RESEARCH ARTICLE

Technologies for Agricultural Transformation and Food Security in Africa

Akinwumi A. Adesina,* Colm Foy,† Innocent Musabyiamana,‡ Solomon Gizaw,§ and Martin Fregene‖

Abstract: Agricultural productivity in Africa has remained stubbornly low, and, in the past, production has increased largely by expansion of farming area, not by the intensification of production. The African Development Bank's answer to raising agricultural productivity is the "Feed Africa" strategy, which aims to achieve food security in Africa, end hunger, eliminate poverty, and secure Africa a place as a net food exporter without compromising environmental sustainability. This paper analyses some of the results from this approach, in particular, selected outcomes of the Technologies for African Agricultural Transformation (TAAT) programme, which aims to rapidly expand access of smallholder farmers in low-income Regional Member Countries to high-yielding and climate-smart agricultural technologies. TAAT is currently being implemented in 34 African countries. Over the past five years, TAAT has delivered improved varieties of climate-resilient rice, wheat, and maize seeds, along with their accompanying technologies, to over 13 million farming households and increased food production by more than 12 million metric tonnes per year. Four case studies – wheat in Sudan and Ethiopia, rice in Côte d'Ivoire, and maize in Kenya – are examined to illustrate the contributions of TAAT to enhanced food security.

Keywords: TAAT, African Development Bank, Feed Africa, Ethiopia, Kenya, Sudan, Cote d'Ivoire, agricultural productivity.

https://doi.org/10.25003/RAS.14.02.0003

* President, African Development Bank, Abidjan, Cote d'Ivoire, World Food Prize Laureate, 2017
† Consultant, African Development Bank, Abidjan, Cote d'Ivoire, colmfoy@gmail.com
‡ TAAT Coordinator, African Development Bank, Abidjan, Cote d'Ivoire
§ Head of TAAT Clearing House, International Institute of Tropical Agriculture (IITA), Cotonou, Benin Republic
‖ Director, Agriculture and Agro-Industry, African Development Bank, Abidjan, Cote d'Ivoire

Africa's population continues to grow, but the productivity of its agricultural land has not kept pace with this growth. Its population is increasing at a rate of 2.37 per cent per year, adding 33.7 million individuals annually. That rate is not expected to slow until 2035, when the population of the continent would reach over 1.7 billion people (United Nations Department of Economic and Social Affairs [UN DESA], Population Division 2022). African agricultural productivity is low, while the overall productivity of cereals is behind every other region (Figure 1), averaging only 1.7 tonnes per hectare (Ritchie 2022).

In addition, the per capita value of Sub-Saharan African production of agriculture and fisheries is actually falling (Figure 2).

The reasons for this low agricultural productivity are complex and varied, and the contrast with the experience of South Asia is compelling. Africa's agricultural yields are rising at a much slower rate than its needs: the growth of yield across the continent was only 3 per cent between 2015 and 2022 (United States Department of Agriculture, Economic Research Service [USDA ERS] (2023). To illustrate this point further, Europe's average cereal yield in 2021 was 5.6 tonnes per hectare whereas in Sub-Saharan Africa, it was only 1.6 tonnes per hectare (TheGlobalEconomy.com n.d.). Furthermore, much of the increase in the production of African cereals since 1980 has come about through the expansion of the area of land used for crop production, rather than from productivity increase via technological advances. While the yield per hectare has remained intractably low, total production has

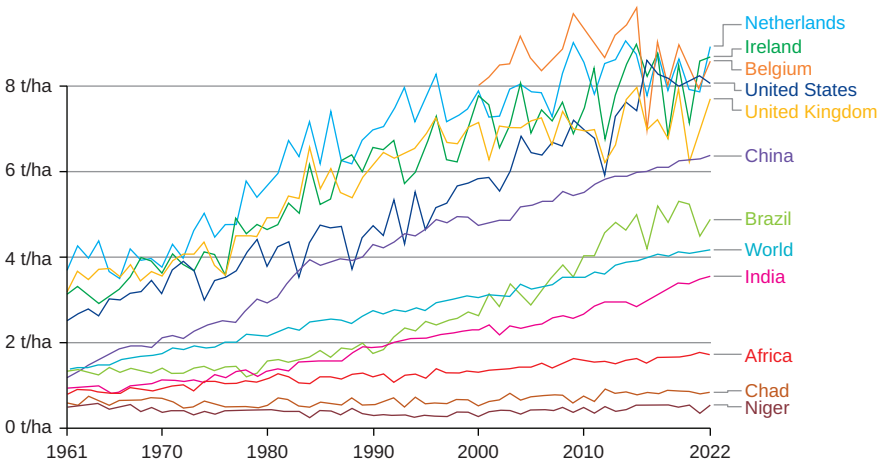

Figure 1 *Comparative cereals yields by country, 1961–2022* in tonnes per hectare
Note: Yield is measured as the quantity produced per unit area.
Cereals include wheat, rice, maize, barley, oats, rice, millet, sorghum, buckwheat, and mixed grains.
Source: Our World in Data, Ritchie (2022).

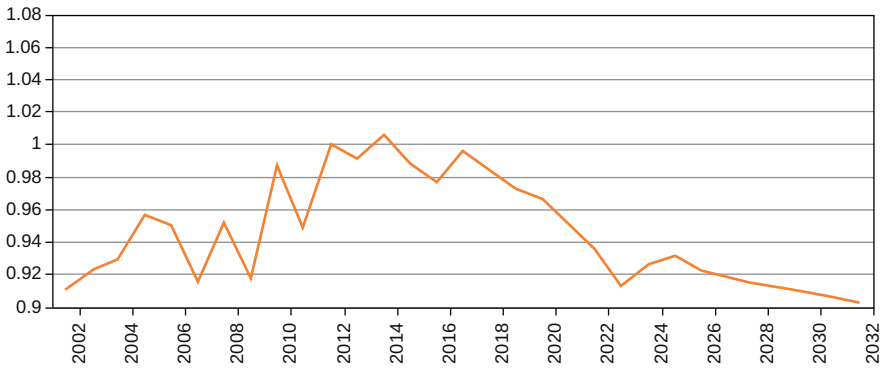

Figure 2 *Per capita net value of agriculture and fish production, Sub-Saharan Africa, 2002–32*
Note: Index values with 2012 = 1.
Source: Food and Agriculture Organization (FAO) (2021); Organisation for Economic Co-operation and Development-FAO (OECD-FAO) (2021).

increased by 300 per cent from expanding production into previously uncultivated lands (Figure 3) (Ritchie 2022). This expansion of agricultural land in the absence of increased unit area productivity is not environmentally sustainable.

This situation contrasts strongly with the experience of South Asia (Figure 3). Cereal production clearly increased between 1980 and 2018 in both South Asia and Sub-Saharan Africa. While most of Africa's increase is driven by land use expansion, much of the increased cereal production in South Asia is attributed to yield increases from better use of modern technologies and improved crop varieties. Africa must now make a shift in its food production trajectory by accelerating the use of improved agricultural technologies that allow for increased food production

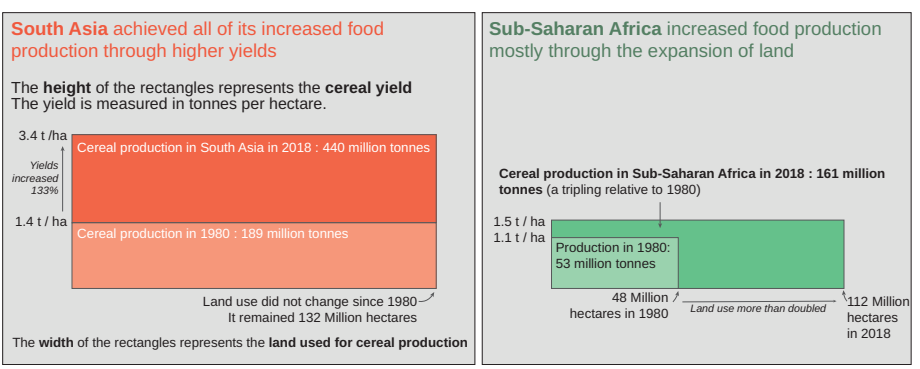

Figure 3 *Sources of increase in food production, South Asia and Sub-Saharan Africa, 1980 and 2018*, in million tonnes and tonnes per hectare
Source: Our World in Data, Ritchie (2022).

per unit area, instead of continued land conversion to agriculture. Increasing production through expansion of land into fragile ecosystems accelerates environmental degradation and contributes to climate change.

Alliance for a Green Revolution in Africa (AGRA) currently focuses on catalysing the transformation of African agriculture through influencing policy and investments that target resilient and sustainable food systems (AGRA 2021). It provides support to African regional economic communities (RECs) and governments using contracted experts to lead the development of agricultural policies at the regional, national, and local levels. A key area in which AGRA supports government is creating policies conducive to the use of agricultural inputs, such as seeds and agrochemicals, while enhancing the involvement of the private sector. However, AGRA's impact is limited by the fact that it operates only in 11 countries. In addition, there is no apparent guarantee that successful AGRA-initiated programmes will be sustained after they close, especially where government spending on agriculture is low (Vicedom and Wynber 2024). Though lessons are being learned, questions are being raised about the sustainability of the AGRA approach.[1] Bearing this in mind, African policy makers and development partners need to find and develop an approach to raising productivity that both acknowledges diversity and offers tailored solutions that are based not only on securing immediate increases in productivity but also on ensuring long-term sustainability.

