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RESEARCH ARTICLE

The past, current, and future of the Africa Green Revolution: The case study of Kenya, Morocco, and Nigeria

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Abstract

The "Green Revolution in Africa" is an agricultural revolution aiming to ensure food security in Africa. However, dissemination of existing knowledge about the "Green Revolution" is poor. The objective of this study is to investigate the existing knowledge on the "Green Revolution in Africa." A systematic literature review (SLR) is performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The SLR method has identified 149 articles and the Alliance for a Green Revolution in Africa (AGRA) reports on Africa's Green Revolution. Qualitative studies used four main databases, that is, Science Direct, Scopus, Web of Science, and Springer Link. The authors developed three main themes to structure this study: the historic background of the Green Revolution, the status of agricultural development in Africa, and the results of Africa's Green Revolution policy, as well as alternative ways to achieve the Green Revolution in Africa and Sustainable Development Goals under climate change and global crises. The study found that the Green Revolution is far from reaching its initial targets as there is increasing hunger and poor crop productivity. Some studies proposed agro ecology, green technology innovation and smart farming, efficient irrigation, drainage and water management, and adaptation to climate change. For water stressed regions, other policies and strategies should be adopted such as rainfall harvesting, use of nonconventional waters and nonconventional crops and use of less water consuming crops. These are possible approaches to achieve Africa's Green Revolution in a rapidly changing climate and global crises.

KEYWORDS
Africa, AGRA, Green Revolution, systematic literature review

1 | INTRODUCTION

During the great divergence period, in the 19th century, the world witnessed global inequality, especially between Europe and Asia. While the Western World became the largest economy based on the Industrial Revolution and the Technological Revolution, countries struggled with how to feed their populations in many parts of the world. The post-World War II population boom meant that ways had to be found to achieve greater agricultural output to feed the fast-growing population (Frankema, 2014).

The initiation of the Green Revolution can be traced back to Mexico in the year 1940 (Sonnenfeld, 1992). Mexico played a pivotal role in the agricultural landscape as the origin of the paradigm-shifting "Green Revolution" in the mid-20th century. Spanning the period from 1940 to 1965, Mexico experienced an unprecedented surge in agricultural productivity, witnessing a remarkable fourfold increase in output. This remarkable transformation propelled the nation from a state of reliance on food imports to one that could effortlessly satisfy its own domestic food demands. Consequently, Mexico's notable agricultural achievements garnered widespread acclaim, attracting considerable attention from esteemed institutions such the U.S. Agency for International Development (AID) and various other agencies. These entities embraced Mexican agriculture as an exemplary model, utilizing it as a springboard to propagate the adoption of Green Revolution technology packages across the globe (Sonnenfeld, 1992). In 1971 the substantial financial support provided by USAID and other agencies played a pivotal role in facilitating the expansion of the Green Revolution, that aimed to achieve high crop yield through technological innovation in developing hybrid varieties of cereal grain, increased mechanization, irrigation, and fertilizers (Estudillo & Otsuka, 2013).

The Green Revolution program was led and funded by the Rockefeller and Ford Foundations, the U.S. government, the International Rice Research Institute (IRRI), the International Maize and Wheat Improvement Center, the International Institute for Tropical Agriculture (IITA); bilateral aid agencies, agribusiness corporations, and national agricultural research institutions (Ignatova, 2021).

Experiments with new high-yielding varieties of cereal grains started in Mexico in 1943, and were extended to Asia with new wheat and rice varieties in the period ranging from 1960 and 1970 (Frankema, 2014; Perkins, 1990).

The main result of the Green Revolution was transforming Latin American and Asian countries from importers of food to exporters as they shifted from labor-intensive agriculture that depended on weather conditions and community labor to a capital-intensive system based on industrial inputs and mechanization (Ignatova, 2021). The late 20th century then saw the start of an Asian renaissance where Asian high agricultural productivity allowed Asian countries to develop into industrialized nations (Henley, 2012).

In addition to technological innovation, the Cold War's geopolitical context favored the Green Revolution's success. The Green Revolution was launched as a peaceful scientific revolution to combat inequality and share the advances with developing countries like Mexico, India, Pakistan and the Philippines in the hope that this would deter them from seeking help from communist governments under the umbrella of the Red Revolution (Ignatova, 2021).

African countries did not keep pace with the Asian and Latin American countries, since African countries were not independent and lacked the infrastructure to fully profit from the Green Revolution. Food production in Africa declined from the 1960s to the 1990s. Historically epidemic diseases, climate disasters, political conflicts, and wars have caused food shortages in Africa (Iliffe, 1987). According to United Nations Food and Agriculture Organisation (FAO) statistics, more than half of the African countries produced less food per head in 2013 than in 1960, because the rate of food production failed to match the rapid pace of population growth (FAO, 2021).

1.1 | Why did Africa miss the first Green Revolution period? And why would it be different this time around?

Apart from the prevalent dependency and inadequate infrastructure hindering the implementation of the Green Revolution in many African countries, various additional factors contributed to the delay in their participation in this transformative agricultural movement, such as (1) excluding the Sahara and Kalahari deserts, regions that inherently pose significant constraints on sustaining sizable human populations, the preponderance of cultivable land in Africa is predominantly situated within the tropical zones (Frankema, 2014). The tropical rainforest biome is characterized by its warm and humid climatic conditions, which pose limitations on the long-term storage of diverse edible crops. Tropical soils are suitable to grow tubers, roots, and starchy fruits like plantain that are harvested for immediate consumption, alongside cereals (Frankema, 2014); (2) the extensive adoption of livestock breeding in Africa presents an avenue for risk mitigation and wealth accumulation; (3) Tsetse flies in the tropical forest limit the suitability of sizeable cultivable land and the development of mixed farming. The fly posed a high threat to human lives, cattle (for farming), and horses (for transport) and hindered the intensification and commercialization of agriculture (Frankema, 2014); (4) the West African Sahel and East African coastal regions depended on nomadic pastoralist way of life because of the recurrent droughts in the Savannah (Nairobi, 1979; Widgren et al., 2004); (5) the financial underdevelopment and lack of educated staff and the capacity to support the economic policymaking of early independent African countries paralyzed the agricultural sector; and (6) the desire to put ethnic, religious, and tribal interests before the nation's interest and the conflicts this caused hampered the implementation of the Green Revolution (Frankema & Jerven, 2014).

Aware of these issues, international organizations realized there was a need to develop a new agricultural policy, specifically for the sub-Saharan regions. Thus, since the 2000s, an agricultural policy—the new Green Revolution—has been implemented in Africa. The initial and official goals of this agricultural transformation for the countries concerned were to eradicate poverty and enhance food security across all demographic segments (Vilain, 2015).

Since the 1990, the following programs were launched, in chronological order: the Sasakawa Global 2000 program (SG 2000) headed by Norman Borlaug, the instigator of the first Green Revolution; the Grow Alliance program launched in 2003 in partnership with the "NEPAD" (New Partnership for Africa's Development); since 2006, the Alliance for a Green Revolution in Africa (AGRA) program, financed by the Rockefeller Foundation, the main funder of the first Green Revolution, and the Bill and Melinda Gates Foundation; and since 2012, the "New Alliance for Food Security and Nutrition" ("NASAN") launched by the G7 heads of states (Vilain, 2015).

