the quality offered and the demands of the market.

Consumers

Consumers dominate the production-processing chain. Ultimately, they dictate what the farmer can grow. When consumers demand safe foods, good flavours, a healthy image and reasonable price, then farmers are obliged to produce to satisfy this demand; the alternative is failure.

Environment

Issues of sustainability have come to the fore in recent years. Farmers and others are no longer simply seeking yield increases, but are doing so with environmental awareness. The relationship between paddy field and the surrounding areas is symbiotic. There has been – and will continue to be – a better understanding of the need for sustainable production maintaining the harmony of the natural environment. Farmers are becoming increasingly involved with agrochemical free production methods that meet the requirements of the consumer.

Population increase

Food supply normally keeps pace with population increase and technically competent people can generally feed themselves within their socio-economic systems. In the near and distant future it seems likely that paddy rice will be more appropriate than upland rice production as a means of feeding people. With fixed areas of land available and little likelihood of new lands coming into production, R&D in paddy rice will need to be increased in order to help maintain crop yields. Here it will be nutrition value, cooking qualities and niche varieties that will be important so that the consumer can choose protein, fat, mineral and vitamin content to suit his/her particular needs. The future of the crop looks remarkably buoyant.

La production rizicole au Japon

La production rizicole japonaise domine le secteur agricole du pays. Le riz a toujours été de première importance pour l'alimentation de la population et ce n'est qu'à partir du milieu du XX[e] siècle que la demande alimentaire a commencé à se diversifier. Le niveau de production s'est maintenu malgré le rétrécissement des surfaces cultivées; différentes approches technologiques ont été élaborées et mises en œuvre pour multiplier les rendements. Le rendement, à lui seul, ne suffit pas à maintenir l'intérêt du consommateur, et diverses variétés ont été créées en vue d'améliorer le goût, la tenue à la cuisson et la facilité de manutention. Plus récemment, les consommateurs sont devenus conscients de l'impact écologique de la riziculture, et ont commencé à exiger des riz cultivés avec un minimum d'intrants agrochimiques. Les consommateurs s'attachent davantage à la qualité et au contenu des aliments. Il en est résulté pour les producteurs agricoles l'obligation de se plier aux tendances du marché pour pouvoir rester concurrentiels; ils ont bénéficié de l'appui des sélectionneurs, des chercheurs et des ingénieurs agricoles. La production est désormais plus ciblée, centrée sur les besoins de quatre secteurs:

- les petits producteurs;
- les consommateurs;
- l'impact sur l'environnement;
- la croissance démographique.

La producción de arroz en el Japón

El sector agrícola del Japón está dominado por la producción de arroz. Este cultivo siempre ha sido fundamental para alimentar a la población, y la población no comenzó a demandar otros alimentos para su dieta hasta mediados del siglo XX. La producción se ha mantenido pese a la reducción de la superficie cultivada con arroz; se ha desarrollado tecnología agrícola que se explotó para fomentar el rendimiento. Por otra parte, puesto que el rendimiento no alcanza por sí solo para mantener el interés de los consumidores, se han desarrollado variedades con el propósito de potenciar el sabor, la calidad en la cocción y la manipulación del producto. En tiempos más recientes los consumidores han tomado conciencia del impacto ambiental del cultivo de arroz y, lo que es muy importante, ha surgido una demanda de arroz cultivado con un empleo reducido de agroquímicos. La población ha adquirido más conciencia del valor y el contenido de los alimentos que consume. Los agricultores se ven, por tanto, obligados a seguir las tendencias el mercado si quieren mantener su actividad, y en este esfuerzo han recibido el apoyo de fitomejoradores, investigadores especializados e ingenieros agrónomos. La producción se ha hecho así más selectiva, y ahora se orienta fundamentalmente hacia cuatro ámbitos:

- los agricultores,
- los consumidores,
- el impacto ambiental; y
- el incremento demográfico.

The evolution of rice research towards sustainable rice production in Nigeria

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INTRODUCTION

The rice improvement programme in Nigeria started under the British colonial administration in the 1920s with the establishment of the Federal Department of Agriculture (FDAR) at Moor Plantation, Ibadan. In 1939, a recommendation for the establishment of a rice research station to serve all the West African territories was first put forward in a report by the West African Commission (1938–39). By 1945, Nigeria's rice production had increased by about 25 percent over the 1939 level and as a result it was necessary to establish a rice research station in Nigeria. Due to shortage of trained manpower, the project was shelved until 1947 when a plan for three rice research stations was approved by the colonial office, although not put into effect.

The National Cereals Research Institute (NCRI), with headquarters at Badeggi, was established in 1975. The institute has the national mandate for the genetic improvement of rice, soybean, sugar cane and other crops, as well as for research and extension in the middle belt zone. Extension activities are carried out under the Research Extension Farmer Input Linkage System (REFILS) with the participation of farmers, agrochemical companies, non-governmental organizations (NGOs) and other stakeholders (Abo *et al.*, 2003). Early research work in NCRI was conducted on the basis of disciplines, but by 1980 programmes had been established, each dealing with one of the institute's mandate crops and scientists were grouped accordingly.

Rice research activities at Badeggi are centred on shallow swamp and irrigated rice; at Bende on inland valley swamp; at Birnin-Kebbi on deep swamp; and at Warri on tidal swamp. Other research centres include Ibadan, Amakama, Uyo and Yandev – for upland rice – and there are about ten other testing stations across the rice-growing areas of the country. Nigeria's rice research activities are reviewed herein – the long- and short-term strategies and the impact on rice production.

RICE IMPROVEMENT IN NIGERIA

The early years

The initial challenge facing rice research scientists was the production of new varieties in relation to the specific requirements of the four recognizable rice-growing zones (Hardcastle, 1959; Beck and Hardcastle, 1965):

- High-yielding, shallow swamp varieties were produced to replace BG 79 (established in 1921), resulting in the release of FARO 1 (FARO means Federal Agricultural Research *Oryza*) in 1954/55 (FDAR, 1961).
- Early-maturing shallow swamp varieties were then introduced enabling rice cultivation to be extended into the northern areas where rainfall is limited.
- White grain floating varieties – FARO 2, 4, 5 and 6 – were successfully introduced to replace the indigenous red rice, *Oryza glaberrima* Steud, cultivated in the deep flooding valleys.
- Disease-resistant upland varieties were bred for the upland ecologies of Oyo, Ondo and Ogun (in the then midwestern and northern states with adequate rainfall), resulting in the release of FARO 3 in 1958.

Most of the varieties released had high-quality grains, but they were tall and lodged easily, had low to moderate yield, were photoperiod-sensitive and susceptible to prevailing diseases and pests (Ayotade and Fagade, 1986).

The optimum field populations under the various systems of irrigation husbandry were worked out and special attention was given to the behaviour of the rice plant under limited soil-water regimes. Economic rates of application of inorganic fertilizer were established and the time and methods of application were studied. There was a successful programme for mechanizing the wet cultivation of the irrigated fields; the integration of draught cattle into swamp rice cultivation was proposed; and the use of leguminous grain and fodder crops in short-time rice rotation was researched.

From 1962 to 1980

The shallow swamp rice improvement programme observed that the major zones of the non-inundated lowland, could be further subdivided and varieties selected for specific areas within the zones. The rice improvement programme was hence divided to target the individual zones through introduction, adaptation and hybridization work (Imolehin, 1991). In 1963, work on the selection of varieties for the naturally inundated lowlands and for the non-inundated irrigable lowlands continued. Work also commenced on an experimental site in the mangrove swamps of Edbe Island, Warri in 1964. In the same year, research focused on diseases (*Pyricularia oryzae* or *Magnaporthe grisae,* and *Helminthosporium oryzae*) that were severely attacking trials located in the western states. Screening trials identified rice varieties imported from the Congo as the most promising: short duration, with good resistance to *P. oryzae* and generally high-yielding. Post-harvest research was also important: milling studies were conducted and the optimum soaking time for the parboiling of the released varieties in the multiplication scheme was determined (18–48 hours) (Hardcastle *et al.*, 1965) – all activities which set the pace for high-quality rice grain in Nigerian markets. Breeding for resistance to blast continued, with the release of 19 rice varieties with desired quality traits for pest and disease resistance, and nutritional and yield characteristics: two upland varieties (FARO 11 and 25), two deep swamp (FARO 7 and 14), 13 shallow swamp (FARO 8, 9, 10, 12, 13, 15, 16, 17, 18, 20, 21, 23 and 24) and two irrigated swamp varieties (FARO 22 and 26) (Umanah, 1980).

From 1981 to date: coordinated trials

A global network was established by the International Rice Research Institute (IRRI, Philippines) for the systematic collection, evaluation and distribution of genetic materials through the International Rice Testing Programme (IRTP) (renamed as the International Network for Genetic Evaluation of Rice [INGER] in 1989). IRTP/INGER was regionalized in 1995 and INGER-Africa was established with headquarters at the International Institute of Tropical Agriculture (IITA), Ibadan and as a joint programme of IRRI, IITA, the Africa Rice Center (WARDA) and the National Agricultural Research Systems (NARS) in Africa. The early 1980s therefore marked the watershed for the systematic exchange, utilization and spread of improved varieties in the country.

Co-ordinated Rice Evaluation Trials

The first nationally coordinated programme on rice was the National Co-ordinated Research Project on Rice (NCRPR), established in October 1982 and funded in 1983 by the Federal Ministry of Science and Technology. It had three main objectives:

- Develop through appropriate collaborative research efforts improved technology for profitable rice farming in Nigeria.
- Mobilize all available talents and resources on rice in the country and direct them towards solving national rice problems.
- Develop appropriate nationwide acceptable recommendations for growth of the rice crop in different ecologies.

Given the need to increase rice production and boost rice supply to keep pace with the ever-increasing rate of demand, the project focused on the identification of high-yielding, disease- and pest-resistant varieties with acceptable grain qualities for the various ecologies, and the network of Co-ordinated Rice Evaluation Trials (CRET) was established. This network aimed to identify superior, improved cultivars of rice, based on their performance in 2-year multilocation trials in upland, irrigated lowland, rainfed lowland and mangrove ecologies, and in 1986 trials began on specific stresses (e.g. cold and iron toxicity). The same year saw the creation of the National Network on Soil Fertility and Fertilizer Evaluation for Rice (NNSFFER).

The major stakeholders in the CRET network are NCRI (the coordinating institution), IITA, WARDA, IRRI, IRTP and INGER; it is their job to nominate outstanding entries into the CRET network. On-farm varietal evaluation of promising entries from CRET was undertaken by agricultural development projects (ADPs) through the supervision of the National Accelerated Food Production Programme (NAFPP). On the basis of the data collated, NCRI recommended outstanding varieties to the Varietal Release Committee for consideration and release as commercial varieties. Through the CRET network, 21 rice varieties (FARO 30–50) were officially released for commercial production in the country, 10 for lowland and 11 for upland (Fagade *et al.*, 1988; Imolehin *et al.*, 1997a, b).

FARO 44 and 46 are very popular varieties with farmers (Table 1):

- FARO 44 (Sipi 692033) is a high-yielding lowland variety with good grain quality (long slender grains and high amylose content) and was introduced from Taiwan. It is short to semi-dwarf, early-maturing and has moderate tolerance to drought. It is widely adopted in the irrigated ecologies of northern Nigeria, such as Sokoto, Kano, Borno, Jigawa, Kaduna and most shallow swamps and fringes of the central states of Niger, Benue, Plateau and Nasarawa.

- FARO 46 (ITA 150) is about the most widely adopted improved upland rice variety in Nigeria today. With moderate yield (approx. 2 tonnes/ha), it is of intermediate to tall plant type and early-maturing. It has golden paddy grain colour, is easy to thresh and has long grains. It can be intercropped with sorghum, maize, millet or cocoyam in northern parts of the country; in southwest Nigeria, it may be cropped twice in a season.

National Co-ordinated Research Programme on Rice

The subsequent phase of NCRPR was the National Agricultural Research Project (NARP), launched in 1992 by the Federal Ministry of Agriculture and Natural Resources with the assistance of the World Bank, in order to revitalize the agricultural research system. The National Agricultural Research Strategic Plan (NARSP) was thus formulated for the 15-year period, 1996–2010 (Shaib, Aliyu and Bakshi, 1997b). The plan has three main components:

- **Background information** on: the country's macro-economic and policy environment; the agricultural zones and their production potential; the performance of various agricultural subsectors and the constraints faced; and the current status of the national agricultural research system.
- **Strategic research objectives** to guide research for 15 years. Long-term research goals and the Medium Term Research Plan (MTRP) for the first 5 years (1996–2000) with regard to: socio-economics and policy; soils; crops; forestry and tree crops; resource conservation; livestock and fisheries; and the research extension linkage and delivery system (Shaib, Aliyu and Bakshi, 1997a).
- **The strategy for implementation of the MTRP** through NCRPs; hence the birth of the NCRPs for arable crops, including rice (NCRP-Rice).

NCRP-Rice (Misari, Idowu and Ukwungwu, 1996) concentrated on the development of varieties with desirable traits, particularly disease and pest resistance, in accordance with the needs of the farmers in different zones. The plan also focused on integrated pest management techniques, the development of agroforestry/cropping system-based technologies for improving inherent soil fertility and the integration of fish into rice farming. The development of small-scale processing machines was also emphasized.

NCRP-Rice provided a mechanism for the participation of various partners in the National Agricultural Research Systems (NARS): NARIs (national agricultural research institutes), universities, polytechnics,

TABLE 1
Improved upland and lowland rice varieties commonly grown in different zones of Nigeria

Zone	Upland varieties	Lowland varieties
South-West	FARO 3, FARO 11, FARO 45, FARO 46, FARO 49, FARO 53, FARO 54, FARO 55	FARO 26, FARO 27, FARO 37, FARO 15, FARO 44, FARO 52
South-East	FARO 43, FARO 46, FARO 47, FARO 49, FARO 55	FARO 12, FARO 15, IR1416,[a] FARO 35, FARO 37, FARO 44, FARO 51, FARO 52
South-South	FARO 11, FARO 45, FARO 39, FARO 46, FARO 49, FARO 55	FARO 34, FARO 44, FARO 15, FARO 29, FARO 30, FARO 35, FARO 50, FARO 51, FARO 52, BW 348-1[a]
Central	FARO 41, FARO 43, FARO 46, FARO 48, FARO 49, FARO 55	FARO 33, FARO 44, FARO 35, FARO 15, FARO 12, FARO 37, FARO 29, FARO 51, FARO 5, FARO 8, FARO 19, FARO 21, BG 400-1,[a] IR 30,[a] IR 72[a]
North-East	FARO 45, FARO 46, ITA 116,[a] ITA 118,[a] ITA 235,[a] FARO 49, FARO 38, Ex-China	FARO 15, FARO 27, FARO 29, FARO 30, FARO 44, FARO 50, FARO 52 Ex-China,[a] FARO 35, FARO 36, FARO 37
North-West	FARO 45, FARO 46, Ex-China,[a]FARO 49, FARO 55	FARO 15, FARO 27, FARO 29, FARO 37, FARO 44, FARO 50, Ex-China,[a] Paroline,[a] WITA 1[a]

[a] Improved varieties not officially released to farmers.
Source: Abo and Abdullahi, 2004.

development projects, private organizations, ADPs (agricultural development projects), NSS (National Seed Service) and other relevant public and private organizations. With more stakeholders in the circle of varietal evaluation nationwide, CRET's scope was widened. Each crop programme was coordinated by the NARI with the national mandate for research into that particular crop or commodity – in the case of rice, NCRI was charged with the mandate.

The activities of NCRP-Rice culminated in the release of two rice varieties:

- Cisadane: released as FARO 51 for gall midge endemic areas; it is widely adopted by farmers in eastern Nigeria, where gall midge is a serious biotic constraint to lowland rice production (Table 1); it was officially released in 1993.
- WITA 4: released as FARO 52 for the lowland ecology; it is widely adopted by farmers for both rainfed and irrigated ecology (Table 1), combining drought resistance with iron toxicity tolerance (two main constraints to rice production in the rainfed lowland ecology); it is also high-yielding; it was released in 2001.

The Task Force Mechanism

Rice varietal improvement in Nigeria has also benefited from other collaborative research activities; the positive effects already felt will increase in the near future. The main such activity was the creation of task forces (TFs) – promoted by WARDA – to conduct research in collaboration with the national programmes. Production constraints were identified and the relevant task force worked on developing appropriate technologies. The task forces were established in 1991 and drew participation from over 17 West and Central African countries. In 1998 the WARDA TFs were merged with the West and Central African Council for Agricultural Research and Development (CORAF) Rice Network to eliminate duplication and improve efficiency. This gave rise to a single rice research and development (R&D) network – the Regional Rice Research and Development Network for West and Central Africa (ROCARIZ) (WARDA, 1999) – with the following task forces: Rice Breeding (RB), Mangrove Swamp Rice (MSR), Natural Resource Management (NRM), Sahel Natural Resource Management (SNRM), Integrated Pest Management (IPM), Technology Transfer (TT) and Rice Economics (RE).

The key rice-based technologies tested in Nigeria include:

- identification of potential interspecific and intraspecific lines for high yield, resistance/tolerance to rice yellow mottle virus (RYMV) disease, blast, iron toxicity and African rice gall midge (AfRGM);
- study of the weed competitiveness of these new improved varieties; and
- testing of cover crops, edible legumes (groundnut, cowpea), water and nutrient management and use of plant and animal manure for the maintenance of soil fertility.

Oryza glaberrima entries with high resistance to AfRGM have been used successfully to create interspecific lines for the lowland ecology.

Participatory varietal selection

Nigeria participates in farmer participatory varietal selection (PVS), a collaborative rice improvement project between WARDA and the NARS (WARDA, 2001) which puts the farmer first in the varietal selection process: farmer-acceptable rice cultivars are identified and the period between varietal development and release for farmer use is shortened. Since its introduction in 1998, PVS has seen the release of five rice varieties for commercial production:

- ITA 321 (released as FARO 53) – medium-maturing, high-tillering, high yield potential, adapted for hydromorphic and very dry upland ecologies;
- WAB 189-B-B-B-8-HB (FARO 54) – early-maturing, big bold grains, selected by farmers from southwestern Nigeria;
- NERICA 1 (FARO 55) – golden grain variety, early-maturing, high-yielding, gaining in popularity in many states;
- NERICA 2 (FARO 56); and
- tox 4004-43-1-2-1 (FARO 57).

