



AfricaRice

Enhancing resilience, sustainability and competitiveness

Africa Rice Center (AfricaRice) – Annual Report 2021

AfricaRice Headquarters, Côte d'Ivoire

01 BP 4029, Abidjan, Côte d'Ivoire
Telephone: (225) 27 22 48 09 10
Fax: (225) 27 22 44 26 29
Email: AfricaRice@cgiar.org

AfricaRice M'bé Research Station

01 BP 2551, Bouaké, Côte d'Ivoire
Telephone: (225) 27 22 48 09 20
Fax: (225) 27 31 63 25 78
Email: AfricaRice@cgiar.org

AfricaRice Regional Station for the Sahel, Senegal

BP 96, Saint-Louis, Senegal
Telephone: (221) 33 962 64 41, 33 962 64 93
Fax: (221) 33 962 64 91
Email: AfricaRice-Sahel@cgiar.org

AfricaRice Nigeria Country Office

c/o IITA, PMB 5320, Ibadan, Oyo State, Nigeria
Telephone: (234) 80 55 05 59 51, 80 34 03 52 81
Fax: (44) 20 87 11 37 86
Email: f.nwilene@cgiar.org

AfricaRice Madagascar Country Office

c/o FOFIFA, BP 1690 Antananarivo, Madagascar
Telephone: (261) 34 14 950 26
Email: g.mujuwamariya@cgiar.org

AfricaRice Project Office, Liberia

c/o CARI Station, Suakoko, Bong County, Liberia
Telephone: (231) 880 946 266, 770 750 547
Email: i.akintayo@cgiar.org

AfricaRice Project Office, Uganda

c/o National Crops Resources Research Institute
PO Box 7084, Kampala, Uganda
Telephone: (256) 775 914 074
Email: e.twine@cgiar.org

© Copyright Africa Rice Center (AfricaRice) 2022

AfricaRice encourages fair use of this material. Proper citation is required. The designations used in the presentation of materials in this publication do not imply the expression of any opinion whatsoever by the Africa Rice Center (AfricaRice) concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers and boundaries.

Citation:

Africa Rice Center (AfricaRice). 2022. *Africa Rice Center (AfricaRice) Annual Report 2021: Enhancing resilience, sustainability and competitiveness*. Abidjan, Côte d'Ivoire: 27 pp.

ISBN:

Print 978-92-9113-414-4
PDF 978-92-9113-415-1

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: Rice processors from Madagascar using the GEM parboiling system.

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.

Contents

Message from the Board Chair and Director General	2	Toward assessment of performance indicators for sustainability of rice cultivation in Africa	14
Research and innovation highlights	5	Equipping the next generation of rice agripreneurs in Senegal	15
Rebuilding rice value chains after COVID: a prospective analysis	5	Opportunities for young women in the rice value chain	16
Rebuilding seed supply systems after COVID	6	President Buhari's rice revolution: our part in his success	17
Shrinking food baskets: fewer inland valleys will support rice as the climate changes	7	Key achievements of outscaling through TAAT	18
Malaria and rice: no more 'paddies paradox'	8	Annexes	19
Cleaning up the genebank using genomic markers	9	Finance	19
OneRice: a new breeding strategy for the 21st century	10	List of donors	21
Rice quality trait preferences in East and West Africa to support targeted breeding	11	Board of Trustees (as at 31 December 2021)	22
Raising the profile of rice agronomy in Africa: <i>Field Crops Research</i> special issue	12	Training 2021	23
The right mix of nutrients for rice in East Africa	13	Publications 2021	24
		Abbreviations	27



AfricaRice

Message from the Board Chair and Director General

The year 2021 was a challenging period on many fronts. The COVID-19 pandemic continued to disrupt economies, livelihoods and food supply chains around the world. The global crisis also exposed the vulnerability of our food systems and showed the need to make them more resilient and sustainable. In Africa, the pandemic has worsened the effects of climate shocks and conflicts, which were already causing food insecurity in many parts of the region.

Despite the exceptional challenges of working during the pandemic, AfricaRice continued to deliver on its mandate of providing research, innovation and development for the rice sector on the continent. It redoubled its efforts to help its member states ‘build back better’ from the devastation caused by COVID-19, focusing on issues of resilience, sustainability and competitiveness of smallholder rice production systems in sub-Saharan Africa — the theme of our current report.

Recognition of our achievements

Following a trend set at the turn of the millennium, AfricaRice and staff again gained international recognition for their achievements in 2021.

- AfricaRice was honored with the **Republic of Korea Presidential Award of Achievement 2021** for its successful partnership with the Rural Development Administration (RDA) of the Republic of Korea under the Korea–Africa Food and Agriculture Cooperation Initiative (KAFACI).
- Dr Elliott Dossou-Yovo, agriculture and climate change specialist, won the **2021 Norman Borlaug Award for Field Research and Application** for spearheading climate-smart water management strategies in West Africa. He was honored at the World Food Prize awards ceremony in October.
- Dr Ali Ibrahim, systems agronomist and soil scientist, was selected by the American Society of Agronomy (ASA) as its **2021 Emerging Leader for**

African Agricultural Transformation (ELAAT) Award, and included in the ASA 2021 Awards Hall of Fame.

- Mr Jean-Martial Johnson, research associate, was selected for a **One Planet Fellowship (2021)**, an initiative that targets African researchers working on climate change. This initiative is supported by the Bill & Melinda Gates Foundation, BNP Paribas Foundation, the European Union and the International Development Research Centre (IDRC, Canada).

A new rice research and innovation strategy for Africa in the making

AfricaRice began work on a new rice research and innovation strategy in early 2019 with a review of the Center’s performance toward achieving the strategic objectives of its 2011–2020 strategy. After a number of iterations following a series of in-house and stakeholder consultations and efforts made to align with the CGIAR 2030 Research and Innovation Strategy, the draft 2030 Rice Research and Innovation Strategy for Africa was developed. It was approved by the Board and the Center’s National Experts Committee in December for ratification by the Council of Ministers in 2022.

The new strategy: (i) will guide rice research-for-development actions in Africa up to 2030; (ii) is in compliance with the CGIAR 2030 Research and Innovation 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. These values are: (a) sustainable increase in local production of high-quality consumer-preferred rice; (b) enhancement of agribusinesses creation across the rice value chain and strengthened opportunities for higher income generation potential for women and youth; (c) increased resilience of rice-based agri-food systems; and (d) improved nutritional status to tackle malnutrition.

Research and innovation highlights

AfricaRice's research-for-development (R4D) and capacity-building activities contribute to achieving the Sustainable Development Goals and feed into the five impact areas of the CGIAR Research and Innovation Strategy: (1) nutrition, health and food security; (2) poverty reduction, livelihoods and jobs; (3) gender equality, youth and social inclusion; (4) climate adaptation and mitigation; and (5) environmental health and biodiversity.

Throughout 2021, AfricaRice continued to provide support for the recovery of the rice sector in African countries through research (page 5) and direct development (page 6) activities.

Pre-empting the needs and challenges of the future are increasingly important features of our work. This year we report on the likely impact of climate change on inland valley suitability for sustainable rice production (page 7) and the end of the 'paddies paradox' of the late 20th century when lowland rice farming families were no more susceptible to malaria than non-rice farmers (page 8).

In pre-breeding activities, we now have quality control in our genebank to check for accession classification errors (page 9). And in breeding, we look at the new OneRice breeding strategy (page 10), and East and West African consumers' preferences for rice characteristics and their impact on breeding for consumer acceptability (page 11).

To mark AfricaRice's 50th anniversary celebration in 2021–2022, a special issue of Elsevier's *Field Crops Research* on 'Sustainable productivity enhancement of rice-based farming systems in Africa' was published, effectively celebrating successes in agronomic research for rice in Africa over the past 30–50 years (page 12). We also look at the role of micronutrients in rice in East Africa (page 13).

To complete the research loop, it is important that we not only monitor and evaluate our work, but

that we also have the tools to assess performance across interventions and over time. In the midst of a climate emergency, it has become increasingly clear that we need to combine production, economic and environmental performance indicators to monitor and improve the *sustainability* of rice production on the continent (page 14).

One of the most pressing needs for the world's most youthful continent is employment, and the agri-food sector is a major opportunity for all in the context of burgeoning populations. AfricaRice has been involved in various training and employment-creation initiatives over the past decade. This year, we report on the first graduation from agCelerant Academy in Senegal (page 15) and the 'Youth employment in agribusiness and sustainable agriculture' (YEASA) project in Nigeria (page 16).

In terms of pure development, we report on our part in the success of Nigerian President Buhari's rice revolution (page 17) and the achievements of the 'Technologies for African agricultural transformation' (TAAT) project (page 18).

Financial situation

The Center was able to improve its financial performance in 2021 (compared with 2020). AfricaRice recorded an operational surplus of \$0.59 million in 2021 compared with the operational deficit of \$1.02 million in 2020. Most of the Center's financial performance indicators are still very close to the recommended CGIAR level. The short-term solvency (liquidity) indicator level registered a reduction from 111 days to 88 days (CGIAR recommended level: 90 days). The long-term financial stability ratio similarly reduced to 67 days, down from 79 days. The audited Indirect Cost Rate for AfricaRice improved with a reduction to 14.3% from 20.9%. And the current ratio increased from 1.19 to 1.27 (CGIAR recommended level: greater than 1.0), indicating that the Center can meet its liability in the short term.