These programs were funded by many international financial institutions and donors, namely, the World Bank, the African Development Bank, USAID, Philanthropic foundations, the NEPAD, and the Consultative Group for International Agricultural Research (CGIAR). The agricultural policies adopted by the African countries have also played a crucial role to reach the Green Revolution goals. In 2006, the Minister of Agriculture of the African Union (AU) in Abuja, Nigeria, recognized "the need and urgency of a Green Revolution; the use of fertilizer as a strategic product; reaching the level of 50 kg of fertilizer per hectare by 2015; the need to develop 'agro shops' and train 'agro dealers'; to develop the necessary infrastructure; to ensure the necessary assistance and support to farmers; and the need to subsidize fertilizer, inputs, etc." Moreover, the African countries have implemented the Comprehensive African Agricultural Development Program (CAADP) to discuss how Africa's Green Revolution can be achieved. In order to reach the UN's millennium development goal of hunger reduction by 2015, the CAADP set a goal of 6% annual growth rate in agricultural production. Furthermore, the resolution of the African Green Revolution Conference in Oslo prompted the consideration of public–private partnerships to promote self-sustaining changes in African agricultural growth (Bationo et al., 2011).

The Green Revolution in Africa was led by the Alliance for a Green Revolution in Africa (AGRA). Established in 2006, the AGRA is funded by both the Rockefeller Foundation and the Bill & Melinda Gates Foundation. Its mission is "to unleash a truly African Green Revolution that will transform African agriculture into a highly productive, efficient, competitive and sustainable system that ensures food security and lifts millions out of poverty." These goals planned to reduce food insecurity by 50% in at least 20 countries; double the productivity and incomes of 30 million small-scale food producers by 2020, (9 million directly and 21 million indirectly) and to put 15 countries on track to sustain and support the Green Revolution on their own. AGRA is actively working in Burkina Faso, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Tanzania, Uganda, and Zambia (Vilain, 2015).

As the instigator of the Green Revolution in Africa, AGRA intended to achieve these objectives through four main axes: better soil productivity (through the use of chemical fertlisers), the use of seeds (hybrid, improved genetically modified organisms [GMO]), market liberalization and better market connections between producers, distributors and consumers whether at the local, regional, national or even international level; and finally, the development of agricultural policies.

Furthermore, AGRA favors a synergistic partnership approach between two main actors, the public and private sectors, and a secondary partner represented by civil society. Also, the Public-Private-Partnership is a central element of AGRA's strategy (AGRA, 2014).

The principal objective of this review is, therefore, to identify the Green Revolution status quo in Africa: the achievements, the future challenges and the alternatives to boost the African agricultural policy. To explore these objectives the following research questions were formulated:

Q1. What are the achievements of the Green Revolution so far in Africa?

Q2. What are the challenges impeding the progress in the Green Revolution in Africa?

Q3. What are the alternatives to the Green Revolution?

Given the above questions, a systematic literature review (SLR) based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), was conducted to answer the research questions. In order to perform the SLR in relation to the addressed topic, qualitative studies were used from high research quality databases, such as ScienceDirect, Scopus, Web of Science and SpringerLink databases.

2 | METHODOLOGY

SLR avoids research biases or missing essential information by attempting to identify, appraise and synthesize all relevant studies (Petticrew & Roberts, 2006). The SLR method is increasingly common in climate change, water and food security subjects (Candel, 2014; Cisternas et al., 2020; Islam et al., 2020; Thi Hong Phuong et al., 2017). The main reason that led us to write this paper is the lack of properly compiled knowledge on the Green Revolution in Africa.

The protocol used to perform this systematic research consists of developing a search strategy to identify relevant literature. This search strategy was focused on two databases: Scopus and Web of Science as well as relevant reports, magazines, and books related to the Green Revolution in Africa.

The comprehensive search conducted encompassed the entire database timeline, spanning from its inception to the period between 2015 and 2022. The search included a wide range of literature such as journal articles, review papers, research reports, books, conference papers, and reports published in both English and French languages. For the period from 1965 to 2015, we selectively incorporated relevant articles and reports that elucidated the fundamental concept of the Green Revolution and its specific targets in Africa.

The selection criteria were based on the PRISMA statement. The search mainly focused on mapping existing literature on the Green Revolution in Africa in the field of Engineering, Agricultural and biological sciences, Biochemistry, Genetics, and Molecular Biology. Out of 472 papers, 256 research articles were excluded, 216 records were extracted.

The study is based only on original research articles, review papers, books, conference papers and reports. Abstracts of the articles were checked to ensure the quality and relevance of academic literature included in the review process. A detailed evaluation of each research paper was carried out at a later stage. The next exclusion criterion was to limit the papers to publications in English and French. The article selection procedure is detailed in Figure 1.

In the data extraction phase 149 sources were selected, the characteristics of extraction are as follows:

1- Articles must be original papers, review papers and conference papers, published reports, working papers, theses, and case studies
2- The articles must be in English or French language and from the field of Engineering Agricultural and biological sciences, Biochemistry, Genetics, and Molecular Biology, social sciences and environmental sciences

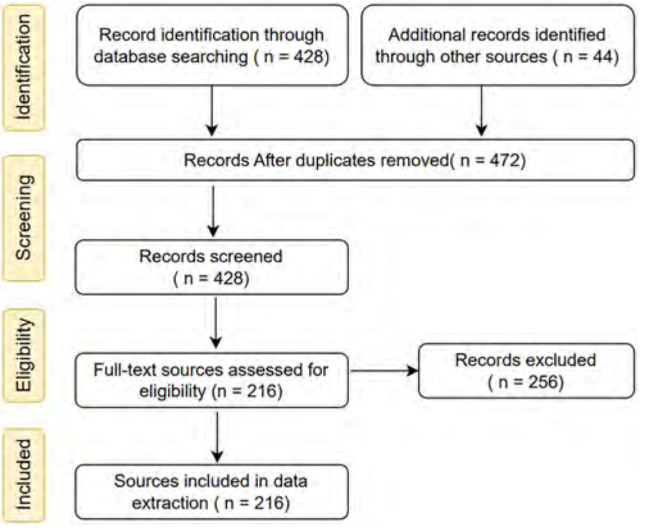

FIGURE 1 PRISMA flow diagram according to Moher et al. (2009).

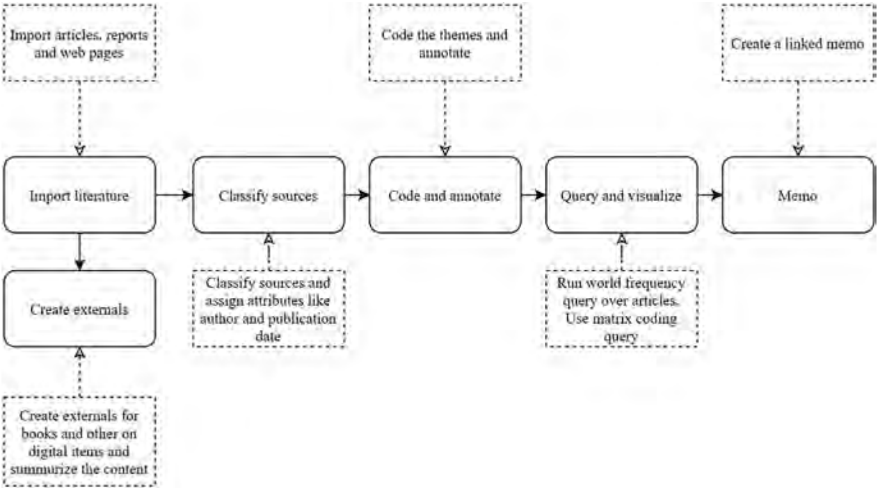

FIGURE 2 Literature review process using Nvivo software (Siccama & Penna, 2008).