The Rice Box Technology

Collaborative work by some national institutions has led to the development of the conservation tillage practice known as "R-Box" (Rice Box). Organizations involved in 2003 include The Candel Company Limited, NCRI, the Federal Department of Agriculture (FDA), Premier Seed Company, NSS and ADPs. R-Box aims to standardize the planting culture in both upland and lowland rice, by adopting appropriate planting materials and spacing, conservation tillage (using Round-up®), post-emergence control of weeds (Orizoplus®), top-dressing (Boost xtra®), and pest control (Delphos protex®). The stepwise operations are contained in an advisory leaflet – R-Box® Rice Production Technology Package. This technology has increased yields from 1.5 to 3–5 tonnes/ha. The package is adopted in the execution of the Presidential Initiative on Rice Production, Processing and Export, a programme launched in 2002 with the objective of enhancing household food security and income, eliminating imports and generating exportable surpluses.

Minimum tillage has the following advantages:

- Yield increase: the soil quality is improved and the soil retains moisture.
- Money saving: less labour is required for land preparation and weeding.
- Time saving: much less time is required for land preparation and weeding.
- Less drudgery: it is easier to prepare land and control weeds by spraying Round-up® than by digging.
- Soil protection: minimal disturbance of the soil and covering the ground with mulch improves soil fertility and protects land from soil erosion.

DEVELOPMENT OF RICE PRODUCTION PACKAGES

The development of high-yielding varieties is the first stage, typically followed by the development of a production technology package. Over the years, NCRI – in collaboration with other research institutes and organizations – has developed comprehensive packages for the production of rice in the three ecologies (rainfed upland, irrigated lowland and shallow swamp).

A production package for any particular ecology incorporates the following: high-yielding varieties; seed rate; land preparation method; time of planting; seeding method; fertilizer rate/method and time of application; integrated pest management; weed control; water management; bird/vertebrate pest control, time of harvesting and storage method. Each component practice differs from one ecology to another and across the agroclimatic zones. The following packages have been developed to date:

- Production technology for lowland rice in Nigeria.
- Production technology for upland rice in Nigeria.
- Guide to integrated pest management in rice.
- Guide to raising rice seedlings.
- R-Box planting with conservation tillage.
- Guide to production of high-quality rice breeders' seeds.
- Rice processing technologies in Nigeria.

Some of these production technology packages have been translated into the major languages spoken and are already available, with rice farmers receiving assistance to increase yield vertically as access to more riceland is increasingly limited.

DEVELOPMENT OF RICE PROCESSING TECHNOLOGY

Rice processing research focuses on the development of a processing technology to produce wholesome edible rice with high milling quality. In 1996, with the assistance of the World Bank, the Engineering and Fabrication Unit of NCRI developed a rice processing technology for small-scale processors; it entailed a parboiling method to produce high-quality milled rice and a rice mill that is simple to operate but also efficient. Known as the "NCRI Rice Processing Technology", it comprises the following components: rotary parboiler, dryer, rice mill and the pneumatic cleaner.

Parboiling

There have been intensive studies on the process of soaking, steaming, drying and tempering (Sluyters, 1963; Sluyters, 1964). The parboiling process is as follows:

- The paddy is cleaned in a wet cleaner to remove stones and impurities.
- The cleaned paddy is then transferred to the steamer and water from the boiler is released to the steamer to cover the paddy (left for 6–8 hours).
- The remaining water in the boiler is heated further to generate steam which is released into the steamer for 40–50 minutes.
- The parboiled paddy is spread on a concrete slab, polythene or tarpaulin for a period of 5–6 hours in the sun (depending on the intensity of sunshine); or it is put in a steam rotary dryer until it reaches a moisture content of 16–17 percent.
- The dried paddy is left in the shade for tempering to a moisture content of 13–14 percent.
- The rice is milled and packaged.

The rice mill

The rice mill developed by NCRI is made for over 90 percent using local components; only the electric motor is imported. A hopper is mounted on a half hollow cylinder containing a solid fluted cylinder that rotates within the assembly. The lower half of the cylinder is made of perforated metal (a screen). A grain outlet is incorporated at one end of the upper half of the hollow cylinder. Power is provided by a 16 horse power engine or 15 horse power electric motor. The rice is released into two rubber rolls which dehusk the rice. An aspirator separates the husks from the grains, while the scouring unit finally polishes the rice.

Small- and medium-scale processors can now process and market high quality milled rice in Nigeria and in the West African subregion. The potential of the rice processing technology is limitless.

DISSEMINATION OF RESEARCH RESULTS

The results of R&D efforts are destined for use by the end-users – i.e. the rice producers and processors. The extension arm of research institutes has the role of extending research results to end-users. However, with the promulgation of the research institute's 1975 decree which gave various research institutes specific mandates, the extension system was reorganized on a zonal basis (Abo *et al.*, 2003). The country was divided into five zones: northeast, northwest, middle belt, southwest and southeast. Under the Research-Extension-Farmer-Input Linkage System (REFILS), a research institute was mandated to coordinate extension activities in each zone; in the middle belt zone, the mandated institute was NCRI.

REFILS is an extension system in which farmer participation is important in research project design, testing and adoption; there is constant feedback from farmers and end-users on the viability adaptability and sustainability of technologies from research institutions. Under REFILS, technology packages emanating from research institutes are taken to the farmer or end-user by means of the following:

- on-farm trials (OFTs);
- multilocation trials (MLTs);
- on-farm adaptive research (OFAR);
- small plot adoption technique (SPAT); and
- mass adoption.

Each technology differs in content, sophistication and application, hence the need to simplify and adapt them to the conditions of farmers and other end-users. Various tools are used to disseminate proven technologies, including:

- training of trainers (TOT) workshops;
- monthly technology review meetings (MTRMs), where messages are passed to subject matter specialists (SMSs) of the agricultural development programmes (ADPs) in the states;
- SPATs and management training plots (MTPs), where the technology package is demonstrated and validated to prove its superiority over the local or traditional method;
- advisory pamphlets and farmers guides;
- farmers field days;
- farm broadcasts;
- agricultural shows, exhibitions and trade fairs;
- role play and film shows;
- incentives to farmers;
- farmers meetings; and
- gender specific programmes.

The MTRMs and diagnostic and thematic surveys provide the foci for feedback from farmers. This feedback is actually the premise from which research begins and hence the bottom-up farmer-driven technology generation activities of research institutes.

STATUS OF RICE PRODUCTION

Rice is the only crop grown throughout all agro-ecological zones of Nigeria (Singh *et al.*, 1997). The potential area available for the cultivation of the crop in the country is close to 5.0 million ha. Several reports have indicated marked increases in rice production in Nigeria from the 1970s to date (Nyanteng, 1986; Adpokdje, Lancon and Erestein, 2001). Production figures have risen from about 500 000 tonnes to over 3 million tonnes. The increase in production is attributed mainly to the expansion in cropped ricelands, which rose from 225 000 ha in 1970 to about 3 116 000 ha in 2002. The annual growth rate of rice area at over 10 percent is the largest in the world and the growth rate in output of between 8 and 10 percent is also amongst the largest in the world. These figures have all surpassed the projections in the national agricultural development plans (FMA, 1993). Unfortunately the paddy yield per unit area, has remained relatively low (± 1.9 tonnes/ha), resulting in an inability to attain self-sufficiency in rice production.

The demand for rice in Nigeria is growing faster than for any other major food staple, with consumption increasing across all socio-economic classes, including the poor. This is the result of, for example, increasing population, higher income levels due to oil, rapid urbanization, changes in family structure and ease of preparation. An average Nigerian consumes 23.3 kg of rice a year (Maclean *et al.*, 2002). The annual demand for rice in the country is estimated at 5 million tonnes, while production is about 3 million tonnes of milled rice, resulting in a deficit of 2 million tonnes. Rice is imported to bridge the gap and, according to the Central Bank of Nigeria (CBN), the rice import bill was US$ 259 million in 1999, almost tripling to US$ 655 million in 2001 and reaching US$ 756 million in 2002.

Self-sufficiency in rice production has not been attained nor the potential for export explored until recently, because appropriate policies and programmes were not put in place to address some of the constraints that limit production. The constraints include the following:

- poor maintenance of irrigation facilities;
- inadequate and irregular input supply such as seeds, fertilizers and credit;
- lack of small farm equipment, especially for post-harvest operations;
- poor maintenance of developed swamps;
- poor drainage and iron toxicity in undeveloped swamps; and
- lack of well-defined rice policy.

Past government policies and programmes include: NAFPP, set up in 1974; the World Bank Assisted Development Programmes (1975); Operation Feed the Nation (OFN) (1976); the River Basin Development (RBD) Authority (1977); the Back to Land Programme (BLP) and the Directorate of Food, Roads and Rural Infrastructure (DFRRI) (1988); and the National Land Development Authority (NALDA) (1995).

Most of these interventions were found to be ineffective. Through the recently introduced Presidential Initiative on Increased Rice Production, Processing and Export, a solid foundation has been laid for sustainable rice production and development for the future. The programme comprises the following components: production, inputs and crop protection; irrigation and land management; and processing and marketing. It promotes the policy of enabling private-sector-led rice production. Rice farmers and processors receive government support through the provision of inputs and services at affordable prices as private sector operators.

The adoption of the "R-Box" technology with adequate publicity given to the project has given rise to:

- increased national output of over 0.8 million tonnes;
- declining trend of import bills;
- conservation of foreign exchange;
- enhanced employment, income and living standards of farmers and stakeholders; and
- increases in other downstream businesses.

CONCLUSION

Despite the fact that rice research in Nigeria began about 85 years ago, the structural conduct and performance have not changed much. The structural operational unit is small, the conduct is traditional, with increasing productivity at a decreasing rate. Yields and resource-use efficiency have been very low and labour-land inputs considerably underutilized. Capital inputs in chemical, biological, mechanical and financial terms are yet to make any meaningful impact on increasing rice production. In general, output per unit of input is very low and much of the agricultural output is for subsistence.

If the Presidential Initiative on Rice Production, Processing and Export is to play its full and proper role in effectively contributing to economic growth and if the food problems bedevilling the national economy are to be rapidly resolved, rice research and production must be given a more meaningful direction. Where there is national and household food security, there is generally strong support to agriculture, careful consideration of economic incentives for agricultural production, and human and economic investments in research, extension and training.

The Government should therefore work to ensure a clear focus on poverty alleviation in national and international research efforts, giving priority in research and investment to applications such as soil fertility and biological pest and weed control that can give higher and environmentally sustainable yields at lower costs to enhance the competitiveness of local rice with imported rice. Adaptive breeding trials should be encouraged for varieties suited to vulnerable and marginal areas.

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L'évolution de la recherche rizicole vers la durabilité de la production de riz au Nigeria

Le programme nigérian d'amélioration rizicole a commencé sous l'administration coloniale britannique dans les années 20. Le développement de variétés de bas-fonds à haut rendement a été démarré en 1921 et les variétés de riz flottant FARO 2, 4, 5 et 6 ont été introduites avec succès en remplacement du riz rouge indigène, *Oryza glaberrima* Steud, cultivé dans les vallées profondes inondables. Durant la période 1962–1980, la recherche s'est concentrée sur la phytopathologie, notamment sur les champignons *Pyricularia oryzae* (également appelé *Magnaporthe grisae*) *et Helminthosporium oryzae*, à l'origine de sévères infestations sur des essais implantés dans les États de l'Ouest. Des expériences de sélection ont abouti à l'identification de variétés de riz importées du Congo comme étant les plus prometteuses. Ces variétés avaient une végétation rapide, avec un degré élevé de résistance à *P. oryzae* et étaient généralement considérées comme d'un meilleur rendement. Depuis 1981, des essais coordonnés de résistance ont été poursuivis en collaboration avec l'IRRI (Institut international de recherches sur le riz), l'IITA (Institut international d'agriculture tropicale) et WARDA (Centre du riz pour l'Afrique) avec pour résultat l'obtention et la diffusion de plusieurs variétés améliorées et à haut rendement, tant pour les écosystèmes de bas-fonds que de hauts plateaux des différentes parties du pays. Plus récemment, l'accent a été mis sur l'élaboration de kits intégrés de production rizicole et de technologies de transformation du riz. Dans le cadre du REFILS (Research-Extension-Farmer-Input Linkage System, Système d'interactions vulgarisation-exploitants-intrants), des kits technologiques émanant d'instituts de recherche sont amenés au niveau de l'exploitant ou de l'utilisateur final via les processus qui suivent: essais sur champ en exploitation; essais en multilocation; recherche en exploitation sur l'adaptation des kits technologiques; et la technique de l'adoption de petites parcelles (SPAT), le but d'ensemble étant d'arriver à une adoption généralisée de l'innovation. Cependant, l'autosuffisance du pays en riz n'est toujours pas atteinte, en raison de l'absence de politiques et de programmes appropriés visant les contraintes qui limitent la production. Ces contraintes comprennent: le mauvais entretien des installations d'irrigation; un approvisionnement irrégulier et insuffisant en intrants (par exemple semences, engrais, crédit); le manque de petits matériels agricoles, notamment pour les activités de post-récolte; le mauvais entretien des bas-fonds aménagés; un mauvais drainage et une toxicité due au fer dans les bas-fonds non aménagés; et l'absence d'une politique rizicole bien définie. Récemment introduite, l'Initiative présidentielle sur l'accroissement de la production, de la transformation et de l'exportation de riz pose une fondation solide pour une production rizicole durable et son développement futur dans le pays.

Evolución de la investigación arrocera para una producción sostenible de arroz en Nigeria

El programa de mejoramiento del arroz en Nigeria comenzó durante la administración colonial británica, en la década de 1920. El fomento de variedades de alto rendimiento en ciénagas someras empezó en 1921, y se introdujeron con buenos resultados las variedades flotantes FARO 2, 4, 5 y 6 en sustitución del arroz rojo autóctono *Oryza glaberrima* Steud, que se cultivaba en valles profundos inundables. En el período comprendido entre 1962 y 1980 la investigación se centró en las enfermedades, principalmente *Pyricularia oryzae* (también denominada *Magnaporthe grisae*) y *Helminthosporium oryzae*, que infligían graves ataques a las parcelas experimentales situadas en los estados del oeste. En ensayos de selección se determinó que las variedades de arroz importadas del Congo eran las que prometían mejores resultados. Ofrecían un ciclo breve, una resistencia elevada a *P. Oryzae* y, en general, un rendimiento considerablemente mayor. Desde 1981 se realizaron ensayos coordinados de evaluación del arroz en colaboración con el IRRI (Instituto Internacional de Investigación sobre el Arroz) y el

ADRAO (Centro Africano del Arroz), que permitieron desarrollar y entregar diversas variedades mejoradas y de alto rendimiento para su cultivo tanto en ecologías de tierras altas como de tierras bajas en diferentes zonas del país. Recientemente los esfuerzos se han orientado hacia el desarrollo de paquetes productivos y tecnologías de procesamiento del arroz. En el marco del sistema REFILS, que establece un vínculo entre la investigación, la extensión, los agricultores y los insumos, los paquetes tecnológicos elaborados por los institutos de investigación se hacen llegar hasta los agricultores, sus usuarios finales, mediante los siguientes procedimientos: ensayos en las explotaciones; ensayos en múltiples localidades; investigación adaptativa en las fincas; y técnicas de adopción en pequeñas parcelas. La finalidad de este proceso es la adopción generalizada de dichas tecnologías. Sin embargo, la producción de arroz aún no ha alcanzado la autosuficiencia, y esto se debe a la falta de políticas y programas apropiados para hacer frente a los obstáculos que limitan la producción. Dichos obstáculos incluyen el escaso mantenimiento de los sistemas de riego; un suministro irregular e insuficiente de insumos (como semillas, fertilizantes y crédito); la falta de pequeños equipos agrícolas, especialmente para las actividades de postcosecha; el mantenimiento deficiente de las ciénagas que han sido objeto de ordenación y, en las que no lo han sido, el escaso drenaje y la toxicidad provocada por el hierro; por último, la falta de una política arrocera bien definida. De cara al futuro, la reciente iniciativa presidencial orientada a incrementar la producción, elaboración y exportación de arroz proporciona una base sólida para la producción y desarrollo sostenibles de este cereal en Nigeria.

Potential of broadcasting seedlings for making savings in seed, water and labour in irrigated rice production systems in Sri Lanka

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INTRODUCTION

Rice is the staple food of the majority of people in Sri Lanka and annual consumption is about 100 kg per capita. The total land area of the country is about 6.84 million ha, of which about 25 percent is used for agriculture. Rice is grown on about 720 000 ha, of which 550 000 ha are cultivated during the wet season (Oct.–Feb.) and 310 000 ha during the dry season (Mar.–Sept.). Sri Lanka may be divided into three major agro-ecological zones on the basis of annual rainfall:

- dry zone (<1 400 mm)
- intermediate zone (1 400–2 500 mm)
- wet zone (>2 500 mm).

The dry and intermediate zones are the major rice-growing areas with, respectively, 63 and 19 percent of total production. Approximately 80 percent of rice is irrigated – 55 percent in major irrigation schemes (> 80 ha with tank/reservoir resources) and 25 percent in minor (< 80 ha). The remaining 20 percent is rainfed. (Abeysiriwardena, 2000).

Most farmers in major irrigation schemes prefer to cultivate high-yielding and high-quality rice varieties that mature around 120 days. However, the irrigation authorities in Sri Lanka are currently encouraging rice farmers to cultivate varieties with short-maturity duration (i.e. 90–105 days) for a more equitable division of the resources, guaranteeing water supply to all farmers throughout the cropping season. When there is sufficient water in the reservoirs, however, the authorities will release water for 120–150-day cropping, enabling the cultivation also of long-duration varieties.

In Sri Lankan rice cultivation, more than 90 percent of farmers choose to broadcast seed (MoADR, 1989). Studies have shown that under good management there is no significant difference in yield between broadcasting and transplanting (Bandara, 1984), so farmers adopt broadcasting and harness the economic advantage of saving labour at the expense of producing and planting paddy. However, more water is used in land preparation and weed control in the early stands of rice, accounting for around 40 percent of total crop water requirements.

MAJOR ISSUES OF RICE PRODUCTION

Rice production in the country has been facing a number of issues with a potential impact on sustainable rice production in the long run. The major issues are:

Water requirements

Water requirements depend on soil type, climate, duration through to maturity of the variety, and cultivation system used. Average water requirements for rice cultivated under irrigated conditions can be as high as 2 100 mm in the dry and intermediate zones (Jayathilaka, 2000). However, water scarcity is an increasingly important issue as a result of the inconsistent rainfall in recent years and the competition for water from other users; it is probable that not even the major irrigation schemes will be able to guarantee sufficient supply to growers. The efficiency of water use for rice production must be enhanced, particularly in the formal irrigation sector.