As regards undernutrition, only two countries in Africa – Algeria and Ghana – have brought down undernourishment to below 5 per cent of the population, while two others – Central African Republic and Somalia – have the highest rate of undernourishment in the world, in excess of 60 per cent of the population (Food and Agriculture Organization [FAO] 2023a). The remainder of the continent falls somewhere in between, which means a third of the world's hungry reside in Africa and a quarter of its people suffer from hunger (FAO *et al.* 2023). Reversing undernourishment and increasing the productivity and efficiency of the agricultural sector, as well as reducing the cost of food imports that stifle economic growth, requires an integrated approach to agricultural development that incorporates technological innovation, policies that support farmers' production needs, and better access to markets that can absorb expected production gains and consequent surpluses.

Food and nutrition security are, therefore, at the forefront of the development agenda in Africa. This is the context in which, building upon its 2013–22 10-year strategy (African Development Bank n.d.), the African Development Bank established five priority areas – the "High 5s" – for economic and social development in African countries (African Development Bank 2016a). These priority areas are: Feed Africa (African Development Bank 2016b); Light Up and Power Africa (African

[1] For a summary of the critiques and the responses to them from Alliance for a Green Revolution in Africa (AGRA) and its backers, see Brzeziński (2022).

Development Bank 2016c); Industrialise Africa (African Development Bank 2016d); Integrate Africa (African Development Bank 2016e); and Improve the Quality of Life for the People of Africa (African Development Bank, 2016f).

This paper deals with the Feed Africa strategy, whose overarching goal is to accelerate the achievement of food security in African countries based on the recognition of the diversity of their advantages and needs. In doing so, the focus is also on scaling up access of farmers to climate-resilient agricultural technologies by means of the Technologies for African Agricultural Transformation (TAAT) programme. The Bank acknowledges that the situation varies significantly across countries and that the initiatives to combat food insecurity need to be flexible and adapted to national, local, and possibly micro circumstances.

This paper analyses selected outcomes of the TAAT programme by means of four case studies. The case studies deal with wheat in Sudan and Ethiopia, rice in Côte d'Ivoire, and maize in Kenya and illustrate the contributions of TAAT to enhanced productivity and production of selected crops.

Global Context

The Feed Africa strategy and TAAT component have been affected by three emergent crises: the severe effects of climate change, the Covid-19 pandemic, and the war in Ukraine.

Climate change has led to more unpredictable weather events, which have disrupted crops and grazing lands, damaged fisheries, and decimated herds throughout Africa. The World Meteorological Organisation's (WMO 2023) *The State of the Climate in Africa 2022* notes that

> the rate of temperature increase in Africa has accelerated in recent decades, with weather- and climate-related hazards becoming more severe. More than 110 million people on the continent were directly affected by weather, climate, and water-related hazards in 2022, causing more than USD 8.5 billion in economic damages.

Covid-19 was disruptive of agricultural supply chains in Africa through the impact of lockdowns and their effect on labour movement and trade (Partner Africa *et al.* n.d.). Household incomes declined, as did localised trade in agricultural goods.

As in other countries, the negative effects of the pandemic on non-agricultural employment led to a perceptible return to the countryside and re-entry into agriculture as "buffer" employment (Amankwah, Gourlay, and Zezza 2021). Harvests do not appear to have increased over the period, and rural incomes appear to have diminished rather than increasing.

> Before the outbreak, 76 per cent of Nigerian households were involved in agriculture (either crop or livestock farming), but the share increased to 84 per cent soon after.

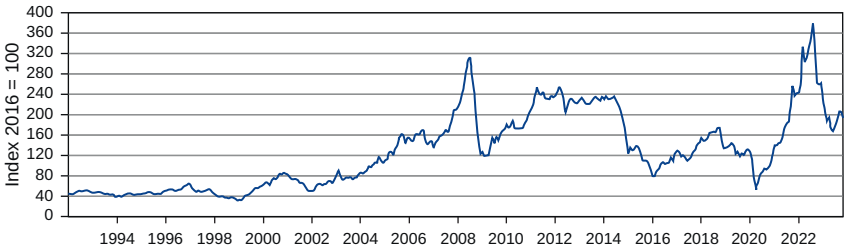

Figure 4 *Global price of energy index, 1994–2022*
Source: International Monetary Fund (IMF) (2024a).

> Similarly, in Malawi and Uganda, 91 per cent and 79 per cent of households [were involved in agriculture during the pandemic] . . . compared to the pre-pandemic levels of 84 and 76 per cent, respectively. (Amankwah, Gourlay, and Zezza 2021)

The pandemic slowed down plans to modernise the agricultural sector in many countries (FAO 2021).

In February 2022, Russia invaded Ukraine, with serious repercussions for many African countries in terms of food security. More than half of these countries source between 40 and 100 per cent of their wheat, oilseeds, and fertilizer from Ukraine and Russia. Global energy prices rose from 56 per cent of a 2016 baseline index to over 376 per cent in August 2022. The food price index rose from its 2016 baseline of 100 to almost 166 in April 2022 before dropping to 133 in November 2023 (Figures 4 and 5).

By October 2022, the International Monetary Fund (IMF) had warned that "with food and energy accounting for half of household consumption in Sub-Saharan Africa, living costs across the region have spiralled" (Bolhuis and Kovacs 2022). Indeed, African countries are highly dependent on imports of food, especially from Russia and Ukraine (Figure 6). "Ukraine and Russia are major exporters of wheat, maize, sunflower oil, and barley. Ukraine and Russia accounted for nearly 30 per cent of global wheat exports before the Russian invasion of Ukraine" (Trading Economics n.d.). The Russia-Ukraine conflict sent the prices of these grains and oilseeds

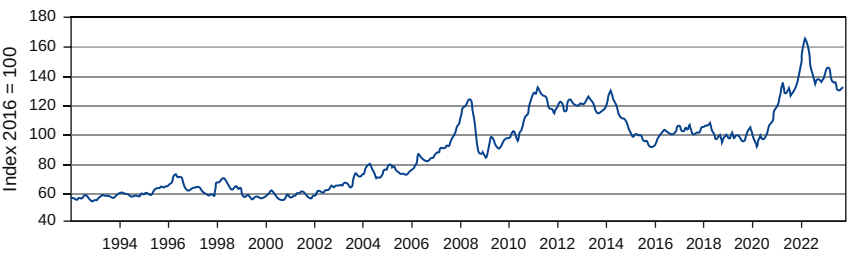

Figure 5 *Global price of food index, 1994–2022*
Source: IMF (2024b).

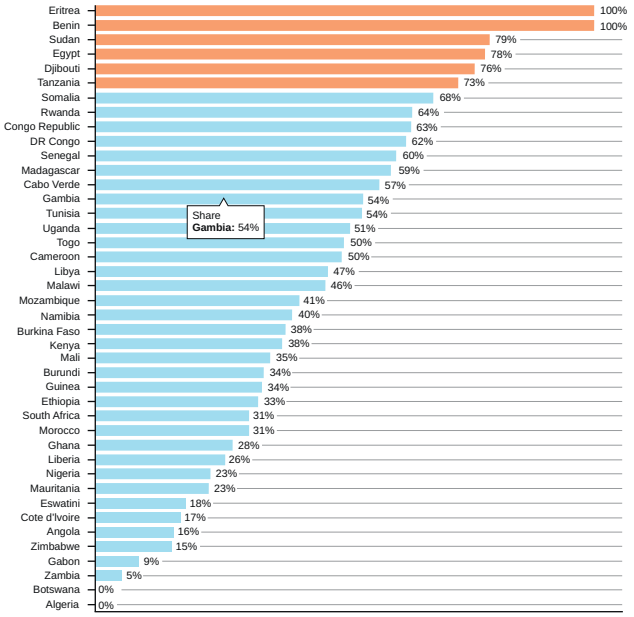

Figure 6 *Dependence of African countries on Russia and Ukraine for wheat imports*, 2018–20 in per cent
Source: Trade data from CEPII, average exports 2018–20.

soaring. In Africa, wheat prices increased by over 40 per cent in some countries (FAO, Famine Early Warning Systems Network [FEWS NET], and World Food Programme [WFP] 2022).

At the same time, fertilizer shortages worsened. Ukraine and Russia together supply 20 per cent of the world's potash, and Russia provided 14 per cent of globally traded urea (the most widely applied nitrogen fertilizer) and 11 per cent of MAP and DAP (the most widely applied phosphorus fertilizers). Fertilizer prices in most African countries rose three to four times from their 2020 levels (Hebebrand and Glauber 2023). The shortages and price spikes created a 2 million tonne supply gap for fertilizers across the continent, threatening agricultural production as countries headed into the 2022 planting season (African Development Bank 2023b). Prices for the three key types of fertilizer rose from between USD 200–300 per tonne in 2020 to between approximately USD 500–800 per tonne from 2022 (Figure 7). This had a powerful and negative effect on uptake.