3- Extracted articles were published between 2015 to 2022
4- The published papers concern Africa

The SLR according to the PRISMA statement was performed using Nvivo Software. The bibliographic data was imported from Mendeley software. Nvivo software was used for data analysis and finding patterns and themes within different sources of information (Figure 2).

2.1 | Limitations and implications

Despite its attempt to provide a review of a body of literature that is as comprehensive as possible, this review has some limitations. First, only documents written in English and French were included. Second, the review is heavily skewed toward Engineering, academic peer-reviewed articles. Although some book chapters, conference proceedings, and literature documents were included, complementing the body of literature with dissertations and more gray literature could have led to additional insights.

3 | RESULTS

The analysis of the keywords used by the authors shows a high occurrence of the following words: "Agricultural," "Farmers," "Agriculture," "Soil," "Food," "Africa" (Figure 3).

The analysis of the distribution of publications by year of appearance shows that the highest number of publications related to the Green Revolution appeared in 2013 and 2015. This is the result of the high demand created for evaluation and monitoring of the end of millennium development goals output. Starting from 1965 until 2015, we included just the relevant articles and reports that show the basic concept of the Green Revolution as well as the set targets in Africa, which explains the inconsistent publication of peer-reviewed articles.

After 2015, the number of published articles related to the Green Revolution in Africa dropped, possibly due to the first years of the Sustainable Development Goals (SDG's) and the need of a new agricultural strategy in Africa (Figure 4).

Bearing in mind the criteria of sources selection, the data analysis shows that the peak of distribution of publications by reference type consists of peer-reviewed journal articles. The most used sources are as follows: journal articles (97), books (30), reports (10), working papers (3), and conference proceedings (2) (Figure 5).

Among the 216 selected publications, 35 serve to highlight the achievements of the Green Revolution in Africa (Research Question 1). In addition, 30 publications answered the second research question about the challenges impeding the Green Revolution in Africa.

FIGURE 3 The word cloud of the authors of the selected papers.

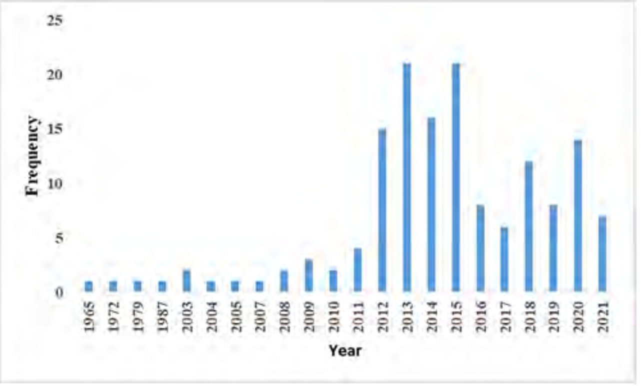

FIGURE 4 Distribution of the Green Revolution publications by year of publication.

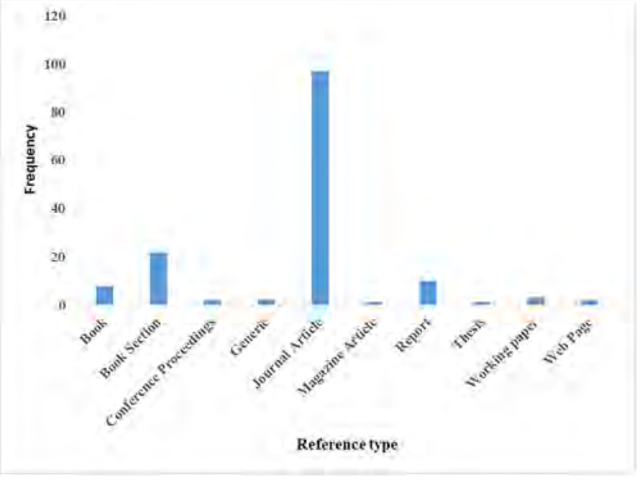

FIGURE 5 Distribution of Green Revolution publications by reference type.

Twenty-eight publications were selected to propose alternatives to the Green Revolution (Research Question 3) (Figure 6).

3.1 | Research question 1: What are the achievements of the Green Revolution in Africa?

Before answering the three research questions according to the academic literature, it is important to highlight the definition of the Green Revolution. Hayami and Ruttan provided the first definition of the Green Revolution in 1971: Green Revolution refers to the development and diffusion of high-yielding cereal technology (Hayami & Ruttan, 1971).

Since the new Green Revolution program was launched by the AGRA institution in 2006, it has reached 553 million US dollar in investment, including 25.1 million for smallholder farmers, 30% of whom are female. Among the beneficiaries reached by the Green Revolution

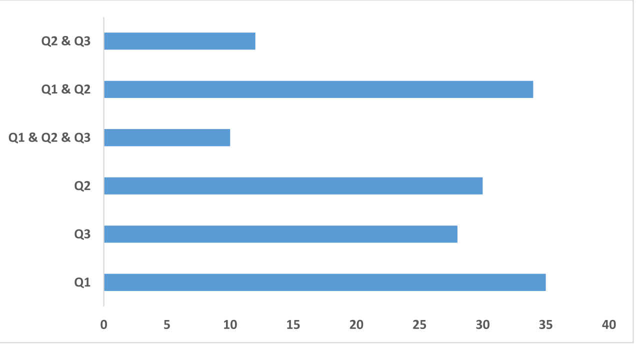

FIGURE 6 Number of publications that answer a specific research question.

program, AGRA reached 5.3 million farmers with knowledge of Integrated Soil Fertility Management (ISFM) and 1.8 Million farmers using ISFM. In addition, the program contributed with 1.4 billion US Dollar to support the implementation of nine flagships. The program also provided services to help farmers via village based advisors (AGRA, 2021b).

Despite all these programs and funding, Africa remains the only continent that did not fully benefit from the effects of the Green Revolution experienced in the 1960s. Indeed, the programs that vowed to implement the Green Revolution in Africa have failed (Bassermann & Urhahn, 2020; Vilain, 2015; Wise, 2020). For the Grow Alliance program, the targets are not clearly identified, nor the period over which results are expected defined. Nonetheless, according to their 2014 annual report, there is a growth in production ranging from 0.9% (Ghana) to 7.8% (Mozambique), or an average of 4.51% growth per year. For the Sasakawa Global 2000 program, there is a lack of clearly quantified targets. However, in 2012, they published a strategic plan for the period 2012–2016 that explains how to disseminate the program through five main themes: "improving agricultural productivity; developing post-harvest systems and agribusiness; developing public-private partnerships and market access; developing human resources; and using evaluation and learning to spread their program in the countries involved" (Bassermann & Urhahn, 2020; Vilain, 2015; Wise, 2020).