Seed paddy production and requirements

Seed paddy requirement per unit of land is high due to the Sri Lankan practice of sowing at high density. The recommended seed rates for direct seeding are 100 kg/ha for normal-size and 75 kg/ha for small grains. However, in some areas, seed rates may be as high as 250–400 kg/ha to aid weed control (Mettananda *et al.*, 1990). At a rate of US$ 320/tonne of seed paddy, the seed cost for one hectare at the recommended rate is US$ 32, i.e. about 15 percent of the total cost of cultivation. The

Department of Agriculture and private sector seed producers produce only about 15 percent of the current annual certified seed paddy requirements (AgStat, 2004).

Cultivation costs

The cost of rice cultivation is about Rs 50 000/ha (US$ 500/ha), with labour accounting for about 50 percent of the total costs. Compared to other rice-growing countries in the region, wage rates in Sri Lanka are high (US$ 3.5–4/day). For transplanted rice, about 15 percent more labour is needed than with direct seeding. During the past 20 years, labour costs have increased threefold, and they continue to rise. With a rapidly developing industrial and service sector, it is increasingly difficult for rice producers (and farmers in other agricultural sectors) to pay enough to attract and keep skilled labour. Mechanization is one solution to labour shortages and it has already been accepted in the region's industrialized rice-producing countries. Sri Lanka is likely to follow a similar pattern of rural development.

Methods of establishing a stand

Stand establishment depends on climate, soil, the availability of water, the availability and cost of labour and the choice of variety. In Sri Lanka, three methods are generally used to establish a stand of rice:

- broadcasting
- transplanting
- row seeding

Seed broadcasting is the traditional system, practised since rice was first introduced into the country, and may be "dry" sowing or "wet" sowing.

Dry sowing is typical of areas in which rice is largely rain dependent. The land (characterized by sandy soil) is ploughed after the first rains; a few days after ploughing, the seeds are broadcast and harrowed into the soil. Sri Lanka is becoming rapidly industrialized and mechanization is creeping into agriculture as labour costs rise. The land is cultivated by tractors and animals – buffalo and mammoties. Following the rains, the seeds germinate and the fields are flooded. Seed rate varies depending on the environmental conditions: it is generally 150–300 kg/ha, but in eastern parts of the country, for example, it is 300–400 kg/ha. The seed rate for dry seeding is 3–4 times higher than the recommended rate for wet seeding. High seed rates mean high seed costs and also high incidence of pests (e.g. brown planthopper) and disease (e.g. sheath blight) (Mithrasena, Adhikari and Wickramasinghe, 1987).

Wet sowing is typical in low-lying areas where water is plentiful. In Sri Lanka, the majority of paddy fields are sown to wet-seeded rice: pregerminated seeds are uniformly sown into well-puddled, well-levelled and well-drained fields. Seed rate varies according to the size of the seeds sown and the region. When the seedlings are about 1 week old, the fields are flooded.

SEEDLING BROADCASTING – A POTENTIAL TECHNOLOGY

Seedling broadcasting was first introduced into Sri Lanka from China, and is now widely recommended by the Rice Research and Development Institute for the establishment of a stand of rice. Seedling broadcasting helps to reduce the seed rate and related costs, while not exceeding the labour costs of seed broadcasting techniques. Seedlings with 12–15 day growth in root balls are broadcast-sown in well-prepared fields, thus reducing the need for transplanting. Seedlings are raised in specially adapted plastic trays (59 × 34 cm^2) containing 434 embedded holes. The method is particularly suited for hybrid rice. The principal advantage is the reduction in labour costs as transplanting is expensive. The seed is used more efficiently and the method is therefore particularly adapted to hybrid rice as hybrid rice seeds are very expensive (Jayawardena *et al.*, 2004).

Procedures for seedling broadcasting

About 750 trays are required to raise the seedlings required for 1 ha of crop. To propagate the seedlings for 1 ha, a seedbed of an average 250 m^2 is required. Nurseries can be established just about anywhere – uplands, lowlands or in specially adapted planthouses. In lowland nurseries, seeds are sown in raised beds 75 cm wide and 12–15 cm high; the length varies depending on the land available and the choice made by the grower. Seedling trays are located in the beds, and the holes in the trays are filled with a mix of mud and the surface levelled. Pregerminated seed is sown evenly over the tray, targeting one seed per hole, which means that only 10 kg of seed is required to plant 1 ha of land (at about 15 × 20 cm^2 spacing). The trays are then covered with any local materials freely on hand – banana leaves, cajans and other materials that provide the seed or seedling with adequate shelter from prevailing winds and rain and prevent them moving. In upland systems, raised beds are not required and the trays can simply be placed on the soil surface. Daily watering is essential for an upland nursery, but once every 2–3 days is usually adequate in lowland nurseries; much, however, depends upon the prevailing weather conditions. It is essential that the seedlings do not become water-stressed. Growers normally apply small quantities of insecticide to control pests such as thrips, stem borers and gall midges. After 12–15 days in the nursery, the seedlings are ready for broadcasting. The grower transports the seedlings to the field in their trays or separately packed in baskets or bags. Seedlings are pulled from the trays and thrown into the field. In a single handful, the grower can broadcast 15–20 seedlings. If the fields are small, broadcasting can be done from the security of the bund, and the grower does not have to wade into the field.

Performance of seedling broadcasting

Trials comparing traditional seedling with seedling broadcasting methods have been undertaken under R&D and field conditions to help establish the production parameters required.

There were no significant yield differences between transplanting and seedling broadcasting (Table 1). Pilot testing was undertaken in 2003 on two sites in farmers' fields in the dry zone with the collaboration of extension staff and farmers. There were differences between the two seeding methods with respect to the number of hills/m^2 and the number of panicles/m^2; in a real production situation, seedling broadcasting gave higher yields (Table 2).

Estimated labour requirements for nursery establishment, uprooting and placement, and field establishment are shown in Table 3. Labour requirements for each activity required of seedling broadcasting are lower than for transplanting. The labour requirements of seedling broadcasting are approximately 50 percent lower than those of transplanting for stand establishment. Seedling broadcasting uses seed more efficiently than standard broadcasting, with 5–10 times less seed required for the same crop or yield. If 1–2 seeds are placed in each tray hole, only 10–20 kg/ha of seed is required; conventional seeding rates for broadcasting are 100 kg/ha.

Seedling broadcasting results in savings not only in labour and seed, but also in water. Typical practice is to apply water every 7–10 days; for a crop with a duration of 3.5 months, about 12 applications are required. Savings of around 15–20 percent are made with seedling broadcasting for the following reasons:

- In a nursery, just two irrigations are sufficient, with additional water applied by hand.
- The nursery area is small and so requires little water compared to the flooding of an entire field using conventional methods.

TABLE 1
Grain yield of BgHR12 under manual transplanting and seedling broadcasting at RRDI, Sri Lanka during 2002/03 wet and 2003 dry seasons

Stand establishment method	Season		
	2002/03 wet	2003 dry	**Mean**
	Grain yield (*tonnes/ha*)		
Manual transplanting	6.09	5.66	**5.87**
Seedling broadcasting	6.06	5.28	**5.67**
Mean	6.07	5.47	**-**

TABLE 2
Comparison of manual transplanting and seedling broadcasting with BgHR12 at two sites in farmers' fields in 2003

Characteristics	Site					
	Weera Pedesa		Jayanthipura		**Average**	
	SBC[a]	TRP[b]	SBC[a]	TRP[b]	**SBC[a]**	**TRP[b]**
No. hills/m^2	38	42	49	39	**44**	**41**
No. panicles/m^2	321	293	291	302	**306**	**298**
Grain yield (*tonnes/ha*)	8.79	8.45	8.97	8.51	**8.88**	**8.48**

[a] SBC: seedling broadcasting. [b] TRP: manual transplanting.

TABLE 3
Estimated labour requirements for manual transplanting and seedling broadcasting with BgHR12

Activities	Labour requirements (*workdays/ha*)[a]	
	TRP[b]	SBC[c]
Nursery establishment and management	5	5
Uprooting and placement	5	3
Field establishment	20	8
Total labour requirements	**30**	**16**

[a] Average for minor and major seasons in 2003.
[b] TRP: manual transplanting.
[c] SBC: seedling broadcasting.

- A broadcasted seedling crop matures more quickly than a seeded crop, and less water is needed for the growing crop.

Such savings are important, given the increasing competition for water among farmers and in the light of the failures that farmers sometimes experience with maturing crops of traditionally sown rice. The water control authorities on the major irrigation schemes prefer a 120-day crop as it provides more efficient use of water, and will discriminate against those growing crops for longer. The other advantages of seedling broadcasting are as follows:

- Improved bird control: little or no damage to seedlings in the nursery and the field.
- Promotion of the use of hybrid rice where broadcasting is used.
- Reduction of the quantity of macronutrients and insecticides used for seedlings in the nursery, minimizing environmental effects and reducing input costs.
- Increased timeliness of land preparation and seeding. Farmers make the most of changes imposed by the coming of rains, water availability and the willingness of the irrigation authorities to release water quickly: farmers who already have nurseries of seedlings available are quickly able to cultivate and plant their land. With traditional methods, on the other hand, seed has to be broadcast and germinated before the growing crop can use the water provided.

CONCLUSION

The advantages of seedling broadcasting are well recognized by both farmers and extension advisors. Several hundred demonstrations were held across the country during the 2004/05 wet season: many farmers have adopted the methods and R&D experts have been quick to train the extension advisors. The supply of trays has not been able to keep up with demand – one leading company, Messrs Hayles Agro, has imported large numbers of trays from China, and more local companies are being encouraged to produce trays to meet demand and lower the costs of purchase.

A major constraint is cost as farmers must purchase the seedling trays required; however, the trays are durable and may be used for at least three seasons, thus lowering annual costs. Another constraint is the crop damage that can occur when heavy rains follow seedling broadcasting; the uniformity of the crop stand is reduced and greater efforts are required for crop care and harvesting.

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La distribution de plants et le potentiel qu'elle représente pour des économies en semences, eau et main-d'œuvre dans les systèmes de production rizicole irriguée du Sri Lanka

Les méthodes de production rizicole faisant appel à la production de plants de repiquage pour démarrer les campagnes rizicoles ont été introduites au Sri Lanka à partir de la Chine et rapidement adoptées par les producteurs. Les expériences réalisées – tant dans le cadre de la R-D que sur des sites pilotes – ont mis en évidence les avantages indéniables de la production de plants de repiquage. Les économies portent sur la main-d'œuvre (environ 50 pour cent), l'eau (environ 15 pour cent) et les semences. De fait, la quantité de semences nécessaires quand les plants sont produits en pépinières n'est que d'environ 10 à 20 pour cent de la quantité requise par les méthodes traditionnelles de repiquage, ce qui se traduit par des économies substantielles quand les variétés utilisées sont des hybrides aux semences coûteuses. Les plants issus de pépinières produisent une récolte plus homogène et le grain récolté à partir de ces plants est donc en général d'une qualité meilleure et plus uniforme. Compte tenu de la hausse rapide des coûts de main-d'œuvre et des autres intrants de la production rizicole au Sri Lanka, ainsi que de la concurrence croissante qui se fait sentir pour l'utilisation des ressources en eau, le passage à la distribution de plants de pépinières est activement encouragé par les autorités responsables de l'irrigation, entre autres. En comparaison des avantages de cette méthode, les inconvénients sont mineurs; il s'agit essentiellement de l'obligation pour les agriculteurs d'acheter et d'utiliser des pots pour les plants, dans le cadre de l'utilisation de pépinières. Les agriculteurs doivent également acquérir et mettre en œuvre les connaissances techniques nécessaires, notamment pour la conduite des pépinières de plants de riz. Il ne s'agit pas là de contraintes lourdes et les agriculteurs s'y sont pliés sans réticence.

Las técnicas de esparcido de plántulas y sus posibilidades de economizar semillas, agua y mano de obra en los sistemas de producción de arroz de regadío en Sri Lanka

Los métodos de esparcido de plántulas para el establecimiento de arrozales se introdujeron en Sri Lanka desde China, y fueron adoptados con rapidez por los agricultores. La experimentación – tanto en actividades de investigación y desarrollo como en parcelas piloto en las fincas– ha revelado las evidentes ventajas que ofrecen estas técnicas, ya que permiten economizar mano de obra (alrededor del 50 %), agua (15 % aproximadamente) y semillas. De hecho, la producción de plántulas en vivero sólo requiere de un 10 a un 20 % de las semillas que se necesitarían para la siembra al voleo tradicional, lo que entraña un ahorro considerable cuando se utilizan variedades híbridas de costo elevado. Las plántulas que crecen en viveros forman un cultivo más uniforme, y una vez esparcidas producen, por lo general, un grano más homogéneo y de mejor calidad. En vista del aumento exponencial de los costos de la mano de obra y otros insumos agrícolas en Sri Lanka, así como de la competencia cada vez mayor por el acceso al agua, la adopción de las técnicas de esparcido de plántulas es fomentada activamente por las autoridades responsables del riego, entre otros. Las desventajas de estos métodos, menores que sus ventajas, residen principalmente en que los agricultores deben adquirir y utilizar cajas de plántulas como parte de los procedimientos que requieren los viveros. Además, es indispensable que comprendan y apliquen los cuidados técnicos necesarios, en particular, en los viveros que producen las plántulas. No obstante, no se trata de obstáculos insalvables, y los agricultores han adoptado rápidamente estas prácticas.

Rice production situation in Uruguay

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INTRODUCTION

Uruguay is located between the 30th and 35th parallels of the Southern Hemisphere. Rice production only began at the end of the 1920s and just one crop per year is sown; low temperatures may occur during the crop reproductive phase. More than 90 percent of the rice produced is exported, while the domestic consumption of elaborated rice is between 10 and 11 kg/person/year.

Research, production and industry are closely interconnected – research facilitates the adoption of new technologies and the production demand is thus met. The production and industry sectors join forces to obtain the grain quality demanded by international markets, while respecting the environment.

THE ENVIRONMENT OF RICE PRODUCTION

According to the agrometeorological station at the Paso de la Laguna Experimental Unit (eastern Uruguay), the average annual rainfall in the past 33 years is 1 375 mm, approximately 50 percent of which falls during the rice-growing period (Oct.–Mar.). Table 1 shows the average records of the main climatic variables, considered important for rice growth; the figures are means and do not show the great variability of the climatic variables.

Rice is the principal user of irrigation. Uruguay has important sources of natural waters: rivers, brooks and lagoons, with over 400 intakes installed; in addition, there are 800 artificial reservoirs (> 90 percent assigned to rice). There are three production zones (eastern, central and northwestern) with specific characteristics related to the soil, topography and climatic conditions). Low temperatures in the central and eastern zones during the crop reproductive period reduce productivity and high doses of nitrogen can have negative effects – when there are several consecutive days with daily minimum temperatures below 15 °C in the immediate period before/after flowering, plants that have absorbed high quantities of nitrogen increase the spikelet sterility percentage. In the last few years, 180 000 ha have been planted and average yields have improved significantly: > 6 tonnes/ha in 7 and > 6.5 tonnes/ha in 5 of the last 10 years (Table 2).

There are just under 600 rice-producing farmers: 46 percent are exclusively agricultural; 54 percent have a mixed rice-livestock enterprise. In 75 percent of farms, the land is rented for sowing. Irrigation systems are private and on average, 45 percent of farmers purchase water to irrigate their crops. With regard to business, 27 percent

TABLE 1
Meteorological data registered at INIA Treinta y Tres, 1973–2005

	Month												
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	**Annual**
Temperature (*°C*):													
Mean	10.7	11.9	13.4	16.4	18.7	21.4	22.7	22.1	20.8	17.3	13.8	11.1	**16.7**
Max. mean	16.2	18.0	19.3	22.4	25.0	27.7	29.4	28.3	27.0	23.4	19.8	16.7	**22.7**
Min. mean	5.6	6.7	7.9	10.5	12.3	14.4	16.7	16.6	15.0	11.6	8.3	5.8	**11.0**
Frost (*days*)	4	2	1	0	0	0	0	0	0	0	1	5	**12**
Luminosity[a]	4.7	5.4	6.0	6.8	8.0	8.5	8.6	7.6	7.1	6.2	5.4	4.7	**6.6**
Rain (*mm*)	133	99	113	98	103	98	119	149	106	114	123	120	**1 375**

[a] Daily mean of sun hours.

TABLE 2
Rice production, yield and harvested area, 1995–2005

Year	Harvested area (*ha*)	Yield (*tonnes/ha*)	Production (*tonnes*)
1995	146 300	5.509	806 100
1996	150 500	6.468	973 500
1997	155 500	6.583	1 023 800
1998	169 901	5.086	864 158
1999	208 089	6.382	1 328 222
2000	189 402	6.383	1 209 139
2001	153 676	6.703	1 030 198
2002	160 234	5.863	939 489
2003	153 400	5.904	905 700
2004	186 465	6.771	1 262 600
2005	184 000	6.600	1 214 500

Source: FAOSTAT.

of farmers have a manager, 77 percent receive technical assistance and 81 percent keep management records.

RICE PRODUCTION AND RESEARCH

Large grain varieties are being cultivated, both *indica* and tropical *japonica* (American quality). Over 95 percent of the national area is covered by the varieties, El Paso 144, INIA Tacuarí and INIA Olimar. Certified seed is being used on 85 percent of the cultivated area: the quality and purity of certified seed contribute to generating a uniform product and controlling rice. The crop is sown mechanically in rows or broadcast in dry soil, drained on the surface during October and November.

The main weed is barnyard grass – a complex of the *Echinocloa* genus, where the *crus-galli* species predominates – and it is controlled by aerial applications of herbicides in early post-emergency. Fertilization depends on each crop's needs: 40–70 kg/ha of P_2O_2 and 45–70 kg/ha of N are applied. Thanks to the presence of natural predators, it is not necessary to apply insecticides.

Disease management varies according to the land's previous use, the fertilizer use and the environmental conditions during the crop reproductive phase. There is positive correlation between nitrogen content in the rice plants and their susceptibility to stem diseases. During the 140–150-day period between sowing and maturity, the soil remains flooded for 55–70 percent of the time.

The rice crop shares the use of the soil with livestock, which uses the majority of the natural resources in the rotation period. After rice has been sown for 2 or 3 consecutive years, improved pastures (grasses and legumes) are sown by plane without any soil tillage, for 3 to 5 years. Alternating forage and livestock production generates unquestionable benefits to the environment: the alteration of the soil's physical conditions is diminished and fewer agrochemical applications are made. The crop absorbs greater quantities of nitrogen than those applied by the farmer; there are studies on the action of microbial populations that may be affecting biological fixation.

