AKADEMIYA 2063

zef
Center for
Development Research
University of Bonn

FROM POTENTIALS TO REALITY: TRANSFORMING AFRICA'S FOOD PRODUCTION

Investment and policy priorities for sufficient, nutritious and sustainable food supplies

PARI

Program of Accompanying Research for Agricultural Innovation

OCTOBER 2020
research4agrinnovation.org

PREFACE AND ACKNOWLEDGEMENTS

Instigated by the German Federal Ministry for Economic Cooperation and Development (BMZ) the study comes at an opportune time, when Africa, the EU and Germany intensify their consultations and cooperation on a broad range of development issues. These include joint strategies in the areas of green transition, digital transformation, coping with COVID-19, sustainable growth, jobs, and migration, as well as to support peace and sound governance. Food security and agricultural development in Africa are central to all these big agenda items. There is an opportunity to advance this agenda by putting forward concrete proposals for investments and policies that can lift millions of people out of hunger and malnutrition. The agenda proposed here is to be a long-term one that should be sustained, yet initiated in the short term with concrete steps now.

German and African research partners developed this study, drawing on their long term and ongoing collaborative research on agriculture and opportunities for achieving food security.

The study was supported by the “Program of Accompanying Research for Agricultural Innovation” (PARI), which is funded by the BMZ.

We would like to thank Joe Hill for the language edit of this study as well as Katharina Zinn and Yesim Pacal for the layout. We are also grateful to Niklas Müller, Amy Newsome and Theodor Rathgeber for their support in translating the report into German. Katharina Gallant, Julia Machovsky-Smid and Tea Qendrai provided valuable research assistance.

CONTRIBUTORS

Heike Baumüller, Center for Development Research (ZEF), University of Bonn, Germany

Joachim von Braun, Center for Development Research (ZEF), University of Bonn and Malabo-Montpellier Panel, Germany

Assefa Admassie, University of Addis Ababa and Center for Development Research (ZEF), University of Bonn, Ethiopia

Ousmane Badiane, Akademiya2063 and Malabo-Montpellier Panel, Rwanda

Evelyn Baraké, formerly Center for Development Research (ZEF), University of Bonn, now International Development Research Centre, Canada

Jan Börner, Institute for Food and Resource Economics, University of Bonn, Germany

Izidora Bozic, Center for Development Research (ZEF), University of Bonn, Germany

Bezawit Chichaibelu, Center for Development Research (ZEF), University of Bonn, Germany

Julia Collins, Akademiya2063, Rwanda

Thomas Daum, Ruthenberg Institute of Agricultural Science in the Tropics, University of Hohenheim, Germany

Tsegaye Gatiso, Institute for Food and Resource Economics, University of Bonn, Germany

Nicolas Gerber, Center for Development Research (ZEF), University of Bonn, Germany

Tigabu Getahun, Policy Studies Institute, Ethiopia and Center for Development Research (ZEF), University of Bonn, Germany

Katrin Glatzel, Akademiya2063 and Malabo-Montpellier Panel Secretariat, Rwanda

Sheryl Hendriks, Institute for Food, Nutrition and Well-being, University of Pretoria and Malabo-Montpellier Panel, South Africa

Oliver Kirui, Center for Development Research (ZEF), University of Bonn, Germany

Lukas Kornher, Center for Development Research (ZEF), University of Bonn, Germany

Zaneta Kubik, Center for Development Research (ZEF), University of Bonn, Germany

Eike Lüdeling, Institute of Crop Sciences and Resource Conservation, University of Bonn, Germany

Alisher Mirzabaev, Center for Development Research (ZEF), University of Bonn, Germany

Papa Gora Ndiaye, Réseau sur les Politiques de pêche en Afrique de l'Ouest, Senegal

Tekalign Sakketa, Center for Development Research (ZEF), University of Bonn, Germany

Meera Shah, Imperial College London and Malabo-Montpellier Panel Secretariat, UK

Getaw Tadesse, Akademiya2063, Ethiopia

John Walakira, Uganda National Fisheries Resources Research Institute and World Aquaculture Society-Africa Chapter, Uganda