Despite 1.4 billion US Dollar in funding by AGRA to encourage their farmers, disappointing results had been recorded at the time of the AGRA program deadline in 2020. Indeed, the number of hungry people in the 13 Alliance countries for the Green Revolution in Africa (Burkina Faso, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Tanzania, Uganda, Zambia) had risen by 30% between 2006 and 2020. There was chronic hunger. Africa accounts for half of the 12 million children under the age of five dying each year, which is a long way from achieving the millennium development goals (MDGs) or the SDGs. Over a 14-year period, the AGRA results show that poverty remained high and that the Green Revolution had only recorded a slow increasing rate of crop productivity by 2020. Furthermore, the outcome achieved by farmers that were reached was disappointing and the number of the farmers using ISFM was poor (Bationo et al., 2011; Wise, 2020).

Considering the 2004–2006 average as a reference baseline to assess the productivity improvement over the period ranging from 2006 to 2018, maize production increased by 87%, thanks to a 45% increase in harvested area, which improved the yield by 29%.

Figure 7 shows the productivity improvement as a function of the percentage growth in production, harvested area (hectare), and yield (MT/ha) over the period 2006–2018 for the

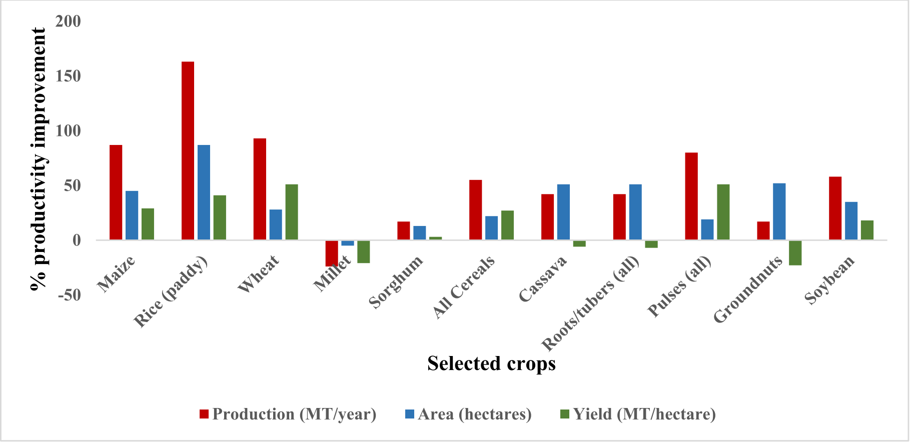

FIGURE 7 Productivity improvement for 13 Alliance for a Green Revolution in Africa countries: Burkina Faso, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Niger, Nigeria, Twanda, Tanzania, Uganda, Zambia.

13 Alliance countries for a Green Revolution in Africa. It shows that the peak of production is observed in rice, which increased by 163% thanks to an increase in harvested area by 51%; however, productivity improvement only grew by 41%. It should be noted that the priority crop policy has led to a significant decline in nutritious and climate-resilient crops, like millet and sorghum, which had been key components in healthy diets. Indeed, millet production fell by 24%, due to a decline in the harvested area by 5%, which led to the drop of the productivity by 21%. Sorghum production grew by 17%, due to a 3% increase in harvested area, but yields barely increased, with a growth of 3%. The maximum productivity improvement was recorded for wheat, which grew by 51%; however, groundnuts productivity decreased by 23%. Also, cassava productivity had dropped by 6%. The reduction of millet and sorghum and the introduction of maize as a forage crop, which appears to be the most economically efficient and water-efficient crop, did not succeed. Maize is sensitive to water availability, especially without access to groundwater and irrigation, and requires a significant investment for a short period of time (4 months) which requires a significant cash flow. It is obvious that the implementation of the AGRA crop policy requires a great effort for the farmer paradigm shift, in a way to convince the farmers to change their cropping practices. Looking at the “yield index,” which is the weighting of the yield growth for each crop based on area harvested in 2017, the maximum yield growth over the period that ranged from 2006 to 2018 was recorded in Rwanda (24%); however, yield had dropped significantly in Burkina Faso, Kenya, and Nigeria by −10%, −7%, and −8%, respectively, as shown in Figure 8 (Wise, 2020). Using examples from farmers’ maize and rice fields, Ajakaiye and Janvry (2015) argued that the Green Revolution in Africa produced localized successes rather than transformational change.

Despite the huge investment made by AGRA to halve hunger in Africa, the number of undernourished has increased by 30%, from 100.5 million to 131.3 million for the period ranging from 2006 to 2018. Figure 8 shows that the maximum percentage increase of undernourished people over the period ranging from 2006 to 2018 was in Nigeria, with an increase by 181%. However, a decline of number of undernourished people was recorded in Ethiopia, Kenya, Ghana, Malawi, and Mali (Bassermann & Urhahn, 2020; Wise, 2020). Using a case study of Malawi, Kerr (2015) showed that the Green Revolution intensified inequalities,

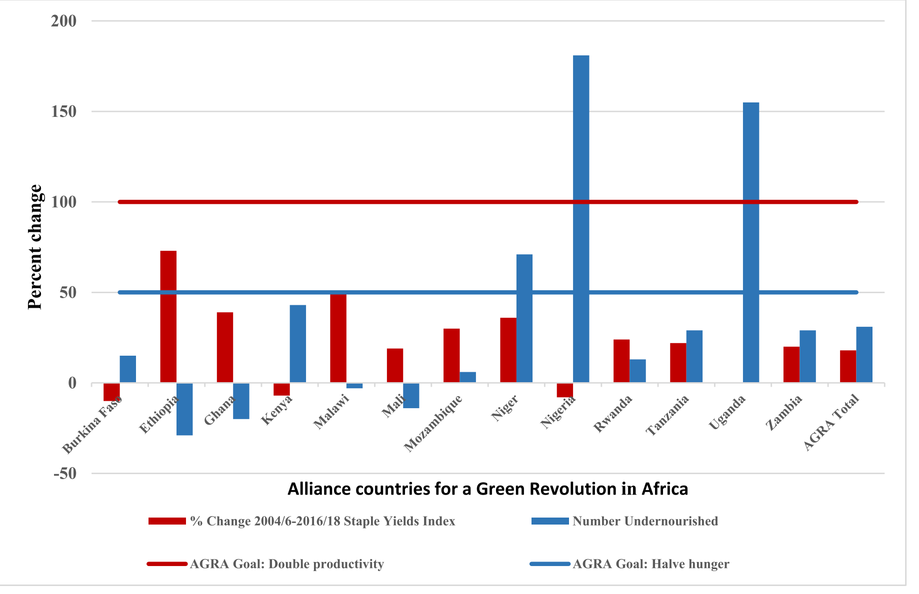

FIGURE 8 Yield index variation and change in number undernourished over 3-year averages 2004/6 and 2016/18 (FAO, 2021).

increased environmental degradation, and exacerbate malnutrition. Also Dawson et al. (2016) argued the Green Revolution had failed to achieve improvements in the lives of smallholder farmers.

