Delivering resilient, gender-responsive and market-driven innovations

Africa Rice Center (AfricaRice) – Annual Report 2022

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Citation:

Africa Rice Center (AfricaRice). 2023. *Africa Rice Center (AfricaRice) Annual Report 2022: Delivering resilient, gender-responsive and market-driven innovations.* Abidjan, Côte d'Ivoire: 36 pp.

ISBN:

Print 978-92-9113-418-2

PDF 978-92-9113-419-9

Writing and editing:

Green Ink (www.greenink.co.uk)

Photo credits:

All pictures are by staff members of AfricaRice, and networks and consortia convened by the Center.

Cover: Mechanized direct seeding at AfricaRice M'bé station, Côte d'Ivoire.

AfricaRice

About Africa Rice Center (AfricaRice)

Africa Rice Center (AfricaRice) is a pan-African Center of Excellence for rice research, development and capacity-building. It contributes to reducing poverty, achieving food and nutrition security, and improving livelihoods of farmers and other rice value-chain actors in Africa by increasing the productivity and profitability of rice-based agri-food systems, while ensuring the sustainability of natural resources. AfricaRice is a CGIAR Research Center — part of a global research partnership for a food-secure future. It is also an intergovernmental association of 28 African member countries. AfricaRice headquarters is based in Côte d'Ivoire. Staff members are located in Côte d'Ivoire and in AfricaRice research stations in Liberia, Madagascar, Nigeria, Senegal and Uganda. For more information, visit www.AfricaRice.org.

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Message from the Board Chair and Director General

The rice sector in Africa was affected in different ways by the reduced availability of wheat and fertilizers in the international market because of the war between Ukraine and Russia — major producers of the two products. The decline in the availability of wheat meant that many African countries reverted to rice, while the reduction in the fertilizer negatively affected yield in rice fields. These, once again, brought AfricaRice to the forefront of agricultural policy in several countries across the continent. AfricaRice proposed policy options aimed at mitigating the negative effects of yet another crisis that added onto the climate challenge and the COVID-19 pandemic.

Despite these challenges, AfricaRice continued to deliver resilient, gender-responsive and market-driven innovations aimed at transforming the rice sector in Africa.

Recognition of AfricaRice achievements

- **Agricultural & Applied Economics Association (AAEA) Quality of Research Discovery Award** for the publication entitled 'Contract farming and rural transformation: Evidence from a field experiment in Benin', co-authored by Aminou Arouna (Program leader for Policy, Innovation Systems and Impact Assessment at AfricaRice), Jeffrey D. Michler (Associate Professor at the University of Arizona) and Jourdain C. Lokossou (PhD scholar at Laval University and previously Research assistant at AfricaRice). The paper was published in the *Journal of Development Economics*.
- **21st Century Hope Prize** of the 7th **Niigata International Food Award** to Kazuki Saito, Agronomist.
- **International Fertilizer Association (IFA) Emerging Scholar Award 2022** to Jean-Martial Johnson, Consultant supporting the CGIAR Excellence in Agronomy Initiative.
- A **Japan International Award for Young Agricultural Researchers 2022** to Tovohery Rakotoson, Consultant supporting the CGIAR Excellence in Agronomy Initiative.

High-level interactions with member countries

Interactions pursued with high-level government officials of member countries resulted in the following key achievements: (i) increased awareness to pay annual contributions and a consequent upsurge in the amount of arrears and annual contributions paid by member countries; (ii) new requests from key stakeholders in member and non-member countries for continuing provision of technical assistance (Central African Republic, Comoros, Democratic Republic of Congo, Guinea, Malawi, Mauritania, Mozambique, Rwanda, Tanzania, Zambia and Zimbabwe); and (iii) signing of 50 new partnership agreements, notably with private seed enterprises in eight member states (Benin, Burkina Faso, Côte d'Ivoire, Guinea Bissau, Mali, Niger, Nigeria and Senegal), to enhance the production of quality seed of improved rice varieties.

The new offices in Abuja, allocated to AfricaRice by the Federal Ministry of Agriculture and Rural Development of Nigeria (FMARD), are now functional. This is creating more visibility of the Center's support to Nigerian government efforts to increase domestic rice production through training of rice value-chain actors and breeder and foundation seed production.

New office space was allocated to AfricaRice in Antananarivo, Madagascar, which is also hosting two other CGIAR Centers, IITA and CIP — a contribution to the concept of One CGIAR. In addition, offices and farmland allocated to AfricaRice by the National Agricultural Research Institution of Madagascar (FOFIFA), in Mahitsy, Analamanga Region, enhanced breeder seed production and breeding research in general.

In June, a delegation led by Dr Claudia Sadoff, CGIAR Executive Managing Director, and including the AfricaRice Director General, visited Madagascar for a weeklong event of intensive and productive consultations of CGIAR leadership with government ministries, research partners and funders in Madagascar. This resulted in the co-creation of a country-specific research and development agenda for enhancing nutrition and food security, and a profitable, inclusive, resilient and sustainable agricultural sector for the people of Madagascar.

AfricaRice held more than 15 strategic regional and international consultations, both virtually and in person, with partners including the following: regional economic communities (EAC, ECOWAS and SADC); research and innovation institutions such as FARA and its constituent subregional organizations including ASARECA, CCARDESA and CORAF/WECARD; and development partners (AfDB, Bill & Melinda Gates Foundation, GIZ, IFAD, IsDB, JICA, USAID, WFP and World Bank). These consultations included examining opportunities for the transformation of the rice sector in Africa. They also contributed to enhancing the visibility of the Center and in particular its capacity to deliver rice-based innovations that can contribute to accelerating the attainment of rice self-sufficiency in Africa.

Research for development

The ***2030 Rice Research and Innovation Strategy for Africa*** was endorsed by the AfricaRice Council of Ministers (CoM). The strategy: (i) will guide rice research-for-development actions in Africa up to 2030; (ii) is aligned with the One CGIAR 2030 Research and Innovation Strategy in the sense that its implementation will strongly contribute to delivering the One CGIAR Strategy; (iii) envisions the sustainable improvement of food and nutrition security for a healthy and prosperous Africa; and (iv) proposes value to the rice sector and its stakeholders in Africa.

In commemoration of its 50th anniversary, AfricaRice released ***50 Years of rice research for development***,[1] which encapsulates the key long-term and large-scale impacts delivered by the rice research-for-development activities carried out by the Center and its partners in Africa over the last five decades. Overall, AfricaRice interventions have contributed to lifting 15 million people out of poverty and generated a cumulative gross research benefit of US$ 37 billion with a $3.49 benefit for each dollar invested in rice research and development.

The **2022 AfricaRice Science Week**, 'Consolidating partnerships to implement the 2030 Rice Research and Innovation Strategy for Africa' (12–16 December, M'bé, Côte d'Ivoire), included representatives of national agricultural research systems (NARS) directors, project partners, private sector and NGOs, and members of the Africa-wide rice tasks forces (agronomy, breeding, gender and policy). This strategic interaction provided valuable pointers for the future of research, development and partnerships.

- AfricaRice and CGIAR Centers are renowned for the delivery of science and innovations to create an impact on our society, but require an enabling environment to do so.
- There must be subsidiarity between the NARS and One CGIAR in the way of doing business.
- There are ongoing needs for dedicated funding to strengthen the capacity of research and innovation institutions in Africa.
- Value-chain actors need to be better organized for quality assurance and branding, especially in the production of inputs such as seeds.
- 'AfricaRice village' concept to be promoted for empowerment of farmers to drive the value chain while engaging in contracting agreements.

1 www.africarice.org/post/release-of-new-africarice-publication-commemorating-50-years-of-rice-innovation-and-impact

- Promotion of the COSEMRiz model to enable seed entrepreneurs and millers to effectively contribute to improving the rice value chain.
- Capacity-strengthening of the rice value-chain actors, especially youth and women.
- Due consideration to be given to gender, youth and social inclusion for inclusive growth.

Research and innovation highlights

AfricaRice's research for development (R4D) and capacity-building aim to deliver 'solutions' to the big questions in Africa's rice-based agriculture posed by the 3Cs of climate change, conflict and COVID-19, responding to value-chain actors' and consumers' demands (i.e. they are market driven), and increasingly striving for gender equity. These are reflected in the selection of highlights for this year's report.

We have already touched upon the impact of the Russia–Ukraine war, and AfricaRice was quick to provide a policy brief to assist decision-makers of its member states in mitigating possible negative impacts in the short, medium and long term (page 8). The impact of CGIAR research on small-scale farmers has been highlighted with a focus on Africa and AfricaRice (the Association) (page 9).

With the advent of One CGIAR, AfricaRice opted to base initiation of all its breeding at M'bé station (building on the long legacy of breeding expertise at the main research station). This report highlights some of the successes from the past year (page 10). Meanwhile, seed dormancy has hampered the use of African cultivated rice (*Oryza glaberrima*) for many years. However, thanks to the work of our genebank research staff and in particular a PhD student, the Center has succeeded in developing a dormancy-breaking protocol to overcome this barrier (page 12).

Rice spikelet infertility caused by high temperatures around flowering has become an increasing concern in all agro-ecosystems. Our scientists have determined that prediction of sterility requires knowledge of panicle temperatures and not just air temperatures, with some surprisingly good news for irrigated systems in the Sahel (page 13). Regarding the issue of water use by the rice crop, 2022 saw the publication of a review of water management research at AfricaRice spanning a 30-year period. The review provides some useful pointers for future R4D (page 14).