Research is carried out principally by the National Institute of Agricultural Research (INIA): technical staff and farmers attend field days and the transfer of results is carried out mainly by private professionals, who then transfer them to the farmers. INIA also holds annual meetings with rice mills so as to understand the needs of the industry and in particular achieve the quality demanded by the international markets.

CONCLUSION

In recent years, rice production has adopted the agro-ecosystem approach – i.e. the soil remains in rainfed conditions and fast irrigations are provided prior to the establishment of the definitive flooding. The water-use requirement period is thus reduced, herbicides are applied in the rainfed phase without releasing water to adjacent fields, and the risk of substances damaging the rice is diminished during the oxygen exclusion period (gas and organic acids production, iron precipitation). Uruguay produces a quality rice grain – free of residues and contaminants, meeting the high standards demanded by consumers – while successfully maintaining a correct relationship with the environment. The country must rise to the challenge of sustainable rice production.

La production de riz en Uruguay

La production rizicole est relativement récente en Uruguay. Il y a trois zones de production aux caractéristiques pédologiques, topographiques et météorologiques bien spécifiques, et au cours des récentes années 180 000 ha ont été ensemencés avec des variétés à gros grain – *indica* et *japonica* tropical (qualité américaine). Les récoltes de riz se font en alternance avec les cultures fourragères et le pacage de bétail, entraînant des avantages incontestables pour l'environnement. La recherche sur le riz est principalement du ressort de l'Institut national de recherche agricole (INIA). Plus de 90 pour cent de la production est exportée. L'Uruguay se trouve à présent face au défi non négligeable de la mise en place à court terme d'une production rizicole.

La producción de arroz en el Uruguay

La producción de arroz es relativamente nueva en el Uruguay. Tiene lugar en tres zonas cuyo suelo, topografía y clima tienen características particulares; en los últimos años se plantaron 180 000 ha con variedades de grano grande, tanto *indica* como *japonica* tropical (calidad americana). El cultivo de arroz se alterna con la producción ganadera y de forraje, con indudables ventajas para el medio ambiente. De la investigación sobre el arroz se encarga principalmente el Instituto Nacional de Investigación Agropecuaria (INIA). Del arroz producido, más del 90 % se destina a la exportación. Uruguay se enfrenta con el importante desafío de lograr, en tiempo oportuno, una producción arrocera sostenible.

WWF-FAO-IRRI global initiative to improve food security, enhance livelihoods and reduce water conflicts in irrigated rice – a concept note

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THE CHALLENGE

Almost one billion people live in conditions of extreme poverty, with many more struggling to sustain livelihoods that are directly dependent on the world's finite and threatened natural resources. Yet the population, especially in the world's poor countries, continues to increase at an alarming rate. The world urgently needs to find ways to massively increase its supply of affordable food.

This challenge is perfectly captured by the first Millennium Development Goal (MDG 1): *Eradicate extreme poverty and hunger*. While the breakthrough in rainfed agriculture is eagerly awaited, rainfall in regions where it is most needed tends to be erratic, seasonal and, with climate change, increasingly unreliable and unmanageable. There is no advantage in planting drought-resistant varieties or in water conservation if no rain falls at all, or if it all falls at once or at the wrong time. Even when rainfall is adequate, the poor, risk-averse farmer can only know at the end of the season (not at the start) whether or not to invest in the barely affordable inputs necessary to protect the crop against pests or fertilizers and to increase yield. Rainfed farming is likely to remain unreliable and suboptimal for the foreseeable future.

Most experts agree, therefore, that increases in the world's irrigated areas and in crop productivity are crucial for the achievement of MDG 1, at least in the short to medium term.

Irrigation is expensive, however, and an investment must have a return. As far as public investments in irrigated food staples are concerned, recent studies suggest that rice is the most likely to prove viable. The future role of rice in relation to global food security is therefore unequivocal and the production of more rice is to be encouraged. Indeed, even if per capita consumption continues decreasing, it is estimated that total demand will still increase by 25 percent to 770 million tonnes of milled rice by 2030.

Rice is typically grown in submerged paddy (i.e. irrigated wetland) fields, therefore also irrigated rice has a high level of water consumption. In a typical year, global production of the three main staples – rice, maize and wheat – is more or less the same in terms of tonnes, but only some 15 percent of maize and 30 percent of wheat is usually irrigated, compared with between 50 and 60 percent of rice. In very approximate terms, the global paddy crop requires up to five times the irrigation withdrawals needed by the other two major cereals combined – even before any presaturation requirements and distribution losses are accounted for, even though the evapotranspiration of rice is similar to other cereals.

Freshwater resources are becoming increasingly scarce as a result of excessive, unmanaged human demand, which goes against MDG 7, which requires that any strategy intended to ensure the global food supply will also *ensure environmental sustainability*.

The high water demand of irrigated wetland rice is not necessarily a problem during the rainy season when:

- there is no competition for water;
- there is a neutral to beneficial impact on biodiversity;
- wetland rice fulfils a secondary livelihood role (rice-fish systems, the sale of hunting licences, or the presence of a lush landscape);
- it is necessary for leaching of salts or the prevention of saline intrusion; or

- it contributes to flood mitigation, groundwater recharge or river flows through return flows.

Wetland rice culture is beneficial to both the environment and the livelihoods of those dependent on it, including downstream populations. Also, in terms of water quality, while intensive cultivation practices may pollute water resources, wetland paddy fields may act as purifiers.

When water is scarce (i.e. during the dry season), however, the economic, environmental and even social costs of irrigating wetland rice may not be justifiable. Similarly, where water is unreliable, persistent wetland rice cultivation in one location can contribute to food insecurity in another. Yet the dietary, social and cultural significance of irrigated wetland rice, together with its food security potential, further underscores the need to grow more. It is necessary to do so in ways that enhance the positive environmental role that wetland rice plays in some locations while minimizing the negative effects that result or could result elsewhere. New-build rice schemes are likely to be more costly in environmental terms, especially in sub-Saharan Africa where much of the new-build is expected, at least for the next 20 to 30 years. New-build schemes could be destined for wetland rice but also for other forms of rice irrigation.

There is increasing knowledge of how to grow more rice while reducing the negative impact on the freshwater environment. Various on-farm practices that increase yields or reduce water requirements have been developed – from improved wetland cultivation to systems that eliminate the wetland nature of the paddy fields for existing fields or which do not create wetland conditions. Irrigation system-level strategies to improve overall efficiency and water productivity are better understood, while progress is being made in applying integrated water resource management concepts and instruments in river basins. Nevertheless, there are constraints:

- Some technologies are unproven or considered controversial.
- Most on-farm practices require radical change to off-farm service delivery and regulatory mechanisms which are often overlooked, while typical basin or system-level interventions do not usually support the introduction of improved on-farm practices or may not result in improved water productivity.
- No practices have to date been included at international development policy level; their adoption tends to be the exception rather than the norm.
- The expected gains in water productivity are often not achieved for a variety of reasons:
  - Various vague or non-rigorous definitions of water-use efficiency and productivity are adopted on one particular scale (e.g. the field); it is therefore impossible to evaluate the potential for water saving on different scales in a comprehensive framework based on sound water balances.
  - There is a lack of understanding of the water delivery or drainage services which farmers need to receive in order to adopt the recommended field practices.
  - Local interventions are not considered part of a larger context both geographically and institutionally.

The challenges lie herein!

THE OPPORTUNITY

A similar situation arose in the 1980s around crop pest management. At the time there was limited consensus with regard to the concept of integrated pest management (IPM), but following a process not dissimilar to that proposed herein, IPM is now established as a global standard, administered by the Food and Agriculture Organization of the United Nations (FAO).

As a result of an international workshop coorganized by the World Wide Fund for Nature (WWF), the International Rice Research Institute (IRRI), the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) and the Philippine Rice Research Institute (PhilRice), and hosted by IRRI at its headquarters in Los Baños, Laguna, Philippines on 7–8 March 2006, there is now an opportunity to develop a similar concept for irrigated rice. It could take the form of mutually agreed guidelines established at international development policy level and aimed at development agencies and the community of field practitioners; as with IPM, they could be applied in the planning stage of future irrigated rice initiatives as well as during the rehabilitation and upgrading of existing schemes.

Difficulties have arisen from the differing frameworks of understanding about key issues:

- the definition of water-use efficiency and productivity;

- the level within the catchment or basin at which it should be measured;
- the crucial difference between consumption and withdrawal;
- the relative merits of investment versus institutional approaches; and
- service linkages and how discrete institutional entities might best be functionally integrated for effective, multi-objective service delivery.

Participants at the Los Baños workshop – drawn from academia, the Consultative Group on International Agricultural Research (CGIAR) network, WWF, research institutions, public institutions, the NGO (non-governmental organization) sector, FAO and private practices – came from a wide range of relevant disciplines including agronomy, economics, development practice, irrigation engineering, institutions, social sciences, the environment and conservation.

After wide-ranging and at times intense discussion of the various issues, the following was agreed:

- On-farm approaches to water saving in irrigated rice identified to date have the potential for wider, normative adoption in the development process.
- Most of the on-farm approaches require off-farm measures, including the provision of the right infrastructure, effective service delivery, easily understood incentive mechanisms and appropriate institutions.
- The various system-level water management strategies to improve water productivity and efficiencies at system level are also increasingly understood and adopted.
- The evaluation of the potential for water savings and improving productivity or efficiency requires a framework with clear concepts of water-use efficiency and productivity on different scales.
- To be mainstreamed into the development process, both on-farm approaches and off-farm measures need some sort of validation from a well-respected international panel of distinguished experts supported by a technical core group of researchers.
- Decision-making by farmers and the adoption of new practices does not take into account only water-related factors but also a range of socio-economic factors.
- In line with MDG 8 – *develop a global partnership for development* – a partnership approach is needed.

THE PARTNERSHIP

The following organizations have agreed to form a partnership with the intention of seizing the opportunity to establish global guidelines for sustainable irrigated rice production within the next 3 years:

- Food and Agriculture Organization of the United Nations (FAO)
- International Commission on Irrigation and Drainage (ICID)
- International Crops Research Institute for the Semi Arid Tropics (ICRISAT)
- International Food Policy Research Institute (IFPRI)
- International Rice Research Institute (IRRI)
- International Water Management Institute (IWMI)
- World Wide Fund for Nature (WWF)

National and regional institutions in the partnership include:

- PCARRD (Philippine Council for Agriculture, Forestry and Natural Resources Research and Development);
- DRRI (Directorate of Rice Research Institute) of ICAR (Indian Council of Agricultural Research);
- WARDA (Africa Rice Centre); and
- Latin American institution – yet to be defined.

These partners will call on civil society organizations and NGOs, with the whole exercise supported by a broader coalition of other international agencies, national/governmental organizations, NGOs, civil society and professional entities, development practitioners and researchers.

THE CONCEPT

The objective

The initiative is intended to contribute to the following overall objective:

Increased water productivity in irrigated rice production contributing to the achievement of MDGs 1 and 7.

There will be a single component with five outputs, intended not to copy or replicate other initiatives but to build on, complement, facilitate or add value to them. These other initiatives include but are not limited to:

- the International Rice Commission (IRC) with its mandate to promote national and international action

with regard to the production, conservation, distribution and consumption of rice;
- the ground-breaking and timely work carried out under the multi-agency, Comprehensive Assessment of Water Management in Agriculture;
- FAO knowledge-based, pro-poor field work programmes;
- the Intergovernmental Group on Rice (IGGR);
- the International Network for Water and Ecosystem in Paddy Fields (INWEPF);
- the long-standing work of IRRI on the development of water-saving technologies in rice production;
- the work of IWMI, not least with regard to the adoption of basin level water management indicators;
- the work of ICID; and
- the work of IFPRI regarding the economic allocation of natural resources.

Furthermore, this initiative will be time-bound with a specific exit point under the following immediate objective:

Guidelines for environmentally responsible irrigated rice culture agreed and acknowledged in international development policy by mid-2010.

The approach

Before global guidelines can be offered to the international development community, a thorough evaluation and high-level peer-review is required. A high-level advisory panel is to be established, supported by a technical core group and operational secretariat, with the following mandate:

- Validate a comprehensive multiscale and multidisciplinary framework to assess the farm, system and basin level options and their linkages.
- Identify indicators suggested by the framework to facilitate assessment of options, potential benefits, related constraints and necessary accompanying measures and jointly monitor food security and the sustainable use of natural resources.
- Assess the validity and suitability or otherwise of the options in specific agroclimatic zones and socio-economic contexts, taking into account gender issues and the circumstances of vulnerable groups, with attention to quantitative issues, but not at the exclusion of qualitative issues wherever relevant.
- Identify the off-farm measures necessary to facilitate and encourage widespread adoption of on-farm options, and also measures required at other levels to ensure the adoption and effectiveness of system and basin-level options. In the latter case, attention must be paid to:
  - what investment proposals need to achieve in terms of water productivity in the broader basin level context;
  - the type of legal and policy frameworks needed to legitimize, regulate, monitor and realize the full potential of such investments;
  - the nature and purpose of service delivery and the differences accruing to scale at various levels within the catchment and basin; and
  - intersectoral coordination and capacity-building.

- Identify constraints to the adoption of the options and establishment of the enabling environment; suggest ways to remove them.
- Validate the most promising options and strategies in different contexts and subsequently build and expand consensus with respect to them.
- Craft global guidelines to be followed for investments and other interventions in irrigated rice production.
- Facilitate adoption of the guidelines by the international development community, especially funding institutions such as international development banks and bilateral donors.

This is expected to require five substantive steps:

1. Develop, with inputs from a broad-based consultation, and agree on an appropriate framework for the assessment of the on-farm, system- and basin-level options and the identification of associated off-farm measures necessary to facilitate the adoption of the on-farm options.
2. Agree on a set of appropriate indicators reflecting the assessment framework.
3. Collate, call for and review the baseline literature and field case studies relevant and applicable at farm, scheme and basin levels.
4. Commission technical studies, field assessments and targeted consultations necessary to fill any knowledge gaps and validate promising options; it is expected that these studies and consultations will be largely specified by the panel, but not exclusively

so, and other study proposals can emanate from or be channelled through the technical core group for the consideration and authorization of the panel.

5. Assess and validate recommended on-farm, scheme- and basin-level options and accompanying measures; prepare and disseminate a technical report presenting and justifying the panel's conclusions and recommendations.

Meanwhile, a draft technical manual and modular training material will be developed in close consultation with the panel and a strategy proposed for their adoption and dissemination. They will be targeted at practitioners and piloted in different institutional contexts and regions before being finalized on the basis on any feedback arising and under the supervision of the panel.

The outputs

Output 1 entails wide agreement among development practitioners, especially those working at international development policy level, with regard to:

- the environmental challenges and opportunities associated with irrigated rice;
- the on-farm, scheme and basin options available to reduce environmental costs or enhance environmental benefits in irrigated rice production;
- off-farm institutional, regulatory and incentivization measures – without which the on-farm options will have limited uptake and success or the scheme and basin options will have limited impact; and
- the pressing need to adopt both on- and off-farm measures sooner rather than later.

In oredr to achieve Output 1 the panel must consult with and involve a wide range of stakeholders through workshops, e-based fora and consultations, and expert meetings.

Output 2 comprises a detailed technical report describing the work, conclusions and recommendations of the advisory panel. Developed from the baseline literature survey, relevant case studies and follow-on technical studies, the report will be subject to widespread peer review and revision before final dissemination.

Output 3 comprises guidelines for the wise use of water in irrigated rice production. Although the actual format and contents are difficult to define before the panel completes its deliberations, it is expected that the guidelines will be based *inter alia* on an assessment of stakeholder perceptions; needs are likely to include assessment and project preparation checklists, methodologies, and status, monitoring and impact indicators.

Output 4 is a technical manual targeted at practitioners, similar in form to the FAO Irrigation and Drainage Papers; it is to describe the analytical techniques and procedures necessary to implement the guidelines, and sections are planned to cover all on- and off-farm measures from scheme to basin level.

Output 5 comprises an "off-the-shelf" training kit for students and development practitioners working in the irrigated rice sector. Although based very much on the technical manual, the training kit will be modular in form so that courses can be site-specific or technically focused according to the specializations of the students – agronomists, engineers, environment or institution specialists.

THE ADVISORY PANEL AND ITS SUPPORT

For maximum impact, the panel will:

- comprise highly respected members with distinguished track records and international reputations, including senior representatives of major international development finance agencies;
- include members with an interest in the food security potential of rice, rural development and the sustainable management of natural resources (as opposed to research) – i.e. members from rice-growing countries. Rice has limited trade potential and its expanded production is likely to be of more relevance to national food security than to international trade. There is also the additional advantage that rice-growing, food-insecure countries represent the demand side of the equation and their representatives may have a strategic advantage when it comes to converting the options and measures into standard development practice.

The strategy of the advisory panel will be consultative, inclusive and based on a series of meetings and consultations (open and specialist) at regular intervals and at critical milestones for the duration of the initiative. By definition, participants will not be involved in the minutiae of the operations, whether technical or administrative. The initiative will therefore be supported by:

- an operational secretariat, which FAO has offered in principle to host at its Regional Office for Asia and the Pacific in Bangkok; and
- a technical core group to undertake focused research, field assessments and consultations to inform and support the panel's deliberations.

Membership of the technical core group will be demand-driven and adaptive, comprising subject matter specialists assigned temporarily to tasks at the request of the advisory panel and for the purpose of providing the advisory panel with technical briefings.

For the purposes of consistency and convenient peer review, the core group will in the initial stages be based on a roster of known and respected experts, including those involved to date. As a reflection of the inclusive paradigm of the advisory panel, work carried out by members of the core group will, as far as possible, pay due regard to the work of other experts and institutions with whom linkages will be established wherever meaningful. Annual expert meetings are proposed to share the ongoing work of the initiative with a broader constituency and so that the core group may benefit from external advice and experience.

Finally, some sort of management structure will be required. Its form and modus operandi will be developed at a later stage in order to reflect the specific monitoring and general oversight conditions of the initiative's eventual donors and sponsors (yet to be identified).

CONCLUSION

The initiative is an excellent opportunity for conservation, development and research communities to make a joint contribution towards achieving three Millennium Development Goals. The results will be relevant to the search for environmentally responsible, socially equitable food security, and highly significant given the new areas of cooperation to be explored and exploited.