The Green Revolution policy led by AGRA was based on extending harvested areas rather than on intensification and resulted in rapid degradation and depletion of natural resources while increasing further greenhouse gas emissions. Unfortunately, the challenge to double productivity has not been achieved by AGRA; the maximum productivity achieved is 41% in rice as a staple food. The mean production improvement is 57%, with a mean extended harvested area of 36% and a mean productivity improvement of 14% (Wise, 2020).

Unfortunately, Africa has missed the Green Revolution goals due to an impoverished agricultural resource base, unfavorable socioeconomic, and policy environments for investment in the agricultural sector development as well as the emerging challenges associated with unfavorable weather and climate change (Wise, 2020). In this context, time is up to change the course toward an efficient agricultural policy. Hunger is already rampant and the United Nations warns that Africa could see a 73% surge in undernourishment by 2030 if policies do not change. Forecasts are shocking: The World Food Programme (WFP) expects the number of people affected by acute hunger to double by the end of 2020—from 135 million to around 270 million people. Scientists and political decision-makers have become increasingly aware of the limitations of input-intensive agricultural systems, particularly when having to respond to climate change. The UN Intergovernmental Panel on Climate Change (IPCC) recently documented the impact of industrial agriculture on climate change and called for profound changes to both mitigate against and help farmers adapt to climate disruptions. In its Global Assessment on Biodiversity and Ecosystem Services, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is even more explicit and identifies industrial agriculture as a major driver of nature destruction. Accordingly, agriculture intensifications are leading to accelerated pollution of soils and waters, among others. Furthermore, changing the agricultural policy is crucial as the continent faces climate change and rising hunger due to the COVID-19 pandemic.

3.2 | Research question 2: What are the challenges impeding the Green Revolution in Africa?

According to the AGRA report related to Building Sustainable and Resilient Food Systems in Africa, published in 2021 (AGRA, 2021a), the challenges impeding the Green Revolution in Africa are the growing incidence of conflict, political instabilities, natural hazards, pandemics, climate change, economic crisis, and macro-economic volatility (Choularton et al., 2015; Zseleczky & Yosef, 2014).

According to the Armed Conflict Location and Event Database, the number of armed conflicts has increased since the year 2000. Figure 9 shows that there were 184,849 armed conflict incidents in sub-Saharan Africa between 1997 and 2020, which resulted in 666,107 fatalities.

The threat of natural hazards impedes the continent's progress. According to the International Disaster Database, CRED between 1991 and 2020, natural hazards have killed 191,638 in sub-Saharan Africa. The most lethal natural hazard was epidemics causing 142,692 deaths, followed by flood causing 18,859 deaths, drought causing 21,127 deaths, and storms causing 5089 deaths (AGRA, 2021a; CRED, 2020) (Figure 10). Furthermore, climate change characterized by temperature and precipitation changes can significantly affect Africa's food production system (Engelbrecht et al., 2015; Souverijns et al., 2016).

According to the FAO (2020), Mugume and Muhumuza (2021), and the World Bank (2021), COVID-19 has affected households, communities, and the economy, which include jobs losses, company insolvency, cross border insolvency, the closure of food retail stores, and a disconnect between urban and rural settings, which reduced mobility, logistics, and trade and increased food costs. Moreover, the macro-economic parameters, namely, the exchange rate, trade policies, export bans, food price volatility, and inflation can dramatically impact the countries' food security (Dorosh & Minten, 2003; Gustafson, 2013; Porteous, 2017). According to Ajakaiye and Janvry (2015), there are many detrimental aspects to take into consideration when designing policies regarding the Green Revolution in Africa. In fact, domestic support and export

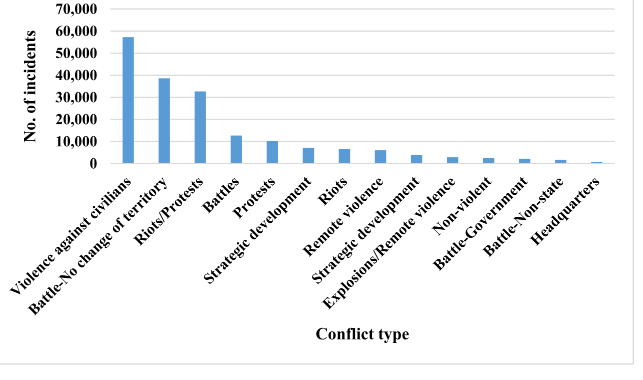

FIGURE 9 Armed conflicts by type, cumulative from 1997 to 2020. *Source*: Armed Conflict Location and Event Database (AGRA, 2021a; CRED, 2020).

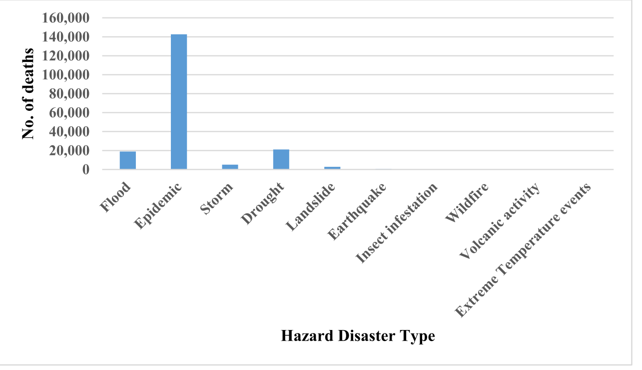

FIGURE 10 Natural hazards by type, cumulative from 1991 to 2020. *Source*: The International Disaster Database (AGRA, 2021a; CRED, 2020).

subsidies to agriculture in the Organization for Economic Co-operation and Development (OECD) countries are detrimental as it displaces producers both in third-country markets and in their own domestic markets. Furthermore, sanitary and phytosanitary prices are costly to meet, due to nontariff barriers. Technologies are difficult to access due to the intellectual property policy. Finally, there is an unbalanced correlation between international and farm-level prices regarding international value chains.

All these challenges are likely to slow down Africa's economic transformation and progress toward sustainable development and Green Revolution. In this context what are the alternatives toward a Green Revolution in Africa?

3.3 | Research question 3: What are the alternatives to the Green Revolution?

To overcome the challenges faced in meeting the Green Revolution as well as ensuring sustainable economies and achieving the SDGs and Agenda 2063 Goals, resilient and sustainable food systems are required. Dawson et al. (2016) concluded that the Green Revolution should be based on impact assessment with objective indicators rather than on pro-poor projects.

Resilience in agriculture is the capacity of the food system to quickly recover from risks and to better withstand them in the future (Cutter et al., 2008). Agri-food system resiliency is a function of three variables: (1) mitigation, which refers to the ability to proactively minimize the impact of a risk or disturbance before it occurs; (2) recovery, which is the ability to cope with the risk; and (3) adaptation, which is the capacity of the agri-food system to adapt to shocks that permanently affect the ecosystem (Stone & Rahimifard, 2018).