The debilitating effects of malaria on rice farmers has remained a concern (as reported last year). The current report highlights the important outcome of an assessment of mosquito control methods (page 15).

Mycotoxins are a well-known health hazard in crops such as groundnuts. What was not known was just how much mycotoxin contamination occurred in rice being marketed in Africa. Our findings are shocking, and we are providing advice and assistance to limit fungal growth and contamination of rice from farm to plate (page 16).

A major concern among the young population of Africa is unemployment, yet in general young people are not interested in farming. Meanwhile, smallholders struggle to adopt capital-intensive technologies. AfricaRice is currently testing business models aimed at aligning farming and businesses that the youth consider more attractive (page 17). In a similar vein, we are looking at farmers' willingness to pay for mechanized weeding services — with a view to determining the gap between perceived value and cost (page 18).

AfricaRice's application of gender techniques is growing. First, we look at ex-ante and ex-post gender analyses of technology dissemination (page 19). Next, interdisciplinary research leading to the establishment of women's seed business and 'saving' rainfed lowland rice farming in central and southern Senegal (page 20). This report also highlights the effectiveness of GEM in improving the livelihoods women in East and Southern Africa (page 21).

Long on the radar, but generally receiving little attention, rice–fish cultivation has transformed rice-based systems in Liberia (page 22). With their appetite for mosquito larvae (see page 15), it is just possible that rice–fish could be the next 'big thing'.

Last, but not least, are some highlights of how the outcome of the program Technologies for African Agricultural Transformation (TAAT) Rice Compact component is transforming the Senegalese seed system (now industry) while ensuring the industry's resilience (page 23).

One CGIAR

AfricaRice scientists continue to be involved in the implementation of 9 of the 33 **One CGIAR initiatives** and 1 of its 5 platforms: two initiatives under System Transformation research area, two under Resilient Agri-food Systems, four under Genetic Innovation and one under the Gender Platform.

With the support of Research and innovation director Prof. Abdulai Jalloh, AfricaRice scientists have increased alignment of various projects and the programs of the Center to the **One CGIAR Operational Structure**. The Rice Sector Development Program remains a stand-alone program to highlight the important role and place of 'development' as the central theme of the transformation process of the rice sector.

Interactions with various CGIAR entities focused on providing adequate support to the transition to One CGIAR, including: (i) preparation of and launching calls for managerial appointments for the One CGIAR operational structure; (ii) refining documents that outline the development and management of CGIAR portfolio and initiative budgets for the 2023 financial plan and the future; (iii) establishing the One CGIAR Unified Pipeline for bilateral projects; and (iv) implementing CGIAR research initiatives.

The DG was involved in high-level meetings with key research and innovation stakeholders in Africa, including the African Union and AfDB, to outline a strategy for strengthening stakeholder engagement and rolling out the One CGIAR agenda in countries and regions.

The DG was appointed as Managing Director (MD) of Regions and Partnerships, one of the six MD positions of the apex structure of One CGIAR. In the One CGIAR operational structure, regions and countries are positioned as central dimensions of partnership to maximize impact. A new engagement framework that builds an enabling environment for partnerships has been elaborated.

The DG, as MD Regions and Partnerships, participated as speaker/panelist in several high-level events: (i) CGIAR webinar in the side event of the Eighth Tokyo International Conference on African Development (TICAD 8); (ii) Tropentag 2022, organized by the Czech University of Life Sciences in Prague in which AfricaRice was the featured CGIAR Center; (iii) AGRF 2022 Summit, supporting CGIAR Executive managing director, Claudia Sadoff; (iv) High-level Roundtable as part of a 2022 Norman E. Borlaug International Dialogue side event; (v) CGIAR–AfDB–FARA meeting to strengthen collaboration with African research and innovation institutions and NARS. These meetings resulted in increased awareness of progress in the transition to One CGIAR and in stakeholder engagement on how CGIAR intends to roll out its agenda in countries and regions.

As MD Regions and Partnerships, the DG is leading several consultations, both internally to appropriately position Regions and Partnerships in the Integrated Matrix structure of One CGIAR. And externally, especially with key stakeholders operating in Africa (AUC, FARA and its constituencies including the sub-regional organizations [SROs] and NARS, AfDB, EU, etc.) to strengthen collaborations between One CGIAR key research and innovation institutions in Africa.

Financial situation

The Center had a financial surplus by 2022 year-end. Most of the Center's financial performance indicators are very close to the recommended CGIAR thresholds. The current ratio increased from 1.27 in 2021 to 1.36 in 2022 (CGIAR recommended level greater than 1.0), indicating that the Center can meet its liabilities in the short term.

Human resources

The workforce stands at 265 staff members: 36 internationally recruited staff (IRS: 31 men, 5 women); 189 general support staff (GSS: 134 men, 55 women); and 43 consultants (33 men, 10 women). Research staff make up 62% (165) of the workforce and administrative support staff 38% (100).

AfricaRice staff geographical distribution stands as follows: Côte d'Ivoire (56%), Senegal (18%), Madagascar (13%), Nigeria (4%), Liberia and Uganda (2% each). Home-based staff make up an estimated 5% of the workforce.

A recruitment process for a new Director General of AfricaRice and One CGIAR Regional Director of West and Central Africa followed the announcement, by the Board Chair to the CoM during its 32nd ordinary session in March 2022, of the former Director General's decision to terminate his contract on 31 December 2022. With the support of executive recruitment firm Perrett Laver, the Board of Trustees of AfricaRice successfully identified Baboucarr Manneh for the DG position.

Governance

The 32nd ordinary session of the Council of Ministers held in March passed the following resolutions.

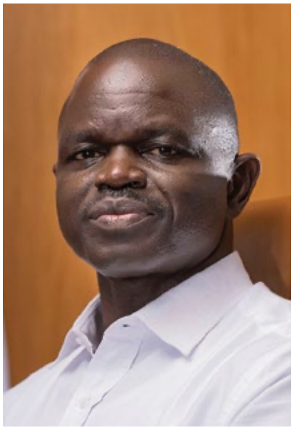
1. Member states should endeavor to pay their annual contributions in a timely manner and pay all their arrears by the end of 2023.
2. National agricultural research institutes (NARIs) of member states of AfricaRice and AfricaRice management should establish and execute plans for rendering AfricaRice and its research products more visible to governments of member states.
3. Member states and management of AfricaRice should work with development banks, such as AfDB, to exploit ways and means of sourcing a one-off payment of arrears of annual contribution from rice value-chain projects, where possible.
4. AfricaRice management should lead the development of an innovative financing mechanism involving partnerships with the private sector and market-led financing approaches, to raise additional funds for sustaining the operations of AfricaRice, with considerations given to the development of solid business models, benefit-sharing especially between AfricaRice and its partner NARIs of member states, intellectual property rights issues and measures for the protection of farmers' rights.
5. AfricaRice management should support member states in using strategic information derived from the Continental Investment Plan for accelerating Rice Self Sufficiency in Africa (CIPRiSSA), established for 11 countries with support from AfricaRice, to advocate for investments that would increase the performance of rice value chains and the attainment of rice self-sufficiency in member states.
6. AfricaRice management should consolidate its links with NARIs, subregional research and innovation institutions, and regional economic communities, especially in the Central and Southern African regions, in a bid to strengthen their capacity in rice research and development and to strengthen the policy environment — to enable the creation of impact on the livelihoods of the African population.

7. The Board of Trustees and management of AfricaRice and One CGIAR should pursue their work in aligning their governance and operational frameworks without compromising the tenets of the AfricaRice Constitution and disrupting the privileges AfricaRice benefits from its host countries.

8. One CGIAR, in its partnership with AfricaRice, should provide all the necessary support to AfricaRice that will result in strengthening the capacity of AfricaRice and its partner NARIs in member states, to deliver on the mission accorded to it by its 28 member states of strengthening the rice sector and attaining rice self-sufficiency in Africa.

Management continued to be mindful of the challenges of the 3Cs — climate change, conflict and COVID-19 — along with the One CGIAR transition process, and worked to mitigate any major risks that these challenges might bring to the functioning of the Center.

Over the year, focus was placed on amplifying the achievements of AfricaRice, enhancing its visibility, contributing to the creation of impact at scale and maintaining the financial stability of the Center — all within the context of aligning to the new One CGIAR Strategy and operating through the Integrated Matrix Structure and Integrated Framework Agreement. This focus has facilitated the initiation of measures that will strengthen the position of the staff of AfricaRice to deliver on its mission. The DG continued to foster actions that will lead to a more effective and efficient engagement of AfricaRice scientists and its partner NARS in the delivery of the new rice research and innovation strategy and the One CGIAR Research and Innovation Strategy, to contribute to transforming the complex challenges of the food system in Africa in a climate crisis.



Director General
Baboucarr Manneh

Chair of the Board of Trustees
Kanayo F. Nwanze

Limiting the impact of the Russia–Ukraine war on rice value chains in Africa

Both Russia and Ukraine have been major exporters of both wheat and fertilizers for many years to many countries including African countries.

The Russia–Ukraine crisis has disrupted fertilizer supply, thereby putting new pressure on the prices of fertilizers and wheat. This had a knock-on effect on the price of other staple foods such as rice, which almost immediately exacerbated the food security situation in many developing countries.

