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Science for resilient livelihoods in dry areas

The Future of Wheat Research and Production in Sub-Saharan Africa

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TECHNICAL BRIEF

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Wheat in Sub-Saharan Africa

In the 1960s, Africa's average cereal yield was about 57% of the world average. This average became only 42% and 35% of the world average, respectively, in 1990 and 2017 (FAOSTAT, 2020; World Bank, 2021) – indicating cereal productivity in Africa is far below the rest of the world. However, areas under cereal production have more than doubled since the 1960s (Stewart & Lal, 2018). Partial narrowing of yield gaps could significantly impact local and global food supplies in sub-Saharan Africa (SSA) (Larson *et al.*, 2016), where yield gaps and poverty have been found to be closely correlated (Dzanku *et al.*, 2015; Frija *et al.*, 2020). The demand for cereals in SSA is also expected to more than double by 2050 (Kruseman *et al.*, 2020). Wheat remains one of the most important staples in the continent, and its demand is continuously growing due to the rapid population growth and changes in consumption habits (Baudron *et al.*, 2019; Kruseman *et al.*, 2020; Tadesse *et al.*, 2019). Strategic highlights and guidance for future wheat perspectives and agendas are, however, lacking in most countries. The majority of SSA countries are also characterized by a lack of institutional capacity, and very low investments in agricultural research (Tadesse *et al.*, 2018) and extension services (Mukembo & Craig Edwards, 2015), which in turn will affect the rapidity and effectiveness of wheat technology transfer.

In 2017, SSA countries produced a total of 7.5 million tons of wheat, on a total area of 2.9 million ha, accounting for 40% and 1.4% of the wheat production in Africa and at global levels, respectively (FAO, 2017, Tadesse *et al.*, 2019). Growing wheat demand in SSA has clear implications on biodiversity, land and water resources (Jacques & Jacques, 2012; Kihara *et al.*, 2020; Rattalino Edreira *et al.*, 2018). Under a context of climate change and land degradation, wheat areas are expanding not only in regions traditionally known as major wheat growers, but also in new and diverse regions and agroecologies. However, this expansion is not necessarily matched with the available appropriate technical packages and wheat varieties (Tadesse *et al.*, 2019). Wheat varieties and management practices that are well-adapted to each region/agroecology and the associated agronomic, water, and other natural resource management packages are needed to avoid resource degradation (Jacques & Jacques, 2012; Kihara *et al.*, 2020) and future domestic supply gaps and subsequent reliance on imports. Thus, wheat research and development agendas in Africa need to closely coordinate for better framing an overall strategy for sustainable inclusion of this cereal crop in the existing major African agricultural production systems, and to ensure stability and increases of future wheat yields and supply. The objective of this brief is to summarize the major available findings in terms of wheat foresight in Africa, including the prospects for future genetic, agronomic, seeds and political economy under different climate change and socioeconomic scenarios. We first start with an outlook of historical and future trends of wheat areas, yields, and consumption by 2050, in selected SSA countries (Ethiopia, Kenya, Mozambique, and Nigeria).

Projections of Wheat Production and Demand in SSA

The following outlook of wheat production and consumption are developed based on FAO data (1961 to 2020). This source of data qualified as imprecise and unreliable for the specific case of wheat in SSA, as this is a newly introduced crop for which appropriate disaggregated statistics are still lacking in most cases. This lack of reliability in wheat production statistics is reported in this brief as one of the significant constraints for better understanding of the wheat dynamics in SSA. Nevertheless, given the lack of other data sources, we provide some trend analysis based on available information at FAO datasets. While annual figures need to be read carefully, the overall trend (which we want to analyze here) would provide a good estimate of future dynamics.

Figure 1 shows that wheat areas and consumption are expected to rapidly increase in the four selected SSA countries. The projections, however, show that this is not the case for wheat yields, which remain highly fluctuating with sometimes decreasing or stagnant trends (Nigeria and Mozambique). This confirms that there is growing demand for wheat cultivation land in SSA, and wheat commodity for consumption. This demand requires additional attention for sustaining wheat yields through appropriate research and development (R&D) investments that can help in overcoming the major sector growth perspectives highlighted in the introduction of this brief.