The first alternative to make the agri-food system more resilient and meet the food production requirement is raising yields and productivity on existing farmland. Increasing yields and productivity can be achieved by crop sustainable intensification, especially for countries that do not have vast tracts of uncultivated arable land. Crop intensification will reduce pressures on land expansion and water resources and protect lands from degradation, while limiting further greenhouse gas emissions, as well as preserve valued forest, grassland ecosystems, and biodiversity (AGRA, 2021a).

Concepts of agro ecology, green innovation technology, smart farming, and circular economy, practices such as converting organic wastes into productive inputs in farm production, water recycling, and so forth, have gained tremendous traction internationally. Many studies have demonstrated that agro-ecology, with its innovative combination of ecological science and farmers' knowledge and practices, can restore degraded soils, make farms more resilient to climate change, improve food security and nutrition by growing and consuming a diversity of crops (Wise, 2020).

Green innovation in agriculture refers to the use of technologies applying sustainable development principles to agriculture in order to ensure higher efficiency in production in the face of climatic, agro-ecological, and socio-economic risks. Earlier, the primary concern of the design and adoption of agricultural technologies were to increase production and farm income. With the passage of time, agricultural intensification resulted in rapid degradation and depletion of natural resources. In the changing context, the contribution of technology and innovation to sustainable agriculture has become a prime concern. To address the issue, innovation in ecofriendly technologies related to energy-saving, pollution prevention, waste recycling, and so forth is of utmost importance for sustainable agriculture and rural development. The awareness and evidence of the limits of natural resources and pollution of soil, air, and water are pushing for sustainable farming, which, respecting the social, economic, and environmental concerns, can provide decent income, jobs, food, and other goods and services for the majority of people living in rural areas. Farming and related activities make up the basic fabric of rural life, contributing significantly to the overall state of rural regions in terms of employment and business opportunities, infrastructure, and quality of the environment. Thus, sustainable agriculture and rural development are interlinked in many dimensions. Ajakaiye and Janvry (2015) argued that the Green Revolution in Africa could be achieved through technology transfers, local adaptation, investments in irrigation infrastructure and market facilities, and the emergence of agro-dealers supplying factors and agro-industries transforming products. In addition, Ajakaiye and Janvry (2015) proposed seed fertilizer technologies as an alternative to speed up the African Green Revolution.

The basic concepts and policy perspective of Green Innovation are as follows:

- Aquaponics: environmental friendly and sustainable food production systems;
- Trichoderma enhanced compositing technology;
- Multistoried agriculture with solar power irrigation;
- Community bio-gas plants for the production of renewable energy and organic fertilizer;
- Women in seed entrepreneurship;
- Low-cost deep tube well (borehole) and its multipurpose use for sustainable development;
- Grow bag technology and zero tillage in agriculture; and
- Integrated pest management

Precision agriculture is now a driving force of a successful Green Revolution in Africa.

Agro ecology, green technology, and circular economy must be implemented in all the agri-food systems, which encompass the generation and distribution of farming inputs and services, production at farm level, post-farm marketing, processing, packaging, distribution and retail, and the policy and regulatory environment. The resilient agri-food system will require the following (Wambugu, 2015):

i. Greater attention to technical innovation
ii. Irrigation adoption to reduce rain-fed production systems fragility

iii. Greater support to the agricultural institutions that generate it, namely, agricultural Research, Development, and Extension (R&D&E) systems.
iv. Rapid adoption of biotechnology ranging from drought-tolerant seed varieties to bio fortification of staple and other widely consumed foods;
v. Sustainable water and land use through sound agronomic practices which promote soil conservation, and preservation of the environment;
vi. The establishment of an enabling regulatory and policy environment that creates more space for competitive entrepreneurship, especially Small and Medium sized Enterprises (SMEs);
vii. Setting high food standards that promote human and animal health, especially in informal food value chains;
viii. Enhancing the security of supply chains;
ix. Building early warning systems;
x. Developing insurance markets;
xi. Protecting productive assets;
xii. Providing humanitarian relief after a natural or man-made disaster has occurred.

In addition, smart farming, which aims to increase the yield of crops, as well as reduce the variability and input costs, is certainly an important alternative to achieve Green Revolution in Africa. Measures and technologies that can be adopted include information technologies (IT), like remote sensors, global navigation satellite system (GNSS), nanosensors, unmanned aerial systems (UAS), unmanned aerial vehicles (UAV), unmanned ground vehicles (UGV), variable rate technology (VRT), wireless sensor networks (WSN), and precision agriculture to recognize temporal and spatial variations in the production resources, facilitating the application of the necessary amount of water, fertilizers, and treatment at the right moment (Cisternas et al., 2020).

4 | GREEN REVOLUTION CASE STUDY FROM MOROCCO

Agriculture is the main engine of development in the Kingdom of Morocco. Indeed, the structural association of agriculture with the rural areas, which represent 40% of the Kingdom's area, instead of its socio-economic and environmental dimension, make the agriculture an essential pillar of development in Morocco. The importance of the agricultural sector is manifested by its significant contribution to the production of the National Gross Domestic Product by 13% and 40% of job creation, especially in rural areas where agriculture remains the leading sector of employment with a tremendous share employment rate of 80% and source of income of 1.5 million farmers; 80% of water resources in Morocco are consumed by agriculture (World-Bank, 2017). According to the Ministry of Equipment, Transport, Logistics, and Water, the aquifers are overexploited by 1 billion m^3/year. Indeed, 40% of irrigation demand is provided from groundwater, contributing to 50% of agricultural economic added value (Tanouti, 2017). Shifting from surface/gravity irrigation to drip irrigation was a priority for the Ministry of Agriculture, Fisheries, Rural Development, Forest and Water, to ensure water conservation by enhancing irrigation efficiency. Indeed, water conservation was a cross-cutting action in the Moroccan Green Plan (MGP). Launched in 2008, the Green Morocco Plan strategy aims to accelerate growth, reduce poverty, and ensure long-term agriculture sustainability by implementing 500 projects with an investment budget of 149 billion dirham (15 billion US$) over 10 years. The main objectives of the MGP by 2020 are as follows:

- The creation of 1 to 1.5 million additional jobs;
- The reduction of poverty by multiplying the income of nearly 3 million rural people by a factor of 2 to 3;
- The increase of the Gross Domestic Product Agricultural (AGDP) from +60 to 90 billion Dirham (+6 to 9 billion US$);
- The doubling of exports;
- Increase the value of exports to 44 billion Dirham (4.4 billion US$)
- The sustainable management of resources (water saving from 20 to 50%)
- Limiting the impact of climate change and preserving natural resources

Additionally, the MGP aims to reach 450,000 ha of irrigated agriculture by 2035. Along with the agricultural investment, the Moroccan government plans to build five more dams to alleviate water resource pressure. Irrigation water policy is an integral part of the MGP and aims to meet the development requirements to reach more productive, competitive, and sustainable agriculture. The objective is to rationalize the use of water in agricultural activity and to mobilize water resources with the maximum effectiveness and efficiency to guarantee valuable and sustainable use of these resources (MAPM, 2012).

The National Program for Water Saving in Irrigation is one of the transversal actions adopted to mitigate the effects of water resource scarcity and improve the efficiency of water use in irrigation (Tanouti, 2017). It consists of shifting to drip irrigation on the plot with subsidies reaching 100% for small farmers (Molle & Sanchis-Ibor, 2019), over an area of 550,000 ha, with an average rate of equipment deployment of 55,000 ha/year. Along with the National Program for Water Saving in Irrigation, Morocco has launched the National Priority Program for Drinking Water Supply and Irrigation, aiming to mobilize water resources through the construction of new dams, wastewater reuse, and seawater desalination.