Message from the Board Chair and Director General

One CGIAR

AfricaRice's alignment with and eventual merger into One CGIAR was upheld, supported and promoted by the Center's management team, Board of Trustees, National Experts Committee and Council of Ministers.

Planning for and transition to One CGIAR continued throughout the year. AfricaRice leadership and scientists actively participated in the development of the CGIAR 2030 Research and Innovation Strategy. To deliver on this strategy, a new portfolio of Research Initiatives was launched to transform food, land and water systems amid climate crisis. AfricaRice scientists have been actively involved in the design of some of these Initiatives. The Director General has provided strategic support, especially to the leads and co-leads of the West and Central Africa, and the East and Southern Africa Regional Integrated Initiatives.

Progress was made in the alignment of the Center's structure and work, including mapping of three of the

Center's four programs and all of its projects to the One CGIAR action-research areas. The year also saw the recruitment of Prof. Abdulai Jalloh as Research and Innovation Lead, and the Director General appointed as Regional Director of the One CGIAR East and Southern Africa Region.

We commend AfricaRice staff and partners for their tremendous efforts and achievements at a very difficult period and express sincere thanks to our donors for their continued generous support. As we write this message, the world is facing an even more ominous challenge: because of the war in Ukraine, global prices of food and fertilizers have risen significantly, further exacerbating food insecurity in Africa. More than ever before, there is an urgent need to deliver the knowledge and innovations required for a food-secure continent.



A handwritten signature in black ink, appearing to read 'Harold Roy-Macauley', written in a cursive style.

Director General
Harold Roy-Macauley



A handwritten signature in black ink, appearing to read 'Carol S. Kramer', written in a cursive style.

Chair of the Board of Trustees
Carol Kramer-LeBlanc

Research and innovation highlights

Rebuilding rice value chains after COVID: a prospective analysis

To support National Rice Development Strategies within the Coalition for African Rice Development, AfricaRice and the Food and Agriculture Organization of the United Nations (FAO) conducted rice policy reviews for Côte d'Ivoire, Ghana and Mali in 2019.¹ The study used the Ex-ante Carbon-balance Value Chain tool (developed by FAO in 2016) to assess the rice value chain's environmental (climate mitigation and climate resilience) and socio-economic impacts. The tool compares a business-as-usual scenario from 2020 to 2030 (pre-2020 practices, growth, etc. assumed to continue) with a defined upgrade scenario for the same period.

Value chain upgrading includes good agricultural practices, reducing crop losses, postharvest practices, input use and mechanization.

Under the 'upgrade' scenario, Mali is likely to reach rice self-sufficiency by 2030, while Côte d'Ivoire could increase total production by 109% and Ghana by 142%. All three would see increased average rice farmer income of between 79% (Mali) and 121% (Côte d'Ivoire). And all three would see an increase in employment in the rice value chain, ranging from 60,000 new jobs in Ghana to 240,000 in Mali.

In terms of environmental impact, only Ghana would see a net increase in greenhouse gas emissions, and that by 285,000 tonnes CO₂-equivalent or just 0.03%, but even here, emissions per tonne of rice produced would be halved from 1.4 t CO₂-e to 0.7 t CO₂-e.



Stakeholder consultation for prospective analysis in Côte d'Ivoire

Meanwhile, both Côte d'Ivoire and Mali would see significant decreases in emissions of 30–40% net and 40–70% per tonne.

At this point in history, Africa's drive toward rice self-sufficiency is facing major challenges in the form of climate change, COVID-19 (post-pandemic recovery) and international crises (e.g. the situation in Ukraine). However, countries can continue to upgrade their rice value chains while limiting increased environmental impact. To achieve this, the value chains need to attract investment — from the public sector and from (local and international) private investors.

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

¹ Ouédraogo SA et al. 2021. *Rice value chain in Ghana – prospective analysis and strategies for sustainable and pro-poor growth*. FAO, Accra. <https://doi.org/10.4060/cb1659en>; Ouédraogo SA et al. 2021. *Analyse de la chaîne de valeur riz en Côte d'Ivoire : optimiser l'impact socio-économique et environnemental d'un scénario d'autosuffisance à l'horizon 2030*. FAO, Accra. <https://doi.org/10.4060/cb1506fr>; and Ouédraogo SA et al. 2021. *Chaîne de valeur riz au Mali – analyse prospective et stratégies pour une croissance inclusive et durable*. FAO, Accra. <https://doi.org/10.4060/cb1504fr>

Research and innovation highlights

Rebuilding seed supply systems after COVID

Food supply was typically disrupted by travel restrictions and closure of markets for both inputs and products imposed to contain the spread of COVID-19. Seed supply was identified early on as a critical part of the rice value chain that was under threat from COVID-19 restrictions.² Consequently, in 2021, the German Federal Ministry for Economic Cooperation and Development (BMZ) provided funds for the 2-year ‘COVID-19 response rice seed’ (CORIS) project, implemented by AfricaRice in collaboration with Centre for International Migration and Development, Multi Actor Partnership for Rice (a GIZ task force), Competitive African Rice Initiative and GIZ Green Innovation Centers in Benin, Burkina Faso, Côte d’Ivoire, Mali and Nigeria.

CORIS is delivered by 33 members of the Consortium of Rice Seed Enterprises and Millers (COSEM-Riz).³ Each participant enterprise received an innovation package comprising a selection from the following: breeder seed of climate-resilient and consumer-preferred rice varieties, good seed production and storage flyers (721,000 in total), rice harvester (motor scythe; 60), ASI thresher–cleaner (33), grain moisture meter (110), hermetic seed storage bags (570,800; illustrated), digital agricultural production and monitoring tool for the 33 COSEM-Riz members, and seed quality control and certification support services provided by authorized national seed quality control and certification agencies.

Beneficiary enterprises supported by National CORIS Project Coordinators were charged to produce foundation and certified seeds to be made available to farmers.

AfricaRice and national research institutes have already supplied 20.2 t of breeder seed, from which the national research institutes and seed companies have produced 920 t of foundation seed. The seed



Hermetic seed storage bags at NAFASO, Burkina Faso (Photo courtesy of Eliane Bayala)

companies and farmer cooperatives are growing that seed to deliver 26,600 t of certified seed in 2022. By the end of 2022, the project is expected to have directly benefited 14,400 seed producers and 360,000 producers, with indirect benefits accruing to 72,000 value chain actors (input suppliers, processors and certification agencies) and 1.8 million farm workers and consumers. By extrapolation, the project should have effectively delivered 475,200 t of milled rice. The seed supply chain is expected to become self-sustaining, with AfricaRice and national institutes providing breeder seed annually.

While it has clear development goals, the project is also a test-bed for the scaling model.

Contact: Sali Ndindeng, Grain quality and postharvest technology scientist and Rice Sector Development Program leader <s.ndindeng@cgiar.org>

2 See ‘Policy options to increase the resilience of domestic rice value chains during and after the COVID-19 pandemic’, *AfricaRice annual report 2020*, pages 7–8.

3 See ‘Consortium of Rice Seed Enterprises and Millers’, *AfricaRice annual report 2020*, page 9.

Shrinking food baskets: fewer inland valleys will support rice as the climate changes

The march of climate change is relentless. Year on year we are seeing massive changes in our climate across the world — and this is only the beginning.

While it is widely acknowledged that climate change will impact agriculture in a huge way, little attention has been paid to land suitability for rice under future climate regimes. Thus, a team from AfricaRice, International Water Management Institute, the University of Energy and Natural Resources, Ghana, and the University of Twente, Netherlands, investigated the changing suitability of West Africa’s food basket for rice production, its inland valleys. The study was carried out in the form of a case study of Benin and Togo.⁴

The team used a spatially explicit modeling approach using two machine-learning algorithms (Boosted Regression Trees and Random Forest) for four time periods (the 2030s, 2050s, 2070s and 2080s) under four Representative Concentration Pathways (RCP2.6, RCP4.5, RCP6.0 and RCP8.5).

The results are staggering. In the best-case scenario, 59% of inland valleys will no longer be suitable for rice cultivation by the 2080s, while in the worst-case scenario the figure raises to 63% (Figure 1). The principal drivers of these losses in suitability are rainfall and ‘isothermality’, that is the amplitude between day and night temperatures relative to annual amplitudes. In many places, rice will not cope with warmer nights and consequent reduced differences between day and night temperatures.

Meanwhile, some areas become or remain suitable for rice often because of predicted increased rainfall.

Reaction to this is vitally important if West African countries are to continue in their quest for rice self-

sufficiency. First, governments and planning agencies must choose new inland-valley sites for rice production carefully, taking their long-term suitability into consideration. At the farm level, producers need to seriously consider adopting drought-tolerant varieties, water-harvesting technologies and changing the timing of their crop season to match the local climate.

Given the similarities in climate and future scenarios, “the team is confident in applying these findings on a wider scale across West Africa,” says Agriculture and climate change specialist Elliott Dossou-Yovo. “However, inland valleys in East and Central Africa and Southern Africa are predicted to become more suitable for rice cultivation with predicted changes in temperatures.”