Although Sub-Saharan African countries use less fertilizers than many others, they still depended on Russia and Ukraine. Russia was the second-largest supplier of fertilizers to countries in ECOWAS. And as many as 25 African countries imported more than a third of their wheat from the two countries.

The crisis thus exposed African food markets to heightened risks by unmet import demand and increases in the prices of foodstuffs and fertilizers.

As in the days of global economic recession and consequent rice price crisis in 2007–2008, and more recently in response to COVID-19 global restrictions on transportation, AfricaRice was quick to issue ‘Emergency policy options’ to advise African governments on actions to take to mitigate the effects of a new crisis, with particular emphasis on the rice sector.[2] These options are recommended to see the countries through the current crisis and bolster the rice sector in preparation for the next.

“In early 2022, we expected the Russia–Ukraine crisis to be brief,” says impact assessment economist Aminou Arouna. “However, its protraction beyond the end of the year has demonstrated that we were wise to include medium- and long-term policy options in our analysis.”

Examples of the 18 policy measures

- Scale up adoption of good agricultural practices (GAPs): while there has been great area expansion over the past 15 years, the yield gap in Sub-Saharan Africa is still high (average yields 2.2 tonnes/ha cf. global average of 4 t/ha); GAPs will also improve input-use efficiency in the face of high fertilizer prices.
- Enable farmers to access credit to buy fertilizers in the quantities needed before the start of each season.
- Implement short-term fertilizer subsidies.
- In the long term, develop agricultural investment plans, for example water management infrastructure — water management in particular leads to more efficiency as risk is reduced.
- Establish fertilizer production plants on a regional basis: some African countries have the raw materials for fertilizer production (e.g. Mali, Nigeria); these can act as hubs to produce and supply fertilizers for the continent’s agriculture sector.

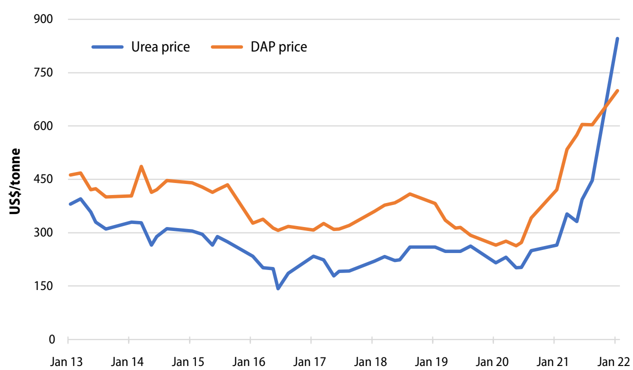


Figure 1. International urea and diammonium phosphate (DAP) fertilizer prices were climbing steeply before the war

Source: Index Mundi.

Contact: Aminou Arouna, Policy, Innovation Systems and Impact Assessment Program leader, and Impact assessment economist <a.arouna@cgiar.org>

2 Arouna A, Saito K, Yergo W and Roy-Macauley H. 2022. Emergency policy options to increase resilience of rice-based agri-food system actors in the context of the Russia-Ukraine crisis. Africa Rice Center, Abidjan. Available at: www.africarice.org/post/emergency-policy-options

Significant impact of CGIAR rice innovations on smallholder farmers

Rice production has increased significantly over the past 50 years thanks to efforts of CGIAR Centers and national governments.

In a collaboration between Arizona State University, AfricaRice, IRRI and CIAT, 17 ex-post impact assessment studies (2016–2021) were reviewed — covering rice varieties, agronomic practices, institutional arrangements, post-harvest, and information and communications technologies (ICTs) used by rice farmers in Africa, Asia and Latin America.[3]

In Africa, improved rice varieties developed by AfricaRice and partners have been released and adopted by farmers in many countries. Between 2000 and 2014, these varieties had average yield advantages of 0.15–0.75 t/ha and increased rice-based incomes by US$20–70 per capita. Moreover, adoption of NERICAs improved household food security by an average of 14 percentage points.

In Côte d'Ivoire, adoption of *Rice yellow mottle virus*–resistant WITA 9 increased yields by 0.7 t/ha and incomes by $91/ha (cf. traditional varieties). It also fetches higher market prices, similar to imported rice.

Adoption of Smart-valleys, promoted by AfricaRice for adapting to climate change, increased yields by 0.9 t/ha and incomes by $267/ha in Benin and Togo.

The RiceAdvice app brings fertilizer and other crop management recommendations to the field level. In Nigeria, use of RiceAdvice increased rice yield by 7% and profit by 10% compared with using regional blanket fertilizer recommendations, without affecting the total amount of fertilizer used.

Meanwhile, contract farming has become popular in both Africa and Asia. Contract farmers in Africa increased their rice area by 23%, their yields by 29% and thereby their incomes by an average of 50%. Moreover, simple contracts had almost as much impact as more complex ones.

Overall, the review demonstrates the success of improved rice varieties and sustainable crop management practices developed by CGIAR Centers and partners in enhancing productivity, food security and rural livelihoods across Africa.

Over the past half century, rice yields in Sub-Saharan Africa have been on a slow upward trend (Fig. 2). This contrasts with the situations in Asia (downward trend) and Latin America (a more strongly upward trend). However, rice area expansion and consequently rice production have grown tremendously, especially since the early to mid-2000s. There is definitely room for improvement on the yield front and AfricaRice/CGIAR technologies are a valuable key to unlocking that potential. Countries and development partners should continue supporting the widescale promotion of these technologies that have proven track records.

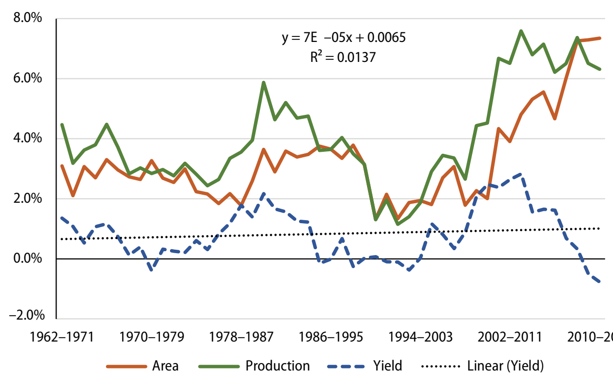


Figure 2. Average annual growth rates (%) of area, production and rice yield in Sub-Saharan Africa, 1962–2019

Contact: Aminou Arouna, Policy, Innovation Systems and Impact Assessment Program leader, and Impact assessment economist <a.arouna@cgiar.org>

3 Mishra AK, Pede VO, Arouna A *et al.* 2022. Helping feed the world with rice innovations: CGIAR research adoption and socioeconomic impact on farmers. *Global Food Security*, 33: art. 100628. https://doi.org/10.1016/j.gfs.2022.100628

Developing climate-resilient varieties that meet the demands of rice producers and consumers in Africa

Breeding line development is centralized at AfricaRice M'bé station, Côte d'Ivoire, with a streamlined 3-year breeding cycle — significantly reducing the previous 6–7 year cycle.

Year 1: crossing, F_1 verification through genotyping using a specific set of diagnostic SNP markers, and F_2 seed production.

Year 2: advancement of F_2–F_4 generations via Rapid Generation Advancement, using single seed descent method.

Year 3: F_5 line testing and seed amplification, marker-assisted selection implementation on priority traits for a market segment in the breeding pipeline, evaluation of Observational Yield Trials and their fingerprinting. This period also includes screening for tolerance to both biotic and abiotic stresses, along with grain quality analysis, which typically spans in the second half of the third year.

Selection decisions for parents and lines are based on data and defined product profile. The approach is based on elite-by-elite crossing, with a targeted genetic gain of 1.5% and a selection intensity of 5–10% superiority over established checks across all breeding pipelines. Early-stage line evaluations are carried out at all AfricaRice stations in Côte d'Ivoire, Madagascar, Nigeria and Senegal. Late-stage testing is conducted through the breeding task force.

The Africa-wide Rice Breeding Task Force comprises 30 national agricultural research and extension system partners conducting field testing of materials from different breeding pipelines. Data collected from these trials are quality controlled before analysis. As part of its commitment to modernization of national breeding programs throughout Africa, AfricaRice organized a series of training sessions focused on digital data capture and introduced participants to the adoption of the Enterprise Breeding System. A total of 21 men and 5 women took part in these workshops. Simultaneously, AfricaRice provided support to 18 NARS representatives from 17 countries by equipping them with various digital tools, including tablets, digital scales and moisture testers.

On this journey of NARS breeding modernization, AfricaRice has shared the concept of Target Product Profiles (TPPs) and provided a comprehensive template for documenting the key components of TPPs. Subsequently, participants were encouraged to assemble teams of stakeholders in their own countries to initiate the development and validation of TPPs for new varieties. AfricaRice has successfully guided the development of TPPs in some countries in West and Central Africa, and East and Southern Africa. These efforts are ongoing, with plans to extend the process to additional countries.

The Korea–Africa Food and Agriculture Cooperation Initiative (KAFACI) selected advanced breeding lines to enter national performance trials and 27 market-oriented and climate-resilient varieties were released in 2022 in eight countries (Table 1). These varieties had yielded about 5–9 t/ha in irrigated lowlands and 2.5–5 t/ha in rainfed uplands. In addition, evaluation of 48 Tongil-type varieties from KAFACI showed a yield increase of 14.4% over the dominant variety, Sahel 108.