Available research findings and perspectives

Genetics

Recent studies conducted across the African continent revealed that current wheat production (about 7 million tons annually on 3 million ha in SSA) is only at 10-20% of its potential. It is, however, physically possible and economically profitable for African nations to grow more wheat using high yielding and heat-tolerant varieties, along with improved agronomic packages. Wheat breeding in SSA is generally carried out by national agricultural research institutes and universities, except in South Africa where private breeding companies do play a significant role. Most of the national programs depend on international centers, such as the International Maize and Wheat Improvement Center (CIMMYT) and Intenational center for Agricultural research in the Dry Areas (ICARDA), as sources of elite germplasm, which is received annually through the international nursery trial systems. These elite genotypes are evaluated for adaptation, resistance and agronomic traits across different agroecologies of the countries, using the national or regional variety trial system over 2-3 years (Tadesse *et al.*, 2018). Following the national variety registration/release mechanism of each country, many varieties have been released directly from the CGIAR (CIMMYT and ICARDA). In the last seven years alone, more than 25 wheat varieties of ICARDA origin with high yield potential, heat tolerance, and resistance to rusts have been released by the national programs in SSA.

There has been good progress in achieving expected genetic gains, ranging from 1.3 to 2.3% (Tadesse *et al.*, 2019) from the currently existing and released varieties. However, most of the released varieties did not reach farmers due to lack of seed availability, as the seed production and supply system in most SSA countries is