Contact: Elliott Dossou-Yovo, Agriculture and climate change specialist <e.dossou-yovo@cgiar.org>

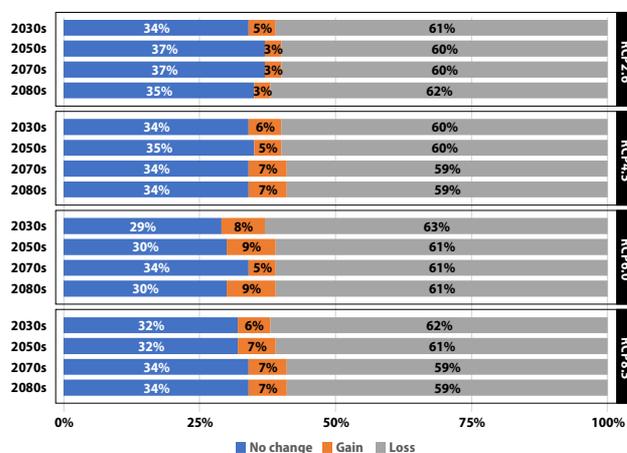


Figure 1. Suitability of inland valleys for rice cultivation compared with 2020 — in 2030, 2050, 2070 and 2080

No change = same status as 2020 (whether suitable or unsuitable); Gain = formerly unsuitable (in 2020) to become suitable; Loss = formerly suitable (in 2020) to become unsuitable.

⁴ Akpoti K, Groen T, Dossou-Yovo E, Kabo-bah AT and Zwart SJ. 2022. Climate change-induced reduction in agricultural land suitability of West-Africa’s inland valley landscapes. *Agricultural Systems*, 200: art. 103429. <https://doi.org/10.1016/j.agsy.2022.103429>

Research and innovation highlights

Malaria and rice: no more ‘paddies paradox’

In 2001, J.N. Ijumba and S.W. Lindsay coined the term ‘paddies paradox’ for the counterintuitive observation that people living in lowland rice-producing villages were no more susceptible to malaria than those living in non-rice-producing villages some distance from the nearest paddies. The observation itself was supported by AfricaRice research in the early 1990s under Thomas Teuscher.⁵ The theory is that while establishment of rice paddies did indeed provide a superabundance of mosquito breeding habitat, growing rice also brought new wealth to farmers, who invested in prevention measures (such as insecticide-treated bednets) and malaria treatment.

However, much has changed in terms of malaria control in Africa since 2001–2005, with huge campaigns to eradicate mosquitoes, reduce transmission (especially by using bednets) and improve access to treatment. Consequently, the number of deaths attributable to malaria decreased by over 44% between 2000 and 2019. Meanwhile, rice cultivation is growing at a phenomenal rate that is not expected to slow until the continent reaches self-sufficiency. With increased equity in disease prevention and treatment, the time was ripe for a re-evaluation of the ‘paddies paradox’.

London School of Hygiene and Tropical Medicine research assistant and PhD student Kallista Chan led a meta-analysis of published research on malaria and rice farming covering the period 1900 to 2020. Fifty-three studies (covering 113,160 participants across 14 countries) met the stringent criteria of the meta-analysis and were analyzed for two time periods: before 2003 and from 2003 onwards.⁶

The results clearly demonstrate that the ‘paddies paradox’ no longer holds. “Now that less-intense transmission is becoming the norm in all communities and, as there is greater equity between rice and non-rice villages, rice farmers no longer have the advantage in prevention and treatment,” says Chan. “As transmission has been reduced, the contribution of rice to the malaria burden has increased markedly and is expected to become even more conspicuous.”

This has direct implications for the ongoing expansion of rice cultivation across the continent. “Rice has to move from being part of the problem to part of the solution to malaria,” says Chan. To that end, other aspects of her PhD research have looked at mosquito population dynamics in rice fields and various crop management practices to assess their impact on vector density.

Contact: Kallista Chan, Research assistant, London School of Hygiene and Tropical Medicine <Kallista.Chan@lshtm.ac.uk> and Kazuki Saito, Agronomist <k.saito@cgiar.org>

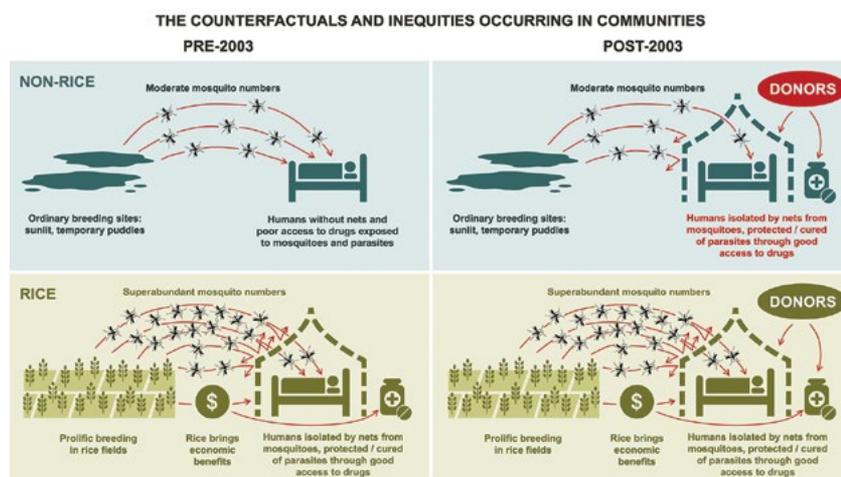


Figure 2. The ‘paddies paradox’ as in the 1990s (left) compared with the situation today (right) — the situation in rice-growing areas is essentially unchanged, but donors have leveled up non-rice communities

5 See ‘Rice cultivation: kill or cure?’, *WARDA annual report 1996*, pages 27–31.

6 Chan K, Tusting LS, Bottomley C, Saito K, Djouaka R and Lines J. 2022. Malaria transmission and prevalence in rice-growing versus non-rice-growing villages in Africa: a systematic review and meta-analysis. *Lancet Planet Health*, 6: e257–269. [https://doi.org/10.1016/S2542-5196\(21\)00349-1](https://doi.org/10.1016/S2542-5196(21)00349-1)

Cleaning up the genebank using genomic markers

The AfricaRice genebank houses the world’s largest collection of germplasm of rice and its wild relatives originating in Africa. With current methods of classification subject to errors of 3–28%, and rice genotyping being difficult and expensive, a quicker and cheaper method is required for routine genebank use.

AfricaRice uses the Diversity Arrays Technology-based genotyping by sequencing (DARtseq) platform and has identified 339 DARtseq-based single nucleotide polymorphic (SNP) markers that differentiate rices with the AA genome (*O. barthii*, *O. glaberrima*, *O. longistaminata* and *O. sativa* subsp.). Testing of 3,134 accessions of these species and subspecies indicated a 3% classification error rate in the AfricaRice genebank.⁷

AfricaRice sent details of 224 SNPs to LGC Biotech Technologies service laboratory (UK), which successfully designed Kompetitive allele-specific

PCR (KASP) oligonucleotide assays for 158 of them. These assays were tested on 80 DNA samples from AA rice species/subspecies, and 65 that were taxonomically diagnostic were then validated using 625 DNA samples.

After statistical analysis, 36 markers/assays were selected that clearly differentiate the five taxa; these will be used as a panel for routine quality control in the AfricaRice genebank (Figure 3).⁸

“This is a great achievement,” says head of Rice Biodiversity Center for Africa and genebank manager Marie-Noëlle Ndjiondjop. “We can now verify the identity of accessions (germplasm) quickly and cheaply. Moreover, because some of our partners have limited budgets, we also designated KASP assay panels of 10 and 24 which also identify these rices.”

Contact: Marie-Noëlle Ndjiondjop, Head of Rice Biodiversity Center for Africa and genebank manager <m.ndjiondjop@cgiar.org>

Tax	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
Ob	■		■	■	■				■		■							■		■	■		■	■	■					■				■	■		
Og	■		■	■	■				■		■							■		■	■		■	■	■					■					■	■	
OI													■	■												■			■		■						
Osi		■					■	■		■		■			■	■			■								■		■				■	■			
Osj		■				■	■	■		■		■			■	■											■						■	■			

Figure 3. Distribution of 36 KASP-SNP markers across four species and two subspecies of *Oryza*

Ob, *Oryza barthii*; Og, *O. glaberrima*; OI, *O. longistaminata*; Osi, *O. sativa* subsp. *Indica*; Osj, *O. sativa* subsp. *japonica*; Tax, taxon.

7 Ndjiondjop MN *et al.* 2018. Development of species diagnostic SNP markers for quality control genotyping in four rice (*Oryza* L.) species. *Molecular Breeding*, 38: art. 131. <https://doi.org/10.1007/s11032-018-0885-z>

8 Gouda AC *et al.* 2021. Development and validation of diagnostic SNP markers for quality control genotyping in a collection of four rice (*Oryza*) species. *Scientific Reports*, 11: art. 18617. <https://doi.org/10.1038/s41598-021-97689-3>

OneRice: a new breeding strategy for the 21st century

AfricaRice and the International Rice Research Institute (IRRI) began discussions on rationalizing and modernizing rice breeding in about 2019. With the subsequent decision to ‘create’ One CGIAR, the discussions expanded to include the International Center for Tropical Agriculture (CIAT).

“While the details are still being worked out in practice, the basic OneRice strategy has now been concretized,” says Baboucarr Manneh, interim leader of the Genetic Diversity and Improvement program and irrigated rice breeder.