Initiative globale WWF-FAO-IRRI pour l'amélioration de la sécurité alimentaire, l'accroissement des moyens d'existence et la réduction des conflits liés à l'eau en riziculture irriguée – note conceptuelle

Le riz est une des cultures alimentaires de base les plus importantes dans le monde, mais c'est la seule à être produite essentiellement sous irrigation. Il en résulte que les besoins en eau de la production mondiale de paddy sont cinq fois supérieurs à ceux, combinés, des deux autres céréales de base. Les études confirment que l'instauration d'une sécurité alimentaire réelle à l'échelle mondiale devra probablement faire appel à une extension substantielle de la superficie dévolue à la riziculture irriguée. L'eau douce est soumise à une pression de prélèvement croissante et il est essentiel de réduire au maximum les impacts négatifs, sur les écosystèmes de l'eau douce, des modes de production tant actuels que futurs. Des approches prometteuses sont en cours d'identification au niveau de l'exploitation agricole, mais ces approches tendent à dépendre de l'existence complémentaire de mesures en dehors de l'exploitation, telles que l'offre de services spécifiques, des réglementations incitatrices et des définitions novatrices de l'efficience en matière d'utilisation de l'eau. De plus, tant les mesures à l'échelle de l'exploitation que les mesures hors de son champ doivent être validées et standardisées en termes de pratiques internationales du développement. L'initiative de partenariat décrite ci-après est conçue dans ce but précis. Elle propose de mettre en place, pour une durée de trois ans, un Groupe de travail consultatif international de très haut niveau, disposant du soutien d'un groupe technique central et d'un secrétariat permanent. Il passera commande des études et analyses nécessaires pour les validations évoquées ci-dessus, et en fera l'évaluation. Outre les rapports techniques destinés aux décideurs en matière de politiques de développement, le groupe de travail produira des directives et du matériel de formation faisant l'objet d'une large distribution à l'intention des praticiens du développement.

La iniciativa mundial del WWF, la FAO y el IRRI para mejorar la seguridad alimentaria, mejorar los medios de vida y reducir los conflictos por el agua en la producción de arroz de regadío – nota de exposición de conceptos

El arroz es uno de los principales cultivos de alimentos básicos del mundo, pero es el único que se produce principalmente mediante regadío. La consecuencia es que los requerimientos de agua de los arrozales del mundo son cinco veces mayores que los de los otros dos cereales sumados. Los estudios confirman que en el futuro, para la seguridad alimentaria mundial se requerirá probablemente un aumento considerable de la superficie mundial de arrozales de regadío. En vista de la presión creciente sobre el agua dulce, es indispensable que tanto en los sistemas nuevos como en los viejos se reduzcan al mínimo las repercusiones negativas en los servicios de suministro de agua dulce del ecosistema. Se están identificando métodos prometedores que podrían aplicarse en las fincas, pero éstos suelen depender de la aplicación de medidas complementarias no agrícolas que incluyen la prestación de servicios, incentivos reglamentarios y una definición innovadora del uso eficiente del agua. Además, tanto las medidas que se adoptan en las fincas como las que han de aplicarse fuera de ellas deben validarse e incorporarse a la práctica internacional en materia de desarrollo. La iniciativa de asociación aquí descrita tiene justamente esa finalidad: propone el establecimiento de un Panel consultivo internacional para un período de tres años, con el apoyo de un grupo técnico básico y una secretaría. El Panel encargará y examinará los estudios y análisis necesarios para los fines de la validación. Los productos que han de obtenerse incluyen no sólo un informe técnico destinado a los responsables de la elaboración de políticas, sino también directrices y material de capacitación a los que se dará una distribución más amplia entre los profesionales del desarrollo.

Bringing hope, improving lives Raising productivity in rainfed environments: attacking the roots of poverty

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INTRODUCTION

Most of the regions with extensive poverty in Asia are dominated by rainfed ecologies where rice is the principal source of staple food, employment and income for the rural population. Success has been limited in increasing productivity in rainfed rice systems.

Rice yields in these ecosystems – home to 80 million farmers who farm a total of 60 million ha – are low (1.0–2.5 tonnes/ha) and tend to be variable because of the erratic monsoons. Soil moisture is too high in the wet season and too low in the dry season, which limits opportunities for crop diversification. Given the low productivity in food production and limited employment opportunities elsewhere, the poor lack the capacity to purchase food, even at low prices. People in rainfed areas often belong to ethnic minorities and their plight may therefore be compounded by social and political marginalization.

Rainfed systems are hindered by drought, submergence, problem soils and other abiotic stresses. Over the last three decades, potential solutions to many of these problems have been discovered in cultivated and wild rice germplasm, making genetic enhancement a viable strategy for improving the livelihood of the rural poor. Following the scientific advances made in recent years, researchers have identified promising genetic materials and clear breeding strategies for the development of varieties with several important traits that were difficult to address using conventional methods. There are good prospects for breeding into high-yielding rice varieties several important traits, such as tolerance to drought, submergence, phosphorus deficiency and saline soils.

IRRI is able to bring together the research of advanced research institutes (AdRIs) and the private sector in industrialized countries with research by National Agricultural Research and Extension Systems (NARES) in developing countries. The efficiency of breeding activities is enhanced through allele mining and gene discovery using functional genomics. Given the level of poverty, the small size of farms, insecure tenure and the risks involved in rainfed rice farming, farmers are unwilling to invest in improved rice production and resource management techniques, and they instead continue to adopt inappropriate farm practices that degrade natural resources. Soil conditions and the method of crop establishment affect nutrient availability and management, weed competition, soil water extraction and the rice plant's adaptive strategies for successful performance.

Water stress is the main limitation to rice productivity and yield stability in rainfed systems. The development and transfer of improved farm level resource management strategies require: a deeper understanding of the interaction of soil, water and pests; the integration of knowledge into the development of improved crop management options; and the evaluation and refinement of options with farmer participatory research. The risk involved in rice cultivation can be reduced by: enhanced seedling vigour; improved crop establishment methods to avoid drought and submergence; better tolerance of sodium, iron and aluminium toxicity and phosphorus and zinc deficiency; and resistance to biotic stresses, in particular blast. Women – the principal rice farmers in poverty stricken areas – must be involved in farmer participatory research for screening improved varieties and validating improved crop management options if the technologies are to be widely adopted.

THE RAINFED PROGRAMME

In rainfed areas, there is limited scope for increasing income through rice cultivation alone due to:

- the small farm size in rice-based systems; and
- the policy of maintaining rice prices at an affordable level.

By increasing rice productivity, area becomes available for the production of non-rice crops and for other farm enterprises.

Additional employment for landless households can result from diversification: products that are perishable and more commercial than rice generate employment in processing, storage and marketing activities. The adoption of shorter-duration rice varieties, improved crop and resource management options, changes in timing of crop establishment etc. can facilitate intensification and diversification of low productivity rice-based systems to optimize system productivity and improve the livelihoods of marginal and small farmers.

The rainfed programme aims to:

- develop superior germplasm and improved crop and natural resource management practices that facilitate the intensification and diversification of rainfed systems; and
- find innovative and effective ways to communicate these practices so as to facilitate adoption by resource-poor farmers.

IRRI, in partnership with NARES and AdRIs in industrialized countries, will integrate upstream research in genomics, genetics and physiology with applied and adaptive research on crop improvement and management to develop elite germplasm and best management options that would substantially increase and stabilize yield under stress conditions compared to currently grown varieties; this germplasm will be shared with NARES partners through the International Network for Genetic Evaluation of Rice (INGER).

IRRI will also facilitate and use the Consortium for Unfavorable Rice Environments (CURE, established in 2002) to understand the site specificity of problems, validate and adapt new technologies with farmer participatory research involving men and women, and fast-track the diffusion of knowledge-intensive technologies by facilitating linkages among research, extension and development. While raising productivity in rainfed systems, IRRI and its partners will ensure that the quantity and quality of natural resources – soil, water and biotic resources – are maintained so that the capacity of future generations to satisfy their food requirements is not compromised.

IMPACT PATHWAYS

The intermediate outputs of the programme are:

- standard phenotyping capacity for crop improvement research on drought and submergence tolerance;
- the genetic basis of traits (QTLs – quantitative trait loci) from genotypes tolerant of abiotic stresses;
- markers for introgressing the traits into widely grown improved varieties; and
- improved knowledge of the physiology of stress tolerance.

Breeders in NARES will use these outputs to develop improved varieties. Elite lines with high yields, resistance to key pests, superior grain quality, and tolerance of abiotic stresses developed under NARES-IRRI breeding networks and shuttle breeding programmes will be shared among NARES through INGER to evaluate their suitability under specific agroecological conditions.

NARES will use the knowledge and elite lines in their crop improvement programmes and will eventually release superior germplasm as varieties to farmers through national extension systems. IRRI and NARES – via the CURE platform – will validate and adapt new technologies and improved crop and resource management practices to optimize the yield of improved varieties and fast track technology dissemination; farmer participatory experiments will be community-based, recognizing the central role of women. Geographic information systems (GIS) and systems modelling will be used to map areas suitable for extension of the improved technologies. Impact assessment activities will be undertaken to assess constraints to the adoption of technologies by the intended users, as well as the economic, social and environmental impact of the diffusion of technologies.

RESEARCH APPROACH TO DEVELOP INTERNATIONAL PUBLIC GOODS

In most cases, research activities will focus on a specific problem affecting several countries. Applied and adaptive research will be conducted at key sites representing specific subecosystems for several countries and working groups will be organized for collaborative research between IRRI and participating NARES. Annual review and planning meetings will be held to plan research activities, review work progress and share research outputs. Research on a single country will be undertaken only if the product or knowledge has generic value that can benefit several countries facing the same problem.

ELABORATION OF PARTNERS' ROLES

Programme 1 has a wide range of partners in NARES, universities and AdRIs, in addition to other CGIAR (Consultative Group on International Agricultural Research) centres and challenge programmes. The main vehicle for research partnership under this programme is CURE – a NARES-constituted network established in mid-2002 to tackle high priority problems facing resource-poor farmers in monsoon Asia. CURE is governed by a steering committee, composed of key NARES representatives from seven countries and the IRRI deputy director general for research. The steering committee provides overall guidance to the research agenda of the consortium; approves funding proposals, budgetary allocations and work plans; and facilitates all research activities and dissemination of research outputs within participating countries.

The consortium coordinating unit, which serves as the secretariat of CURE, facilitates the initiation and establishment of the working groups – interdisciplinary teams of researchers from NARES and IRRI which may also include other international agricultural research centres (IARCs), AdRIs, and NGOs. In consultation with the steering committee, the consortium coordinating unit coordinates fundraising, provides administrative support and facilitates communication among the working groups, which hold at least one review and planning workshop each year. A progress report is presented at the annual CURE steering committee meeting when the following year's work plans are put on the table for approval. The participatory mode in which the working groups operate ensures that NARES and other in-country partners have ownership of all project outcomes as well as the ability to deploy them beyond the project period.

PROGRAMME OUTPUTS

The rainfed programme comprises the following five outputs:

1. Superior drought-tolerant and aerobic rice germplasm and management options developed for water-short rainfed environments by 2012

Almost half of the 60 million ha of rainfed lowlands and plateau uplands in Asia are drought-prone or have a short monsoon season. Variation in rice production is closely related to total annual rainfall, but even when total rainfall is adequate, shortages in critical periods markedly reduce productivity. The inherent risk in rice cultivation in the drought-prone ecosystem reduces productivity even in favourable years, because farmers avoid using optimal quantities of inputs when they fear crop loss. Risk-reducing technologies can therefore encourage higher investment in inputs and adoption of high-yielding varieties, thereby increasing productivity and reducing poverty.

Research at IRRI and AdRIs has shown that conventional breeding for reproductive stage tolerance is complicated by the strong relationship between plant phenology and sensitivity to stress. The difficulty of selecting for improved yield under drought stress has led to efforts in recent years to identify alleles for QTLs affecting drought response, and to introgress them into popular high-yielding varieties through marker-assisted backcrossing. QTLs with enough effect on grain yield to be useful in marker-assisted breeding are yet to be identified.

2. Superior germplasm and management options to overcome submergence stress developed by 2012

More than 40 million ha of ricelands (including land using supplementary irrigation during the rainy season) in South and Southeast Asia are affected annually by flash flooding from heavy rains and runoff from higher elevations, causing temporary submergence of rice plants. Complete submergence for 10 days or more can occur at any time during the growing season, resulting in re-planting of seedlings, or partial to total crop failure. Previous research has succeeded in fine-mapping a major gene (Sub1) which accounts for most of the variation in tolerance of submergence in rice varieties. A marker linked to this gene can facilitate its transfer into new or existing high-yielding varieties that are locally adapted and possess the quality aspects preferred by local consumers. Sources of tolerance of submergence during germination have also been identified and this trait needs to be transferred into high-yielding varieties.

Combining superior germplasm with suitable management strategies (e.g. nursery, seedling and nutrient management) can substantially reduce losses from submergence. Agronomic and physiological studies will be conducted on existing varieties and improved lines to assess the effect of the Sub1 gene on yield, grain quality, seedling vigour and other agronomic traits. New and existing management options – including nursery and nutrient management options to produce robust seedlings and enhance plant recovery after submergence – will be developed and validated in farmers' fields. Studies on farmers' indigenous knowledge and practices, and criteria for the selection of technologies, will be conducted to understand the constraints to technology uptake and devise policy options for fast-tracking technology diffusion.

3. Superior germplasm with tolerance of salinity and other soil problems, together with suitable management options, developed by 2012

In South and Southeast Asia, problem soils (excess salt, nutrient deficiencies and toxicities) limit rice productivity on more than 30 million ha. A major problem in coastal areas of India, Bangladesh, Viet Nam and Indonesia is salinity from salt intrusion that renders the soil unproductive or unsuitable for rice farming. Inland, salinity and alkalinity from groundwater irrigation have been expanding in northwestern India, Pakistan and central Myanmar. Salinity is also associated with abiotic stresses such as phosphorus and zinc deficiency and iron deficiency and toxicity.

Most rice soils are characterized by high P and Zn fixing ability and currently about 50 percent of ricelands are P deficient. In these areas, rice yields are low because suitable tolerant high-yielding rice varieties are not available. In coastal areas, farmers often grow only one crop: during the monsoon season when freshwater is available and rainfall helps flush salinity from the soil. Poverty is extensive because of the land's poor productivity; in some areas, in an attempt to improve livelihoods, farmers have resorted to traditional shrimp farming using brackish water with negative consequences for the environment.

There is considerable potential for increasing rice productivity in salt-affected and other problem soil areas and physiological and biochemical studies have highlighted a few useful traits underlying tolerance of these stresses in rice. Two major QTLs, one for seedling stage salt tolerance (Saltol) and one for P deficiency tolerance (Pup1), together with some other QTLs, are being tagged for marker-assisted breeding. Candidate genes are being identified which could help combine superior alleles for tolerance of salt and other abiotic stresses associated with problem soils. Nursery and nutrient management options together with proper handling of seedlings during transplanting could reduce seedling mortality and improve crop stand. Various soil reclamation methods and water management techniques could be effective in mitigating the harmful effects of excess salts and nutritional problems during the most sensitive stages of plant growth. Further research to build on past achievements could contribute to higher levels of tolerance in high-yielding varieties beyond the levels observed in any of the tolerant but low-yielding landraces currently grown in affected areas. The new varieties could bring additional land and water resources into use for rice cultivation.

4. Superior germplasm and improved management options for uplands developed by 2012

Upland rice-based systems in Asia are estimated to cover around 15 million ha, including both the area sown and land used as a part of the rice-based rotation. Sloping and plateau uplands account for a substantial rice area in the Lao People's Democratic Republic, Viet Nam, Myanmar, northeastern and eastern India, and Nepal. Much of the Asian upland is characterized by high incidence of poverty, poor physical access to markets, ill functioning markets and subsistence-oriented agriculture with low productivity. Many households belong to minority ethnic and tribal groups that are economically and socially marginalized and are the poorest of the poor. Rising population pressure and the consequent intensification of marginal areas for food production have contributed to environmental degradation and a further reduction in agricultural productivity.

IRRI's approach to upland research has undergone a major paradigm shift in recent years: the focus has changed from "upland rice" to "rice in the uplands." The new approach calls for intensification of favourable pockets in uplands for food production, in order to reduce pressure to intensify food production in less favourable and more fragile areas. It involves integrated land, water and forest management at landscape level for uplands. The major biophysical constraints to productivity growth of rice in uplands are low soil fertility, soil erosion in sloping areas, severe weed infestation, rodents, blast fungus, nematodes and root aphids. Over the past decade, important scientific progress has been made in addressing this seemingly intractable set of constraints, thus substantially improving the likelihood of reducing poverty and protecting the environment. These scientific gains need to be further consolidated and translated into specific technologies suited to major production systems in the uplands.

5. Resource management options and strategies for intensification and diversification of rainfed systems developed by 2012

For areas with short and erratic monsoons, such as the plateau uplands in eastern India and Bangladesh, system productivity and farmers' livelihoods could be improved through the development and deployment of shorter maturity rice varieties so that residual moisture could be used for growing pulses, oilseeds and vegetables in the seasonally fallow land after rice. In coastal areas with brackish water, the expansion of highly profitable shrimp farming has affected the long-term sustainability of the resource base, creating social tension between resource-rich and resource-poor households. Opportunities exist for developing a more harmonious and sustainable rice aquaculture system that would optimize the productivity of fresh and brackish waters in coastal areas.

There is also a need to develop sustainability indicators to monitor ecosystem health and thereby minimize the adverse environmental effects that may be associated with rice intensification. IRRI will work with NARES and other CGIAR centres at the systems level to match shorter-duration rice varieties with suitable varieties of non-rice crops and aquaculture species, and to develop optimal resource management practices for improving system productivity and farmers' livelihoods while sustaining the natural resource base for future generations.

Susciter l'espoir, améliorer les conditions de vie – augmenter la productivité dans les environnements pluviaux: s'attaquer à la pauvreté à sa source

En Asie, la plupart des régions où la pauvreté est généralisée sont dominées par des écosystèmes pluviaux. Les rendements du riz dans ces écosystèmes – où l'on compte environ 80 millions d'agriculteurs – restent faibles à 1,0-2,5 tonnes/ha, et les pauvres vivant dans ces écosystèmes n'ont pas les moyens d'acheter des denrées alimentaires. L'Institut international de recherche sur le riz (IRRI) met actuellement en oeuvre un nouveau programme « Augmenter la productivité dans les environnements pluviaux: s'attaquer à la pauvreté à sa source », dans le but de stimuler la productivité de ces environnements et, ce faisant, augmenter les revenus des riziculteurs. L'initiative est fondée sur le Consortium de recherche sur la riziculture en environnement défavorable, créé en 2002. Il travaille en collaboration avec les instituts de recherche de pointe et le secteur privé dans les pays industrialisés et avec les systèmes nationaux de recherche et de vulgarisation agricoles dans les pays en développement.