Four candidate upland lines — ARICA14 (CRAM1), ARICA15 (CRAM2), ART3-3-10-1-1-B-1 (CRAM3) and ART15-16-12-3-1-B-1-B-3-1 (CRAM4) were selected from on-farm trials carried out with 320 rice farmers at Korhogo, Duekoué and Vavoua in Côte d'Ivoire. These lines are early maturing, drought tolerant, resistant to blast and lodging, and have high yields compared with local varieties. They are now being evaluated in a national performance trial (NPT) for release in Côte d'Ivoire.

Table 1. Varieties released in 2022 by market segments and countries

Country	Market segment	Varieties (No.)	Yield (t/ha)
Ghana	Transplanted, medium duration, long grain, soft cooking, for rainfed lowland	CRI-TuoMo, CRI-KangMo, CRI-KoreaMo, CRI-Baakoye, CRI-Agyapa, CRI-Onuapa (6)	7~9
DR Congo	Medium duration, long grain, soft cooking	Rizikiyetu, Kiboko, Nakafaci, Kiringyemulezi, Basimka, Super kafaci (6)	5.7~6.3
Mali	Medium duration, long grain, soft cooking	Kafaci 2, Kafaci 3 (2)	5~7
Rwanda	Medium duration, long grain, soft cooking	Gwiza, Umutebo, Cyuzuzo (3)	6.5~7.6
Senegal	Early, long grain, soft cooking, for irrigation	ISRIZ 16, ISRIZ 17 (2)	9
	Direct seeded, early maturing, long grain, soft cooking, for rainfed upland	ISRIZ P01, ISRIZ P02 (2)	2.5~5
Tanzania	Early, long grain, soft cooking	TARI-RICE3 (1)	6.5~7.5
Uganda	Early, long grain, soft cooking	Ukafaci 39 (1)	6.7
Zambia	Early, long grain, soft cooking	Zakafaci 1, Zakafaci 2, Zakafaci 3, Zakafaci 5 (4)	6.8~8.5
Total		**27**	**2.5~9**

In a comprehensive study of the performance of elite rainfed lowland rice breeding lines across various environmental stresses in Nigeria, three lines exhibited tolerance to more than one stress under field conditions. ART1453-B-B-1-5 showed remarkable adaptability, having 52.5% survival rate after 14 days of submergence, and grain yield 21.4% higher than the highest-yielding check, FARO 67, under direct seeding. ART1460-B-B-1-9 was the best under iron toxicity and stagnant flooding, displayed a 45.6% survival rate post-submergence and had a 22% yield advantage over the most tolerant standard check, FARO 57, under iron toxicity. ART1471-B-B-B-1-30 exhibited a high anaerobic germination rate of 60%, and yielded higher than all checks under stagnant flooding. These elite rice lines were developed to address the challenges posed by climate change. Their adaptability and resilience offer a promising outlook for sustainable rice farming in the region. They are now being tested on farm in seven countries in West and Central Africa.

Another five breeding lines with higher yields under saline environments than current popular varieties (Sahel 108, Sahel 134, Sahel 177) were reported in the irrigated lowland pipeline in Senegal. These lines also exhibited *Rice yellow mottle virus* (RYMV) and blast resistance, plus grain quality that meets the preference of customers according to their TPPs. Two promising climate-resilient breeding lines are currently in the final phase of the NPT in Madagascar. These lines exhibit traits such as cold tolerance, salinity tolerance, resistance to blast, early maturity and the ability to withstand submergence. Three varieties recently released in Madagascar — FOFIFA 194, FOFIFA 195 and FOFIFA 196 — have cold tolerance, disease resistance, early maturity, high yield and exceptional nutritional qualities. A substantial promotional effort is underway, with the establishment of demonstration plots in three regions spanning 24 sites. The goal is to reach 3000 farmers in Madagascar with these innovative varieties.

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Breaking dormancy associated with the African rice

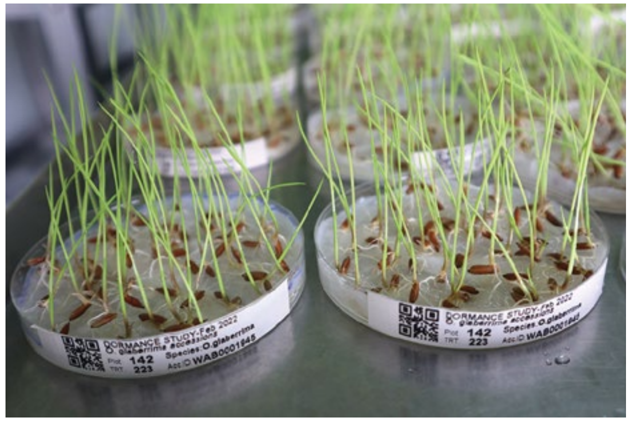
Of the approximately 22,000 accessions in the AfricaRice genebank, about 15% are of the African cultivated species, *Oryza glaberrima*. Domesticated in central West Africa, this species is adapted to African environments and stresses, and is therefore a valuable source of genes, not only for Africa but worldwide. However, the seeds of *O. glaberrima* do not germinate well, which limits its use in breeding and pre-breeding activities.

'Seed dormancy' is the temporary suspension of visible growth of the meristem; it is one factor that affects germination. In nature, it prevents germination until conditions are favorable for plant development. But it is a problem when we want to use the rice in research and breeding. In the genebank, *O. glaberrima* seed dormancy can be a significant disadvantage when an efficient treatment to break dormancy is not applied. It could result in misleading viability data, which can lead to erroneous management decisions.

PhD student Arnaud Gouda was recruited by AfricaRice to work out how to break *O. glaberrima* seed dormancy to enable seed to be taken from the genebank, treated and used. Genebanks set high standards for the germination ability of the seeds they store, and in rice genebanks such as the AfricaRice one these are 90% for long-term storage and 85% for medium-term storage.

"The first step was literature research," says Gouda, "through which I gained a better understanding of how seed dormancy works and various methods used to break it." Gouda identified three general methods used to break the dormancy of seeds of various species, and tested them on *O. glaberrima*: chemical, hormonal and heat treatment. The three most commonly used chemical solutions for breaking dormancy proved inefficient. Hormonal treatment, while successful, did not result in target levels of germination. That left heat treatment.

"I subjected the seeds to heat of various temperatures for various durations (counted in days)," says Gouda,



Good germination of O. glaberrima *after application of the new dormancy-breaking protocol*

"and we identified a temperature-and-duration combination that appeared to work. We then tested that protocol on 300 accessions of the mini-core collection, which represent a high proportion of the genetic diversity in the whole *O. glaberrima* collection, and it works, delivering almost 90% germination!"

"With this new protocol we can now make the full diversity of *Oryza glaberrima* available to breeders and other researchers worldwide to create the varieties we need for adaptation to the changing climate and associated abiotic and biotic risks, and guarantee that the seed we supply will germinate well," says head of the Rice Biodiversity Center for Africa, Marie-Noëlle Ndjiondjop.

And the protocol itself? [redacted]
[Unfortunately, this information has to be withheld until officially published — Ed.]

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Improving prediction of heat-induced spikelet sterility in rice under climate change

Global climate change with current and anticipated temperature increases across Africa is a worry for rice farmers and researchers alike, as rice is susceptible to extreme heat during flowering, resulting in spikelet sterility with consequent reduced grain production.

Led by the Institute for Agro-Environmental Science of the National Agriculture and Food Research Organization of Japan (NIAES) and Japan International Research Center for Agricultural Sciences (JIRCAS), this study established a multi-site monitoring network of canopy micrometeorology and heat stresses of rice under climate change (MINCERnet) across major rice-growing regions using standardized methods. Micrometeorological Instrument for the Near-Canopy Environment of Rice (MINCER) — a radiation-shielded, solar-powered, force-ventilated system — recorded the temperatures and humidity within rice canopies. The network covered 11 sites in 11 countries, including AfricaRice-managed trials in Cotonou, Benin and Fanaye, Senegal. The aim was to improve understanding of the microclimate inside rice canopies and its role in heat-induced spikelet sterility.[4]

During the hot dry season in the Senegal River valley, the air temperature above the rice canopy reached 45°C, but the temperature inside the canopy was 32°C due to strong evaporative cooling. This kept panicle temperatures around 31°C and spikelet sterility lower than expected despite the extreme air temperatures.

In contrast, in Benin during the wet season, air temperatures inside and above the rice canopy were similar, around 29°C. However, panicle temperatures were higher than air temperatures, reaching over 31°C because the high humidity suppressed evaporative cooling. Consequently, spikelet sterility was among the highest rates observed across all sites. This was reflected across humid sites (including Hubei, China). The risk of spikelet sterility is likely to increase more during climate warming in wetter climates (e.g. Benin), compared with drier climates (e.g. Senegal).

MINCER in a field of rice

The study demonstrates that rice production in the hot dry Senegal River valley is 'safe' at present; however, with likely temperature rises of 1.5–2°C by 2050 and 2–2.5°C by 2070,[5] the longer-term prospects may be markedly different.

Overall, the key conclusions were that panicle temperatures, as well as air temperatures, should be used to predict risk of heat-induced spikelet sterility, which is strongly correlated with panicle temperatures during flowering hours. Measuring humidity is also critical for accurate predictions, since humidity strongly affects internal canopy microclimates. MINCERnet provided detailed data to improve crop yield predictions under climate change.