CONTENT

FIGURES

TABLES

ACRONYMS

AfCFTA	African Continental Free Trade Area
AGRA	Alliance for a Green Revolution in Africa
AMU	Arab Maghreb Union
BMZ	Federal Ministry for Economic Cooperation and Development
CAADP	Comprehensive African Agricultural Development Programme
CEN-SAD	Community of Sahel-Saharan States
CEMAC	Central African Economic and Monetary Community
CGIAR	Consultative Group on International Agricultural Research
COMESA	Common Market for Eastern and Southern Africa
CORAF	Conference of Heads of African and French Agricultural Research
DAC	Development Assistance Committee
D4Ag	Digital solutions in the agriculture sector
EAC	East African Community
ECOWAS	Economic Community of West African States
ECCAS	Economic Community of Central African States
EEZ	Exclusive economic zone
EPA	Economic Partnership Agreement
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
FDI	Foreign direct investment
FMO	Farmers' Marketing Organization
FO	Farmers' Organisation
GALVmed	Global Alliance for Livestock Veterinary Medicines
GFCF	Gross Fixed Capital Formation
GDP	Gross Domestic Product
GHI	Global Hunger Index
GIC	Green Innovation Centres
GIS	Geographic information systems
GIZ	Gesellschaft für Internationale Zusammenarbeit/ German Development Agency
ICN2	Second International Conference on Nutrition
ICTs	Information and communications technology
IGAD	Intergovernmental Authority on Development
IPCC	Intergovernmental Panel on Climate Change
LSU	Livestock unit
LULC	Land use and land cover
MDG	Millennium Development Goal
MFI	Micro-finance institution
NAFSN	New Alliance for Food Security and Nutrition
NARI	National agricultural research institute
NARS	National agricultural research system
NEPAD	New Partnership for Africa's Development
NoU	Number of undernourished people
OECD	Organisation for Economic Co-operation and Development
ODA	Official development assistance
PEN	Poverty and Environment Network
PoU	Prevalence of undernourishment
R&D	Research and development
REC	Regional economic community
SADC	Southern Africa Development Community
SDG	Sustainable Development Goal
SME	Small and medium-sized enterprise
SSA	Sub-Saharan Africa
TFP	Total Factor Productivity
TVET	Technical and vocational education and training
WAEMU	West African Economic and Monetary Union
ZEF	Center for Development Research, University of Bonn, Germany

1 SUMMARY AND PROPOSED INVESTMENT AND POLICY ACTIONS

The aim of this study is to identify how Africa may transform its potentials into realities and actually secure its supply of food for affordable and healthy diets from the sustainable use of resources. Africa's food imports amount to about US$ 60 billion per year. In net terms, cereals account for about US$ 25 billion per year, meat and dairy for US$ 8 billion, the sugar sector for US$ 4 billion and the vegetable oil sector for US$ 9 billion. This market, which is primarily urban, holds great potential for African agriculture and food industries. So, the opportunities of capturing a growing market share by expanded African own food production are high. Moreover, the case for related investments can be easily made: cost of undernutrition in Africa is on average 11 percent of its annual gross domestic product, and every dollar invested for improved nutrition generates US$ 16 in economic returns (IFPRI, 2016, 2015).

Food and agriculture is at the heart of the economies of almost all African countries. Agriculture – here defined to include crop production, animal husbandry, fisheries and forestry, and the manufacturing and processing related to these – has the capacity to stimulate growth through rising rural incomes, enhance economic transformation in Africa, create jobs, increase government revenue, and ensure accelerated economic growth and development. Increasing producers' income is a key objective in itself and has large positive effects for poverty reduction and food and nutrition security.

Yet agriculture itself needs transformation in order to play its transformative role in economic development. A policy bias against agriculture used to be prevalent among African policy makers and development partners. That has changed significantly and the important role of agriculture in contributing to food and nutrition security is reflected in the African Union Heads of State Malabo Declaration (AU, 2014) and in its prioritization in the Comprehensive African Agricultural Development Programme (CAADP), an integral part of the New Partnership for Africa's Development (NEPAD). There the strategic directions are articulated well, but progress toward set goals needs acceleration. Indeed, there are growing opportunities for such acceleration through innovations, investments and market development, now increasingly supported by African governments, development partners and the private sector. The adverse economic effects of COVID-19 for markets and demand creation are temporarily hampering these agricultural opportunities.