L'on s'attend à ce que les options ci-après soient mises au point d'ici à 2012:

1. Options en matière de matériel génétique supérieur de riz (variétés aérobies résistantes à la sécheresse) et de gestion pour les environnements pluviaux manquant d'eau.
2. Options en matière de matériel génétique supérieur et de gestion visant à vaincre le stress dû à la submersion.
3. Options concernant le matériel génétique supérieur tolérant la salinité et d'autres problèmes du sol, ainsi que des options de gestion appropriées.
4. Options en matière de matériel génétique supérieur et de gestion améliorée pour les hautes terres.
5. Options et stratégies concernant la gestion des ressources pour l'intensification et la diversification des systèmes pluviaux.

Nuevas esperanzas y una vida mejor – aumento de la productividad en zonas de secano para combatir las causas de la pobreza

En la mayoría de las regiones de Asia con situaciones extendidas de pobreza predominan las ecologías de secano. En estos ecosistemas, en los que residen 80 millones de agricultores, el rendimiento del arroz es escaso – de 1,0 a 2,5 toneladas por hectárea – y la población pobre carece de capacidad para comprar alimentos. El Instituto Internacional de Investigación sobre el Arroz (IRRI) está ejecutando un nuevo programa de aumento de la productividad en zonas de secano para combatir las causas de la pobreza, con el propósito de fomentar la productividad en entornos de secano para incrementar así los ingresos de los agricultores. La iniciativa, que se basa en el Consorcio para los entornos arroceros desfavorables (CURE) establecido por el IRRI en 2002, comporta la colaboración con investigaciones de instituciones de investigación avanzada y del sector privado en países industrializados, así como de los sistemas nacionales de investigación y extensión agrícolas de países en desarrollo.

Los productos que se espera obtener de la iniciativa para 2012 consisten en la elaboración de las siguientes opciones técnicas:

1. Germoplasma superior de arroz aeróbico y resistente a la sequía y opciones para la gestión de entornos de secano con escasa disponibilidad de agua.
2. Germoplasma superior y opciones de gestión para superar la tensión debida a la sumersión.
3. Germoplasma superior con tolerancia a la salinidad y otros problemas del suelo, junto con opciones de gestión idóneas.
4. Germoplasma superior y opciones mejoradas de gestión para las tierras altas.
5. Opciones para la gestión de los recursos y estrategias de intensificación y diversificación de los sistemas de secano.

The African Rice Initiative: history and achievements[1]

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INTRODUCTION

Rice is the world's leading food crop and one of the major staples for millions of people in sub-Saharan Africa (SSA). It is the most rapidly growing food source in Africa and is of significant importance for food security in an increasing number of low-income food-deficit African countries. The annual demand for rice in sub-Saharan Africa is increasing at an unprecedented rate of 6 percent per annum, fuelled to a certain extent by rapid population growth, increasing urbanization and associated lifestyle changes, and by the relative ease of preserving and cooking rice (Nwanze *et al.*, 2006).

Rice consumption in eastern, western, central and southern Africa outweighs production by far. In order to meet demand, over US$ 1.5 billion in foreign exchange is spent annually on rice imports, placing increasingly heavy demand on the scarce foreign currency reserves of the region's countries, which are among the most impoverished in the world (Nwanze *et al.*, 2006). Urgent attention is required to reverse this trend if SSA is to achieve the United Nations Millennium Development Goal of reducing extreme poverty and hunger by half by 2015.

Approximately 20 million farmers are engaged in the rice sector in SSA and about 100 million people depend on it for their livelihoods (Nwanze *et al.*, 2006). However, the sector is plagued by a number of constraints, including:

- biophysical constraints (e.g. poor soil fertility; drought and poor rainfall in upland rice; iron toxicity in lowland rice; salinity problems in irrigated rice);
- insufficient use of appropriate technologies (e.g. improved rice germplasm in uplands and lowland/irrigated fields; harvesting and post-harvest processing technologies; fertilizers and other inputs);
- poorly developed lowlands and poor field-level water management practices in lowland/irrigated rice; and
- inappropriate policies, organizational and institutional factors (e.g. limited capacity of the national agricultural research and extension institution; poor infrastructure and market development; absence of national seed policies; and limited working resources and competing activities).

DEVELOPMENT OF NERICA VARIETIES

To tackle these constraints, the Africa Rice Center (WARDA) created a new plant type: high-yielding and resistant to local stresses, designed specifically for smallholder farming conditions in SSA. WARDA scientists initially focused attention on the upland (dryland) ecology, as it represents about 40 percent of the total area under rice cultivation in West Africa and employs about 70 percent of the region's rice farmers, many of whom are women (Nwanze *et al.*, 2006). The most widely grown rice species, *Oryza sativa*, is originally from Asia and was introduced into Africa only 450 years ago. Another, less well-known rice species, *O. glaberrima* (Steud), is originally from Africa and was domesticated in the Niger River Delta over 3 500 years ago (Viguier, 1939; Carpenter, 1978). The Asian species (*O. sativa*) is known for good yield, absence of lodging and grain shattering, and high fertilizer returns. The African rice species (*O. glaberrima*) often has good weed competitiveness and exhibits resilience against some major African biotic and abiotic stresses (Koffi, 1980; Jones *et al*., 1997).

[1] The authors thank all WARDA scientists, research assistants and technicians for their availability and the quality of data provided. Gratitude is expressed to all donors, especially the Rockefeller Foundation for its support to the Coordination Unit since the inception of ARI, the African Development Bank for funding the Multinational NERICA Dissemination project, and the Japanese Government, JICA and UNDP for their invaluable support to WARDA and ARI.

In 1992, WARDA and its partners launched the Interspecific Hybridization Project (IHP) in an attempt to combine the useful traits of both cultivated rice species (*O. sativa* and *O. glaberrima*). The result was the first interspecific rice progenies from cultivated varieties (Jones *et al.*, 1997). With the support of donors from Japan and the United States and in collaboration with numerous partners in the IHP, WARDA developed interspecific lines with desirable traits tailored to African conditions. In 1999, the interspecific lines were named New Rice for Africa: NERICA (WARDA, 1999) and this name was trademarked by WARDA in 2004. In 2000, WARDA received the prestigious CGIAR King Baudouin Award for its achievements with NERICAs (WARDA, 2000). This award was later followed by the World Food Prize, awarded to Dr Monty Jones in 2004 in recognition of his leading role in the development of upland NERICA lines, and by the Fukui International Koshihakari Rice Prize of Japan, awarded to Dr Moussa Sié in 2006 for his work on lowland NERICAs.

NERICA represents one of the most important advances in the field of rice varietal improvement in recent decades (Nguyen and Ferrero, 2006). It constitutes a wide range of interspecific varieties with different characteristics: high-yielding; early-maturing (80–100 days); resistant and tolerant to Africa's major pests and diseases; tolerant to drought and to iron toxicity.

ABOUT THE AFRICAN RICE INITIATIVE

Guinea was one of the first countries where NERICA was tested. Following the success of the tests, WARDA and partners joined forces to create a mechanism to scale up the dissemination of the technology throughout SSA. This culminated in the launch of the African Rice Initiative (ARI) in March 2002.

The main goal of ARI is the promotion and dissemination of NERICAs and other new improved rice varieties and related technologies in sub-Saharan Africa, where they can make a significant contribution to poverty reduction and food security.

ARI is a non-core programme of WARDA. It is governed by a steering committee comprising: a representative from each pilot country and from non-pilot countries, two WARDA representatives, Sassakawa Global 2000 (SG2000), UNDP (United Nations Development Programme – representing the donor community), a representative from FARA (Forum for Agricultural Research in Africa) and from farmers' organizations, as well as the ARI secretariat coordinator. FAO (Food and Agricultural Organization of the United Nations), the Rockefeller Foundation, the African Development Bank (ADB) and other interested donors are accepted as observers.

ARI currently receives support from ADB (funding a multinational NERICA dissemination project in seven countries), the Japanese Government, JICA (Japanese International Cooperation Agency), the Rockefeller Foundation, UNDP and CIDA (Canadian International Development Agency).

It also benefits from strong partnerships established with FAO, SG2000 and subregional organizations such as FARA and CORAF.

ACHIEVEMENTS

Establishment of stakeholders' platforms

The first activity was the establishment of a stakeholders' platform in each pilot country to serve as discussion and planning fora for all related rice sector issues in each country.

Introduction of new materials to farmers

While farmers cultivate previously released varieties, over 100 examples of new material have been introduced through a PVS (participatory varietal selection) approach during a 4-year period, and many new promising varieties have been identified by farmers: NERICAs 8, 9, 10 and 11 are the most popular; they are extra early and have good grain quality.

Varietal characterization and maintenance

To facilitate adoption and increase utilization, all named or newly introduced varieties are characterized and results are made available to the public (Table 1). Seed purity and homogeneity are also addressed regularly in order to ensure the good quality of the seed produced and distributed to end-users.

Seed production and distribution

Seed availability is a key constraint to NERICA dissemination. Demand is very high and increases every season – Nigeria alone has projected a requirement of more than 30 000 tonnes of NERICA 1 for 2007.

ARI therefore produces foundation seed in addition to breeder seed. This is necessary because the seed system has collapsed in most SSA countries and private seed companies are reluctant to invest in rice seed businesses.

TABLE 1
Main characteristics of NERICA 1–18

Variety	Plant height (*cm*)	Tillering ability	Days to maturity (*days*)	Potential yield (*kg*)	Resistance to leaf blast	Resistance to insects	Resistance to lodging
NERICA 1	100	Good	95–100	4 500	Medium	Good	Good
NERICA 2	100	Good	90–95	4 000	Resistant	Good	Good
NERICA 3	110	Good	95–100	4 500	Medium	Good	Good
NERICA 4	120	Good	95–100	5 000	Medium	Good	Good
NERICA 6	130	Good	95–100	5 000	Resistant	Good	Good
NERICA 7	130	Good	95–100	5 000	Medium	Good	Good
NERICA 8	100	Good	75–85	5 000	Good	Good	Moderate
NERICA 9	105	Good	75–85	5 000	Good	Good	Moderate
NERICA 10	110	Good	90–100	6 000	Good	Good	Moderate
NERICA 11	105	Good	75–85	7 000	Good	Good	Moderate
NERICA 12	115	Good	90–100	5 500	Good	Good	Moderate
NERICA 13	120	Good	90–100	6 000	Good	Good	Moderate
NERICA 14	110	Good	75–85	5 000	Good	Good	Moderate
NERICA 15	130	Good	90–100	5 000	Good	Good	Moderate
NERICA 16	130	Good	90–100	6 000	Good	Good	Moderate
NERICA 17	115	Good	90–100	6 500	Good	Good	Moderate
NERICA 18	130	Good	90–100	5 000	Good	Good	Moderate

Between 2003 and 2006, the coordination unit produced over 80 tonnes of foundation seed of released NERICAs – 60 tonnes in 2006 alone (Figure 1) – for distribution to NARS (National Agricultural Research Systems). The foundation seed received from the coordination unit was used to produce over 3 000 tonnes of good quality registered seed for distribution in seven pilot countries.

ARI coordination has also dispatched seed to many non-pilot countries, including post-conflict countries such as Liberia and Sierra Leone, where over 3 tonnes of NERICA seed were dispatched in 2006, thanks also to the logistic support of FAO and the United Nations Mission in Liberia (UNMIL).

Status of NERICA dissemination

With the support of FAO, JICA, SG2000, WARDA, NARS, UNDP and the Rockefeller Foundation, NERICA has been tested in nearly all SSA countries. As a result, 18 upland and 60 lowland NERICAs have been named, of which 18 upland and 11 lowland NERICAs have been released (in 20 countries) or adopted (in 7 countries) (Tables 2 and 3).

They are currently cultivated on over 150 000 ha, with the largest areas in Guinea, Nigeria, Côte d'Ivoire and Uganda.

Development of complementary technologies

To increase the productivity of the NERICAs, complementary technologies (e.g. fertilizer rate and timing, crop density, weeding regime, sowing depth and harvest timing) are under evaluation: results will be published in appropriate journals.

Diversification of the use of rice as food

While dissemination is the primary activity, ARI has also focused on the diversification of the use of rice as food, developing a range of NERICA-based processed products, such as cookies, biscuits, pancakes, cakes and wafers (Photo 1). The quality of the products indicates that rice flour is a perfectly valid replacement for wheat flour in many types of baking and confectionery. Furthermore, introduction of the new technologies to rural communities will create added value for rice and empower women in SSA countries.

PHOTO 1
NERICA-based products

FIGURE 1
Trends in seed distribution (tonnes)

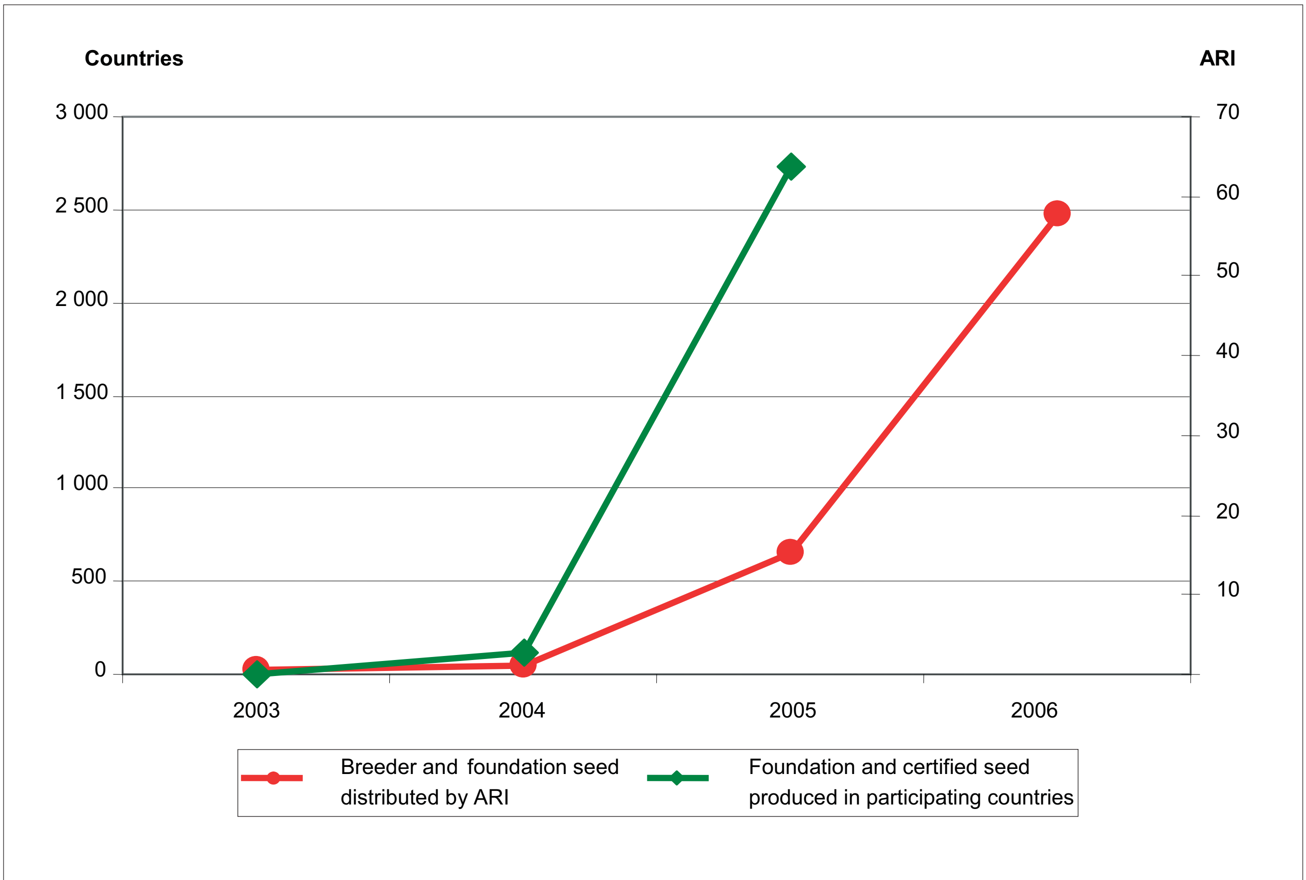

TABLE 2
Upland NERICA varieties adopted/released[a] in selected sub-Saharan African countries

Country	NERICA																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	**Total**
Benin	A	A		A															**3**
Burkina Faso												R	R		A		R	A	**5**
Congo										A									**1**
Democratic Republic of the Congo				A		A	A												**3**
Côte d'Ivoire	R	R	A	A	A														**5**
Ethiopia	A	A	R	R															**4**
Gambia	A	A	A	A	A	A	A												**7**
Ghana	R	A																	**1**
Guinea	R	R	R	R	R	R	R												**7**
Kenya	A			A						A	A								**4**
Madagascar			A	A															**2**
Mali				R				A	A					A				A	**5**
Nigeria	R	R	A																**5**
Sierra Leone	A	A	A	A	A	A													**6**
Sudan				A			A												**2**
Togo	A		A	A															**4**
Uganda	A		A	R															**3**
Total	**11**	**8**	**9**	**13**	**4**	**4**	**4**	**1**	**1**	**2**	**1**	**1**	**1**	**2**	**1**	**0**	**1**	**2**	

[a] A: adopted, R: released.

TABLE 3
Lowland NERICA varieties adopted/released[a] in selected sub-Saharan African countries

Country	NERICA-L								WAS 161-B-9-2	WAS 122-IDSA-15-WAS-6-1	WAS 127-B-5-2	Total
	19	20	34	39	41	42	49	60				
Burkina Faso	R	R			R			R				**4**
Cameroon	A											**1**
Gambia									R	R	R	**3**
Mali	R					R						**2**
Niger				R			R					**2**
Sierra Leone	A	A										**2**
Togo	A		A									**2**
Total	**5**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	

[a] A: adopted, R: released.

Capacity building

To enhance the capacity of NARES in seed production, training has been provided for 30 seed technicians from pilot and non-pilot countries; they have in turn contributed to the training of numerous colleagues and over 400 farmers. Over 20 monitoring and evaluation specialists have also been trained and they are currently assessing project progress, in particular in the pilot countries.

In collaboration with WARDA and JICA, ARI has conducted four international workshops where NERICAs were discussed. More than 200 participants from several SSA countries attended the workshops.