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4 Yoshimoto M, Fukuoka M, Tsujimoto Y, Matsui T, Kobayasi K, Saito K *et al*. 2022. Monitoring canopy micrometeorology in diverse climates to improve the prediction of heat-induced spikelet sterility in rice under climate change. *Agricultural and Forest Meteorology*, 316: art. 108860. https://doi.org/10.1016/j.agrformet.2022.108860

5 van Oort PAJ and Zwart SJ. 2017 (2018). Impacts of climate change on rice production in Africa and causes of simulated yield changes. *Global Change Biology*, 23(3): 1029–1045. https://doi.org/10.1111/gcb.13967

Review of 30 years of water management research in Africa

The 50th anniversary of AfricaRice was a good time to take stock of past research and achievements in water management for rice-based systems in Africa and to identify critical research gaps and missing partners.[6]

"There were very few studies on water management in rice prior to the launch of the Inland Valley Consortium (IVC) in the 1990s," says Elliott Dossou-Yovo, lead author and AfricaRice agriculture and climate change specialist, "so we rather focused on the 30-year timeframe." IVC research extended into irrigation governance, salinity and iron toxicity in irrigated systems in general.

AfricaRice water-management research has focused on water constraints to rice production, impacts on yield, and technologies to mitigate these constraints and increase rice productivity. The major water-related constraints to rice production in Africa are drought, flooding, iron toxicity, salinity and alkalinity. A few studies looked at rice area expansion impacts on biodiversity, ecosystem services, and irrigation infrastructure management.

There have been great technology successes, including Participatory Learning and Action Research for Integrated Rice Management (PLAR-IRM), Sawah system, alternate wetting and drying (AWD) and Smart-valleys.

The review highlighted certain shortcomings of rice-related water management research to date: its narrow focus on very few indicators (water use and water productivity), all being at the field level and all about the rice crop alone.

Avenues for future research and development

- Water management at community and landscape levels, involving partners such as IITA, IRRI and IWMI (already started under the One CGIAR initiative Transforming Agri-Food Systems in West and Central Africa).
- Water management (WM) for rotation crops such as vegetables for crop and diet diversification.
- Economic indicators, such as cost–benefit analyses and livelihood impacts, especially for women and youth.
- Reducing uncertainty levels in land suitability assessments: filling data gaps for climate and soil models, refining assumptions about rice cultivation areas (including marginal areas), and introducing data related to technology adoption.
- Refining abiotic stress maps with higher-resolution geospatial and groundwater data.
- Research on greenhouse gas (GHG) emissions from irrigated rice (started in 2019). Testing and promoting technologies that mitigate or reduce GHG emissions while increasing land and water productivity.
- Collaborating with development agencies and policy-makers for out-scaling.
- Collaborating with the private sector to develop business models for technology adoption.
- Yield and water productivity impacts of direct seeding rice.

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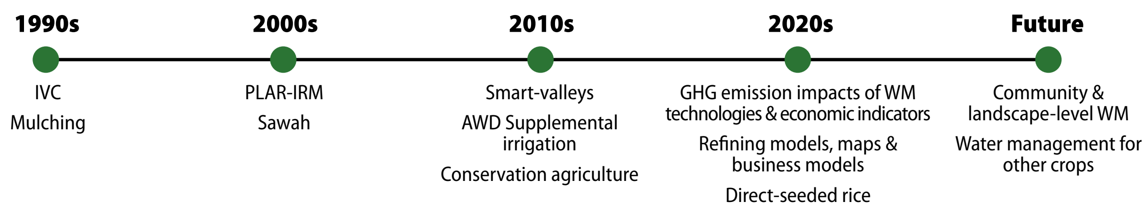

Figure 3. Timeline of water-management research for rice in Africa

6 Dossou-Yovo ER, Devkota KP, Akpoti K, Danvi A, Duku C and Zwart SJ. 2022. Thirty years of water management research for rice in Sub-Saharan Africa: Achievement and perspectives. *Field Crops Research*, 283: art. 108548. https://doi.org/10.1016/j.fcr.2022.108548

Control of malaria vectors in rice fields

The prevalence of malaria around lowland, especially irrigated, rice perimeters is a growing concern as rice area is expanded to try to meet domestic demand.[7] The larvae of the vector mosquitoes thrive in shallow, sunlit, semi-vegetated water — just the habitat that lowland rice provides. Numerous methods of malaria vector control have been proposed and tested over many centuries, but the co-benefits of malaria control on rice have not received so much attention.

A systematic review and meta-analysis showed that four major practices are used to control malaria vectors in rice fields worldwide: biological larvicides, synthetic organic chemicals, fish and intermittent irrigation.[8] The effectiveness of these practices ranged between 35% and 84%, with the highest reduction in vectors observed in the integrated rice–fish system.

"Essentially, a lot of the interventions work to bring down vector numbers," says London School of Hygiene and Tropical Medicine research fellow Kallista Chan, lead author of the review. "What is lacking is farmer adoption of control actions, agricultural sector promotion of control methods, and greater collaboration between agricultural and medical scientists." Farmer acceptability assessment showed that biological larvicides are not economically effective, while rice–fish provides additional income and a source of protein.

In a study of farmers' perceptions of the rice–malaria problem in Côte d'Ivoire, only those close to the paddies made the link between irrigated cultivation and mosquitoes. And overall there was a serious lack of understanding about mosquito breeding habitats and the viability of control methods at the field level. Enhancing awareness and training on the rice–malaria link are needed for agricultural and health extension workers, as well as farmers.

Monitoring mosquito larvae in the field is very labor intensive

"There is a lot of scope for integrated research in this area," says Chan. "We should be monitoring healthcare and agriculture concurrently, and looking for ways to maximize benefit between the two. Our ultimate goal is to decrease mosquito populations while still increasing rice yields."

One area that Chan identifies for major improvement is monitoring mosquitoes in rice fields. This is currently a very labor-intensive activity involving sampling of irrigated rice water in situ. There may be a role for machine learning and artificial intelligence (AI), for example in analyzing photographs of paddy water for the presence and density of mosquito larvae. It may also be worth investigating monitoring of adult mosquitoes in and around the fields.

There is a long way to go in rice–malaria research, but progress needs to be made fast if we are going to avoid health crises and yet not have negative impact on the environmental health and biodiversity we depend on.

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7 See 'Malaria and rice: no more "paddies paradox"', *AfricaRice annual report 2021*, page 8.
8 Chan K, Bottomley C, Saito K, Lines J and Tusting LS. 2022. The control of malaria vectors in rice fields: A systematic review and meta-analysis. *Nature Scientific Reports*, 12: art. 19694. https://doi.org/10.1038/s41598-022-24055-2

Monitoring mycotoxins in rice through rapid detection and control[9]

Mycotoxins are toxic substances created by fungi that infect plant material. Above certain concentrations mycotoxins in foodstuffs are toxic to people. Mycotoxin-producing fungal infection and growth — and hence mycotoxin contamination — are promoted by favorable temperatures (27–37°C) and relative humidity (75–100%, where rice grain moisture content is > 16%). They are also favored by high proportion of broken grains, chalky grains and poor hygiene during handling. The environmental and handling conditions of cereals, especially rice, in Africa provide the conditions for mycotoxigenic fungi to thrive.

Samples of both domestic and imported milled rice were purchased from 54 markets across five African countries. The samples were analyzed for mycotoxins in the laboratory at M'bé station using state-of-the-art single-step lateral flow immunochromotographic assays (Reveal Q+ kits, Neogen Corporation).

Some 70% of the 540 samples tested for aflatoxin were contaminated, with a staggering one third of the samples (180) having contamination levels above the maximum regulatory limit (MRL = 4 ppb) (Table 2). Meanwhile, 20 of the 50 samples tested for other mycotoxins were contaminated with zearalenone (6 above MRL, 75 pbb). However, while 9 were contaminated with fumonisin, none had toxin levels over the MRL (1 ppb), and none had deoxynivalenol contamination.

"I was surprised and shocked by the levels of mycotoxin, particularly aflatoxin, contamination," says grain quality specialist and postharvest technology scientist Sali Ndindeng. Moreover, imported rice samples were just as contaminated as domestic ones. Thus, there is an urgent need to reduce fungal infestation of rice and to minimize the risks of infection and contamination throughout the value chain.

Practices for minimizing the risk of mycotoxin contamination in rice in Africa

- Use uncontaminated quality seeds for planting.
- Keep all equipment used along the value chain clean to reduce cross-contamination.
- Dry harvested paddy to the recommended moisture level (14% in many countries) as soon as possible after harvest and do not allow it to rehydrate.
- Thresh and mill with appropriate equipment to minimize grain breakage.
- Store seeds under conditions that do not favor fungal growth (e.g. in dry conditions, 8–10% moisture content), ideally in hermetic (airtight) storage systems.
- Store grains under conditions that do not favor fungal growth (e.g. in dry conditions, 12–14% moisture content), ideally in hermetic storage systems.
- Consumers should also store rice under appropriate conditions, and should wash rice with hot water before cooking.

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Table 2. Mycotoxin contamination of rice from African markets

Toxin	No. samples	Range	Samples considered contaminated	MRL*	No. samples > MRL
Aflatoxin (ppb)	540	0.99–89.8	380	4	180
Fumonisin (ppm)	50	0–0.09	9	1	0
Zearalenone (ppb)	50	9.5–596.7	20	75	6
Deoxynivalenol (ppm)	50	0–0.13	0	0.7	0

* MRL according to EU, USDA, Codex Alimentarius for aflatoxin and FAO–IITA for others.
MRL, maximum regulatory limit; ppb, parts per billion; ppm, parts per million.