Crucial components of the OneRice strategy are: it is data-driven; varietal creation guided by formally approved target product profiles; harmonization of breeding processes across centers; and use of shared services.

At the operational level of the OneRice strategy is the use of rapid generation advancement (RGA); elite × elite crosses to create breeding populations; routine use of molecular tools for quality control, forward breeding and gene discovery; digitized data capture and mechanized operations to increase efficiency; and broadened partnerships for varietal testing and dissemination, emphasizing linkages with the private sector.

RGA shortens the time from crossing to fixed lines. “Early generations after a cross are still segregating, that is they do not breed true, and there is a lot of variability in plants and seed,” says Manneh. Given the amount of variability present in the material, breeders do not need lots of material, so there is no need to wait for all the seeds to ripen before harvest.

Other tricks to speed the process include using minimal fertilizer so that plants flower and seed quicker, chemically inducing early flowering, and growing generations back-to-back. In this way, breeders can push material through three or four generations a year. Plants are also grown at higher density than conventional seed production; this works because the breeder wants only a single tiller, a single panicle and just one seed from each plant (single seed descent).

“We use RGA to reach the fourth generation very quickly,” says Manneh. “The fifth generation (F₅) seeds and plants are already 97% homozygous [i.e. very nearly true breeding], and there we start visual selection. We adopt ‘forward breeding’ from F₆ onwards, in which we use genetic markers to select traits rather than growing all plants to maturity.” This is essentially marker-assisted selection, a technique with which regular readers of this report should be familiar. “Observational yield trials or nurseries typically start at F₆,” says Manneh, “and in OneRice that can be as early as year 3 after the cross as opposed to year 7!” Thus, the typical time to develop varieties can be reduced from 10 years to 5 or 6 years.

Another highlight of the year was the release of three cold-tolerant, red rice varieties in Madagascar with high nutritional value (FOFIFA 194, 195 and 196) and four irrigated lowland rice varieties in Uganda (NARORICE 1, 2, 3 and 4). NARORICE 1 is aromatic (a trait highly valued in Ugandan markets) and also perennial — well-suited to intensified production systems.

Contact: Baboucarr Manneh, Regional representative, Senegal; Irrigated rice breeder; and Genetic Diversity and Improvement Program interim leader <b.manneh@cgiar.org>

Rice quality trait preferences in East and West Africa to support targeted breeding

Despite national drives toward rice self-sufficiency across the continent, uptake of new, improved varieties remains low. Many of these varieties are believed to have consumer-desired traits,⁹ so where are we going wrong?

To better understand the demand for quality traits, especially among consumers, AfricaRice visited markets in eight East and West African countries (Benin, Cameroon, Côte d'Ivoire, Ghana, Kenya, Madagascar, Nigeria and Uganda) and purchased 2,116 (1,513 white and 603 parboiled) rice samples at market price. The samples were analyzed for physicochemical traits, including cooking characteristics.

The white and parboiled rice were separately graded into three classes based on grain quality associated with price: high, moderate and low. In all countries, the market was dominated by moderate-quality rice, except Nigeria, where low-quality parboiled rice predominated.

Statistical analysis (Kendall dissimilarity Agglomerative Unweighted pair-group average method) separated countries into clusters per rice type on the basis of the top two apparently preferred traits (those for which customers pay more). Preferences for white rice were country specific, although Benin and Ghana clustered together, as did Côte d'Ivoire and Nigeria (thus, six 'nodes'). Meanwhile, the attribute of primary interest for parboiled rice was length-to-width ratio (LWR), with slender grains (LWR ≥ 3) being preferred in all eight countries, yet clustering in four nodes. Second-placed quality characteristics for parboiled rice varied by country, though with some clustering mostly by parboiling quality.

1,513 market-purchased white milled samples

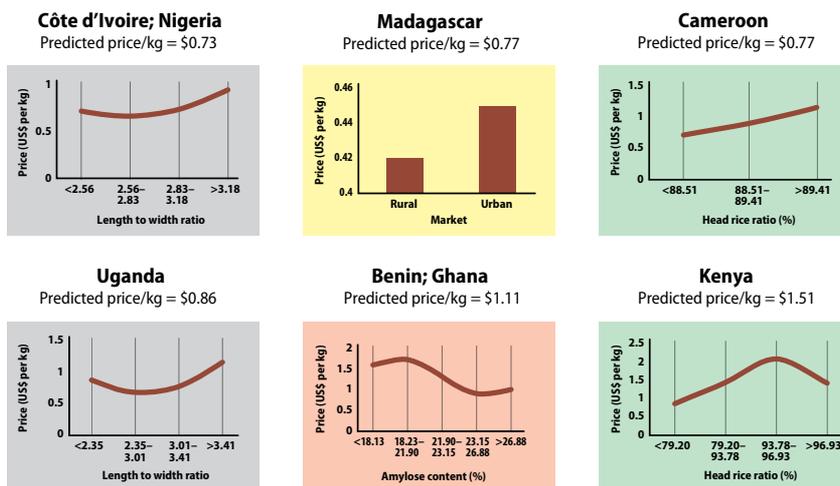


Figure 4. Segmentation of white rice samples from East and West African markets

The result for parboiled rice is not surprising, as slender grains are known to parboil better than non-slender grains.

“With this information, we are able to advise breeders on rice quality,” says grain quality and postharvest technology scientist and Rice Sector Development Program leader Sali Ndindeng. The clear message is that breeding varieties for white rice production has to be country specific. “Breeders should target the two most popular quality traits identified for each country,” confirms Ndindeng. “We ask them to breed for high quality, as these varieties are what consumers want. This should ultimately lead to improved income for value chain actors and reduced price of quality rice for consumers.”

It looks like the breeders' job just got that little bit more complicated.

Contact: Sali Ndindeng, Grain quality and postharvest technology scientist and Rice Sector Development Program leader <s.ndindeng@cgiar.org>

9 See “What do you want from your rice, madam?” — Consumer preferences for rice attributes’, *AfricaRice annual report 2011*, pages 22–24 (also as AfricaRice News blog, 30 January 2013, <http://africarice.blogspot.com/2013/01/>).

Raising the profile of rice agronomy in Africa: *Field Crops Research* special issue

To commemorate AfricaRice's 50th anniversary, Elsevier agreed to publish a special issue of its high-profile agricultural research journal *Field Crops Research* on 'Sustainable productivity enhancement of rice-based farming systems in Africa'.

The 19 papers are written by researchers who are at the forefront of rice agronomy research in Africa, many of them past or present AfricaRice staff. The papers cover a wide range of rice production environments and subregions, and a variety of topics. Essentially, the special issue fills major gaps in and complements AfricaRice's magnum opus, *Realizing Africa's rice promise* (2013),¹⁰ which did not cover agronomic aspects in such detail.

This special issue addresses three main, overarching questions: (1) what has been achieved in the past five decades in terms of rice agronomy in sub-Saharan Africa, (2) what is the state of the art in technology development and (3) what are the likely or required future directions? The broad topics covered are yield trends and yield gap analyses; soil and nutrient, water, weed and integrated crop management; cropping systems; genetic improvement; crop simulation modeling; and assessment of farmers' rice cultivation practices and their sustainability. The papers presented in this special issue describe the state of the art in rice agronomy in sub-Saharan Africa, and provide direction on ways to sustainably enhance rice production and self-sufficiency in the region.

In their synthesis of the special issue, Rodenburg¹¹ and Saito draw out six main recommendations for future agronomic research in sub-Saharan Africa:

1. Focus on the dominant rainfed systems.
2. Pay more attention to work at farming systems and landscape levels, and integrated cropping, farming sys-

tem and agronomic solutions to biophysical constraints.

3. Center future research on sustainability.
4. To operationalize number 3, develop and use sustainability production indicators.
5. Develop more labor-saving technologies.
6. Work in partnership with non-agronomy researchers and non-research stakeholders.