Technologies for the African Agricultural Transformation (TAAT) Programme

The TAAT programme is a flagship of the Feed Africa strategy that was established to take technological innovation in agriculture to African farmers at scale. The increase in fertilizer prices required that the economic returns to fertilizer addition be recalculated by the TAAT programme and recommendations adjusted accordingly.

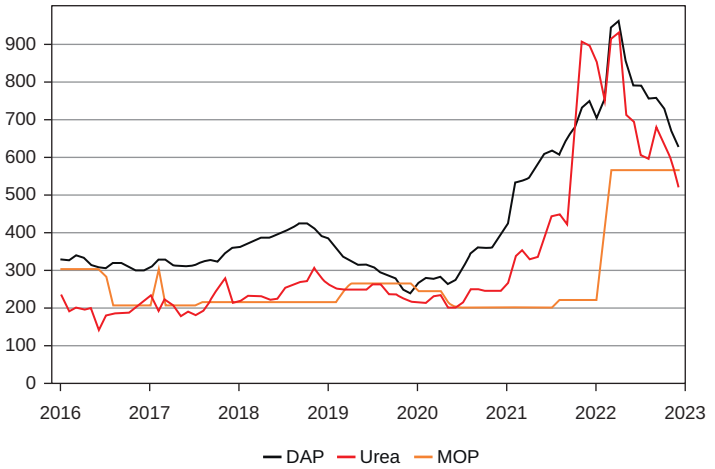

Figure 7 *International fertilizer prices, 2016–23* in USD per metric tonne
Note: DAP = diammonium phosphate, MOP = muriate of potash, mt = metric tonne. Last observation is dated December 2022.
Source: World Bank.

According to the World Bank,

> Fertilizer prices have eased from their early 2022 peaks, but they remain at historically elevated levels. The price easing partly reflects weak demand as farmers cut back fertilizer field applications due to affordability and availability issues. Weakening local African currencies also erased any advantages of falling prices. The industry is also affected by supply-side issues, including a production crunch in Europe, disruptions due to sanctions on Russia, and trade restrictions placed upon China. (Baffes and Koh 2023)

In response to these unforeseen disruptions to agricultural development, in May 2022, the African Development Bank launched a special fund to develop and distribute locally adapted crop varieties, establish sources of fertilizers for African countries, and deliver appropriate training to Africa's farmers to reduce reliance on imported food. The special facility, known as the African Emergency Food Production Facility (AEFPF), targets 20 million African smallholder farmers with support for certified seeds and fertilizers to produce 38 million tonnes of food over two years, worth USD 12 billion. The initiative now supports farmers with extension services, advice on post-harvest management, market development, and policy initiatives that facilitate farmers' access to modern inputs. Since the launch, the African Development Bank has approved USD 1.6 billion for 34 countries, with an additional USD 313.4 million funding support from Japan, Norway, Germany, the Netherlands, and the United States.

The TAAT programme is actively working in 33 AEFPF countries to contribute to, among other things, the development of seed roadmaps aligned with the countries'

strategies and targets, the provision of high-quality climate-resilient seed varieties adapted to agroecological zones, capacity strengthening of National Agricultural Research System (NARS) in early generation seed production, and extension agents in good agronomic practices. Building on the success of the TAAT programme, the AEFPF is designed to bring about long-term change to insulate the continent as far as possible from the vagaries of the international food system by reducing the volume and value of imports until the flow is reversed and Africa becomes a net exporter of food.

The impact and repercussions of climate change, the Covid-19 pandemic, and the war in Ukraine on African agriculture make the effort to boost productivity and reduce food insecurity even more urgent. This effort involves supporting the widespread availability of improved crop varieties; promoting better farming practices; and making judicious use of environmentally safe fertilizers, pesticides, and herbicides. It is based on the principle that demonstration of modern technologies, robust supply chains for seeds and fertilizer, farmer extension, and the inclusion of women and youth in agricultural development are all essential ingredients for success. TAAT also strives to avoid the intensive use of chemical fertilizers and pesticides that are inimical to environmental sustainability. Through supportive policies – fair prices for farmers, investment in infrastructure, access to finance, and capacity-building initiatives – Africa can unleash the potential of agro-processing, contribute to economic development, and create a sustainable agricultural sector.

TAAT is designed to double crop, livestock, and fish productivity by expanding access to proven technologies to more than 40 million smallholder farmers across Africa by 2025. This achievement is expected to produce an additional 120 million tonnes of food per year, achieving food security and providing produce for value addition and profitable export. TAAT's operations are based upon three principal mechanisms:

- Creating an enabling environment for technology adoption by farmers;
- Facilitating effective delivery of appropriate technologies to farmers through a regional technology delivery structure; and
- Raising agricultural production and productivity by identifying and deploying strategic interventions that include demonstrating and accessing proven technology packages (TAAT Africa n.d.).

For the most part, TAAT operates through other established national programmes, public bodies, and the private sector. The overall goal of TAAT is to improve agriculture as a business across Africa by deploying proven technologies for 11 priority commodities (cassava, wheat, rice, maize, sorghum/millet, orange-fleshed sweet potato, high iron beans, soybean, vegetables, aquaculture, and small livestock). These commodity-based interests are also advanced through three cross-cutting enablers: Youth in Agri-business, Policy Support, and Capacity Development

(African Development Bank 2022). Its reach is enhanced through interaction with the private sector, seeking investors and demonstrating to them the viability and profitability of the modernised agricultural sector (TAAT 2023a). Furthermore, TAAT operates along the entire agricultural value chain, including input suppliers, transporters, wholesalers, warehouses, farmers, their families, and their co-operatives. The International Agriculture Research Centres of the Consultative Group of International Agricultural Research (CGIAR), led by the International Institute of Tropical Agriculture (IITA), play a major role in TAAT, operating through decentralised but integrated regional research programmes, each working on major staple crops and agricultural constraints in Africa. This approach allows for simultaneous concentration on commodity value chains, farming systems, and the underlying agricultural and natural resource base, all within the context of a flourishing socioeconomic environment (IITA n.d.). The implementation of TAAT is co-ordinated by IITA in partnership with 11 other regional and international research institutions.[2]

This flagship programme of the African Development Bank "has brought together the international agricultural research centres of the CGIAR, national and regional research centres, seed and fertilizer companies and agribusinesses to deliver climate resilient agricultural technologies at scale" (Adesina 2023). Further, by taking a regional approach to technology delivery, harmonising national and regional regulations in seeds and other farm inputs, a faster spread of technologies across agro-ecological zones and national boundaries is possible. To illustrate this, in 2019, when severe drought hit 11 countries including the Southern Africa region, TAAT accelerated the distribution of 20,111 metric tonnes of certified seeds through its partnership network and deployed an additional 6,598 tonnes of 35 water-efficient and drought-tolerant maize varieties, which were cultivated on over 0.84 million hectares, thus providing food security to 1.3 million farm households or 5.2 million persons across the region.

Since its establishment in 2018, the total funding from the African Development Bank to East Africa has amounted to: USD 207.99 million for Ethiopia; USD 109.18 million for Kenya; and USD 592.39 million for Sudan; while Côte d'Ivoire received funding amounting to the equivalent of USD 448.29 million.

From 2019 until 2023, the TAAT Clearinghouse, through project design and country engagement missions, has successfully integrated productivity-enhancing TAAT-vetted technologies into investment projects funded by the Bank worth USD 3.6

[2] They include the African Agricultural Technology Foundation (AATF), Africa Rice Centre (AfricaRice), the Alliance of Biodiversity International and the Center for Tropical Agriculture (CIAT), the International Potato Center (CIP), the Forum for Agricultural Research in Africa (FARA), the International Centre for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Fertiliser Development Corporation (IFDC), the International Livestock Research Institute (ILRI), the International Water Management Institute (IWMI), and the WorldFish centre.

billion in 34 countries. The Clearinghouse has proved to be a worthwhile investment with high potential for generating large social and economic returns on investment. Specifically, if the technologies already integrated into agricultural development projects (valued at USD 1 billion) improved agricultural and economic outcomes by only 5 per cent, this would be an eight-fold return on the USD 6 million investment (Siegal, Usmani, and Strull 2022).

The TAAT Clearinghouse has gathered, profiled, and validated 140 technologies so far, with e-catalogues that showcase profiles of these technologies having been developed by the TAAT Clearinghouse (n.d.). The e-catalogues have been designed for decision-makers in governments and in the private sector.

Over the five years till the end of 2023, TAAT delivered climate-resilient, disease tolerant, and nutrient-dense crop varieties to over 13 million farm families in 34 countries that helped increase food production by an additional 12 million tonnes per annum (Woomer, Mulei, and Zozo 2021; TAAT 2023b)."

Case Studies of TAAT Interventions

The four cases discussed here have been selected on the basis of progress in implementation, their measured results, and the lessons they provide for future initiatives.