9 Special thanks to the European Union HealthyDiets4Africa, the CGIAR Plant Health Initiative, Transforming Agri-Food Systems in West and Centre Africa for financially supporting this study.

Business models to increase the adoption of rice technologies

How do we create jobs in the agricultural sector for youth and women? And how do we create business models for scaling proven technologies? If the technologies can fit in the business models.

Training young people in driving and maintaining agricultural machinery in Senegal

Nigeria[10]

A survey of youth showed that while many were interested in the agricultural sector they were not interested in small-scale farming. Meanwhile, smallholders struggle to adopt technologies, especially where capital outlay is involved. So, could youths design businesses around technologies, provide services and achieve a profit?

In joint research with the Czech University of Life Sciences and the University of Nicosia, an adapted version of the Canvas business model was applied to two AfricaRice technologies, the 'ASI' thresher–cleaner[11] and RiceAdvice.[12] The two were then combined for a thresher–RiceAdvice business model. These were tested in Kano State with 700 farmers.

While the thresher business model showed an internal rate of return (IRR) of 23% and the RiceAdvice model 28%, the combined offering model suggested a business IRR of 33%.

Senegal

The ASI thresher is already well established in Senegal, especially in the Senegal River valley. However, early use of RiceAdvice by entrepreneurs has had problems with recovering payment from farmers at the end of the season.

Working with the Center for Mechanized Agriculture (CEMA) to combine use of RiceAdvice services with mechanization services for land preparation, harvesting and threshing not only increased farmers' rice yields but also made fee recovery easier to control.

Built on the groundwork developed by Syngenta Foundation, and with the PEJERIZ project funded by the former CTA and the Rice Agripreneurship Project funded by Mastercard Foundation, CEMA combined services are now established in the Senegal River valley.

A second approach in Senegal was to establish two youth innovation platforms (IPs). Unlike earlier AfricaRice-facilitated IPs, these were specifically created to develop service businesses. The IPs gave the opportunity to introduce the technologies to groups of youths, propose business solutions and discuss avenues for financing the start-ups. The youth IPs are currently registered as enterprises, while registration as 'associations' is ongoing.

"The youth IPs are very dynamic and have drawn in many partners to help with access to finance," says agricultural economist Mandiaye Diagne. Moreover, the IPs are drawing interest from other rice value-chain actors and could soon become something much more akin to the multistakeholder IPs that AfricaRice has facilitated for many years.

"The CEMA and Nigeria examples are complementary for our understanding of technology-based business models," says impact assessment economist Aminou Arouna. "Our assessment of CEMA is ex post, based on actual outcomes, while the work in Nigeria was very much ex ante — using the model to predict business viability."

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10 Amoussohoui R, Arouna A, Bavorova M *et al.* 2022. An extended Canvas business model: A tool for sustainable technology transfer and adoption. *Technology in Society*, 68: art. 101901. https://doi.org/10.1016/j.techsoc.2022.101901

11 www.africarice.org/asi-thresher

12 www.africarice.org/riceadvice

Determining farmers' willingness to pay for motorized weeding service

Smallholder rice farmers require efficient, affordable and labor-saving weed management technologies. In Madagascar, two prototype motorized weeders were imported by AfricaRice in 2020. These machines were piloted in the western region of Menabe and some adaptations were made together with a local fabricator to match the spacing of rice used by farmers there.

Two seasons of testing on 20 farms in 2021 demonstrated the machine's quick and efficient weeding and most of the farmers who saw the demonstrations indicated that they would like to buy and own such a weeder. Unfortunately, local fabricators cannot manufacture and sell motorized weeders because engines are not available locally. One option is for the fabricator or other entrepreneur to sell a motorized weeding service to farmers using the two existing weeders.

Experimental auctions were conducted in two locations (Ankilizato and Malaimbandy) to elicit 162 farmers' willingness to pay for motorized weeding service on a per-are (100 m^2) basis.[13] Farmers (62 of who were women) expressed their willingness to pay for the motorized weeder service. However, 95% of participants were unwilling to pay 20,000 Malagasy ariary (about US$ 4.60) per are (the actual price of the service). (For the purposes of the experimental auctions, AfricaRice paid the fabricator-cum-service provider the difference between the farmers' winning bids and the actual price.)

In Ankilizito, farmers were willing to pay an average of 7000 ariary per are, while in Malaimbandy it was 10,000 ariary. Of potential interest is the fact that 7000 ariary is the daily rate for a laborer to hand-weed, though the area one laborer can weed in one day is highly dependent on the density of weeds.

Motorized weeder prototype in demand

Meanwhile, the prototype motorized weeder for rainfed lowland and irrigated conditions adapted by AfricaRice in 2017 in collaboration with private company Intermech Engineering Ltd Morogoro and national partners in Tanzania has become increasingly popular. The weeder was developed by combining the most suitable features of double-row Indian- and Japanese-type motorized weeders for effective weed control.

Intermech has reported that a consignment of its locally manufactured powered paddy weeders was recently dispatched to Bukavu, Democratic Republic of Congo. It had earlier exported the motorized weeder to Côte d'Ivoire, Kenya, Madagascar, Rwanda and Uganda.

For the mechanized weeder service to become a viable business proposition, it would be necessary to bring down the price of the service with improved efficiency to cover more customers per unit time.

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<K.Senthilkumar@cgiar.org>

Rice farmers testing the motorized weeder during demonstration in western Madagascar

13 Raharimalala AS and Kalimuthu S. [2022]. Experimental auction for motorised weeding service in Madagascar. AfricaRice, [Antananarivo], Madagascar. https://cgspace.cgiar.org/bitstream/handle/10568/128024/Report%20on%20Experimental%20Auction_Motorized%20Weeder_2022.pdf

Ex-ante and ex-post gender analyses in rice research for development

Mali (ex ante — preliminary results)

Baseline gender analysis was conducted to determine the role of women in rice farming to better target technologies. A survey was conducted in 19 villages across 6 regions of Mali as part of the initiative Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA). Some 383 households were surveyed, each comprising a man and a woman.

Topics covered socio-demographics, climate-smart agriculture (CSA) and climate information services (CIS), roles in decision-making regarding production and income generation, and the main gender-related constraints in rice-based activities.

A significant number of farmers are unaware of CSA and CIS — approximately equal numbers of men and women. Men and women were about equally constrained by access to seed of improved varieties, formal credit facilities, labor and fertilizers. However, women were at a distinct disadvantage in terms of access to land, machinery and extension services.

"Typically, rainfed rice is a women's activity, while irrigated rice is done by men. Moreover, men have more livelihood opportunities than women," says gender focal person Gaudiose Mujawamariya.

"The large gap between men and women farmers in ease of access reflects an unbalanced social organization against women," says AICCRA gender and social inclusion person Fatoumata Diabaté. "This requires finding a mechanism to encourage men to value the contributions of women in agricultural activities as full actors rather than subordinates or laborers."

Benin and Togo (ex post)[14]

AfricaRice technology Smart-valleys has been disseminated and promoted in Benin and Togo for some years. This study explored gender differences among 1120 rice farmers in their access to technology information and knowledge (TIK) and therefore Smart-valleys.

"Smart-valleys is a gender-biased technology," says Mujawamariya, "requiring access to valley-bottom land and labor, both laborers' time and physical strength — women do not always have access to these."

Communication sources for TIK of Smart-valleys comprised research teams, extension services, NGOs, lead farmers and neighbors. Research teams were the main source of TIK in Benin, and communicated better with men than women. Meanwhile, extension services and neighboring farmers were main sources in Togo. NGOs communicated better with men than women in Benin and better with women than men in Togo.

Dissemination of Smart-valleys was dominated by men-only and mixed-gender teams, with just 2% being women-only teams. Both dominant teams targeted men better than women. However, women-only teams communicated better with women than the others did.

As shown in Togo, it is possible to ensure gender equality in agricultural TIK communication — if gender mainstreaming and equity actions are undertaken during technology diffusion. Given the efficacy of women-to-women communication, involving women communicators will reduce gender inequality in TIK diffusion.

On-farm demonstration was identified as the most effective approach, for both TIK communication and ensuring gender equity in access to the TIK. Therefore, on-farm demonstration combined with oral explanations should be adopted as the main approach in complex, gender-biased technology diffusion in general, and for Smart-valleys in particular.

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14 Madagbe FMK, Floquet A, Mongbo RL, Aoudji KNA, Mujawamariya G and Adjovi NRA. 2023. Gender and access to complex and gender-biased agricultural technology information and knowledge: Evidence from Smart-valleys in West Africa. *Outlook on Agriculture*, 52(1). https://doi.org/10.1177/00307270221150659

Interdisciplinary action-research brings women in Senegal into seed production business

In central and southern Senegal, rice cultivation was traditionally a women's activity in the lowlands and dedicated to food production, while men typically grew cash crops such as groundnuts, maize and millet in the uplands.

With the increase in investment in rice, fueled by the self-sufficiency objectives of the Senegalese government, rainfed rice became a cash crop, with investment focused on the male-dominated uplands. Many women rice farmers lost heart in the face of seemingly insurmountable obstacles (drought, floods, salinity, iron toxicity and lack of access to improved technologies) and abandoned rice cultivation.

Interdisciplinary action-research involving plant breeders and socio-economists enabled the successful introduction of stress-tolerant lowland varieties, selected by women rice farmers. These women were then trained in seed production and, later, business skills.