Contact: Kazuki Saito, Agronomist <k.saito@cgiar.org>

Box 1. Sustainable productivity enhancement of rice-based farming systems in Africa

Ed. Jonne Rodenburg and Kazuki Saito, 2021–2022
Field Crops Research special issue
www.sciencedirect.com/journal/field-crops-research/special-issue/10JJB6BWTFJ

Towards sustainable productivity enhancement of rice-based farming systems in sub-Saharan Africa (Rodenburg and Saito); Assessing genetic and agronomic gains in rice yield in sub-Saharan Africa: a meta-analysis (Ibrahim and Saito); Model-based evaluation of rainfed lowland rice responses to N fertiliser in variable hydro-edaphic wetlands of East Africa (Grotelüschen *et al.*); Closing rice yield gaps in Africa requires integration of good agricultural practices (Senthilkumar); Thirty years of water management research for rice in sub-Saharan Africa: achievement and perspectives (Dossou-Yovo *et al.*); Global analysis of yield benefits and risks from integrating trees with rice and implications for agroforestry research in Africa (Rodenburg *et al.*); Progress in research on site-specific nutrient management for smallholder farmers in sub-Saharan Africa (Chivenge *et al.*); Changes in production, yields, and the cropped area of lowland rice over the last 20 years and factors affecting their variations in Côte d'Ivoire (Komatsu *et al.*); Designing low-input upland rice-based cropping systems with conservation agriculture for climate change adaptation: a six-year experiment in M'bé, Bouaké, Côte d'Ivoire (Husson *et al.*); From rice-like plants to plants liking rice: a review of research on weeds and their management in African rice systems (Rodenburg *et al.*); Phosphorus management strategies to increase lowland rice yields in sub-Saharan Africa: a review (Rakotoson *et al.*); Long-term fertility experiments for irrigated rice in the West African Sahel: effect on macro- and micronutrient concentrations in plant and soil (Haefele *et al.*); Application of a Bayesian approach to quantify the impact of nitrogen fertilizer on upland rice yield in sub-Saharan Africa (Asai *et al.*); Assessing rice production sustainability performance indicators and their gaps in twelve sub-Saharan African countries (Arouna *et al.*)¹²; Application of infrared spectroscopy for estimation of concentrations of macro- and micronutrients in rice in sub-Saharan Africa (Johnson *et al.*); Agronomic gain: definition, approach, and application (Saito *et al.*)¹³; History and progress in genetic improvement for enhancing rice yield in sub-Saharan Africa (Futakuchi *et al.*); Feet in the water and hands on the keyboard: a critical retrospective of crop modelling at AfricaRice (van Oort and Dingkuhn); Thirty years of agronomy research for development in irrigated rice-based cropping systems in the West African Sahel: achievements and perspectives (Ibrahim *et al.*)

10 Wopereis MCS, Johnson DE, Ahmadi N, Tollens E and Jalloh A eds. 2013. *Realizing Africa's rice promise*. CAB International, Wallingford, UK. <https://cabidigitallibrary.org/doi/book/10.1079/9781845938123.0000>

11 Jonne Rodenburg, now Professor of Agronomy, Natural Resources Institute, University of Greenwich, UK, formerly AfricaRice agronomist.

12 See 'Toward assessment of performance indicators for sustainability of rice cultivation in Africa', page 14.

13 See 'Excellence in Agronomy 2030: focus on agronomic gain, sustainable intensification, and scale', *AfricaRice annual report 2020*, pages 19–20.

The right mix of nutrients for rice in East Africa

Rice needs a mixture of macro- and micronutrients to produce a good yield. In Asia, where rice has been cultivated continuously for many decades, the crop shows micronutrient deficiencies. In Africa, some farmers use foliar sprays of micronutrients. So, exactly which nutrients does rice need for optimal production and profit?

Experiments in Tanzania and Uganda compared application of (single and multiple) micronutrients with or without macronutrients across the three principal agro-ecosystems.^{14,15} All were grown with good agricultural practices, including field leveling, bunding (in lowlands) and clean weeding, as recommended by AfricaRice for optimizing yields.

Across systems, micronutrient application without macronutrients had no effect on yield. Moreover, in Uganda, micronutrients had no effect on yield even in the presence of macronutrients. Conversely, micronutrients applied along with macronutrients did increase yield in irrigated and rainfed lowlands in Tanzania (Figure 5). Under irrigation, micronutrients increased yields by 0.5 t/ha over simple macronutrient application; in rainfed lowlands without water stress, the effect was even greater at 1.8 t/ha. Micronutrients had no effect in upland fields or rainfed lowland fields experiencing water stress (drought).

“The implications of this are that the value of micronutrient application for rice depends on the soil and its farming history,” says extension agronomist Kalimuthu Senthilkumar. “Micronutrients are likely to be most effective in rice hotspots with a long-term history of rice cropping.”

Concerning macronutrients, in rice fields across East Africa, nitrogen (N) is the most limiting and needs to be applied, potassium (K) is not limiting, and phosphorus (P) is limiting in some sites. However, farmers are constrained by the availability and affordability of fertilizers. Another issue of increasing relevance is the cost of fertilizer. For example, in September 2021, the cost of urea in India was US\$ 0.08 per kilogram, while it was more than \$1.00 in East Africa. While the application of fertilizer in appropriate quantities may lead to yield increase of about 2 t/ha (e.g. in Madagascar), the fertilizer may cost as much as the farmer will receive from the sale of 2 t of paddy, which may mean that fertilizer application is not currently economical with current fertilizer and paddy prices.

Contact: Kalimuthu Senthilkumar, Extension agronomist <k.senthilkumar@cgiar.org>

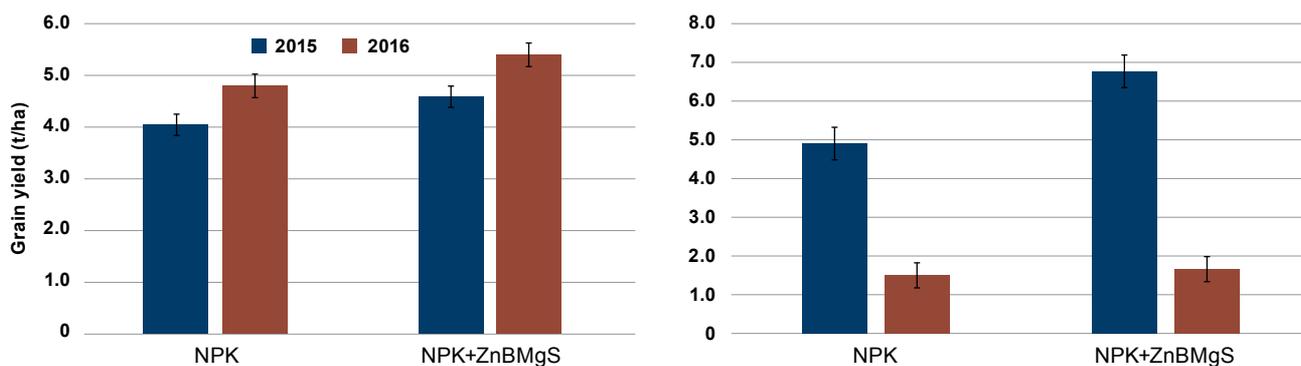


Figure 5. Average effect of micronutrient application over macronutrient application in (left) irrigated and (right) rainfed lowland rice fields, Kilombero valley, Tanzania. B, boron; Mg, magnesium; S, sulfur; Zn, zinc.

14 Awio T *et al.* 2021. Micronutrients in East African lowlands: are they needed to intensify rice production? *Field Crops Research*, 270: art. 108219. <https://doi.org/10.1016/j.fcr.2021.108219>

15 Senthilkumar K *et al.* 2021. Rice yield and economic response to micronutrient application in Tanzania. *Field Crops Research*, 270: art. 108201. <https://doi.org/10.1016/j.fcr.2021.108201>

Research and innovation highlights

Toward assessment of performance indicators for sustainability of rice cultivation in Africa

Historically, crop production indicators such as yield and production have been considered in a narrow sense. However, with increasing awareness of the need to balance production, economics and the environment to ensure food for current and future generations, we need indicators for system sustainability. “To do that, we need to assess different performance indicators to identify appropriate trade-offs to achieve sustainability,” says Aminou Arouna, impact assessment economist and leader of the AfricaRice Policy, Innovation Systems and Impact Assessment Program. Data were collected for five performance indicators (grain yield, net profit, labor productivity, and nitrogen [N] and phosphorus [P] use efficiencies) from 2,907 farmers in two production systems (irrigated and rainfed lowlands) in 12 sub-Saharan African countries (Benin, Cameroon, Côte d’Ivoire, Ghana, Madagascar, Mali, Niger, Nigeria, Senegal, Sierra Leone, Tanzania and Togo).

Overall, yield and other indicators were best in irrigated lowlands, but both systems displayed large variation within each country, indicating potential for improvement. Strong positive correlations existed between yield, profit and labor efficiency, but not with N and P use efficiencies. Nutrient use efficiency

indicators were typically low (only 34–44% of farmers had indicators in the desirable or optimum range), indicating that a majority of farmers were using either too much and thereby wasting a valuable resource and polluting the environment, or using too little and degrading soil health by nutrient mining. There is also a need to consider the trade-off among profit, yield and fertilizer use, especially given current rapidly rising fertilizer prices.

This analysis indicates that the overriding need is for precision nutrient management in rainfed lowlands and low-yielding irrigated systems; however, the authors also provide recommendations for specific categories (farmers, production systems, agroecological zones and countries) to close performance indicator gaps and enable production at scale to achieve sustainable rice self-sufficiency.¹⁶

“For future study, we need more integrated performance analysis, especially including social and environmental sustainability such as gender and soil health,” says agronomist Kazuki Saito.

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

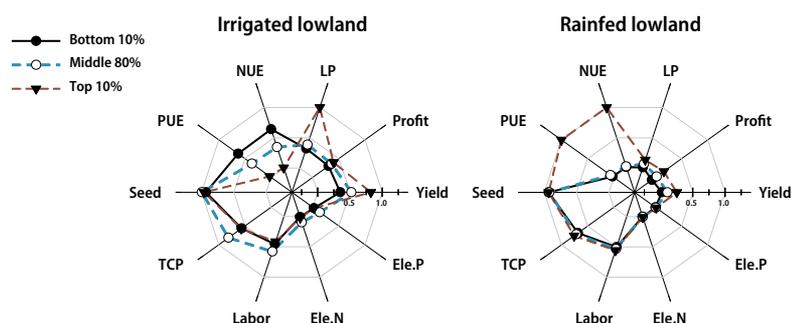


Figure 6. Trade-offs among indicators and inputs — example of Ghana

Ele.N, elemental nitrogen (N); Ele.P, elemental phosphorus (P); Labor, labor input; LP, labor productivity; NUE, N use efficiency; Profit, net profit; PUE, P use efficiency; Seed, seeding rate; TCP, total cost of production; Yield, grain yield.