Since 2000, the Gross Domestic Product shows an upward trend. The MGP allowed an increase in GDP from 79 billion DH (7.9 billion US$) in 2008 to 108 billion DH (10.8 billion US $) in 2016, an increase of 44%. According to the Moroccan Exchange Office, the number of operators in the agricultural sector increased by 2600 from 2007 to 2014. Furthermore, the MGP generated 137,535 jobs in 2015. Definitely, the Morocco Green Plan brings a substantial economic advantage at the global and local scale, by increasing the cash crop and agricultural productivity.

The first impact is economical in which the AGDP grew at an average annual rate of 5.25%, with a doubling of the agricultural sector's contribution to overall economic growth, thus meeting its ambition to become a driving force in the economy. In addition, the agricultural exports have been maximized and experienced strong diversification, despite the difficult global situation like financial crisis, pandemic and war, thus contributing to a clear improvement in the agricultural trade balance deficit. Moreover, the MGP has placed investment at the center of its equation with 104 billion Dirham (10.4 billion US$) of cumulative investments in 10 years, including 63 billion Dirham (6.3 billion US$) from the private sector. Furthermore, the mobilization of agricultural land, notably within the framework of the Public-Private Partnership (PPP), has been a key success factor and a lever for the development of investments.

The second impact is social; as the agricultural employment has improved both qualitatively and quantitatively, nearly 50 million additional working days have been created. Plus, the income of agricultural workers has increased thanks to the improvement of labor productivity, the number of days worked per agricultural job and the daily wage. Moreover, food security has been strengthened, placing Morocco among the top countries in the MENA region in terms of food security.

The third major impact is related to sustainability. First, Morocco emphasized adapting agriculture to climate change through water management, tree plantations, risk mitigation, conservation of ecosystems and biodiversity. Second, agriculture has contributed to the mitigation of greenhouse gas emissions in accordance with the sector's commitments under the Nationally Determined Contribution (NDC). Third, the agricultural sector has shown greater resilience and less volatile growth, particularly due to reduced dependence on cereal crops.

In terms of inclusion dynamics, the Morocco Green Plan (MGP) programs have made it possible to ensure a broader reach for small and medium-sized agriculture, with 2.7 million beneficiaries and a public effort of more than 40 billion Dirham (4 billion US$). Additionally, the dedicated and innovative approach of MGP Pillar II aims at developing solidarity agriculture through the implementation of technically feasible, economically viable and socially appropriate projects in fragile areas (mountains, oases, plains and semiarid plateaus) (Moumen et al., 2019). Furthermore, the development of local products has favored the emergence of a new sector for the benefit of small farmers and fragile areas. Lastly, the support and structuring of the fabric of actors has enabled the creation of nearly 10,000 agricultural cooperatives in 10 years, thus promoting the integration of farmers into value chains.

5 | AGRICULTURE STRATEGY IN NIGERIA

The importance of the agricultural sector in Nigeria is manifested by its significant contribution to the National Gross Domestic Product of 20% and through the creation of 70% of jobs, with 60% of women in agriculture. However, agriculture accounts for less than 2% of total exports (FAO, 2016). Farming systems are mainly smallholder-based, and agricultural landholdings are scattered, averaging 1.25 ha each. Occupying less than 1% of the cultivated area, irrigated production contributes less than 1% of the total grain production and 2.3% of the total vegetable production, although the smallholder farmers with less than 5 ha land play a central role in the Nigerian Green Revolution (Dare Kolawole, 2012; FAO, 2016).

The total agricultural land is 71 million ha, of which the cultivated area is 40.5 million ha. The irrigation potential is between 1.5 and 3.2 million ha, of which 325,100 ha is equipped for irrigation as surface and pressurized irrigation techniques (71.4% combined), and lowlands (28.6%). An additional 681,914 ha constitutes nonequipped flood recession cropping. The classes of the area equipped for full control irrigation are public (61%) and private schemes (39%) (FAO, 2016).

Despite the intervention policies focused on agricultural intensification being in place, the concept of Green Revolution came into action in later years (Dare Kolawole, 2012). In 1980, the Nigerian government introduced the Green Revolution initiative in Nigeria with a principal objective of ensuring self-sustained food production with the use of modern technology. The main objective of this initiative was to ensure adequate, reliable, and safe food supplies for a rapidly growing population, to ensure stability in food commodity markets, to increase the potential to grow any crop anywhere and also eliminate the need to fallow lands (Blueprint, 2022; Famoriyo & Raza, 1982). Before the initiation of the Green Revolution in Nigeria (1975–1995), Agricultural Development Projects (ADPs) were established with the support of World Bank (Ajani & Igbokwe, 2014). The ADP used classical training and visit extension system until 1991 where a policy of Unified Agricultural Extension Service (UAES) was introduced. The UAES aimed at improving the efficiency and effectiveness of ADPs by mandating extension provision through a single agent to the farmer for the complete farming system (Ajani & Igbokwe, 2014; USAID, 2010).

Between 2010 and 2011, Nigeria implemented the Agricultural Transformation Agenda (ATA). The ATA aimed to invest in agriculture as a business sector. The ATA shifted focus toward sustaining agribusiness and promote efficient agricultural production. The ATA strategy aimed at creating 3.5 million jobs by 2015, generating foreign exchange and reducing food import expenses. Among the key achievements of ATA were the restructuring of the federal fertilizer procurement system, the provision of a reasonable basis for further wealth and job growth in Nigeria, and many companies, individuals, and donors are now keen to invest in Nigerian agriculture.

The push for the new African Green Revolution has led incorporation of genetically modified crops in the agricultural development. Using genetically modified crops has significant benefits but negative consequences on biodiversity, human and environmental health, and agro-allied endogenous businesses are critical (Daño, 2007). Nigerian farmers also did not accept the introduction of the innovative crop types due to cultural barriers and literacy levels (Dare Kolawole, 2012). Breisinger et al. (2009) show that the case study of Ghana in using GMO showed that the new Green Revolution only led to economic growth without addressing incorporating the socio-cultural, environmental and human effects. The case of Nigeria is a proof that the new African Green Revolution might not solve the poverty and food insecurity in the region, but rather the implementation of integrated Green Revolution has a sustainable future.