Today, there is a thriving rice sector in these lowlands. Rice farmers can now buy quality seed of stress-tolerant varieties via the new seed producer cooperatives, and obtain acceptable yields. It is hoped this will help stem the hemorrhage of women farmers in these lowlands from rice production and contribute to the country's drive toward rice self-sufficiency.

The business model enables farmers to buy the seed on credit, paying after harvest either in cash or in kind. In one location, a men's farmers' group bought bulk certified seeds from the women — a profitable business transaction.

The program started in 2019 in two regions (Kaolack and Fatick), then was extended to more than 20 villages in a further three regions (Kolda, Tambacounda and Ziguinchor).[15]

Rice nursery of the women's group of Darsalam Bocar village, Saré Coly Sallé commune, Vélingara Department, Kolda Region (ANCAR)

By the end of the project, seed of stress-tolerant rice varieties was being actively produced and marketed by women and their cooperatives in 14 villages across the five regions. However, animal damage and, in particular, an early end to the wet season seriously hampered production in four villages, with three producing no seed at all. This demonstrates the susceptibility of production — even of stress-tolerant varieties — in the face of climate change, and thus the vital importance of continually getting stress-tolerant varieties into the hands of the farmers.

"The project shows the value of an interdisciplinary approach in impacting the lives of vulnerable farmers," says AfricaRice sociologist and research assistant Maïmouna Ndour. "I also learned a lot as a gender researcher."

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15 See *AfricaRice annual report 2019*, page 16, and *AfricaRice annual report 2020*, page 11.

Improving livelihoods of women rice processors in East and Southern Africa

The chance to upgrade the parboiled rice value chain in Mozambique and reintroduce parboiled rice to Madagascar was an opportunity to scale up the GEM parboiling and related technologies.

Women in Ambatondrazaka, Madagascar retrieve paddy from a soaking tank

"Parboiled rice has higher nutritional value than white milled rice," says grain quality and postharvest technology scientist Sali Ndindeng. "Parboiling reduces postharvest losses, grain breakage and grain chalkiness. The product is cleaner and can be stored for longer." This is reflected in the price: In Madagascar, supermarket prices are 13,000–14,000 ariary per kilogram for imported rice and 8500–10,000 ariary/kg for local parboiled rice; local unparboiled rice sells in markets for just 3700–4000 ariary/kg.

The pilot project implemented in 2019–2022 was funded by GIZ. The equipment was manufactured locally and installed for women processors organized in associations or platforms at five locations in Madagascar and three in Mozambique. Over 500 women in Madagascar and 400 in Mozambique were trained on GEM and associated postharvest and processing practices, including use of rice husk as fuel. At the end of the COVID-19 travel restrictions, women processors from Madagascar and actors from Mozambique visited their counterparts in Côte d'Ivoire to learn about the technology and rice value-chain governance.

Because of the travel restrictions, the local fabricators were trained online with detailed technical drawings. The pandemic also hampered the creation of true multistakeholder innovation platforms; however, the women formed a group in each location and these groups have subsequently drawn interest from seed producers and farmer associations, and there were of course linkages with the fabricators. By the end of the project, the eight groups had over 3000 women and men members involved in the rice parboiling and connected activities.

Within a year of installing the GEM equipment, trade increased to more than 13 tonnes in sales in Madagascar and a weekly turnover of 300 kg by just one of the groups in Mozambique.

"Parboiled rice is not yet affordable to all, especially in Madagascar," says rice value chain expert Gaudiose Mujawamariya. "But if processing and awareness can be increased, it should gain a greater share of the market."

"The women groups in Madagascar made a conscious effort to sell their product at a higher price (5000 ariary/kg) than non-parboiled rice sold in the local market on the basis of its improved quality and the processing work involved," says Mujawamariya.

In Madagascar, the national mechanization institute has a GEM set-up and can support training for outscaling, which has been included in the national rice development strategy. Meanwhile, the European Union has requested two units for a separate outscaling project in Madagascar.

Contact: Gaudiose Mujawamariya, Rice value chain expert and Gender focal point <g.mujawamariya@cgiar.org> and Sali Ndindeng, Grain quality and postharvest technology scientist and Rice Sector Development Program leader <s.ndindeng@cgiar.org>

Improving health and wealth through integrated rice–fish farming in Liberia

Rice is the main staple food in Liberia, accounting for a third of the food chain and providing about half of adult calories. Rice and aquaculture are both considered priority value chains by the Liberian government, with fish being the primary protein source. However, domestic supply of both falls below demand, with rice imports alone costing $200 million a year.

Integrated rice and fish farming system

The European Union–funded integrated rice–fish farming project was led by AfricaRice and the WorldFish Center, in partnership with the Ministry of Agriculture, Central Agricultural Research Institute and National Fisheries and Aquaculture Authority, from January 2020 to July 2022. It sought to improve food and nutrition security by making traditional rice–fish production systems more climate resilient, high yielding and resource-use efficient.

Rice inputs, especially fertilizers, are expensive, but fish increase soil fertility and also control weeds and insects. Consequently, Liberians are keen on improved rice–fish systems.

The project focused on the production of rice seeds, fish fry, alternative fish feed and equipment, the establishment of stakeholder innovation platforms (IPs) and capacity-building. Covering about 53 hectares across five counties, the project obtained 5 tonnes rice/ha (and 9.14 t/ha from two harvests of the same plot in a year) and 2.15 t fish/ha (and 4.30 t/ha from two harvests a year); the annual production through the intervention of the project was 167 t rice and 26 t fish.

Training workshops built the technical skills of youths on quality seed and production of tilapia in rice fields, and improved their skills in marketing fingerlings and mature fish. The project also trained national extension officers in efficient service delivery, particularly data collection, scientific writing and business planning in the context of integrated rice–fish farming. Some 1050 people, including 420 youths, increased their knowledge and skills in integrated rice–fish farming systems. Action plans were developed to establish IPs at community, county and national levels.

Awareness was raised of project activities, benefits and achievements through promotional material, press engagement and social media channels.

Inoussa Akintayo, Development of smart innovation through research in agriculture (DeSIRA)-Liberia project coordinator, says "this is one of the best projects in my lifetime, because it gained interest from farmers, donors and the private sector."

The Minister of Agriculture, Jeanine M. Cooper, said that the improved system will be scaled out to all 15 of Liberia's counties. Meanwhile, the EU Ambassador to Liberia, M. Laurent Delahousse, wants the system promoted beyond Liberia. The project has also garnered interest from the Senegalese government, which plans to obtain Islamic Development Bank funding to initiate rice–fish work, and from the World Food Programme, which plans to send a team to work alongside Akintayo and his colleagues. Meanwhile, the EU is funding a project on seed systems to overcome constraints identified by the rice–fish project, extended to cacao, cassava and coffee.

Contact: Inoussa Akintayo, AfricaRice Country representative, Liberia <I.Akintayo@cgiar.org>

Boosting the resilience of Senegal's seed value chains

Rice yields in Senegal have remained low at 3.72 tonnes/ha with 44% self-sufficiency. To boost production and improve food security and rural livelihoods, AfricaRice and partners launched an innovative public–private partnership project to strengthen rice seed value chains, funded by USAID.

The project aimed to develop a vibrant, private sector–led rice seed industry by establishing sustainable commercial seed production and distribution systems nationwide. It focused initially on the Senegal River valley and central and southern parts of the country.

A consortium of 10 seed enterprises together with AfricaRice and the Institut sénégalais de recherches agricoles (ISRA) was created. AfricaRice and ISRA provided improved rice varieties for multiplication. Private companies paid a modest fee for breeder seed and received training in quality seed production, seed conditioning, storage, distribution and business management.

A total of 1290 contracts formalized seed value chain linkages. A private sector seed certification system was established to complement government certification.

Infrastructure and facilities were upgraded at ISRA's Casamance station and at Fanaye research farm (used by AfricaRice and ISRA), including irrigation, processing and storage.

With climate change, post-planting crop failures due to drought, late start and early termination of the rains have become more frequent in Senegal's rice-growing zones. A buffer stock provides seed enterprises with rapid access to foundation seed for multiplication into certified seeds to improve farmer access to quality seed for replanting when needed.

In 2022, the newly established private sector body certified 190 ha for sale to farmers, bringing the total certified area over the project period to 707 ha.

Women in Mangaroungou Santo, Senegal take up rice seed production business

In two years, around 11,000 tonnes of certified rice seed were produced, benefiting thousands of smallholders. A total of 5592 people were trained in seed production, quality control and marketing from 2018 to 2022.

With quality seed, farmers in the Senegal River valley can achieve 6–8 tonnes per hectare, well above the regional average of 2.2 t/ha and close to levels achieved in West Africa's rice powerhouse, Mali. Extending quality seed use along the valley's 35,000 irrigated hectares presents huge rice production potential.

Capacity-building and upgraded infrastructure have laid the foundations for a vibrant, private sector–led seed industry in Senegal, boosting the resilience of seed value chains. The model was extended to other crops — maize, millet and sorghum.

Contact: Ernest Asiedu, formerly TAAT Rice Compact coordinator, now TAAT West Africa regional coordinator at the TAAT Clearing House <e.asiedu@cgiar.org>

Annexes

Finance

The AfricaRice financial situation continues to improve. There was improvement in key financial results during the year ended 31 December 2022 compared with 2021. The following are the highlights of the financial results.