16 Arouna A, Devkota KP, Yergo WG, Saito K *et al.* 2021. Assessing rice production sustainability performance indicators and their gaps in twelve sub-Saharan African countries. *Field Crops Research*, 271: art. 108263. <https://doi.org/10.1016/j.fcr.2021.108263>

Equipping the next generation of rice agripreneurs in Senegal

Such is the demand for vocational training among the youth that there were over 1,200 expressions of interest for the first 40 places at the agCelerant Academy, hosted by AfricaRice in Saint-Louis.

The Academy was established by Manobi Africa and AfricaRice in early 2021 under the Special Initiative Jobs Program funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The Academy provides training and capital resources so that graduates can become self-employed agripreneurs — essentially private sector extensionists — to support local farmers in their efforts to access credit and increase their rice production.

Trainee youths were selected on the basis of their education (master or bachelor of science), location (living in farming communities they can serve) and knowledge (familiar with rice farming). With that background, the agripreneurial training takes just one week. The first 40 trainees were brought up to speed with integrated rice management (IRM), agricultural finance and use of the agCelerant value chain orchestration platform. IRM covered good agricultural practices, including fertilizer, weed, water and harvest management. Meanwhile the agCelerant platform developed by Manobi Africa (www.agcelerant.com) is a mine of information and data, available both off- and online to assist the agripreneurs in their new roles. The platform also includes remote-sensing to enable them to



Five of the first 40 agCelerant trainees celebrating their graduation

monitor their farmers' field activities in near-real time (e.g. whether they irrigate on time).

After graduation, the trainees received a smartphone or tablet to aid data collection and advice delivery, and a motorcycle to enable them to get to farmers' fields. They were also aided to connect with a microfinance or banking institution to access a loan for working capital of about FCFA 700,000.¹⁷

The project set a target for each graduate to recruit 200 farmers to benefit from their services, based on a model of payment-in-kind at the end of the season (30 kg paddy per hectare). In their first season, the 40 new agripreneurs advised 2,436 farmers (in 250 producer groups), helping them achieve an average yield of 6.4 t/ha. Total production was 16,693 tonnes, worth an estimated FCFA 2.17 billion — a good start!

Contact: Mandiaye Diagne, Agricultural economist and value chain specialist <m.diagne@cgiar.org>

¹⁷ US\$ 1 ≈ FCFA 541 (22 February 2021).

Research and innovation highlights

Opportunities for young women in the rice value chain

Youth employment is a big issue on the world's most youthful continent. Meanwhile, the importance of the agri-food sector is growing as African nations seek self-sufficiency to feed their growing populations. Thus, the rice value chain is a potential source of valuable employment opportunities for youth and women. Studies conducted in Madagascar, Nigeria, Senegal and Togo between 2017 and 2021 demonstrated the need to build the technical and managerial knowledge of young value chain actors and support them financially and with start-up equipment to facilitate their engagement in the value chains.

To equip young people (aged 18–35 years) to take up entrepreneurial roles in the rice value chain, the International Fund for Agricultural Development (IFAD) supported the Youth Employment in Agribusiness and Sustainable Agriculture (YEASA) project in Benin and Nigeria — by empowering the youth with a start-up kit (donation) and capital grant. Between 2019 and 2021, AfricaRice trained 74 young women in rice production, value addition (rice-based products) and business management. Of these, 61 went on to receive start-up material in the form of rice seed for seed growers or gas stove and extruders for value-added rice product makers, plus a cash grant to set up their own businesses.

Daramola Victoria graduated from the program in 2020. “From the grant that I got, I was able to get shop space for myself,” she says. “And I have trainees: those that I train — I have those that work with me and I have those that just come for training monthly or weekly . . . I train youths. . . . I didn't

get a job opportunity; that has been my job. I'm not even looking for any other job anyway, so I am self-employed with the help of YEASA.”

Alabi Comfort Oluwatoyin graduated from YEASA in 2021. She says: “When I first started [my business], I had to do awareness for people because it's a new product. I had a positive response. . . . There is growth in my business . . . I have been able to be self-efficient when it comes to finances. . . . The program has really, really helped me in fulfilling my dreams: I've registered my products and I'm looking forward to progressing more.”

The project also trained a total of 126 young men, of whom 104 received start-up kits and capital, primarily to launch seed-production activities, with a few becoming small-scale equipment fabricators (ASI thresher–cleaner).

Contact: Francis Nwilene, Regional representative, Nigeria <f.nwilene@cgiar.org> and Gaudiose Mujawamariya, Rice value chain expert and Gender focal point <g.mujawamariya@cgiar.org>



Practical training session on rice value addition

President Buhari's rice revolution: our part in his success

Upon assuming office in 2015, President Muhammadu Buhari of Nigeria launched the Anchor Borrowers Program through the Central Bank of Nigeria to boost production and processing of key agricultural commodities, including rice. Several other government initiatives — including Agriculture Promotion Policy, the Presidential Fertilizer Initiative, and border closure and total ban on importation of rice — along with support from AfricaRice and its partners contributed to the rice success story in 2021. In January 2022, 'rice pyramids' (pyramids made from sacks of Nigerian rice) were set up in celebration of this achievement.

AfricaRice has been active in Nigeria for many decades, and we share the President's joy in the country becoming (very nearly) self-sufficient in rice. Thanks to AfricaRice, Nigeria has benefited from almost US\$ 14 million in bilateral donor funds through over 20 projects. The two largest projects have been the Multinational CGIAR Support to Agricultural Research for Development on Strategic Commodities in Africa (2014–2017) and the Agricultural Transformation Agenda Support Program Phase 1 (ATASP-1, 2015–2021), both funded by the African Development Bank, with \$5 million from each being invested in Nigeria.

Key activities have included introducing high-yielding and stress-resistant varieties, promoting good agricultural practices (GAPs), supporting the growing private seed sector with quality breeder seed supply and technical know-how, training and supporting young agripreneurs, and supporting the Bukan Sidi Lafia (Nasarawa State) and Goronyo (Sokoto State) innovation platforms (IPs).

FARO 66 and FARO 67 were introduced for flood-prone areas,¹⁸ and breeder seed of those plus FARO 44 and FARO 52 supplied.

GAPs introduced under ATASP-1 helped raise rice yields from about 2 t/ha to 5.7 t/ha. RiceAdvice¹⁹ continues to grow in popularity and is a major focus of youth training; in rice-growing regions of northern Nigeria, RiceAdvice has improved rice profitability in recommending 2–3 sacks of fertilizer where farmers used to apply 10. Meanwhile, the entry point for the IPs was the GEM parboiling technology,²⁰ helping them become major sources of high-quality parboiled rice in the country. The IPs have attracted a lot of attention from other agricultural institutions and programs, and state government delegations.

Contact: Francis Nwilene, Regional representative, Nigeria <f.nwilene@cgiar.org>



Some of the rice pyramids at the Abuja International Trade and Convention Centre, 17 January 2022

¹⁸ See 'Learning to tolerate flooding, a major problem in inland valleys that's worsening as the climate changes', *AfricaRice annual report 2018*, pages 6–8.

¹⁹ See 'RiceAdvice generates additional production worth millions of dollars in Nigeria', *AfricaRice annual report 2020*, page 18.

²⁰ See 'Improving the quality of parboiled rice', *AfricaRice annual report 2016*, page 19.

Research and innovation highlights

Key achievements of outscaling through TAAT

With a burgeoning population, and crises seemingly coming thick and fast — climate change, disease epidemics, conflict — *development* is a key word in Africa.

‘Technologies for African agricultural transformation’ (TAAT) was a huge development project funded by the African Development Bank and led by the International Institute of Tropical Agriculture (IITA) from early 2018 to late 2021. AfricaRice led the Rice Compact.²¹

The Rice Compact supported the production of 79.1 tonnes of breeder seed at AfricaRice M’bé and Ndiaye/Saint-Louis and in Ghana and Uganda, covering 17 climate-smart varieties of Orylux, Sahel, NERICA, NERICA-L and ARICA series, and hybrids. These have been disseminated to 17 countries with estimates of 1,902 t of foundation and over 95,000 t of certified seed to cover over 1.9 million hectares for over 3.8 million farmers by the end of the 2021/22 cropping season.

Multi-stakeholder innovation platforms (MSIPs) were established in Benin, Cameroon, Côte d’Ivoire, Ghana, Madagascar, Nigeria, Senegal and Uganda to bring stakeholders together, including microfinance and market linkages.

The MSIPs typically established GEM rice parboiling and processing facilities and acted as hubs for training, piloting and technology adoption of good agricultural practices and ASI thresher–cleaners through field demonstrations. Enterprises and partnerships

emerging from the MSIPs are expected to continue in the post-project period and become self-sustaining.