Partnership

NERICA dissemination is a complex task requiring collaboration. A strong partnership has therefore been developed with the private sector, seed companies, farmers and NGOs, who are invited to field days and monitoring tours. Over 6 000 farmers and other end-users attended field days in the seven pilot countries during the 2005 and 2006 cropping seasons. Banks and businessmen have thus been sensitized to contribute to seed production and PVS, for example:

- The Regional Bank of Solidarity (BRS) has supplied over US$ 80 000 credit to farmers' organizations for seed production in Benin (Photo 2).
- Tundé Motors, a car dealer, is funding seed production and PVS in several districts of Benin (Photo 3).
- On 10 March 2007, Société BSS-SIPRI SARL launched an ambitious NERICA project in Benin in collaboration with the SATAKE Corporation, with the aim of producing and commercializing NERICA rice in Benin and neighbouring countries.

PHOTO 2
Field visit by the Representatives of BRS-Benin

PHOTO 3
Tundé SA Chairman presenting his vision on rice development in Benin

- Songhaï (NGO based in Benin) has signed an MOU (Memorandum of Understanding) with WARDA and it plans to produce and commercialize NERICA products in Benin and neighbouring countries.

OUTLOOK

Making seeds available to farmers is the main target for the coming years. While continuing to produce breeder and foundation seed at WARDA and in collaboration with NARS, partners among NGOs, farmers' organizations and individual seed growers will be identified and encouraged to produce certified seed. NERICA is popular among farmers and can have a strong impact on livelihoods. Detailed characterization of NERICA varieties is therefore required to support farmers' decision-making. Agronomic and post-harvest technology packages should be developed or released in order to enhance performance and quality. Prerequisites for enabling technologies such as NERICA to raise food security in the region include farmers having improved access to seed and information, as well as favourable policies supporting the development of the agricultural sector. Finally, lowland NERICAs have shown high-yielding ability and efforts are being made to extend them more to farmers.

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Initiative africaine sur le riz: historique et réalisations

Le riz est la culture vivrière la plus importante du monde et l'un des principaux aliments de base pour des millions de personnes en Afrique subsaharienne. Il s'agit de la source d'alimentation qui se développe le plus rapidement en Afrique et revêt une importance considérable pour la sécurité alimentaire dans un nombre croissant de pays africains à faible revenu et à déficit vivrier. La demande annuelle de riz en Afrique subsaharienne augmente à un rythme sans précédent de 6 pour cent par an, stimulée jusqu'à un certain point par la croissance démographique rapide, l'intensification de l'urbanisation, les changements qui s'ensuivent dans les styles de vie et la facilité relative de la conservation et de la cuisson de cet aliment (Nwanze *et al.*, 2006).

Plus de 1,5 milliard de dollars EU en devises sont dépensés chaque année pour les importations de riz dans le but de satisfaire la demande en Afrique – ce qui prouve combien la région est tributaire des approvisionnements extérieurs pour l'un de ses aliments de base.

Pour réduire les importations, l'ADRAO a mis au point une nouvelle variété de riz NERICA pour l'Afrique et a lancé, avec ses partenaires, l'Initiative africaine sur le riz, en tant que mécanisme pour promouvoir NERICA et ses technologies complémentaires partout en Afrique subsaharienne.

Ce document résume les réalisations de cette Initiative à ce jour.

La Iniciativa Africana sobre el arroz, su historia y sus realizaciones

El arroz es el principal cultivo alimentario del mundo, y uno de los alimentos básicos más importantes para millones de habitantes del África subsahariana. Es, además, la fuente de alimento que crece con más rapidez en África, y tiene especial importancia para la seguridad alimentaria en un número cada vez mayor de países africanos de bajos ingresos y con déficit de alimentos. Actualmente la demanda anual de arroz en el África subsahariana crece a un ritmo sin precedentes, del 6 % anual, que puede atribuirse en cierta al rápido incremento demográfico, a la urbanización creciente con los cambios de estilo de vida que conlleva, y a la conservación y cocción relativamente fáciles de este cereal (Nwanze *et al.*, 2006).

Las importaciones de arroz destinadas a satisfacer la demanda de África ocasionan cada año un gasto de más de 1 500 millones de USD en divisas; este dato pone en evidencia que la región depende considerablemente de suministros externos para abastecerse de uno de sus alimentos básicos.

Con el propósito de reducir las importaciones, el Centro Africano del Arroz desarrolló el Nuevo arroz para África (NERICA) y creó, junto con sus asociados, la Iniciativa africana sobre el arroz (ARI) como mecanismo de promoción del NERICA y sus tecnologías complementarias en toda el África subsahariana.

En este documento se resumen las realizaciones alcanzadas por el ARI hasta la fecha.

Rice in Central America at a critical crossroads: FLAR's activities to increase competitiveness of national production[1]

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[a] Agronomist and [b] Director, FLAR-CIAT, Cali, Colombia.

INTRODUCTION

Rice is traditionally grown in Central America in three distinct systems:

- unfavoured upland, predominately on hillsides;
- favoured upland, in high rainfall areas; and
- unimproved irrigated.

During the 1980s, much of the area planted to unfavoured upland production was lost because of non-competitive production and the importation of cheaper rice. In the 1990s, the trend continued and large areas devoted to favoured upland were also displaced. The remaining area in favoured upland and unimproved irrigated rice is currently threatened by imported rice, mainly as a result of the liberation of imported rice under the Central American Free Trade Agreement (CAFTA) with the United States.

The most significant trend in rice in Central America over the last two decades has been the decline in area. Area planted in Costa Rica has declined from over 70 000 ha in 1980 to even less than the current area of 50 000 ha, i.e. a loss of almost one-third. In Honduras, the rice area has decreased by70 percent since 1980; Mexico has lost two-thirds of its rice area; and in Panama it has declined by nearly 10 percent. Only Nicaragua has not witnessed large declines in rice area, but that is due to the fact that the country is recuperating from large declines experienced during the country's civil war.

Overall, the area cultivated to rice in Central America and Mexico declined by approximately 25 percent (> 100 000 ha) in the last two decades. Nevertheless, overall production decreased by only 12 percent due to improved yields in the more favoured upland areas and irrigated systems – a reflection of the transition from low-yielding, unfavoured upland production to the more productive and stable rainfed and irrigated systems.

The rice sector in Central America is clearly under threat from imported rice, which comes almost exclusively from subsidized production in the United States. While the problem has been serious for years, the favoured production systems are now expected to be increasingly threatened by CAFTA (already signed by several countries and in the process of being approved by others). CAFTA permits a progressive increase in the import quotas of rice. These countries already import a significant portion of their domestic needs (85% in Mexico, 50% in Costa Rica, 40% in Nicaragua and 20% in Panama). Rice production in Central America is particularly vulnerable to imported rice as yields are low. The only means of preventing the loss of this important crop – that generates significant revenue and is major source of employment – is to increase yield and reduce costs in order to increase the competitivity of national production.

RESULTS FROM FLAR INTERVENTION

Efforts to increase the competitiveness of national production were initiated in 2003/04 in Costa Rica, Nicaragua and Guatemala with the objective of stimulating yield and reducing production costs. The programme focused on irrigated rice in Costa Rica and Nicaragua and on rainfed rice in Guatemala and southern Costa Rica. The salient features of the technical intervention in the irrigated ecology were based upon six strategic management practices:

[1] The assistance of the agronomists: Norman Oveido, SENUMISA, Costa Rica; Carlos Mendez, ANAR, Nicaragua; and Eduardo Gudiel, ARROZGUA, Guatemala is appreciated. Part of the work was supported by grant funds from the Common Fund for Commodities (www.common-fund.org).

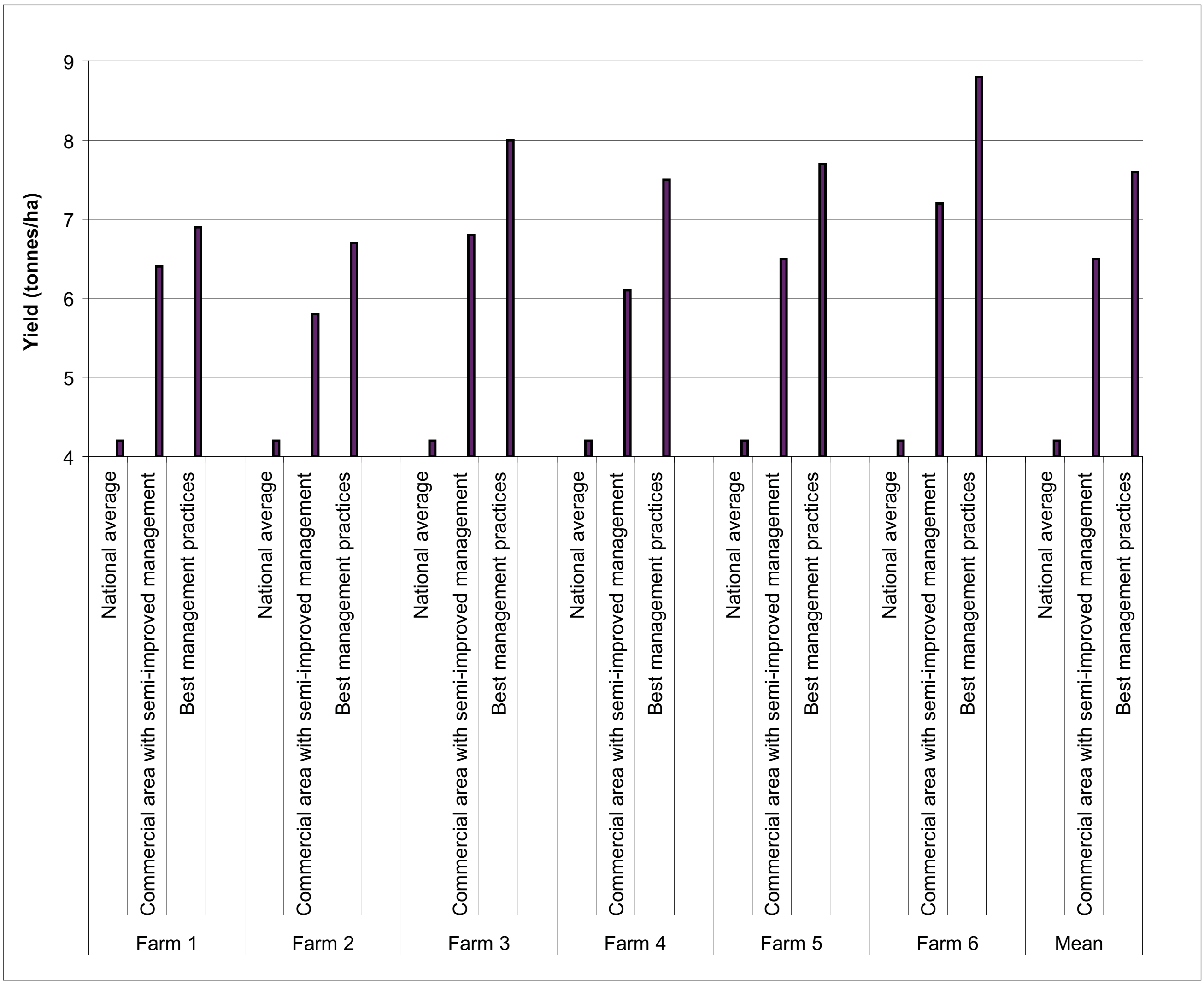
- planting date;
- seeding density;
- early pest management using insecticide-treated seed;
- balanced nutrition to obtain high yield;
- early weed control; and
- appropriate irrigation water management.

Integrated application of the six practices can result in large yield increases. The technology is "knowledge-based" and scale neutral, i.e. it is suitable for farmers of different economic or technical levels. The technology does not require additional investment in equipment or inputs, but focuses on the precision management of already-used inputs. In upland rice areas, the technological improvements are: land preparation and fertilizer practices during the dry season combined with reduced densities, treated seeds (where required) and balanced nutrition.

Costa Rica – irrigated rice

In the first year, the technology was introduced on two irrigated rice farms during the high solar radiation season. On the first, yield increased from 3.5 to 7.2 tonnes/ha. On the second, 200 ha were planted under improved management with a yield of 7.5 tonnes/ha, while 600 ha planted on the same farm using traditional management practices gave a yield of 5 tonnes/ha.

FIGURE 1
Summary of yield data from six commercial farms in Costa Rica comparing national average yield with commercial yields under semi-improved management and demonstration plots with best management practices



In 2004/05, demonstration plots were established on six farms (Figure 1) and farmers began using the improved technology on a commercial basis – referring to it as "semi-improved practices". On all six farms, commercial fields where just some of the improved practices were adopted gave yields 1.5–2.4 tonnes/ha greater than in previous years under conventional management practices. With full utilization of the improved technology (best management practices) a further 1–2 tonnes/ha were achieved.

The figures are derived from 359 ha of demonstration plots and over 1 500 ha of commercial fields. It is clear that yields can readily be increased to over 8 tonnes/ha with only partial use of the improved technologies; it is feasible to increase yields to 9–10 tonnes/ha when all recommended practices are employed.

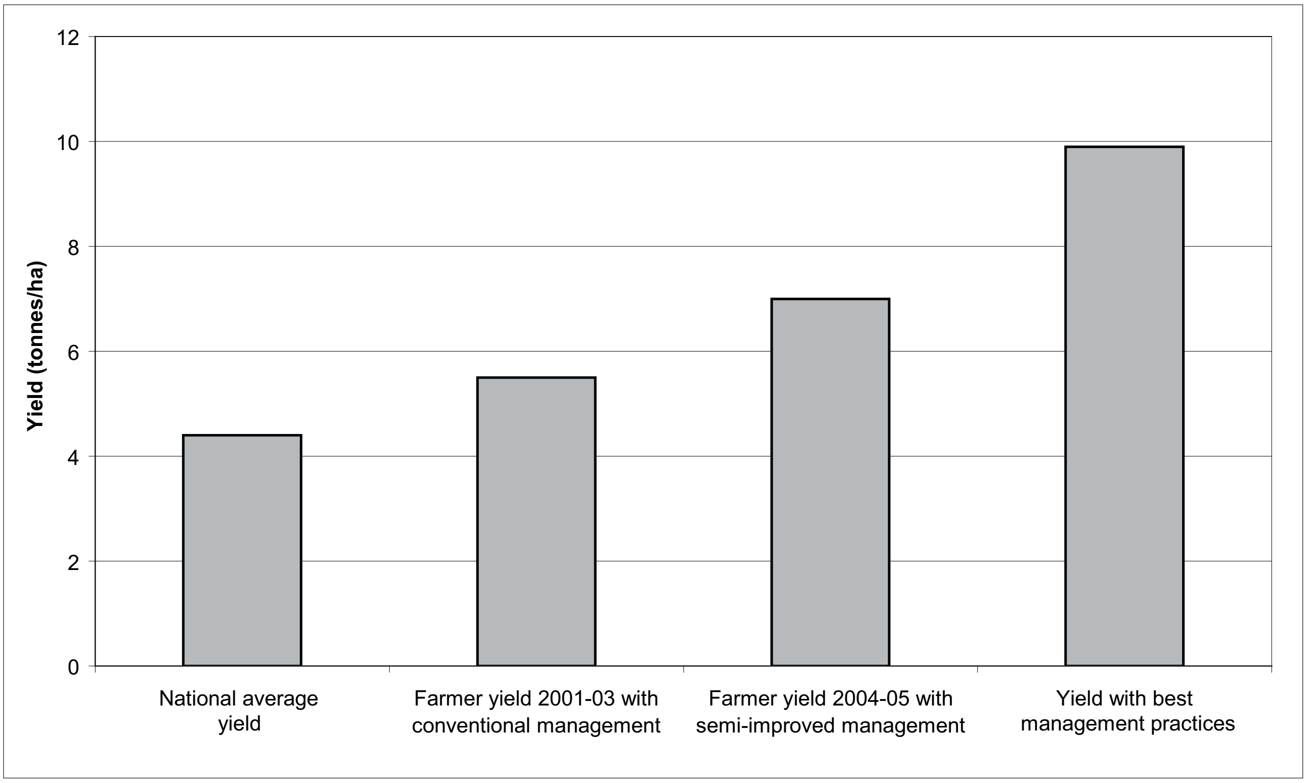
Nicaragua – irrigated rice

Work in Nicaragua commenced in 2003/04 on the farm of just one grower who visited Venezuela and became familiar with the improved management practices. In the first season, yields of 10–12 tonnes/ha were obtained on several 500 m^2 plots. In the following season (2004/05), the programme expanded to cover several farms with demonstration plots as well as commercial areas. A summary of the results are presented in Figure 2. It is clear that improved management practices can readily double yields in Nicaragua. On a commercial basis, yield increased by 2.6 tonnes/ha and on smaller demonstration plots (2–5 ha), yields superior to 10 tonnes/ha were frequent.

Costa Rica – favoured upland rice

Approximately two-thirds of the rice area in Costa Rica is lowland rainfed. Much of upland production occurs in the south under high rainfall and limited solar radiation. National average yield in upland conditions is only 3.2 tonnes/ha, but costs are similar to those for irrigated conditions. Land preparation and fertilizer management are major problems due to the continuously wet field conditions. In addition, farmers use large amounts of agrochemicals (e.g. insecticides, fungicides and foliar nutrients) and, what is more, almost all applications are preventive, i.e. without a scientific basis. In 2003/04,

FIGURE 2
Yield of on-farm demonstration plots in Nicaragua using improved crop management practices compared to historic yields and conventional crop management



small trials were established to evaluate the efficiency of preparation and fertilization on dry land prior to the initiation of the rainy season. This technique permits growers to prepare land and apply and incorporate fertilizers in dry soil, using only inexpensive non-selective herbicides to eliminate weeds – similar to a stale seedbed preparation. This practice greatly reduces the costs of land preparation and weed control while increasing fertilizer efficiency. In addition, insecticide-treated seeds were introduced to eliminate early applications of non-selective insecticides, particularly pyrethrum-based chemicals. Finally, seeding density was reduced to approximately 100 kg/ha (about one-half of normal seeding rates) in order to reduce foliar fungal diseases and produce healthy plants capable of responding to improved fertilizer management. Balanced fertilizer use eliminated the need for expensive foliar applications. In summary, the improved practices reduced production costs by approximately US$ 200–300/ha, roughly equivalent to a gain in yield of 1 tonne/ha.

In 2005, demonstration plots were established on approximately 100 ha in eight farms. Plots on six of the farms gave yields in excess of 6 tonnes/ha, i.e. nearly double the average yield in rainfed conditions (Table 1). Two plots were lost due to lodging since the farmer used excessive quantities of seed (138 kg/ha) and a variety that is particularly susceptible to lodging (CR 4477). The average yield on the six remaining farms was 6.4 tonnes/ha (almost 3 tonnes/ha greater than the national average yield under favoured upland conditions) and costs were approximately US$ 600/ha resulting in a very competitive cost of US$ 100/tonnes.