In this report, our focus is on investment, cooperation and policy actions. We distinguish between systemic and sector-specific investments and actions. **Systemic actions and investments** cut across the whole food and agricultural system and include economy wide policies and governance; **specific sub-sector actions and investments** enhance productivity in crops, animal production, processing and natural resource management. Policy and investment priorities along these clusters are summarized below.

I) Systemic actions and investments for sustainable agricultural development

1. **Skill development:** Up front, we draw attention to investment in people that manage African agriculture and the food system. Investment to advance skills is critical for African food and agriculture. Investments should focus on strengthening agricultural technical and vocational education and training (TVET), drawing on successful examples from the continent as well as experiences from other countries. Vocational training should be strengthened for professions along the entire value chain. Investment per person for agricultural TVET is about US$ 500, but it significantly fosters productivity: differences in farmers' skills account for about 30 percent of the variation in agricultural productivity (Cai, 2011), and explain up to 17 percent of variation in yields (Laajaj and Macours, 2017). Digital technologies play already an import-

ant role and can extend the reach and reduce the cost of vocational training and extension services.

2. **Youth engagement:** The voice of youth must be heard. Efforts to engage young women and men should focus on improving the productivity of those who are already employed in or to make the agricultural sector economically attractive for those who are considering joining the sector, through better access to land, credit, mechanization and digitalization technologies and skills. Provision of land or credit to the youth without providing adequate soft and hard skill training (before and after they establish businesses) does not help sustainable job creation for the youth. Rural areas need to become attractive places to live, not only work.

3. **Gender equality:** Eliminating the gender gap between female and male producers would raise the yield of women-run plots by up to 30 percent and raise the total agricultural output in lower-income countries by 2.5 to 4 percent (FAO, 2011). Investments in the development of agricultural innovations and technologies that benefit women specifically are needed, for instance tools that reduce the amount of labour necessary to complete tasks predominantly done by women. Extension services must become more accessible to female producers. Women's land rights need to be secured through reforms in inheritance laws, and raising awareness of their rights. Policies that encourage the expansion of labour-intensive agro-industrial jobs for women are important for job creation. Women must also be relieved from the drudgery associated with many manual household chores, which will contribute to agricultural productivity and improve their own and their family members' wellbeing.

4. **Research investments in partnership:** Agricultural research is one of the most effective investments to tap potentials. For example, it is estimated that every US$ spent on national agricultural R&D generates average returns in the order of US$ 3 (Fuglie and Rada, 2013). Currently African countries clearly underinvest in agricultural research and innovation. This can only partly be compensated for by international partnerships. The benefits of agricultural R&D could be amplified by improving linkages between formal agricultural research institutes with private sector and informal structures among producers, processors and civil society groups to ensure more effective and participatory research processes as well as adoption of innovations. Efforts should be made to improve linkages between agricultural research and extension providers to promote the widespread dissemination of promising innovations.

5. **Digitalization:** Investments in infrastructure for mobile connectivity are a high payoff priority across Africa as a perquisite for digital tools to be widely and effectively used in the food and agriculture sector. The African Development Bank estimates that an additional US$ 4-7 billion needs to be invested in ICT infrastructure every year (AfDB, 2018). In addition, investments and policies are needed to provide a conducive innovation environment for local providers of digital services. Investments in human capacities are also required to develop and use digital innovations in food and agriculture. Importantly, digitalization will only transform the sector if digital solutions are embedded in broader agricultural and rural development strategies, for instance in the above-mentioned upgrading of skills and extension systems, and if digital service costs come down.

6. **Rural and agricultural finance:** Investing in the establishment and expansion of dedicated agricultural finance institutions is needed for accelerated capitalization of the agricultural production sector as well as for risk management. Specific interventions include strengthening agricultural development banks through sound governance and management. Rural cooperatives and rural credit and saving associations need linkages to banks. Micro-finance systems should be further expanded as part of the institutional landscape for the productive and rural service sectors. Including women farmers in the financial system must be a high priority. Grant-based business investments can be considered too: research shows that for the poor who are credit risk-averse, the internal rate of return and the capital growth was higher for grant-based investments compared to investments that were provided in the form of credit, by 9 and 16 percentage points respectively, because grants had reduced fear of risk (Tadesse and Zewdie, 2019). Crop insurance as an agricultural

finance policy is so far rare in many African countries, but could help tap potentials in risk-prone farming environments. Land rights are crucial for accessing finance and to motivate investment by small-scale producers themselves.