Some 12,000 new jobs were created for women and youth, the former primarily in parboiling business, and the latter mainly as RiceAdvice agents. MSIP food products marketed comprised parboiled rice, baby food (rice flour; illustrated) and ‘black rice’.²²

Average project beneficiary incomes rose from US\$ 459 to \$604, primarily through access to quality seed of new varieties, good agricultural (and postharvest) practices and GEM parboiling. Average yields rose from 2.78 t/ha to 3.40 t/ha. Food produced in beneficiary countries increased from 9.53 million tonnes (Mt) to 10.56 Mt, with the extra 1.03 Mt, mostly of parboiled rice, valued at over \$622 million.

“In addition to the ‘focus’ countries [in which the Compact established the MSIPs], the project also benefited a number of ‘spill-over’ countries,” explains TAAT coordinator Ernest Asiedu, “with seed, training in the technologies adopted and even GEM parboiling technology, which was fabricated in Côte d’Ivoire for use in Niger.”

Contact: Ernest Asiedu, TAAT coordinator <e.asiedu@cgiar.org>



Infant rice flour packaged for supermarkets by MSIP enterprise RINA in Côte d’Ivoire

21 See also *AfricaRice annual report 2019*, pages 13, 14.

22 Black-grained ‘black rice’ is low-glycemic and therefore better for people with diabetes (see also ‘Low-glycemic rice’, *AfricaRice annual report 2020*, page 21).

Annexes

Finance

The AfricaRice Management is pleased to report the improving financial situation of AfricaRice during the year ended 31 December 2021. The following are the highlights of the financial results.

Financial situation

The total operating revenues of the Center increased from US\$ 12.142 million in 2020 to \$19.440 million in 2021, corresponding to an increase of \$7.298 million. The operating expenses also increased, from \$13.161 million in 2020 to \$18.853 million in 2021, corresponding to an increase of \$5.692 million. This resulted in AfricaRice recording an operational surplus of \$0.587 million in 2021, against the operational deficit of \$1.019 million in 2020. Additionally, the net non-operating financial expenses decreased the annual

surplus for the year to \$0.531 million, compared to the deficit of \$1.013 million recorded at the end of 2020. The undesignated net assets of the Center decreased from \$2.662 million at the end of 2020 to \$3.408 million at the end of 2021.

Other indicators of financial health

The short-term solvency (liquidity) indicator level of the Center reduced to 88 days, down from 111 days for 2020, and the long-term financial stability ratio similarly reduced to 67 days from 79 days in 2020. The audited indirect cost rate for AfricaRice reduced to 14.3% during the year, from 20.9% in 2020. The current ratio increased from 1.19 in 2020 to 1.27 in 2021, which is within the CGIAR recommended level (greater than 1.0).

Summary financials (expressed in thousands of US\$)

	2021	2020
Income statement		
Revenues	17,440	12,142
Operating surplus/(deficit)	587	(1,019)
Surplus/(deficit) for the year	531	(1,013)
Balance sheet		
Fixed assets (NBV)	3,084	2,966
Working capital	4,506	3,726
Non-current liabilities	2,733	2,366
Net assets		
Undesignated	3,408	2,662
Designated	1,449	1,664

Annexes

Statements of activity (expressed in thousands of US\$)

	Total 2021	Total 2020
Revenue and gains		
Grant revenue		
Windows 1 and 2	3,302	2,196
Window 3	5,458	5,766
Bilateral	10,620	3,367
Total grant revenue	19,381	12,049
Other revenue and gains	59	93
Total revenue and gains	19,440	12,142
Expenses and losses		
Research expenses	15,047	9,669
CGIAR collaboration expenses	–	–
Non-CGIAR collaboration expenses	1,448	1,221
General and administration expenses	2,358	2,272
Other expenses and losses	–	–
Total expenses and losses	18,853	13,161
Operating surplus/(deficit)	587	(1,019)
Gain/loss on sale of assets	–	2
Restructuring cost/others	–	–
Financial income	–	6
Financial expenses	(56)	(2)
Surplus/(Deficit) for the year	531	(1,013)

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)
- CGIAR Research Program on Rice Agri-Food Systems (RICE)
- 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)
- International Institute of Tropical Agriculture (IITA)
- International Rice Research Institute (IRRI)
- Japan
- Liberia
- London School of Hygiene & Tropical Medicine (LSHTM)
- Mastercard Foundation
- Niger
- Nigeria
- Nigeria – Afe Babalola University
- Rural Development Administration (RDA), Republic of Korea
- Sierra Leone
- Technical Centre for Agricultural and Rural Cooperation ACP–EU (CTA)
- United States Agency for International Development (USAID)
- West African Economic and Monetary Union (UEMOA)

Board of Trustees

(as at 31 December 2021)

Chair	Carol Kramer-LeBlanc, Member, AfricaRice Board *
Vice-Chair	Kanayo F. Nwanze, Member, AfricaRice Board *
Members	Pétronille Acray-Zengbe, Member, AfricaRice Board *
	Comlan Atsu Agbobli, Member, AfricaRice Board *
	Patrick Caron, Member, CGIAR System Board *
	Shenggen Fan, Member, CGIAR System Board *
	Marco Ferroni, Chair, CGIAR System Board *
	Neal Gutterson, Member, CGIAR System Board *
	Philip Idro, Member, AfricaRice Board §
	Alyssa Jade McDonald-Baertl, Member, CGIAR System Board *
	Lindiwe Majele Sibanda, Member, CGIAR System Board *
	Gloria Nwakaegho Elemo, Member, AfricaRice Board §
	Harold Roy-Macauley, Director General, Member, AfricaRice Board §
	Alice Ruhweza, Member, CGIAR System Board *
	Abdoul-Aziz Sy, Member, AfricaRice Board §
	Hilary Wild, Member, CGIAR System Board *

* Voting member

§ Non-voting member

Training 2021

AfricaRice training program (courses)

 **84** Training courses run in 2021

 **42** Locations  in **17** countries

 **6319** Total trainees  **2089** Female  **4230** Male

Postgraduate trainees

 **15** Total female postgrads

 **36** Total male postgrads

 **28** PhD students
... of whom

 **8** Female

 **20** Male

 **23** MSc students
... of whom

 **7** Female

 **16** Male

Publications 2021

Selected titles in Science Citation Index (SCI) and Science Citation Index Expanded (SCIE) journals

Abebrese SO, **Amoah NKA**, Dartey PKA, **Bimpong IK**, Akromah R, Gracen VE, Offei SK and Danquah EY. 2021. Mapping chromosomal regions associated with anther indehiscence with exerted stigmas in CRI-48 and Jasmine 85 cross of rice (*Oryza sativa* L). *Heliyon*, 7(3): art. e06483. <https://doi.org/10.1016/j.heliyon.2021.e06483>

Abera BB, **Senthilkumar K**, Cotter M and Asch F. 2021. Transplanting as an option to cope with abiotic stress in high-altitude lowland rice production systems in East Africa. *Journal of Agronomy and Crop Science*, 00:1–11. <https://doi.org/10.1111/jac.12540>

Akpoti K, **Dossou-Yovo ER**, Zwart SJ and **Kiepe P**. 2021. The potential for expansion of irrigated rice under alternate wetting and drying in Burkina Faso. *Agricultural Water Management*, 247: art. 106758. <https://doi.org/10.1016/j.agwat.2021.106758>

Arouna A, **Devkota KP**, **Yergo WG**, **Saito K**, Frimpong BN, Adegbola PY, Depieu ME, Kenyi DM, Ibro G, Fall AA and Usman S. 2021. Assessing rice production sustainability performance indicators and their gaps in twelve sub-Saharan African countries. *Field Crops Research*, 271: art. 108263. <https://doi.org/10.1016/j.fcr.2021.108263>

Arouna A, Michler JD and Lokossou JC. 2021. Contract farming and rural transformation: Evidence from a field experiment in Benin. *Journal of Development Economics*, 151: art. 102626. <https://doi.org/10.1016/j.jdevec.2021.102626>

Asai H, **Saito K** and Kawamura K. 2021. Application of a Bayesian approach to quantify the impact of nitrogen fertilizer on upland rice yield in sub-Saharan Africa. *Field Crops Research*, 272: art. 108284. <https://doi.org/10.1016/j.fcr.2021.108284>

Awio T, **Senthilkumar K**, Dimkpa CO, Otim-Nape GW, Kempen B, Struik PC and Stomph TJ. 2021. Micro-nutrients in East African lowlands: Are they needed to intensify rice production? *Field Crops Research*, 270: art. 108219. <https://doi.org/10.1016/j.fcr.2021.108219>

Brosseau A, **Saito K**, van Oort PAJ, **Diagne M**, Valbuena D and Groot JCJ. 2021. Exploring opportunities for diversification of smallholders' rice-based farming systems in the Senegal River valley. *Agricultural Systems*, 193: art. 103211. <https://doi.org/10.1016/j.agsy.2021.103211>

Chivenge P, **Saito K**, Bunquin MA, Sharma S and Dobermann A. 2021. Co-benefits of nutrient management tailored to smallholder agriculture. *Global Food Security*, 30: art. 100570. <https://doi.org/10.1016/j.gfs.2021.100570>

De Bauw P, Smolders E, Verbeeck M, **Senthilkumar K**, Houben E and Vandamme E. 2021. Micro-dose placement of phosphorus induces deep rooting of upland rice. *Plant and Soil*, 463(1–2): 187–203. <https://doi.org/10.1007/s11104-021-04914-z>