Wheat in Ethiopia

Ethiopia is the second most important wheat-producing country in Africa, after Egypt, with an annual production of 7 million tonnes of wheat grain (FAO n.d.). The African Development Bank has supported wheat cultivation in Ethiopia since 2012–13 through its Support to Agricultural Research for Development of Strategic Crops in Africa (SARD-SC) project. From 2018–19, the work continued under the leadership of International Center for Agricultural Research in the Dry Areas (ICARDA).

TAAT collaborates closely with the Ministry of Agriculture through the Ethiopian national and regional agricultural research institutes, which have developed a cluster farming approach with small-scale farmers. Some 1.3 million farmers were organised into 30,000 clusters to plant improved varieties using customised fertilizer packages, benefiting from improved agricultural extension support, and harvesting their crops with the machinery that minimises post-harvest losses (USDA Foreign Agricultural Service [FAS] 2023; FAO n.d.).

Nine innovation platforms were established to help smallholder farmers in Ethiopia gain access to quality seeds of climate-smart and heat-tolerant varieties of wheat,

grown under both rainfed and irrigated conditions (*The Brussels Times* 2021).[3,4] Membership of the platforms included farmers' representatives, researchers, civil society organisations, local organisations (including women and youth groups), extension system agents, production input suppliers, processors, seed producers, financial institutions, NGOs, state agricultural officers and local policy makers). Members of the innovation platforms were trained in good agricultural practices, including land preparation, planting, fertilizer application, amount and frequency of irrigation application, weed control, disease and pest management, harvesting, and post-harvest management. In addition, farmers were trained on low-cost irrigation techniques such as the furrow-irrigated raised bed (IITA n.d.), a method of limiting water wastage.

A Theory of Change diagram (Okoruwa *et al.* 2023) was developed to understand the mechanisms by which change came about and whether objectives were met. However, while the theory of change includes a framework for intervention and results, it fails to estimate the long-term and sustainable impact of programme implementation. It would be an asset if the TAAT programme were to include some analysis of the potential sustainability of its interventions *after* implementation, based, for example, on the involvement of partners with an interest and ability to support them through the prospect of continued financial returns and/or coherence with public policies.

The TAAT partnership arrangement in Ethiopia accorded direct contact, technical assistance, and training of farmers to NARS. This had the advantage of making early generation seeds from NARS available to farmer co-operatives and seed companies at the innovation platform sites so that distribution was as wide as possible, in line with the government's objectives.

At the same time, TAAT attempted to support links along the supply chain and in markets that increased employment opportunities in the countryside, particularly for women and youth. Other members of the TAAT Wheat Compact included seed producers, breeders, fertilizer and chemical providers, extension services, processors and millers, and financial institutions. Efforts in Ethiopia captured development elements that include:

- technology validation and demonstration prior to roll-out;
- training and capacity building of farmers and actors along the value chain in wheat and seed production, entrepreneurship, product value addition, and farm machinery operation and maintenance;

[3] The information in this section is largely drawn from ICARDA's own analysis of the results of the programme, available at Okoruwa *et al.* (2023).

[4] "... the Government of Ethiopia has embarked on its goal to achieve wheat self-sufficiency within a period of 3-5 years by expanding production in the irrigable lowland areas ... Ethiopia has a potential to cultivate an additional 3.5 million ha of irrigable land in the Awash, Shebele, and Omo basins. Irrigation-based wheat cultivation piloted in the lowland areas of the country is now being replicated and expanded to the highland areas." (*The Brussels Times* 2021)

- specific training in good agricultural practices – land preparation, planting, fertilizer use, irrigation techniques, weed and pest control, harvesting, and post-harvest storage; and
- demonstration of technology packages combined with seed delivery through the public and the private sector and community collaboration in scaling efforts.

With the continued support of the Ethiopian government for expanding the area under wheat cultivation and the introduction of productivity-enhancing technologies, domestic production of wheat increased consistently over several years.

Since the launching of TAAT in 2018, the programme has distributed more than 136,211 tonnes of heat-tolerant certified seeds through its participants in seven countries in Africa. In Ethiopia alone, the TAAT Wheat Compact distributed 34,166 tonnes of certified seeds of heat-tolerant wheat varieties for cultivation under irrigated lowland conditions. The country's irrigated wheat area expanded from less than 5,000 hectares in 2018–19, to 20,000 hectares in 2019–20, 0.19 million hectares in 2020–21, and 0.40 million hectares in 2021–22. Wheat production on irrigated land rose from about 22,000 tonnes in 2018–19 to 88,000 tonnes in 2019–20 and finally 1.6 million tonnes in 2021–22. The average productivity of irrigated wheat rose from 2 tonnes per hectare to 4.4 tonnes per hectare in 2022, 50 per cent higher than the average productivity of rain-fed wheat. The 2021–22 combined wheat production from irrigated (1.6 million) and rain-fed (5.4 million) systems reached 7.0 million tonnes, generating a revenue of about USD 1.75 billion (Okoruwa *et al.* 2023) (Figure 8).

According to Minister Girma Amente, the Ethiopian government, motivated and encouraged by these recent achievements, aims to expand its irrigated wheat area, and that the Government is "scaling up the experience we gained from wheat to

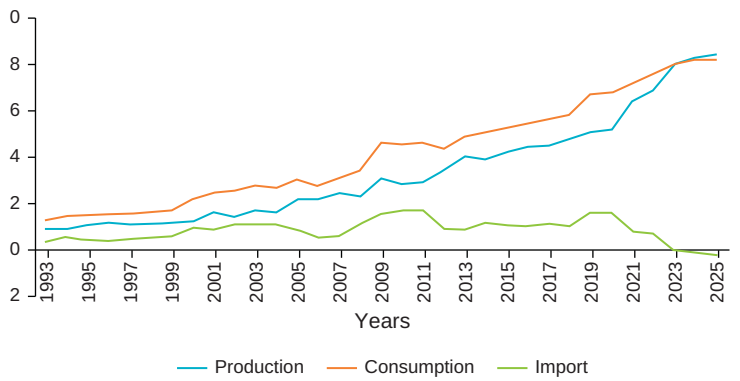

Figure 8 *Trends of wheat production, imports, and consumption with a projection for self-sufficiency and net exporter by 2025, 1993–2025, Ethiopia* in million tonnes
Source: Okoruwa *et al.* (2023).

other crops" (Fana Broadcasting Corporate 2023). The resulting change in output has been dramatic in terms of improving productivity and production of individual small-scale farms. Women have become an integrated part of the value chain, actively encouraged by training to make use of rural advisory services and to work on grain production, seed production, and value addition. Women hold nearly 50,000 jobs (44 per cent) of the 0.11 million created in the TAAT Wheat Compact.

Wheat in Sudan

The population of almost 50 million Sudanese consumes around 65 kg of wheat per person per year, consumption that has historically been dependent on imports. In 2022, Sudan imported wheat valued at USD 1 billion (Milling Middle East and Africa 2023). With rising international grain prices and a falling Sudanese currency, this level and cost of wheat imports is unsustainable. Yet, as the population increases and demand for wheat products rises, national supplies must be found to achieve lasting wheat self-sufficiency and strive for exports to the international market.

In the 2019–20 agricultural year, the TAAT Wheat Compact brought together all the key actors in Sudan's wheat sub-sector to tackle logistics and knowledge management and to enable the implementation of Innovation Platforms (IPs) as mechanisms for deployment of appropriate technologies to farmers (African Development Bank 2023c). A strenuous effort on education and training was made throughout the wheat-growing irrigated areas in the southern part of the country. In that harvest year, Sudan reached almost 50 per cent of its needs through the expansion of national production areas.

> The Wheat Compact achieved this by working with 12 private seed companies and eight farmer community-based seed producers within eight innovation platforms. This led to the production of 65,000 tonnes of certified seed by 2020 as compared to less than 5,000 tonnes of certified seeds before 2018. The Government of Sudan developed a national plan to expand domestic wheat production with the target to achieve 100 per cent self-sufficiency by 2025–26 with support from the African Development Bank. (ICARDA 2020)

In 2014–15, the wheat production area in Sudan was 224,700 hectares at a productivity level of 2.1 tonnes per hectare producing 472,000 tonnes, a self-sufficiency ratio of 28 per cent. Since 2018, wheat yields rose from 2.1 tonnes per hectare to 3.6 tonnes per hectare in 2020–21 in the areas covered by the TAAT interventions. The wheat production area in Sudan significantly increased from 0.20 million hectares in 2017–18, 0.29 million hectares in 2018–19, 0.32 hectares in 2019–20 to 0.38 million hectares in 2020–21. Correspondingly, production rose from 0.47 million tonnes in 2017–18, to 0.90 million tonnes in 2018–19, and then to 1.35 million tonnes in 2020–21. This is the highest level of wheat production ever in the history of Sudan, attaining a wheat self-sufficiency ratio of almost 50 per cent (Figure 9) (African Development Bank 2023c).