Financial situation

The total operating revenues of the Center increased from US$ 19.440 million in 2021 to $21.482 million in 2022, corresponding to an increase of $2.042 million. The operating expenses also increased from $18.853 million in 2021 to $20.405 million in 2022, corresponding to an increase of $1.552 million. This resulted in AfricaRice recording an operational surplus of $1.077 million in 2022 against the operational surplus of $0.587 million in 2021. Net non-operating financial expenses decreased the annual surplus for the year to $0.867 million (cf. surplus of $0.531 million recorded at the end of 2021). The undesignated net assets of the Center increased from $3.408 million at end of 2021 to $4.457 million at the end of 2022.

Other indicators of financial health

The short-term solvency (liquidity) indicator level of the Center increased to 102 days, from 88 days recorded in 2021, and the long-term financial stability ratio similarly increased to 80 days from 67 days. The audited indirect cost rate for AfricaRice increased to 15.2% during the year, from 14.3% in 2021. The current ratio increased from 1.27 in 2021 to 1.38 in 2022, which is within the CGIAR recommended level (greater than 1.0).

Summary financials (expressed in thousands of US$)

	2022	2021
Income statement		
Revenues	21,482	19,440
Operating surplus/(deficit)	1,077	587
Surplus/(deficit) for the year	867	531
Balance sheet		
Fixed assets (NBV)	3,282	3,084
Working capital	5,709	4,506
Non-current liabilities	3,267	2,733
Net assets		
Undesignated	4,457	3,408
Designated	1,267	1,449

Statements of activity (expressed in thousands of US$)

	Total 2022	Total 2021
Revenue and gains		
Grant revenue		
Windows 1 and 2	5,457	3,302
Window 3	4,259	5,458
Bilateral	11,498	10,620
Total grant revenue	**21,214**	**19,381**
Other revenue and gains	268	59
Total revenue and gains	**21,482**	**19,440**
Expenses and losses		
Research expenses	15,812	15,047
CGIAR collaboration expenses	–	–
Non-CGIAR collaboration expenses	1,908	1,448
General and administration expenses	2,358	2,358
Other expenses and losses	–	–
Total expenses and losses	**20,405**	**18,853**
Operating surplus/(deficit)	**1,077**	**587**
Gain/loss on sale of assets	2	–
Restructuring cost/others	–	–
Financial income	–	–
Financial expenses	(212)	(56)
Surplus/(deficit) for the year	**867**	**531**

Annexes

List of donors

AfricaRice sincerely thanks all the donors who have generously contributed to its success:

- AfricaRice Member States
- African Development Bank (AfDB)
- Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA)
- Belgium
- Bill & Melinda Gates Foundation
- CGIAR Excellence in Agronomy (EIA) 2030
- CGIAR Excellence in Breeding Platform (EiB)
- CGIAR Genebank Platform
- CGIAR Platform for Big Data in Agriculture
- CGIAR Research Program on Agriculture for Nutrition and Health (A4NH)
- CGIAR Research Program on Policies, Institutions, and Markets (PIM)
- Côte d'Ivoire
- European Commission (EC)
- Food and Agriculture Organization of the United Nations (FAO)
- The Gambia
- German Corporation for International Cooperation (GIZ) GmbH
- Global Crop Diversity Trust
- Guinea-Bissau
- International Fund for Agricultural Development (IFAD)
- Islamic Development Bank (IsDB)
- Japan
- Liberia
- London School of Hygiene & Tropical Medicine (LSHTM)
- Mastercard Foundation
- Niger
- Nigeria
- Regional Centre of Excellence against Hunger and Malnutrition (CERFAM, World Food Programme)
- Rural Development Administration (RDA), Republic of Korea
- Sierra Leone
- United States Agency for International Development (USAID)
- West African Economic and Monetary Union (UEMOA)
- West and Central African Council for Agricultural Research and Development (CORAF/WECARD)

Board of Trustees

(as at 31 December 2022)

Training 2022

AfricaRice training program (courses)

87 Training courses run in 2022

52 Locations in 16 countries

3055 Total trainees 963 Women 2092 Men

Professional development trainees

17 Total trainees 10 Women 7 Men

Postgraduate trainees

7 Total women postgrads

17 Total men postgrads

13 PhD students
… of whom
4 Women
9 Men

11 MSc students
… of whom
3 Women
8 Men

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AfricaRice staff, consultants and trainees in **bold**.

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Annexes

Abbreviations

3Cs	climate change, conflict and COVID-19
AAEA	Agricultural & Applied Economics Association
ADRAO	Association pour le développement de la riziculture en Afrique de l'Ouest (former French name of AfricaRice)
AfDB	African Development Bank
AfricaRice	Africa Rice Center
AGRF	Africa Food Systems Forum
AI	artificial intelligence
AICCRA	Accelerating Impacts of CGIAR Climate Research for Africa
ARICA	Advanced Rice for Africa (varieties)
art.	article
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASI	ADRAO–SAED–ISRA thresher–cleaner
AUC	African Union Commission
AWD	alternate wetting and drying
CARI	Central Agricultural Research Institute (Liberia)
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Africa
CEMA	Center for Mechanized Services
cf.	compare
CIAT	International Center for Tropical Agriculture
CIP	International Potato Center
CIPRiSSA	Continental Investment Plan for Accelerating Rice Self-Sufficiency in Africa
CIS	climate information services
CoM	Council of Ministers (AfricaRice)
CORAF/ WECARD	West and Central African Council for Research and Development
COSEMRiz	Consortium of Rice Seed Enterprises and Millers
COVID-19	coronavirus disease 2019

CSA	climate-smart agriculture
CTA	Technical Centre for Agricultural and Rural Co-operation
DAP	diammonium phosphate
DeSIRA	Development of smart innovation through research in agriculture (project)
DG	Director General
DR Congo	Democratic Republic of Congo
e.g.	for example
EAC	East African Community
ECOWAS	Economic Community of West African States
Ed.	editor
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
Fig.	Figure
FMARD	Federal Ministry of Agriculture and Rural Development (Nigeria)
FOFIFA	Centre National de Recherche Appliquée au Développement Rural (National Agricultural Research Institution, Madagascar)
GAP	good agricultural practice
GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSS	general support staff
ha	hectare
ICT	information and communications technology
IFA	International Fertilizer Association
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IP	innovation platform
IRM	integrated rice management

IRR	internal rate of return
IRRI	International Rice Research Institute
IRS	internationally recruited staff
IsDB	Islamic Development Bank
ISRA	Institut sénégalais de recherches agricoles (Senegal)
IVC	*former* Inland Valley Consortium
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
JIRCAS	Japan International Research Center for Agricultural Sciences
KAFACI	Korea–Africa Food and Agriculture Cooperation Initiative
kg	kilogram
MD	Managing Director
MINCER	Micrometeorological Instrument for the Near-Canopy Environment of Rice
MINCERnet	multi-site monitoring network of canopy micrometeorology and heat stresses of rice under climate change
MRL	maximum regulatory limit
NARI	national agricultural research institute
NARS	national agricultural research system(s)
NERICA	New Rice for Africa (family of interspecific rice varieties for uplands)
NGO	non-governmental organization
NIAES	National Agriculture and Food Research Organization (Japan)
No.	number (of)
NPT	national performance trial
PEJERIZ	Promoting Youth Entrepreneurship and Job Creation in West Africa's Rice Value Chain (project)
PhD	Doctor of Philosophy (doctoral degree)
PLAR	participatory learning and action-research
pp.	pages
ppb	parts per billion

ppm	parts per million
R4D	research for development
RYMV	*Rice yellow mottle virus*
SAED	Société d'Aménagement et d'Exploitation des terres du Delta et des vallées du fleuve Sénégal et de la Falémé (Senegal)
SADC	Southern African Development Community
SNP	single-nucleotide polymorphism
SRO	sub-regional organization
t	tonne(s)
TAAT	Technologies for African Agricultural Transformation (project)
TICAD	Tokyo International Conference on African Development
TIK	technology information and knowledge
TPP	Target Product Profile
US	United States
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WECARD	West and Central African Council for Research and Development
WFP	World Food Programme

About CGIAR

CGIAR is a global research partnership for a food-secure future dedicated to transforming food, land and water systems in a climate crisis. Its vision is a world with sustainable and resilient food, land and water systems that deliver diverse, healthy, safe, sufficient and affordable diets, and ensure improved livelihoods and greater social equality, within planetary and regional environmental boundaries. CGIAR's research is carried out by CGIAR Centers distributed across the globe in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations, farmers and the private sector.

For more information, visit www.cgiar.org

The Centers

Africa Rice Center (AfricaRice), Abidjan, Côte d'Ivoire

Center for International Forestry Research (CIFOR), Bogor, Indonesia

International Maize and Wheat Improvement Center (CIMMYT), Mexico, DF, Mexico

International Potato Center (CIP), Lima, Peru

International Center for Agricultural Research in the Dry Areas (ICARDA), Beirut, Lebanon

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India

International Food Policy Research Institute (IFPRI), Washington, DC, USA

International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

International Livestock Research Institute (ILRI), Nairobi, Kenya

International Rice Research Institute (IRRI), Los Baños, Philippines

International Water Management Institute (IWMI), Colombo, Sri Lanka

The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), Rome, Italy

World Agroforestry (ICRAF), Nairobi, Kenya

WorldFish, Penang, Malaysia

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