Devkota KP, **Futakuchi K**, **Mel VC** and Humphreys E. 2021. Does wet seeding combined with *Sub1* varieties increase yield in submergence prone lowlands of West Africa? *Field Crops Research*, 276: art. 108375. <https://doi.org/10.1016/j.fcr.2021.108375>

Dossou-Yovo ER, Vandamme E, **Dieng I**, Johnson JM and **Saito K**. 2021. Decomposing rice yield gaps into efficiency, resource and technology yield gaps in sub-Saharan Africa. *Field Crops Research*, 258: art. 107963 <https://doi.org/10.1016/j.fcr.2020.107963>

Dossou-Yovo ER and **Saito K**. 2021. Impact of management practices on weed infestation, water productivity, rice yield and grain quality in irrigated systems in Côte d'Ivoire. *Field Crops Research*, 270: art. 108209. <https://doi.org/10.1016/j.fcr.2021.108209>

Futakuchi K, Senthilkumar K, Arouna A, Vandamme E, Diagne M, Zhao D, Manneh B and Saito K. 2021. History and progress in genetic improvement for enhancing rice yield in sub-Saharan Africa. *Field Crops Research*, 267: art. 108159. <https://doi.org/10.1016/j.fcr.2021.108159>

Gouda AC, Warburton ML, Djedatin GL, Kpeki SB, Wambugu PW, Gnikoua K and **Ndjiondjop MN**. 2021. Development and validation of diagnostic SNP markers for quality control genotyping in a collection of four rice (*Oryza*) species. *Scientific Reports*, 11: art. 18617. <https://doi.org/10.1038/s41598-021-97689-3>

Grotelüschen K, Gaydon DS, Langensiepe, M, Ziegler S, Kwesiga J, **Senthilkumar K**, Whitbread AM and Becker M. 2021. Assessing the effects of management and hydro-edaphic conditions on rice in contrasting East African wetlands using experimental and modelling approaches. *Agricultural Water Management*, 258: art. 107146. <https://doi.org/10.1016/j.agwat.2021.107146>

Hay FR, Whitehouse KJ, Ellis RH, Hamilton NRS, Lusty C, **Ndjiondjop MN, Tia D**, Wenzl P, Santos LG, Yazbek M, Azevedo VCR, Peerzada OH, Abberton M, Oyatomi O, de Guzman F, Capilit G, Muchugi A and Kinyanjui Z. 2021. CGIAR genebank viability data reveal inconsistencies in seed collection management. *Global Food Security*, 30: art. 100557. <https://doi.org/10.1016/j.gfs.2021.100557>

Hengl T, Miller MAE, Krizan J, Shepherd KD, Sila A, Kilibarda M, Antonijevic O, Glusica L, Dobermann A, Haefele SM, McGrath SP, Acquah GE, Collinson J, Parente L, Sheykhmousa M, **Saito K, Johnson JM**, Chamberlin J, Silatsa FBT, Yemefack M, MacMillan RA, Wheeler O and Crouch J. 2021. African soil properties and nutrients predicted at 30 m spatial resolution using two-scale ensemble machine learning. *Scientific Reports*, 11: art. 6130. <https://doi.org/10.1038/s41598-021-85639-y>

Ibrahim A, Saito K, Bado VB and Wopereis MCS. 2021. Thirty years of agronomy research for development in irrigated rice-based cropping systems in the West African Sahel: Achievements and perspectives. *Field Crops Research*, 266: art. 108149. <https://doi.org/10.1016/j.fcr.2021.108149>

Johnson JM, Sila A, **Senthilkumar K**, Keith DS and **Saito K**. 2021. Application of infrared spectroscopy for estimation of concentrations of macro- and micronutrients in rice in sub-Saharan Africa. *Field Crops Research*, 270: art. 108222. <https://doi.org/10.1016/j.fcr.2021.108222>

Kini K, Wonnic I, Silué D and Koebnik R. 2021. Development of two loop-mediated isothermal amplification (LAMP) genomics-informed diagnostic protocols for rapid detection of *Pantoea* species on rice. *MethodsX*, 8: art. 101216. <https://doi.org/10.1016/j.mex.2021.101216>

Kirk GJD, Manwaring H, Udea Y, **Semwal VK** and Wissuwa M. 2021. Below-ground plant–soil interactions affecting adaptations of rice to iron toxicity. *Plant, Cell and Environment*, 45(3): 705–718. <https://doi.org/10.1111/pce.14199>

Kumar PL, Cuervo M, Kreuze JF, Muller G, Kulkarni G, Kumari SG, Massart S, Mezzalama M, Alakonya A, Muchugi A, Graziosi I, **Ndjiondjop MN**, Sharma R and Negawo AT. 2021. Phytosanitary interventions for safe

global germplasm exchange and the prevention of transboundary pest spread: The role of CGIAR germplasm health units. *Plants*, 10(2): art. 328. <https://doi.org/10.3390/plants10020328>

Ndindeng SA, Candia A, Mapiemfu DL, Rakotomalala V, Danbaba N, Kulwa K, Houssou P, Mohammed S, Jarju OM, Coulibaly SS, Baidoo EA, Moreira J and **Futakuchi K**. 2021. Valuation of rice postharvest losses in sub-Saharan Africa and its mitigation strategies. *Rice Science*, 28(3): 212–216. <https://doi.org/10.1016/j.rsci.2021.04.001>

Ndindeng SA, **Twine EE**, **Mujawamariya G**, Fiamohe R and **Futakuchi K**. 2021. Hedonic pricing of rice attributes, market sorting, and gains from quality improvement in the Beninese market. *Agricultural and Resource Economics Review*, 50(1): 170–186. <https://doi.org/10.1017/age.2020.24>

Rodenburg J, Tippe DE, **Tour A**, Irakiza R, Kayeke J and Bastiaans L. 2021. From rice-like plants to plants liking rice: A review of research on weeds and their management in African rice systems. *Field Crops Research*, 276: art. 108397. <https://doi.org/10.1016/j.fcr.2021.108397>

Saito K, Six J, **Komatsu S**, Snapp S, Rosenstock T, **Arouna A**, Cole S, Taulya G and Vanlauwe B. 2021. Agronomic gain: Definition, approach, and application. *Field Crops Research*, 270: art. 108193. <https://doi.org/10.1016/j.fcr.2021.108193>

Senthilkumar K, **Sillo FS**, Rodenburg J, Dimkpa C, **Saito K**, **Dieng I** and Bindraban PS. 2021. Rice yield and economic response to micronutrient application in Tanzania. *Field Crops Research*, 270: art. 108201. <https://doi.org/10.1016/j.fcr.2021.108201>

Twine EE, Adur-Okello SE, **Mujawamariya G** and **Ndindeng SA**. 2021. Targeting millers to improve rice marketing in Uganda. *British Food Journal*, 123(13): 454–468. <https://doi.org/10.1108/BFJ-05-2021-0505>

Wambugu PW, **Ndjioudjop MN** and Henry R. 2021. Genetics and genomics of African rice (*Oryza glaberrima* Steud) domestication. *Rice*, 14: art. 6. <https://doi.org/10.1186/s12284-020-00449-6>

Yuan S, Linqvist BA, Wilson LT, Cassman KG, Stuart AM, Pede V, Miro B, **Saito K**, Agustiani N, Aristya VE, Krisnadi LY, Zanon AJ, Heinemann AB, Carracelas G, Subash N, Brahmanand PS, Li T, Peng S and Grassini P. 2021. Sustainable intensification for a larger global rice bowl. *Nature Communications*, 12: art. 7163. <https://doi.org/10.1038/s41467-021-27424-z>

Abbreviations

ADRAO	Association pour le développement de la riziculture en Afrique de l’Ouest (French name of WARDA)
AfricaRice	Africa Rice Center
ARICA	Advanced Rice for Africa (varieties)
ASI	ADRAO–SAED–ISRA thresher–cleaner
FAO	Food and Agriculture Organization of the United Nations
FCFA	CFA franc(s)
FOFIFA	Centre National de Recherche Appliquée au Développement Rural
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ha	hectare
ISRA	Institut sénégalais de recherches agricoles (Senegal)
IWMI	International Water Management Institute
kg	kilogram
Mt	million tonnes
NARO	National Agricultural Research Organisation (Uganda)
NERICA	New Rice for Africa (family of interspecific rice varieties for uplands)
NERICA-L	New Rice for Africa (family of interspecific rice varieties for lowlands)
SAED	Société d’aménagement et d’exploitation des terres du Delta du Fleuve Sénégal et des vallées du Fleuve Sénégal et de la Falémé (Senegal)
spp.	(unspecified) species (plural)
t	tonne(s)
TAAT	Technologies for African Agricultural Transformation (project)
UK	United Kingdom of Great Britain and Northern Ireland
US	United States
WARDA	West Africa Rice Development Association (former name of AfricaRice)

About CGIAR

CGIAR is a global research partnership for a food-secure future dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources. Its research is carried out by 15 CGIAR Centers in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations 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 Center (WorldFish), Penang, Malaysia



AfricaRice

Africa Rice Center (AfricaRice)

01 BP 4029, Abidjan 01, Côte d'Ivoire

Telephone: (225) 27 22 48 09 10 **Fax:** (225) 27 22 44 26 29 **Email:** AfricaRice@cgiar.org

www.AfricaRice.org