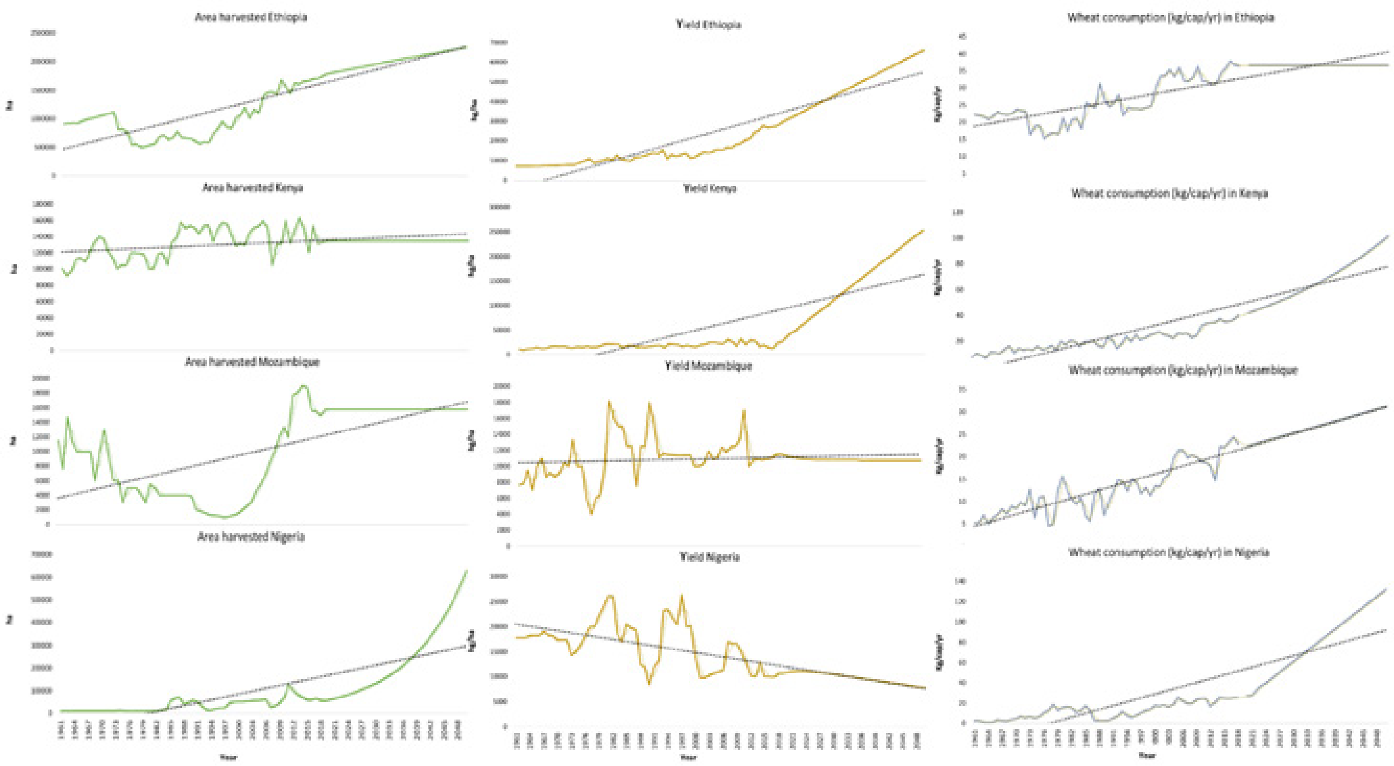

Figure 1. Projections of wheat areas, yields, and consumption in selected SSA countries using the ARIMA method (Box & Jenkins, 1970)

1 The method used for forecasting was ARIMA method (Box, G and Jenkins, G, 1970) based on three steps (model identification, parameter estimation and model checking), The ARIMA procedure of the SPSS 25* time series module allows an automatic calculation and validation of the model, to predict the projection until the chosen date.

very weak. ICARDA, in partnership with the National Agricultural Research and Extension System (NARES) and other stakeholders, has tried to out-scale the heat-tolerant wheat varieties in SSA, particularly Ethiopia, Nigeria and Sudan, through the SARD-SC[2] and TAAT[3] projects supported by the African Development Bank (AfDB). Tremendous success was observed with yield levels of up to 6 tons ha-1 achieved in farmers fields, which in turn resulted in improved farmers' income and livelihoods. In general, further development and deployment of climate-resilient wheat technology packages that combine improved high yielding, disease-resistant and heat-tolerant wheat varieties, and fast-track seed multiplication schemes would be highly required to support the development of wheat in SSA further. It is, however, encouraging that some CGIAR studies are demonstrating SSA farmers' willingness to pay higher prices for enhanced wheat varieties (Teferi *et al.*, 2020).

Agronomy

Improved crop management techniques and site-specific advisories (crop establishment, fertilizer, irrigation, weed management, crop rotation, etc.), along with improved infrastructure, marketing, and policy environments, are key for the success of wheat production in SSA. Crop management is further related to the production costs and market incentives within each country. It is, however, documented that current wheat management and agronomy practices are insufficient and need to be updated while considering local biophysical and socio-economic conditions. Enhanced practices need to be furtherdessiminated through enhanced extension systems and other effective technology transfer and delivery approaches. For cases where wheat is newly introduced, such as Ghana, Mozambique, Nigeria, and some parts of Ethiopia; appropriate cost-effective wheat production packages still need to be tailored and tested through medium- and long-term trials. In their study of cereal intensification in 10 SSA countries using location-specific data, van Ittersum *et al.* (2016) reported that, in addition to closing the yield gaps, it is equally important to consider the other complex and uncertain components of intensification (i.e. increasing cropping intensity, sustainable expansion of irrigated areas, etc.) if the goal of enhancing wheat and cereal production performances in SSA is to be achieved sustainably.

The authors also reported that even if we achieve the best agronomic and yield performances, existing cereal production will not meet SSA's growing demand. With declining soil fertility, limited or no use of fertilizer, and cereal monocropping system, it is important to adopt legume-based rotations and crop-demand-based nutrient management for sustainable intensification of predominantly cereal systems. Given the expected marginalization of legume crops in the rotation system, and their slow growth in terms of area and production, it is anticipated that SSA would have an increasing fertilizer demand, mainly to compensate for depleted soil nutrients and continued degradation (Watts, n.d.). Pesticide use is also expected to increase, as monocropping makes fields prone to pests and diseases. Additional fertilizers and pesticides use add to the countries' import costs and burden national economies. At the ecosystem level – they lead to groundwater pollution, the development of increasingly resilient pests, and other issues. Given the relatively good precipitation (between 350 and 600 mm) in some areas in SSA, supplemental instead of full irrigation would also be convenient to consider, as it would help achieve high yield levels at reduced quantities of irrigation water – thereby enhancing the sustainable use of irrigation water.