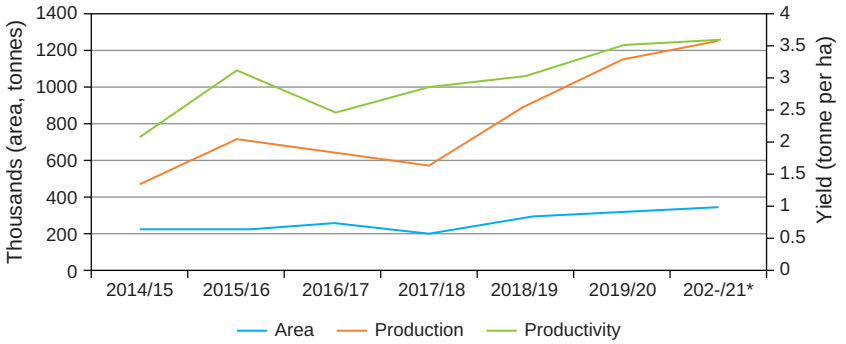

Figure 9 *Trends of wheat by area, production, and productivity, Sudan, 2017–25* in thousand hectares, thousand tonnes, and tonnes per hectare
Note: *Projection
Source: ICARDA (2020).

Average national wheat productivity reached 3.6 tonnes per hectare, whilst the TAAT Innovation Platform intervention sites produced a yield of 3.8 tonnes per hectare. The achievements were due to strong partnerships, support and dedication from all stakeholders, particularly farming communities themselves. Around 39,000 farmers (42 per cent youth and women) directly benefited from the TAAT Wheat Compact's interventions, plus tens of thousands more smallholder farmers gained access to certified seeds of improved heat-tolerant varieties, as well as to field days and travelling workshops. About 76,000 (42 per cent for youth and women) additional jobs have been created by the TAAT Wheat Compact in wheat farming and associated support services.

While we cannot directly attribute this major achievement to TAAT, there can be no doubt that the TAAT Wheat Compact played a significant role in bringing about this

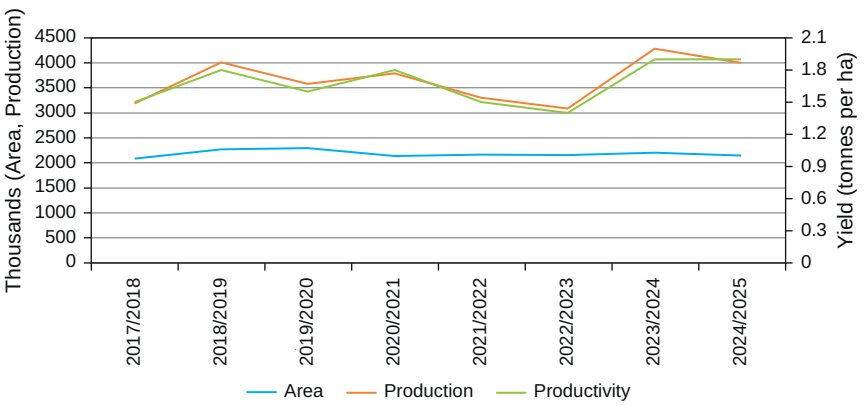

Figure 10 *Trends of maize by area, production, and productivity, Kenya, 2017–25* in thousand hectares, thousand tonnes, and tonnes per hectare
Source: United States Department of Agriculture (USDA) (various years).

change (Agence Ecofin 2023). Indeed, the TAAT Wheat Compact, working closely with the Sudanese Ministry of Agriculture and local seed companies, facilitated the large-scale multiplication of TAAT's certified heat-tolerant wheat seeds. These climate-resilient varieties were chosen based on their adaptability to the country's agroecological conditions and ability to perform in high-temperature regions.

Maize in Western Kenya

Maize is the main staple food in Kenya, with the country producing about 3 million tonnes per year. Average yields are 2.25 tonnes per hectare, higher than the continental average, but according to the Kenya Agricultural and Livestock Research Organization (KALRO), still only 50 per cent of the country's targeted potential (KALRO n.d.). The TAAT programme's operations in Kenya started in August 2019 through engagement by the TAAT Maize Compact. This compact is co-led by the African Agricultural Technology Foundation (AATF) and IITA, and its objective is to "deploy and promote high-yielding, elite, climate-smart maize varieties and accompanying technologies to increase productivity and improve household income" (TAAT 2020). Under the initiative, the compact provided varieties of improved hybrid maize and training in fertilizer use, cultivation, pest and weed management, post-harvest protocols, marketing, mechanisation, and good agricultural practices.

The Maize Compact built upon pre-existing relations to establish a coalition of seed companies, government agencies, agro-dealers, and farmers. With the support of NARS, every partner had a specific role in the roll-out of new maize varieties and accompanying technologies. Prior to seed distribution, quality standards of the seeds were authenticated by the national agency responsible for seed quality control and certification, the Kenya Plant Health Inspectorate Service. Post-harvest storage included extensive training in using hermetically sealed bags to control grain storage pests, including the Purdue Improved Crop Storage (PICS) system (Foy and Wafula 2016), distributed by agro-dealers and preferred by millers.

Forming strategic partnerships with private seed enterprises was essential to this scaling effort focussed on the adoption of recently released drought-tolerant maize varieties. Ten seed companies in Kenya were contracted to produce and distribute over 8,000 tonnes of certified seeds of TEGO, a drought-tolerant maize. To raise awareness within farming communities, the outreach campaign consisted of 2,301 demonstration plots and 508 field days. Also, 15 radio broadcasts and two road shows were conducted. TAAT also leveraged CGIAR to distribute and promote additional climate-smart varieties.

This overall outreach effort resulted in the distribution of 8,185 tonnes of climate-smart hybrid maize seeds to over 0.82 million smallholder farmers, who cultivated approximately 0.33 million hectares of land, resulting in technology delivery at

scale. Private sector participation ensured that the best seed varieties and accompanying fertilizer and pest control products were delivered to farmers through well informed agro-dealer networks.

Farmers who cultivated the drought-tolerant TEGO variety WE 1101 on 0.33 million hectares achieved a bumper harvest with a total production of 1.44 million tonnes of maize grain. Farmers increased their maize yields by 120 per cent to 4.4 tonnes per hectare, while yields of farmers with traditional varieties rarely exceed 2 tonnes per hectare.

The TAAT Maize Compact's engagement with a milling company in Nakuru County demonstrates the potential benefits of working with agro-processors to develop markets further. This miller brought onboard its own out-grower network consisting of 12 farmers' groups. The miller also arranged for payment of out-growers through the electronic banking network M-PESA, allowing for instant payment upon delivery. Through this initiative, Food Chain Millers Ltd has maintained a pool of over 2,400 smallholder farmers who supply them with maize grain annually through formal contractual agreements. Food Chain Millers purchased about 4,320 tonnes of maize grain in 2019–20 and processed 3,600 tonnes and 720 tonnes of maize flour and animal feed, respectively. Food Chain Millers has capitalised on its success in Nakuru and subsequently gained access to the larger Nairobi market, which demonstrates TAAT's role in building up the private sector.

The TAAT Maize Compact and its partners' efforts led to significant change in Western Kenya and demonstrated what can be done through integrated agricultural development efforts that include dissemination of new technologies in combination with farmer training. Farmers were eager to acquire the new varieties once they were known to them, leading to rapid rates of adoption, increased yields, and higher incomes for farmers. All these developments signal Kenyan readiness for an anticipated maize revolution.

Rice in Côte d'Ivoire

Rice is a basic staple in Côte d'Ivoire, cultivated on 57 per cent of the land covered by cereals (National Rice Development Strategy [NRDS] 2024; FAOSTAT 2022) and accounts for 17 per cent of the employment in the agriculture sector. Productivity is variable – from as low as 1.2–3.0 tonnes per hectare for rain-fed rice up to a maximum of 5.5 tonnes per hectare on irrigated lands (Ouédraogo *et al.* 2021). The major challenge to rice production in Côte d'Ivoire is raising productivity levels to overcome its growing dependency upon rice imports, primarily aromatic rice originating from Asia.

The TAAT Rice Compact aimed to increase production based on a sustainable seed system in Côte d'Ivoire that increases rice productivity and builds a resilient food

system protected from future shocks. The Compact was launched in late 2018, relying upon an existing delivery mechanism of partnerships with key stakeholders established under the previous SARD-SC project funded by the African Development Bank from 2012 to 2017. The partners include NARS, private sector enterprises – seed enterprises and millers – farmers' groups, as well as other development partners. It relies upon stakeholder Innovation Platforms to accelerate the production and deployment of the following technologies and innovations: seeds of improved climate-smart varieties; new post-harvest processing technologies; and electronic registration of farmers as a means of offering them better extension and market information services.

The Rice Compact is led by the Africa Rice Centre (AfricaRice), a member of CGIAR and aims to increase the productivity and profitability of the rice sector. At the core of the Rice Compact is the introduction, facilitation, and promotion of three specific rice varietal lines adapted to the conditions of rice cultivation in Côte d'Ivoire: New Rice for Africa (NERICA), Advanced Rice Varieties for Africa (ARICA), and ORYLUX (aromatic) varieties.