6 | AGRICULTURE STRATEGY IN KENYA

Before the Green Revolution in Kenya (1960s) subsistence agriculture with traditional farming methods was used accompanied by tribal land ownership. Post-independence (1963) subsistence farming expanded to large scale production, tribal farming changing to private ownership leading to the birth of Green Revolution in Kenya in the later years (Wu et al., 2019). The Kenyan Green Revolution encompasses substantial increase in agricultural yield, emerging from extensive application of modern inputs such as fertilizers subsidies, high yielding crops, pesticides and irrigation (Odame & Muange, 2011). Kenya is one of the few countries in Africa that has demonstrated the dramatic change in hybrid maize production as a result of Green Revolution (Jones & Gerhart, 1977). Over half of maize producing smallholder farmers in high potential areas (above 1500 m) used hybrid maize in 1974 (Jones & Gerhart, 1977). It is estimated that almost all farmers will have adopted these seeds by now. The importance of the agricultural sector in Kenya is manifested by its significant contribution to the National Gross Domestic Product by 30%–35%, 50%–69% of job creation, 65% of exports, and 60% of export earnings. Smallholder farming contributes about 75% of the agricultural production and 50% of the marketed produce is from farms averaging 0.2–0.3 ha each. On the other hand, large-scale farming focuses primarily on industrial crops (tea, coffee, maize, wheat and ornamental flowers) on farms averaging 50 ha each and livestock on farms up to 30,000 ha (FAO, 2015).

In contrast to the great benefit demonstrated by the Green Revolution (new crop type) in high altitude, the lower altitude and more drought prone areas have been circumspect of the hybrid maize types (Jones & Gerhart, 1977; Wu et al., 2019). In the 1990s, the Kenyan agricultural sector performance was dismal, dropping into the sub-zero growth rates by 2000, leading to bulk import of maize to make up this shortfall (Brooks, 2014; Nyoro & Ariga, 2004). Following this the Kenyan government prepared the Strategy for Revitalizing Agriculture (SRA) (2004–2014) and the Economic Recovery Strategy for Wealth and Employment Creation (ERS) (2003–2007) in a bid to return to self-sufficient food production and improve the overall social and economic development in the country (Odame & Muange, 2011). The SRA is one of the strategies the government implemented for a Green Revolution in the agriculture sector. The new government in 2008 introduced Vision 2030 and Agricultural Sector Development Strategy (ASDS) (2010–2020) to replace the ERS & SRA, respectively. Despite the claim that SRA was implemented successfully, the ASDS remained to tackle five of the six SRA "fast track" priority areas (Poulton & Kanyinga, 2013). The ASDS recommitted to achieve the poverty reduction, food security, and overall country growth SRA plan (World Bank, 2008). The above-mentioned organizations and reforms undoubtedly contributed to the major success in developing the Kenyan agricultural sector, but they were also criticized for uneven temporal and spatial performance (Poulton & Kanyinga, 2013; World Bank, 2008). The beneficiary farmers were mostly better resourced and located in high potential regions than poor smallholders in marginalized areas. Prior to 2015 the total cultivable area was 27.4 million ha, but only 6.33 million ha is cultivated, comprising about 11% of Kenya's land area. The irrigation potential is around 353,060 ha, of which only 150,570 ha is irrigated as pressurized (28.3%), surface (67%), and spate irrigation (4.3%). Formal irrigation schemes are either public (43% small- to medium-holders plus 39% commercial) or private (18%) (FAO, 2015). Kenya has also implemented the Climate Smart Agriculture Strategy (KCSAS) (2017–2026) with an objective to enhance adaptive capacity and resilience of farmers, pastoralists, and fisherwomen/fishermen to the adverse impacts of climate change and unsustainable land/water management; mitigate the emission of the greenhouse gases (GHGs) from agricultural production systems; establish an enabling policy, legal and institutional framework and address cross-cutting issues that adversely impact climate-smart agriculture (CSA) such as human resource capacity and finance (FAO, 2015).

The implementation of the above programs since the mid-2000s in Kenya has led to a strong coalition of actors to stimulate and drive a new Green Revolution through the use of certified seeds, fertilizers and new technologies (Odame & Muange, 2011). As mentioned above, the extensive range of agro-ecological and socioeconomic differences has posed a significant primary obstacle in advancing the new Green Revolution within dryland regions, particularly in the arid and semiarid areas located east and north of Kenya. Due to limited access to improved seeds and the presence of unpredictable rainfall, farmers in these regions rely on diversified farming practices and informal systems of seed saving, selection, and exchange to ensure food security (Brooks, 2014). The successful implementation of the new Green Revolution in western Kenya and the Rift Valley, known as the country's "maize basket," can be attributed primarily to well-capitalized agro-dealers who acted as de facto extension officers, the presence of high-potential land, and improved access to water resources (Brooks, 2014). Agro-dealers are the fundamental actors in the new input delivery system characterizing the Green Revolution. These locally owned businesses dispense seeds, fertilizers and information to smallholder farmers (Odame & Muange, 2011). Programs and policies aimed at promoting the Green Revolution have a detrimental impact on the informal systems prevalent in dryland areas. These initiatives explicitly advocate for the replacement of informal seed systems with formal ones, which indirectly undermines the credibility of informal system seeds by labeling them as uncertified (Brooks, 2014; Brooks et al., 2009). The increasing prevalence of hybrid maize poses a challenge to sustainable production in arid regions as it displaces other crop options and open-pollinated varieties that allow for seed reuse in subsequent years, unlike hybrid seeds (Brooks, 2014; Odame & Muange, 2011). Therefore, the integration of existing and new approaches as an input system plays a tremendous role in implementing successful Green Revolution in a country with extremely agro-ecologically heterogenity such as Kenya.

7 | CONCLUSION

The results of this SLR show that, despite 1.4 billion USD dollar in funding by AGRA to encourage farmers, disappointing results have been recorded with the AGRA Green Revolution program by the deadline in 2020. Indeed, the number of hungry people in the 13 AGRA countries has risen by 30% since 2006. In addition to chronic hunger, Africa accounts for half of the 12 million children under the age of 5 years dying each year from hunger, which is far away from achieving the millennium development goals or the SDGs.

According to the AGRA report related to Building Sustainable and Resilient Food Systems in Africa published in 2021, challenges impeding Green Revolution in Africa are the growing incidence of conflict, political instabilities, natural hazards, pandemics, climate change, economic shocks, and macro-economic volatility. Resilient and sustainable agri-food system are required to overcome the challenges faced in meeting the Green Revolution as well as ensuring sustainable economies and achieving the SDGs and Agenda 2063 Africa Goals.

Therefore, the main conclusions drawn from this SLR emphasize the importance of resilient and sustainable agri-food systems that are tailored to the specific needs of each country. To achieve this, it is crucial to implement key concepts such as agro-ecology, green innovation technology, smart farming, and circular economy practices. Examples of successful agricultural strategies from countries like Morocco, Nigeria, and Kenya can serve as valuable learning experiences for other African nations.

By collaborating and sharing knowledge, African countries can learn from the effective implementation of practices like converting organic waste into productive inputs for farm production, implementing water recycling techniques, adopting efficient irrigation methods, implementing effective drainage and water management systems, and developing robust strategies for climate change adaptation. Morocco, Nigeria, and Kenya have demonstrated success in these areas, and their experiences can provide valuable insights for other countries in the region.

In water-stressed regions, it is imperative to adopt alternative policies and strategies that align with sustainable cropping systems and adaptation strategies. These measures may include implementing rainfall harvesting techniques, utilizing nonconventional water sources, exploring nonconventional crop options, and promoting the cultivation of crops that require less water for irrigation. By incorporating these approaches, regions facing water scarcity can enhance their resilience and ensure the long-term sustainability of agricultural practices.

The PRISMA statement appears to be a useful method to drive consistency and discipline in systematic reporting.

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