Crop Rotation in Wheat-Based Systems

Appropriate legume-cereal rotations would enhance soil fertility, yields, and other agronomic parameters in arid areas (Yigezu *et al.*, 2019) of SSA. Analysis of the general trend in African agriculture reveals that the area under both cereals and pulses has been expanding, at a different speed, over the years. The area under all cereals increased from 57 million ha, in 1961, to 124 million ha in 2018. During the same period, the area under pulses increased from 7 million ha to 25 million ha – showing that though the share of cereals in total area increased from 11% to 17%, pulses still constitute less than a fifth of the total area (FAOStat, 2020). This also refers to a lack of appropriate cereal-legume rotations, which is expected to continue if market incentives for legumes does not become more favorable. The current low share of pulses in total acreage is attributed to few factors: 1) In some African countries, ill-conceived food security agendas provided incentives for cereal intensification, which inadvertently promoted cereal monocropping

2 Support to Agricultural Research for Development of Strategic Crops in Africa (http://sard-sc.org/) funded by the AfDB in 2013-2017.
3 The Technologies for African Agricultural Transformation (TAAT) programme. The program is funded by the AfDB, and aims at helping the continent fulfil its enormous potential in the sector by employing high-impact technologies to boost output.

(Egypt, Morocco and Tunisia are examples); 2) Pulses generally have lower yields, and adoption of improved varieties of pulses in Africa is at a much lower level than that of cereals (Walker and Alwang, 2016); 3) Wheat is easy to mechanize from planting all the way to harvesting, while legumes are largely harvested manually. As a result, in the face of rising agricultural wage rates, pulses are deemed less profitable. However, pulses would be still considered as a profitable option given their relatively higher (but more variable) prices, their capacity to produce high protein yield without nitrogen fertilization and improved nutrient utilization and due to the benefit of legume-based rotations in breaking disease/pest cycles. Hence the associated higher yields of the subsequent cereal crop (rotated with legumes) need to be considered in profitability analyses which consider the whole rotation period. Clear economic advantage to legume-based rotation would then be documented by capturing the yield gains and possible reduction of fertilizer quantities in the following cereal crops after pulses (Yigezu *et al.*, 2019).

Future of Wheat Seed Systems

Seeds remain a conduit to transfer new agricultural innovations to farmers, and play an important role in agricultural transformation. Wider scale adoption for achieving tangible impacts and reaching millions of smallholder farmers requires a robust seed system which ensures the transfer of improved crop varieties and integrated crop management technologies. However, national seed systems in SSA currently operate under heterogeneous environments in terms of agroecology, farming systems, crops and markets (Bishaw, 2019; Tadesse *et al.*, 2019). They face a broad range of constraints, including ineffective policy and regulatory frameworks; inadequate institutional and organizational arrangements; deficiencies in technical and infrastructure for seed production, processing, marketing, distribution and quality assurance; and a lack of trained and skilled personnel limiting technical and managerial capacities in seed enterprise management. These challenges are further compounded by farmers' difficult socio-economic circumstances. Hence, the weak seed delivery system is one of the critical constraints in transforming African agriculture, particularly for the wheat-based systems.