The TAAT Rice Compact has deployed five climate-smart varieties (ORYLUX 6, WAB638-1, NERICA L19, JT11, and BOUAKE AM), which were cultivated by farmers, and four hybrids (AR606H, AR708H, AR051H, and AR032H) that were demonstrated to showcase their yield superiority of up to 12 tonnes per hectare.

Rice seeds were multiplied through the mobilisation of private seed enterprises that were supplied with breeder seeds deployed by AfricaRice to produce foundation and certified seeds. Good agricultural practices related to the cultivation of these new climate-smart varieties were delivered. This includes a toolkit that has a decision support tool (Rice Advice), providing farmers with guidelines for specific field conditions through smart phones and other devices. The Rice Compact toolkits also promote the importance of modern threshing machines that can be manufactured locally. The Rice Compact has actively promoted the axial flow thresher with a high threshing capacity and low fuel costs that is relatively easy to manufacture by local artisans. The "ASI" thresher is the result of the cooperation of AfricaRice, SAED (Senegal's extension agency), and Senegalese Agricultural Research Institute – ISRA (Senegal's national research institute), hence the name. When ASI threshing is combined with optimum harvesting time that avoids shattering, grain loss can be reduced by 23 per cent. Thus, harvesting rice at the optimum maturity time ensures very minimum field losses caused by shattering. In addition, the use of the ASI thresher reduces threshing losses as compared to traditional threshing methods.

The TAAT Rice Compact promotes improved community and farm-level parboiling to raise the value of the crop using an eco-friendly stove that is fed by a solar-powered fan and runs on burning of rice husk, an inexpensive and abundant fuel in rice-producing areas. The "Grain quality enhancer, Energy-efficient and durable Material" (GEM)

parboiling technology significantly improves the physical appearance, consumer appreciation, and nutritional quality of milled rice compared to non-parboiled rice (AfricaRice n.d.). Since rural women in Africa traditionally prepare rice, it can provide a pathway to involving women into agribusiness.

The compact supplied an initial 7.4 tonnes of breeder seed free of charge to private seed companies, resulting in the production of 237 tonnes and 300 tonnes of certified seed in 2020 and 2021, respectively. The compact also supplied 12.5 tonnes of breeder seeds, leading to the annual production capacity of 10,350 tonnes of certified seeds from 2022 onwards, which is enough to supply 0.42 million farmers for 0.21 million hectares of rice cultivation.

For the demonstration of the new hybrids, the TAAT Rice Compact distributed 50 kg of four new hybrid crop varieties (AR032H, AR051H, AR606H, and AR708H), which was multiplied to obtain 583.5 kgs of certified seed with yields varying between 5.8 to 10.0 tonnes per hectare. The coalition of seed companies grouped under the umbrella of the Consortium of Seed Enterprises and Millers (COSEM-Riz) facilitated the distribution of seeds certified by the Côte d'Ivoire National Rural Development Agency (ANADER) that guarantees seed quality to farmers, further encouraging them to take up the improved varieties. This is a promising opportunity for seed companies, the national Agency for Rice Development (ADERIZ), and farmers.

The Rice Miller's Union in Côte d'Ivoire entered into service provision partnerships with women processors and rice farmers. The compact upgraded rice mills to improve the quality of domestic rice. The success of this action led the Government of Côte d'Ivoire to upgrade an additional 22 local mills with destoners. This enabled domestic rice to be marketed in supermarkets in Ivoirian urban centres that previously relied upon imported grain.

Results show that with the new varieties and agronomic practices, rice productivity increased from 2.78 tonnes per hectare to 3.4 tonnes per hectare, resulting in increased household income from USD 459 to USD 604 per year and 3,448 direct jobs created for women and youth through engagement with seed systems and in post-harvest activities. Milled rice production for 2023–24 is projected at 1.2 million tonnes, an 11 per cent increase from 2021–22. Milled rice production for 2022–23 reached 1.1 tonnes, a 3 per cent increase from 2021–22. Imports remained at an estimated 1.4 million tonnes, a 16 per cent decrease from the previous season (USDA 2023).

The TAAT interventions have resulted in increased yield and enhanced value by supporting improvements in post-harvest processing activities, particularly for women. Thus, locally polished rice, rice flour for infant feeding, and nutritionally enhanced parboiled rice have been made available to consumers at a quality that matches that of imports.

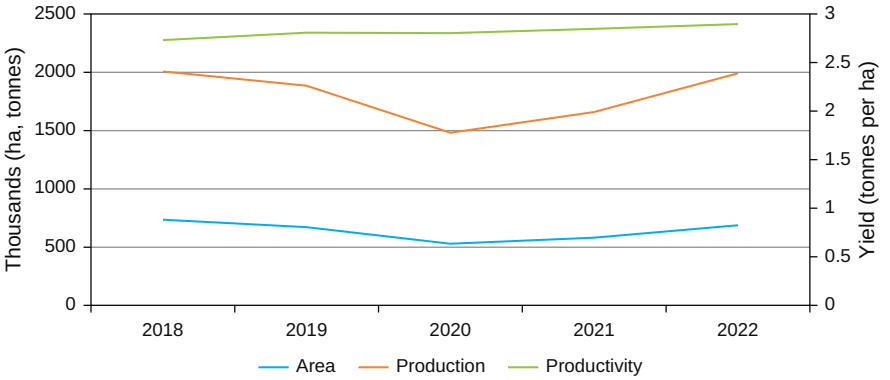

Figure 11 *Trends of rice by area, production, and productivity, Côte d'Ivoire, 2018–22* in thousand hectares, thousand tonnes, and tonnes per hectare
Source: USDA (various years).

So far, the interventions through the TAAT programme have affected close to 30 per cent of rice-growing area nationally. Between 2020 and 2022, the area under rice production increased from 0.53 million hectare to 0.69 million hectares with total rice production increasing from 1.48 million to 1.99 million while paddy yield increased from 2.73 tonnes per hectare to 2.9 tonnes per hectare from 2018 to 2022 (Figure 11).

It is too early to come to any concrete conclusions about the long-term effects of the TAAT rice compact in Côte d'Ivoire because the programme has not yet reached its full potential. Moreover, the negative impact of the Covid-19 pandemic was more lasting than originally anticipated. Nonetheless, the initial results from TAAT indicate measurable positive outcomes.

Lessons from TAAT: Implications for Africa and Global Agriculture

TAAT has shown the power of linking global agricultural research centres, national and regional agricultural research centres, and agricultural value chain players, including seed and fertilizer companies and agribusinesses, to deliver agricultural technologies for millions of farmers. A new way of working has emerged with TAAT in which the focus is no longer on piloting agricultural interventions at a small scale, but rather, on the scaling up of technologies to reach millions of farmers. While research is critical for agricultural transformation, unless products of research reach farmers, food security goals will remain elusive.

The use of commodity-based compacts holds the global, national, and regional agricultural research centres accountable for getting their technologies out to millions of farmers.

As demonstrated in the case studies and as part of its structural approach, TAAT is changing the rather slow conventional approach of testing agricultural technologies

in national contexts and approving their release in other countries, within the same agro-ecological zone, following several years of additional tests by other countries. Technologies developed and appropriate for a given agro-ecological zone could take decades before they were available for release in neighbouring countries. Yet, pests, diseases, and other biotic and abiotic stresses do not respect national boundaries but operate within similar agro-ecological zones. Through TAAT, technologies that have been tested in a given agro-ecological zone within a country are being released in other countries with similar agro-ecological zones.

The Technology Without Borders approach has allowed faster release of technologies for millions of farmers, more rapid scaling up of agricultural interventions, and reforms in technology testing and release systems in Africa. These reforms of the technology-release protocols now allow and enable seed companies to establish and achieve economies of scale, as they can now release crop varieties horizontally across countries with similar agro-ecological zones, without needing to perform repeated and expensive tests that may delay the release of the technologies for decades.

Two good examples of the Technology Without Borders approach are the spread of heat-tolerant wheat varieties across lowland agro-ecologies of Ethiopia, Sudan, and Nigeria by the TAAT Wheat Compact and the sale by seed companies of certified seeds of market-preferred lowland irrigated rice varieties across West Africa. Seed companies can now test and release technologies across agro-ecological zones with implications for economies of scale for seed companies. For new seed technologies to reach farmers more rapidly across Africa, TAAT has provided support mechanisms and leveraged its network to establish an effective seed distribution network that extends across multiple countries.

TAAT is also shaping agricultural value chain projects in Africa. Between 2018 and 2023, TAAT Compacts participated in the design of over 50 agricultural value chain projects, totalling more than USD 2 billion in financing by the African Development Bank, across 40 African countries, leveraging a total of USD 452 million in co-financing by the World Bank, International Fund for Agricultural Development, Islamic Development Bank, and the Global Environment Facility, among others.

Given the successes achieved to date, in July 2022, the board of the African Development Bank approved an additional USD 27.41 million to implement Phase II of the TAAT initiative. The goal is to increase farm households' productivity and incomes by giving them access to climate-resilient technologies in 36 low-income African countries by 2025.