Guatemala – favoured upland rice

Guatemala is not a major rice-producing country and imports nearly 80 percent of national needs from the United States. Nearly all national production is concentrated in the upland sector (as in Costa Rica). On the basis of the initial results from Costa Rica, demonstration plots were established in four farms utilizing dry land preparation and fertilization technology combined with reduced seeding. In addition, unnecessary use of inputs (e.g. foliar nutrient and growth hormones) was eliminated together with preventative applications of insecticides and fungicides. Simply reducing unnecessary input usage reduced costs by the equivalent of approximately 1 tonne/ha (similar to the reduction observed in Costa Rica). Yield increases were also in the range of 1 tonne/ha (again, similar to Costa Rica) (Figure 3).

CONCLUSION

The technology for more competitive production in both the irrigated and upland sector is available, but further effort is required in technology transfer. High yields of irrigated rice (8–10 tonnes/ha) can be readily obtained, making rice production competitive with imported rice. Thanks to the improved production technologies in upland conditions, small growers can be competitive and increase their income.

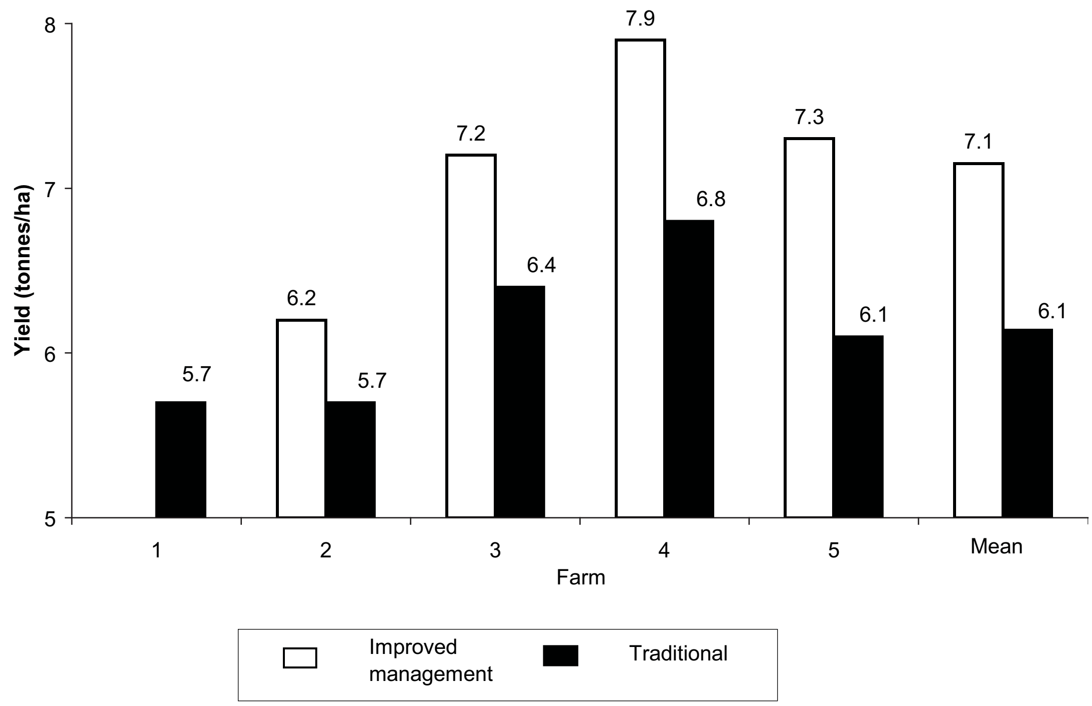
The challenge is to extend the improved production technologies to more farmers, but none of the three countries involved in the project have an extension service for rice. The public sector extension service is essentially inoperative and growers associations are responsible for extending the technologies. Growers associations in Nicaragua and Guatemala are relatively new and the FLAR member in Costa Rica is a consortium of seed companies.

In Costa Rica, a unified extension system can be developed by integrating the management and organizational skills of the private seed sector with the human resources of the growers association.

TABLE 1
Yield in high rainfall upland conditions using improved fertilizer and land preparation practices

Farm	Area (*ha*)	Basic fertilizer (*ppi*)	Side-dressing fertilizer	Planning rate (*kg/ha*)	Treated seeds	Yield (*tonnes/ha*)
3	16	150N-40P-60K	0N-Zn-S	120	Yes	6.2
4	9	150N-40P-60K	0N-Zn-S	110	Yes	6.6
5	4	100N-40P-60K	50N-Zn-S	110	Yes	6.0
6	18	133N-40P-60K	25N-Zn-S	100	Yes	6.3
7	9	150N-40P-60K	50N-Zn-S	110	Yes	7.0
8	8	150N-40P-60K	50N-Zn-S	129	No	6.5
Mean						**6.4**
National average yield						**3.5**

FIGURE 3
Yield of on-farm demonstration plots comparing improved management practices with traditional production practices



In Nicaragua, the key components for a successful technology transfer programme are already in place. Assistance is required to develop an extension methodology and strategy for reaching relatively large numbers of growers. The leadership capacity is present in ANAR (National Rice Growers Association of Nicaragua), which has successfully collaborated with the millers association and the public sector extension service. Assistance is required to provide the technical training and organization of an extension programme led by the growers association.

Guatemala also has the capability to develop in rice via the Guatemalan Rice Association (ARROZGUA) of growers and millers, which is a key resource for developing a successful extension service. The organizational and management skills are already in place, while additional assistance is required in technical areas and technology transfer.

In Costa Rica and Nicaragua, the technology's impact is most immediate in the irrigated sector; the technology is already available, including high-yielding varieties. However, most Central American countries depend heavily upon rainfed rice and the uplands are dominated by small, poverty-stricken rice growers, especially in Nicaragua. In the short term, yield improvement and cost reductions are feasible via aggressive technology transfer. However in the long term, incomes cannot be expected to increase significantly, given that most rice cultivation is in smallholdings and yields will remain relatively low due to the lack of adequate solar radiation during the rainy season.

The only means for small rice farmers to survive in a competitive market is to achieve high yields; this requires irrigation to allow planting during the dry season when there is high solar radiation. Simple water-capturing techniques combined with adequate storage can provide sufficient water resources for supplementary irrigation or complete irrigation during the dry season for small areas. The captured water, normally stored in small ponds, can be used for supplemental irrigation in areas of periodic drought or for production during the dry season when climatic conditions are more favourable for high yields. Assistance is required to introduce and promote known water-harvesting technologies, which – combined with improved crop management practices – can result in high yields and incomes from small areas.

Tournant décisif pour le riz en Amérique centrale: les activités du Fonds latino-américain de réserve du riz irrigué visent à augmenter la compétitivité de la production nationale

En Amérique centrale, la production de riz dans les écosystèmes montagneux défavorables perd du terrain face au riz importé qui est plus économique, tandis que les faibles rendements signifient que la production de riz pluvial dans les zones favorables et de riz irrigué non amélioré est actuellement menacée par la libéralisation du riz importé au titre du Traité de libre-échange entre l'Amérique centrale et les États-Unis. Le Fonds latino-américain de réserve du riz irrigué a été le premier, en 2003/04, à prendre des mesures pour rendre plus compétitive la production nationale dans la région. Il existe des techniques favorisant une production plus compétitive à la fois pour le riz irrigué et le riz pluvial. Il reste à mettre à la portée d'un plus grand nombre de riziculteurs les techniques de production améliorées. Par ailleurs, des techniques simples de captage de l'eau associées à un stockage approprié peuvent fournir des ressources en eau suffisantes pour une irrigation supplémentaire ou une irrigation d'appoint durant la saison sèche dans de petites zones. L'eau captée, normalement stockée dans de petits étangs, servira à compléter l'irrigation dans les zones où la sécheresse frappe périodiquement ou pour la production durant la saison sèche, lorsque les conditions climatiques sont plus favorables à des rendements élevés.

América Central, el arroz en la encrucijada: actividades del FLAR para una mayor competitividad de la producción nacional

La producción de arroz en sistemas de tierras altas poco propicios de América Central viene perdiendo terreno a favor del arroz importado, que resulta más barato. Al mismo tiempo, a causa de su bajo rendimiento la producción en entornos propicios de tierras altas y la de arroz de regadío no mejorado se ven amenazadas por la liberalización del arroz importado en el marco del Tratado de Libre Comercio entre Centroamérica y Estados Unidos (CAFTA). El Fondo Latinoamericano para el Arroz de Riego (FLAR) comenzó en 2003/04 a desplegar esfuerzos para aumentar la competitividad de la producción nacional en la región. Actualmente se dispone en América Central de una tecnología para una producción más competitiva tanto en zonas de regadío como en las tierras altas. Queda pendiente el problema de extender a más agricultores las tecnologías productivas mejoradas. Por otra parte, mediante técnicas sencillas de captación de aguas y con un adecuado almacenamiento es posible proporcionar recursos hídricos suficientes para el riego complementario o el riego completo de superficies pequeñas en la estación seca. El agua captada, que normalmente se almacena en pequeños estanques, se puede emplear para complementar el riego en zonas que sufren sequías periódicas, o en la producción durante la estación seca cuando las condiciones climáticas son más propicias para un rendimiento elevado.

Rice projects currently supported by the FAO Crop and Grassland Service

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The FAO Crop and Grassland Service hosts the Secretariat of the International Rice Commission. In the current 2006–07 biennium, the Service also provides technical support to seven projects related to rice production for food security in member countries and regions of FAO. This paper provides a brief description of the project activities aimed at promoting collaboration with other partners.

TRUST FUND PROJECTS

GCP/RAF/411JPN: Intra-African Training and Dissemination of Technical Know-how for Sustainable Agriculture and Rural Development Project within the Framework of South-South Cooperation, 2006–2011

The Government of Japan recently approved funding of US$ 4 357 025 to support project activities over a 5-year period. The project is designed to contribute to the sustainable spread and dissemination to farmers, foresters, fishermen, extension workers and government officials in 14 selected African developing and least-developed countries (LDCs) of the technological know-how accumulated by African experts who have already benefited from training under past Japanese technical cooperation programmes. Implemented within the framework of South-South collaboration, African experts from advanced developing countries in Africa who have benefited from Japanese training will be used for training and dissemination. The project tentatively covers Angola, Benin, Burkina Faso, Chad, Guinea, Lesotho, Malawi, Mali, Mozambique, Senegal, Sierra Leone, Swaziland, the United Republic of Tanzania and Uganda. The project is consistent with the New Partnership for Africa's Development (NEPAD) – Comprehensive Africa Agriculture Development Programme (CAADP). Its LDC focus and contribution to increased production and trade by addressing supply side constraints mean that it conforms to the spirit of the WTO Doha Round and Japan's commitment to supporting developing countries in achieving the Millennium Development Goals (MDGs), particularly MDG 1 – to reduce world hunger and poverty by half by 2015. The project will organize technical seminars, workshops and training courses for Africans, in Africa, with African trainers. Technical areas to be covered, subject to concurrence by the beneficiary countries, include: market access, small-scale irrigation and water management, aquaculture development and rice cultivation. Inception workshops are to take place soon.

GCP/UGA/035/JPN: Dissemination of NERICA and Improved Rice Production Systems to Reduce Poverty and Food Deficit in Uganda, 2006–08

In 2006, the Government of Japan approved funding of US$ 1 239 983 to support project activities over a 2-year period. Uganda is a landlocked country in central Africa. The 2004 population is estimated at about 26 million, 89 percent of which lives in rural areas. The GDP (gross domestic product) in 2004 was estimated to be US$ 6.9 billion and the GNP (gross national product) was about US$ 270. Rice is not the main staple food in the country, but its consumption has been increasing recently, partly as a result of urbanization and school lunch programmes. Approximately 60 000–70 000 tonnes of rice are imported annually, but since 2000 the Ugandan Government has made increasing rice production a priority. The project aims to increase rice production and the income of resource-poor farmers by improving the dissemination of NERICA and other rice technologies. The project activities are: promotion of the efficient use of natural resources and building national and local capacity in rice-based production systems. It is expected that 30 000 family members will benefit from the project activities, in particular women, as they constitute the majority of upland rice growers. The project will strengthen rice production and milling operations, enhancing the role of the private sector in providing market outlets for locally grown rice with particular attention to disadvantaged farmers. The inception workshop was held in November 2006.

GTFS/RAS/198/ITA: Support to the Regional Programme for Food Security in the Pacific Island Countries – Rice Production in Papua New Guinea (PNG), 23 months

The Government of Italy under the framework of the project GTFS/RAS/198/ITA in May 2005 approved funding of US$ 243 000 to support the activities of Rice Production in Papua New Guinea for a 23-month period. The expected outcomes of the rice development project are that about 3 000 rural households will have access to quality rice seeds, rice cultivation technology, extension services and rice milling facilities for rice production primarily for household consumption and to produce at least 2 500 tonnes of rice over a 3-year period.

TECHNICAL COOPERATION PROJECTS

TCP/EGY/3102 (A): Rice Straw Management and Conservation of Environment, 2006–08, Egypt

In June 2006 FAO approved funding of US$ 287 000 to support project activities during an 18-month period. It has been estimated that 55 percent of the 3 million tonnes of straw residues which are produced by rice growers are burned in-field as a practical means of disposal. Rice producers share these responsibilities, with priority given to clearing and cultivating land within 10–14 days of harvest in preparation for sowing the following crop (wheat or berseem). The opportunities available for the use of residues have not generally been appreciated. This has resulted in considerable loss of value to growers, and created extensive aerial pollution that has become unacceptable to communities living adjacent to or downwind from rice-growing areas. In Cairo it is called "the black cloud". By introducing rice technologies and building up national capacity, the project aims to achieve better utilization of rice straw so as to reduce air pollution and water contamination, improve the ecological environment, enhance soil fertility and increase farmers' incomes. The inception workshop was held in February 2007. The knowledge and skills of about 100 researchers and local extension staff on technologies for integrated management of straw will be improved. By the end of the project, about 1 000 farmers will be trained in new technologies for integrated management of straw, and there will be increased public awareness of the negative sides of burning rice straw.

TCP/INS/3003 (T): Accelerated Adoption, Capacity Building, and Training for RiceCheck-Group Procedures that Increase Productivity and Net Income from Smallholders' Integrated Rice Crop Management, 2006–07, Indonesia

In November 2005 FAO approved funding of US$ 387 000 to support project activities during an 18-month period. The Government of Indonesia accords highest priority to addressing the food-security and import-cost implications of rice importation. The project's objective is to strengthen national capacity to enable rice smallholders to adopt integrated rice crop management (IRCM)-RiceCheck procedures for increasing productivity and efficiency in rice production, thus helping to fulfil the national strategies of sustained increasing rice production and of strengthened rural livelihoods. The knowledge and skills of about 300 researchers, local extension staff and farmers on RiceCheck/IRCM procedures will be improved. At the end of the project, the country will have adequate manpower and expertise for upscaling the transfer of RiceCheck/IRCM procedures.

TCP/INS/3102: Accelerated Training on Improved Rice Production Technologies in Support to the Presidential Initiative to Increase Rice Production by 2 Million Tonnes, Indonesia, 2007–08

In August 2007 FAO approved additional funding of US$ 93 000 to support activities aimed at rapidly enhancing the national capacity for wide adoption of existing improved production technologies in order to increase the productivity of rice cultivation for meeting the objectives of the Presidential Initiative, especially in the following areas: capacity to apply integrated crop management systems (ICMS) in the cultivation of high-yielding and hybrid rice; and production and distribution of registered and certified rice seed.

TCP/SRL/3102 (D): Strengthening National Capacity for Hybrid Rice Development and Use for Food Security and Poverty Alleviation, Sri Lanka

In January 2007 FAO approved funding of US$ 329 000 to support project activities during an 18-month period. Rice is the staple food of 19 million people in Sri Lanka. Significant gains have been achieved in national rice production during the last two decades and national rice yield has increased to 3.9 tonnes/ha. However, paddy production meets only 90 percent of the national requirement. The objective of the project is to assist the Government of Sri Lanka in strengthening national capacity in hybrid rice development and use in order to increase rice production and maximize the return from investment in irrigation and group farming for food security and poverty alleviation. The knowledge and skills of about 100 researchers, extension workers, seed production supervisors and seed growers involved in hybrid rice development and hybrid seed production will be improved. At the end of the project, the country will have adequate manpower and expertise in hybrid rice breeding, F_1 seed production and commercial hybrid rice production for upscaling the transfer of hybrid rice technology to farmers under group farming schemes and associations of F_1 seed production as well as to non-governmental organizations (NGOs) and the private sector involved in rice production in the countries.

TCP/SUD/3101 (T): Training on Improved Rice Technologies for the Enhancement of Irrigated Rice Production in the White Nile State, Sudan, 2006–08

In February 2006 FAO approved funding of US$ 279 000 to support project activities during an 18-month period. The Government of the Sudan intends to make investments to address the growing demand for rice. One of the targeted areas for rice expansion is the White Nile State, where vast swampy areas adjoining the banks of the White Nile have proven to be suitable for rice production. The objectives of the assistance are to: strengthen national capacity and local technology transfer and extension capacities in support of rice production through properly tailored training and by enabling the National Rice Training Centre to plan, implement, train and monitor the rice development programme; provide a platform for enhancing national capacities and facilitating effective future South-South cooperation between the Sudan and other countries; enhance rice crop productivity; and accelerate the implementation of the Rice Revitalization Programme for food security, poverty alleviation and economic empowerment of rural dwellers in the country. Due to unforeseen circumstances, the project's activities were delayed for several months and will be resumed in May 2007.

TCP/VIE/3101 (D): Capacity Building for Improvement of Seed Source Quality and Rice Production for Food Security in the Highland and Mountainous Regions in Viet Nam, 2007–09

In May 2007 FAO approved funding of US$ 257 000 to support project activities during an 18-month period as part of the Government's effort to attain a national strategy for social equity, peace and sustainable development through building up the capacity and expertise for rice production in the highlands and mountainous regions of Viet Nam. The main objectives of the project are: to improve the expertise and capacity in production, conservation and distribution of high quality seeds of locally adapted rice varieties through the training of research and extension staff of the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI) and farmers in five mountainous provinces; and to improve the capacity of extension staff and farmers in rice crop management for high rice yield and sustainable production through participatory on-farm demonstration and farmers field schools on integrated rice crop management technologies.

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