7. **Energy:** Access to energy along the entire agricultural and food value chains is among the most important investment and policy priorities. Programs should focus on improving access to electricity for mechanization, digitalization and irrigation expansion, post-harvest processing, transport and distribution. Innovative community-owned off-grid and mini-grid solutions with renewable energies (solar, wind, biomass) are feasible in many rural African contexts. A liberalization of the energy sector within countries and across borders can promote the engagement of the private sector. Such programs need to be based on context-specific assessments of costs vis-à-vis benefits. The benefits typically include important non-agricultural effects, such as more participation of girls in education and local manufacturing. Investments of about US$ 120 billion per year are needed until 2040 to achieve reliable electricity supple in Africa (IEA, 2019).

8. **Sustainable land and water management:** Adoption of sustainable land management and agro-ecology practices (not only for croplands, but also pastures and forests) should be promoted, especially where land degradation is a risk. Investment in skill development and agricultural research will facilitate adoption of sustainable land and water management practises. Land and environmental legislation, monitoring and enforcement are mechanisms to enhance locally adapted approaches. Sustainable land and water management requires a holistic approach based on secure and enforceable land and water rights. Land registration costs have come down to a few US$ per plot due to digital approaches and remote sensing, but trust in tenure contracts and ownership titles is not yet strong enough in most of Africa. Improvements in soil, infrastructure, irrigation and mechanization will not happen without secure tenure systems and their enforcement. Such investments improve the value of the land itself. Additional investments in effective conflict resolution mechanisms related to land and water use are needed in some regions, based on well-documented land rights and effective management of communal resources.

II) Specific production-enhancing actions and investments

Crop-related innovations and agro-forestry

1. **Seed systems:** Good seeds for farmers remain a top investment and innovation priority. Strengthening plant breeding in Africa that is informed by local agro-ecologies, pest risk and consumer preferences is essential for tapping long-run production potentials. Breeding should focus on crops beyond staple grains and include tubers, roots, fruit, legumes, nuts and vegetables to ensure biodiversity and dietary diversity. African national research organizations, the CGIAR (Consultative Group on International Agricultural Research) and the Green Innovation Centers in the context of the German initiative of ONE World – No Hunger contribute to this. Breeding programmes should pay attention to climate risks and extending the growing season for crops through early and late-maturing varieties. For instance, the use of nitrogen-efficient varieties could increase yields in Africa by 21 percent for rice, and 8 percent for maize compared to projections without improved varieties (Rosegrant et al. 2014). The time and cost associated with releasing tested new crop varieties needs to be reduced, while putting in place sound seed quality control systems which provide space for different types of operators. The potential of cross-country seed testing and certification as well as opportunities for and actual feasibility of public-private seeds production and distribution systems, including multiplication by smallholder farmers, need to be explored. Farmers' participation in seed supply systems, be it own produced or multiplied seeds, should be supported.

2. **Fertilizer and soils:** Soil testing and long-term efforts to improve soil fertility are needed to ensure increasing returns to fertilizer and make fertilizer use more effective. At the same time, the often high cost of fertilizer need to be reduced through investments in logistics infrastructure and intra-regional trade rather than relying on input subsidies. Early interventions in microdosing allowed farmers in Mali, Burkina Faso and Niger

to increase sorghum and millet yields by 44 to 120 percent, and provided better economic returns for farmers than fertilizer application at conventionally recommended rates (ICRISAT, 2009; Okebalama et al. 2017). Importantly, farmers will benefit most from packages of different inputs and innovations: Rezaei and Gaiser (2017) show that combining appropriate nitrogen fertilizer use, supplementary irrigation and new cultivars could double maize yields in Africa.

3. **Mechanization:** As in Asia, Africa's small land holdings are not a constraint for mechanization, as long as farmers can collaborate to hire or share farm-level machinery. Mechanization reduces work burdens and there are yield effects too: A study across eleven African countries found that tractor use increases maize yields by around 0.5 tonnes per hectare or 25 percent (Kirui, 2019). Mechanization in farming and processing can also have positive production and productivity effects by improving the timeliness of operations. A favourable business climate is required to support the emerging private markets for agricultural machinery, and farmer cooperation for sharing systems. Governments for their part should focus on providing capacity-building and mechanization research. Mechanization contributes to the structural transformation of agricultural systems and, if properly introduced, leads to more jobs in the food system and more attractive working conditions. At the same time, safeguards need to be put in place to minimize any potential negative effects of mechanization, for instance in soil management, or for unsustainable farmland expansion.