This is already yielding significant results. The African Emergency Food Production Facility (AEFPF) benefited directly from TAAT Phase II, with the Regional Technology Delivery Infrastructure facilitating production and delivery of 0.35 million metric tonnes of certified seeds of wheat, maize, rice, and soybeans. This

was followed by the delivery of 1.3 million metric tonnes of fertilizer to over 6.6 million farmers within 18 months of the Russia-Ukraine war. An additional 8.3 million metric tonnes of food production has taken place under AEFPF. The initiative has helped TAAT support farmers with seeds and fertilizers.

Conclusions

The Feed Africa strategy of the African Development Bank is based on the premise that, as a continent, Africa should not spend scarce resources importing food when it holds 65 per cent of the world's uncultivated arable land and when 60 per cent of its population is engaged in agricultural work. In 2017, African countries together spent USD 64.5 billion on food imports, a sum that is not only unnecessary but also unsustainable (Africa Development Bank Group 2019). Despite the rapidly growing population on the continent and the impact of two unforeseen disruptions to developmental planning – the Covid-19 pandemic and the Russia-Ukraine conflict – the food import bill has shown a declining trend, estimated by Food and Agriculture Organization to have been USD 61.6 billion in 2023 (FAO 2023b).

At this stage, we argue that the marked change in productivity and production observed in selected countries is clearly linked to the Technologies for African Agricultural Transformation (TAAT) programme though further careful data collection and analysis will be required to fully evaluate the extent of the impact of TAAT.

The success of the TAAT programme has also encouraged African leaders to make a big push, driven by focussed political will, to achieve food security. At Feed Africa's Dakar 2 Summit in January 2023, 34 African heads of state gathered to take action to scale up agricultural interventions to achieve food security, and indeed food sovereignty. Food and agricultural delivery compacts were developed for countries, built on the technological innovations from TAAT, to help ensure that Africa can achieve food security and food sovereignty within five years. The African Development Bank has so far helped mobilise USD 72 billion towards the implementation of the food and agricultural delivery compacts.

By replicating the TAAT approach in more countries, in more contexts, and with more agricultural products, it is reasonable to conclude based on the case studies presented in this paper that the goal of African food security can be attained. For that to happen, we believe, African policy makers, their development partners, and private sector stakeholders will have to continue to provide substantial and long-term support to the TAAT initiative.

References

Adesina, Akinwumi A. (2023), "From Dakar 2 to Des Moines," speech, African Development Bank Group, Norman Borlaug International Dialogue, World Food Prize 2023, Des Moines,

available at https://www.afdb.org/en/news-and-events/speeches/dakar-2-des-moines-speech-delivered-dr-akinwumi-adesina-president-african-development-bank-group-norman-borlaug-international-dialogue-world-food-prize-2023-des-moines-iowa-usa-65380, viewed on November 11, 2024.

African Development Bank (n.d.), "Mission and Strategy," available at https://www.afdb.org/en/about/mission-and-strategy, viewed on August 26, 2024.

African Development Bank (2016a), "The High 5 (2013–2022) for Transforming Africa – Pour Transformer l'Afrique," available at https://www.afdb.org/en/high5s, viewed on August 26, 2024.

African Development Bank (2016b), "The High 5: Feed Africa," available at https://www.afdb.org/en/the-high-5/feed-africa, viewed on August 26, 2024.

African Development Bank (2016c), "The High 5: Light Up and Power Africa," available at https://www.afdb.org/en/the-high-5/light-up-and-power-africa-%E2%80%93-a-new-deal-on-energy-for-africa, viewed on August 26, 2024.

African Development Bank (2016d), "The High 5: Industrialise Africa," available at https://www.afdb.org/en/the-high-5/industrialize-africa, viewed on August 26, 2024.

African Development Bank (2016e), "The High 5: Integrate Africa," available at https://www.afdb.org/en/the-high-5/integrate-africa, viewed on August 26, 2024.

African Development Bank (2016f), "The High 5: Improve the Quality of Life for the People of Africa," available at https://www.afdb.org/en/the-high-5/improve-the-quality-of-life-for-the-people-of-africa, viewed on August 26, 2024.

Africa Development Bank Group (2019), "Feed Africa," Communication and External Relations Department, available at https://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Brochure_Feed_Africa_-En.pdf, viewed on August 26, 2024.

African Development Bank (2022), *Multinational Technologies for African Agricultural Transformation (TAAT) Phase II AfDB Project Appraisal Report*, Jul 15, available at https://www.afdb.org/en/documents/multinational-technologies-african-agricultural-transformation-taat-phase-ii-project-appraisal-report, viewed on November 11, 2024.

African Development Bank (2023b), "Q & A: The Dakar Summit," available at https://www.afdb.org/en/dakar-2-summit-feed-africa-food-sovereignty-and-resilience/q-and-dakar-2-summit, viewed on August 26, 2024.

African Development Bank (2023c), "Scaling Up Heat Tolerant Wheat Varieties in Sudan," available at https://www.afdb.org/en/dakar-2-summit-feed-africa-food-sovereignty-and-resilience/about-dakar-2-summit/scaling-heat-tolerant-wheat-varieties-sudan, viewed on August 26, 2024.

AfricaRice (n.d.), "GEM Rice Parboiler," available at https://www.africarice.org/gem-rice-parboiler, viewed on November 17, 2024.

Agence Ecofin (2023), "Soudan: Les Importations de blé Pourraient Atteindre 3,5 Millions de Tonnes en 2023 avec le Déficit de la Production" ["Sudan: Wheat Imports Could Reach 3.5 Million Tonnes in 2023 with Production Shortfall"], available at https://www.agenceecofin.com/cereales/3003-106990-soudan-les-importations-de-ble-pourraient-atteindre-3-5-millions-de-tonnes-en-2023-avec-le-deficit-de-la-production, viewed on August 26, 2024.

Alliance for a Green Revolution in Africa (AGRA) (2021), *Annual Report*, available at https://agra.org/wp-content/uploads/2022/07/AGRA-Annual-Report-2021.pdf, viewed on November 17, 2024.

Amankwah, A., Gourlay, S., and Zezza, A. (2021), "Agriculture as a Buffer in COVID-19 Crisis: Evidence from Five Sub-Saharan African Countries," available at https://blogs.worldbank.org/opendata/agriculture-buffer-covid-19-crisis-evidence-five-sub-saharan-african-countries, viewed on August 26, 2024.

Baffes, John, and Koh, Wee Chian (2023), "Fertilizer Prices Ease but Affordability and Availability Issues Linger," World Bank Blogs, Jan 5, available at https://blogs.worldbank.org/en/opendata/fertilizer-prices-ease-affordability-and-availability-issues-linger, viewed on August 26, 2024.

Brzeziński, Bartosz (2022), "'Time's Up': Critics Call for End to Western-funded Food Program in Africa," Sep 13, available at https://www.politico.eu/article/critic-call-end-western-fund-food-program-africa/, viewed on August 19, 2024.

Bolhuis, M., and Kovacs, P. (2022), "Africa's Inflation Among Region's Most Urgent Challenges," International Monetary Fund (IMF) blog, available at https://www.imf.org/en/Blogs/Articles/2022/10/20/africas-inflation-among-regions-most-urgent-challenges, viewed on August 26, 2024.

Coalition for Africa Rice Development (2024), "National Rice Development Strategy for the Cote d'Ivoire Rice Sector – Progress Monitoring," available at https://riceforafrica.net/country_site/cote-divoire/, viewed on November 11, 2024.

Fana Broadcasting Corporate (2023), "Ethiopia Is Producing Surplus Wheat for Export After Drive to Boost Output: Report," Sep 9, available at https://www.fanabc.com/english/ethiopia-is-producing-surplus-wheat-for-export-after-drive-to-boost-output-report50853-2/, viewed on August 26, 2024.

Food and Agriculture Organization (FAO) (n.d.), "FAOSTAT – Data," available at https://www.fao.org/faostat/en/#data/, viewed on August 26, 2024.

FAO (2021), "Assessing the Impact of the COVID-19 Pandemic on Agriculture, Food Security and Nutrition in Africa," available at https://openknowledge.fao.org/server/api/core/bitstreams/3ead2305-fa85-4ff8-85f2-496d62c2c003/content, viewed on August 26, 2024.

FAO (2021), FAOSTAT Value of Agricultural Production Database, available at http://www.fao.org/faostat/en/#data/QV, viewed on August 26, 2024.

FAO (2023a), "Suite of Food Security Indicators in FAOSTAT," Rome, available at https://www.fao.org/faostat/en/#data/FS, viewed on August 19, 2024.

FAO (2023b), "Food Outlook: Biennial Report on Global Food Markets," FAO, Rome, available at https://doi.org/10.4060/cc8589en, viewed on August 26, 2024.

FAO, African Union Commission (AUC), United Nations Economic Commission for Africa (ECA), and the World Food Programme (WFP) (2023), "Africa – Regional Overview of Food Security and Nutrition 2023: Statistics and Trends," FAO, Accra, available at https://doi.org/10.4060/cc8743en, viewed on August 26, 2024.

FAO, Famine Early Warning Systems Network (FEWS NET), and World Food Programme (WFP) (2022), "West and Central Africa Market Situation in 2021 and 2022 Outlooks," available at

https://reliefweb.int/report/burkina-faso/west-and-central-africa-market-situation-2021-and-2022-outlooks-february-2022, viewed on November 15, 2024.