A review of the wheat seed system in Africa, and in developing countries elsewhere, has clearly shown that variety replacement and seed renewal rates are far below optimal levels (Bishaw, 2019). A few old varieties dominate the wheat landscape, and most farmers are using seeds from the informal sector. A wheat seed system study in Sudan showed that domestic wheat seed production declined over time and was about 5,000 tons in 2015, sufficient to plant only about 13.2% of the wheat area (Turner and Bishaw, 2017). However, in some seasons, large sums have been spent on importing wheat seeds and on purchasing seeds for distribution to farmers in rainfed areas, with negative consequences on domestic seed production. A similar wheat seed sector study in Ethiopia found that the formal sector supplies only 16%, of seeds in the country and the sector is largely dominated by the public actors with no visible role for the private sector (Alemu and Bishaw, 2016). The same study also indicated that farmers' varietal perceptions and seed commercial behavior are important factors to consider in seed supply. In Morocco, formal sector seed supply is only 23%, where over 90% of the national seed supply is dominated by the public sector (Bishaw *et al.*, 2019).

Some CGIAR centers, especially ICARDA and CIMMYT, in partnership with the AfDB and other donors, are trying to establish and implement functional scaling

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approaches based on innovation platforms (IPs) for wheat technology transfer and seed multiplication in key SSA countries. An ICARDA-led project was able to implement 38 functional IPs and scale 45 improved wheat technologies between 2018-2020. About 5,800 tons of early generation seed, 131,211 tons of certified seed and 8,705 quality declared seeds have been produced in this framework. This was achieved through partnerships with 58 public and private seed companies and seed producer cooperatives, and farmer groups reaching over 1.5 million farmers in target SSA countries. With the ongoing support of key African donors, such as the African Union and the AfDB, these initiatives are expected to multiply given the high awareness of the importance of seed systems. Nevertheless, future research assistance to effectively develop such seeds systems (identifying the major policy, regulatory, institutional and technical challenges, proposing evidence-based interventions in the seed systems, and understanding the underlying causes and effects of varietal adoption and its impacts), in addition to timely mainstreaming climate smart varieties with preferred traits meeting farmers, industry and consumers needs through fast-track variety release and acclerated seed multiplication through broader participation of the private sector would be key for future success.

Conclusions on Knowledge Gaps and Future Research

A few key conclusions can be drawn to highlight current knowledge gaps and potential future perspectives for wheat sectors in SSA. These include:

- There is currently a lack of appropriate wheat information systems, datasets, and reliable statistics, which are disaggregated, and well-structured for all SSA countries. However, it is important to begin developing, with key national, regional, and international organizations, such a system which can guide future technical and economic analysis and policymaking.

- There is a growing need for further development and deployment of climate-resilient wheat technology packages, combining improved high yielding, disease-resistant and heat-tolerant wheat varieties. Accelerated seed multiplication schemes would also be essential to further support the development of wheat in new SSA areas where context-specific technical knowledge is lacking.

- Furthermore, packaging the wheat varieties along with good agricultural practices, including legume-based rotations, sustainable crop establishment methods such as raised beds and conservation tillage, and nutrient and weed management practices, is also lacking in some of the new wheat areas in SSA. Additional R&D investments would be required to fill this gap.

- Soil degradation related to water and soil erosion, mainly from tilled and bared fields, is anticipated in the future. This means that exante environmental impact studies would be required to avoid non-sustainable scaling of high yielding but environmentally non-appropriate technical packages.

- Developing a functional wheat value chain is critical towards raising producvity and increasing production to achieve wheat self-sufficiency. This should be coupled with building infrastructures and logistics for aggregation, storage, and transportation, as well as creating market linkages with flour millers and food factories to transform the sector.

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About ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is a non-governmental, non-profit, CGIAR research center that focuses on delivering innovative solutions for sustainable agricultural development in the non-tropical dry areas of the developing world.

ICARDA is headquartered in the Middle East, with regional offices across North Africa, sub-Saharan Africa, and West, Central, and South Asia. ICARDA works in partnership with national agricultural research systems, governments, civil society, and the private sector to develop scalable agricultural solutions that contribute to poverty reduction, food and nutritional security, and sustainable utilization of natural resources.

We provide innovative, science-based solutions to improve the livelihoods and resilience of resource-poor smallholder farmers in non-tropical dry areas. We do this through strategic partnerships, linking research to development and capacity development and taking into account gender equality and the role of youth in transforming non-tropical dry areas.

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