Foy, C., and Wafula, M. (2016), "Scaling Up of Hermetic Bag Technology (Pics) in Kenya: Review of Successful Scaling of Agricultural Technologies," United States Agency for International Development, Washington, D. C., available at https://agrilinks.org/sites/default/files/resource/files/BFS%20Scaling%20Review%20-%20Kenya%20Report%20REVISED%20508%2011-16-16.pdf, viewed August 26, 2024.

Hebebrand, C., and Glauber, J. (2023), "The Russia-Ukraine War After a Year: Impacts on Fertilizer Production, Prices, and Trade Flows," International Food Policy Research Institute (IFPRI), available at https://www.ifpri.org/blog/russia-ukraine-war-after-year-impacts-fertilizer-production-prices-and-trade-flows, viewed on August 26, 2024.

Independent Development Evaluation (2023), "Project Cluster Evaluation of the Technologies for African Agricultural Transformation (TAAT) Program – Phase I," African Development Bank, May, available at https://idev.afdb.org/sites/default/files/documents/files/TAAT%20I%20Project%20Cluster%20Evaluation_Summary%20Report_0.pdf, viewed on August 26, 2024.

International Center for Agricultural Research in the Dry Areas (ICARDA) (2020), "Bumper Harvests and Record Wheat Production Propelling Sudan Towards Wheat Self-sufficiency," Working Paper 2020/001 available at https://www.afdb.org/sites/default/files/2020/10/08/icarda_sudans_bumper_harvest_final.pdf, viewed on August 26, 2024.

International Institute of Tropical Agriculture (IITA) (n.d.), "About the Product Platform for Agricultural Solutions," available at https://propas.iita.org/en/solutions/furrow-irrigated-raised-bed-wheat-production/86/details/, viewed on August 26, 2024.

IITA (n.d.), "Mission and Vision," available at https://www.iita.org/about-iita/mission-and-vision/, viewed on August 26, 2024.

International Monetary Fund (IMF) (2024a), "Global Price of Energy Index [PNRGINDEXM]", FRED, Federal Reserve Bank of St. Louis, available at https://fred.stlouisfed.org/series/PNRGINDEXM, viewed on January 8, 2024.

IMF (2024b), "Global Price of Food Index [PFOODINDEXM]," FRED, Federal Reserve Bank of St. Louis, available at https://fred.stlouisfed.org/series/PFOODINDEXM, viewed on January 8, 2024.

Kenya Agricultural and Livestock Research Organization (KALRO) (n.d.), "Maize," available at https://www.kalro.org/Maize/, viewed on August 26, 2024.

Milling Middle East and Africa (2023), "Sudan to Import 3.5 Million Tons of Wheat in 2023 to Meet Demand as Local Production Contracts: FAO," available at https://www.millingmea.com/sudan-to-import-3-5-million-tons-of-wheat-in-2023-to-meet-demand-as-local-production-contracts-fao/, viewed on August 26, 2024.

Okoruwa, V., Zozo, R., Kago, K., Opaluwah, A., Lewis, S., Bishaw, Z., Gizaw, S., and Akem, C. (2023), "Agricultural Transformation Through Wheat: An Outcome Evaluation of TAAT Wheat Compact's Interventions in Ethiopia," TAAT Monitoring, Evaluation and Learning (MEL) working document no. 006, available at https://doi.org/10.21955/gatesopenres.1117158.1, viewed on August 26, 2024.

OECD-FAO (2021), "OECD-FAO Agricultural Outlook," OECD Agriculture statistics (database), available at http://dx.doi.org/10.1787/agr-outl-data-en, viewed on August 26, 2024.

Ouédraogo, S. A., Bockel, L., Arouna, A., Fatognon, I., and Gopal, P. (2021), *Analyse de la Chaine de Valeur riz en Côte d'Ivoire: Optimiser l'impact Socio-économique et Environnemental d'un Scénario d'autosuffisance à l'horizon 2030* [*Analysis of the Rice Value Chain in Ivory Coast: Optimizing the Socio-economic and Environmental Impact of a Self-sufficiency Scenario by 2030*], FAO, Accra, available at https://doi.org/10.4060/cb1506fr, viewed on August 26, 2024.

Partner Africa, Ethical Trading Initiative, Mott MacDonald, and UK Aid (n.d.), "The Impact of Covid-19 on Agricultural Supply Chains in Africa," London, available at https://www.ethicaltrade.org/sites/default/files/shared_resources/The-Impact-of-Covid-19-on-Agricultural-Supply-Chains-in-Africa.pdf, viewed on August 26, 2024.

Ritchie, H. (2022), "Increasing Agricultural Productivity Across Sub-Saharan Africa Is One of the Most Important Problems This Century," Our World in Data, available at https://ourworldindata.org/africa-yields-problem, viewed on August 26, 2024.

Siegal, Kim, Usmani, Faraz, and Strull, Rebecca (2022), "TAAT Clearinghouse Evaluation," Mathematica, Bill & Melinda Gates Foundation.

Sigei, Julius (2022), "AGRA's Green Revolution Has Failed, Critics Say," *The Elephant*, Jan 22, available at https://www.theelephant.info/analysis/2022/01/22/agras-green-revolution-has-failed-critics-say/, viewed on August 26, 2024.

TAAT (2020), "Deployment of Maize Technologies in Western Kenya: An Outcome Case Study Report," TAAT: Benin City, available at https://taat-africa.org/wp-content/uploads/2020/11/Deployment-of-Maize-Technologies-in-Western-Kenya-An-Outcome-Case-study-report.pdf, viewed August 26, 2024.

TAAT (2023a), "Breaking Down the Barriers to Food Security: A Closer Look at TAAT's Role in Combating Hunger and Malnutrition in Sierra Leone," available at https://taat-africa.org/news/breaking-down-the-barriers-to-food-security-a-closer-look-at-taats-role-in-combating-hunger-and-malnutrition-in-sierra-leone/, viewed on August 26, 2024.

TAAT (2023b), "TAAT Advocates Innovative Climate-smart Farming Solutions at ACAT," available at https://taat-africa.org/news/taat-highlights-innovative-climate-smart-farming-solutions-at-acat/, viewed on August 26, 2024.

TAAT Africa (n.d.), "About Us," Ibadan, available at https://taat-africa.org/about-us/, viewed on August 26, 2024.

TAAT Clearinghouse (n.d.), "E-catalogs," available at https://e-catalogs.taat-africa.org/, viewed on August 26, 2024.

TheGlobalEconomy.com (n.d.), "Cereal Crop Yield by Hectar - Country Rankings," available at https://www.theglobaleconomy.com/rankings/cereal_yield/European-union/, viewed on August 26, 2024.

The Brussels Times (2021), "Ethiopia to Boost Irrigated Wheat Production," available at https://www.brusselstimes.com/170354/ethiopia-to-boost-irrigated-wheat-production, viewed on August 26, 2024.

Trading Economics (n.d.), "Wheat," available at https://tradingeconomics.com/commodity/wheat, viewed on August 26, 2024.

United Nations Department of Economic and Social Affairs (UN DESA), Population Division (2022), "World Population Prospects: The 2022 Revision (Medium-fertility variant)," available at https://www.worldometers.info/world-population/africa-population/, viewed on August 26, 2024.

United States Department of Agriculture (USDA) (2023), "Côte d'Ivoire: Grain and Feed Annual," USDA, Washington, available at https://fas.usda.gov/data/cote-divoire-grain-and-feed-annual, viewed August 26, 2024.

USDA Economic Research Service (USDA ERS) (2023), International Agricultural Productivity, available at https://www.ers.usda.gov/data-products/international-agricultural-productivity/, viewed on 26 August 2024

USDA Foreign Agricultural Service (USDA FAS) (2023), "Grain and Feed Annual: Ethiopia," Washington, D. C., available at https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain%20and%20Feed%20Annual_Addis%20Ababa_Ethiopia_ET2022-0014.pdf, viewed on August 26, 2024.

Vicedom, S., and Wynberg, R. (2024), "Power and Networks in the Shaping of the Alliance for a Green Revolution in Africa (AGRA)," *Third World Quarterly*, vol. 45, no. 3, pp. 567–88, available at https://www.tandfonline.com/doi/abs/10.1080/01436597.2023.2276820, viewed on August 26, 2024.

Woomer, P. L, Mulei, W. M., and Zozo, R. M. (2021), "New Paradigm in the Delivery of Modernizing Agricultural Technologies Across Africa," in Ahmad, Fiaz, and Sultan, Muhammad (ed.), *Technologies in Agriculture*, IntechOpen, London, available at http://dx.doi.org/10.5772/intechopen.98940, viewed on August 26, 2024.

World Meteorological Organisation (WMO) (2023), "State of the Climate in Africa, 2022," WMO, Geneva, available at https://library.wmo.int/idurl/4/67761, viewed on August 26, 2024.

Date of submission of manuscript: March 30, 2024
Date of acceptance for publication: August 7, 2024