4. **Irrigation and water management:** Irrigation comes in many forms, and at different costs. Costs are not only a matter of technology, but of organizational arrangements and water infrastructures in the context. The most promising investment opportunities in Africa lie in the expansion of small-scale irrigation. Xie et al. (2014) project that exploiting the small-scale irrigation potential across Sub-Saharan Africa could result in additional net revenues of US$ 14-22 billion per year, directly benefitting between 113 and 369 million people. Investments to expand irrigation should promote supply chains and distribution networks for affordable pumps and their spare parts, water-efficient irrigation technologies and equipment. Solar energy-driven drip systems are a great opportunity for smallholders. Better access to finance for smallholders will be a prerequisite to enable uptake of these technologies. To ensure environmentally sustainable water consumption, monitoring of water use through water accounting and aquifer auditing, water saving irrigation technologies and capacity building for water governance institution need to be promoted. Combined investments are particularly effective: Increased nutrient application alone would raise yields to 50 percent of attainable yields for maize and rice, whereas both increased nutrients and irrigation would raise yields to 75 percent of attainable yields (Mueller et al., 2012).

5. **Reducing food losses and waste:** Investments in technological innovations will be needed to reduce food losses and waste, notably low-cost storage solutions such as hermetic bags for grains and reusable plastic crates for the transport of fresh produce. In addition, on-farm practices and collaborations among small- and medium-sized enterprises (SME) along value chains to reduce losses during production and storage need to be implemented. Technologically empowered SMEs, through the use and adoption of advanced technologies, would directly contribute to an 84 percent reduction and indirectly contribute to a 30 percent reduction in food loss in Sub-Saharan Africa (Hatibu, 2019). Practical measures need to be supported by national strategies, financing, public-private partnerships and research. Food waste in cities at retail and household levels is at a high level also in Africa and needs to be addressed through education, incentives and modern low-energy cold storage. Because of its importance, we emphasize investments in food processing here from a loss and waste reduction perspective, and again further down in the context of market improvements. Having accessible ways of aggregating produce for canning, bottling, fermenting, drying and freezing is a huge pull factor for production. Currently farmers often only produce enough to meet households and local market demand in the particular season, but if the excess produce can be sold to processors, they can drive up production, smooth seasonality on

consumption and ensure year-round availability of vitally nutritious foods, especially for perishable goods. The immense spill-overs between investments in infrastructure and the reduction of food losses and waste need to be taken into account when calculating the benefits of improved infrastructure and market access.

6. **Agroforestry:** Sectoral policies affecting forestry and agricultural land uses need to be better aligned and regulated to encourage agroforestry practices and incentive-based conservation, taking into account customary land tenure systems. To reduce pressure on forest resources, efficiency of forest biomass uses need to be improved while promoting alternative clean energy supply for forest-dependent rural households. In addition further research is urgently needed for high-frequency and high-resolution monitoring of tree cover and wildlife dynamics as well as for the development of science-based tools to assess potential economic, social, and environmental impacts of adopting agroforestry innovations at landscape scale.

Animal husbandry

7. **Livestock producers** should be invested in for improved services, skills and knowledge via extension services. Quality of nutritious feeds needs to be assured through grading, labelling and certification in the markets. In addition, investments in animal health and animal breeding have high pay-offs and crucial safety elements to prevent zoonotic disease outbreaks. The animal products sector is demand-driven, expecting a tripling of demand in the coming three decades. This is an income opportunity for African production. To make this sustainable, attention should be paid to increasing technical support to livestock research programs, enhancing investments in IT-based data systems and strengthening analytical capacities, with a focus on animal science, genetics and health. Specific investments should be targeted at establishing and strengthening animal input supply and distribution systems such as artificial insemination, establishment and strengthening of community-based forage seed production of improved varieties, and all services for a functioning **dairy** system, as that sector has high growth potentials given that many dairy products are imported.

Fisheries

8. To promote the **aquaculture and capture fisheries** sector as a whole, ongoing African efforts to develop a sustainable Blue Economy strategy and mainstream related measures in national and continental development plans need to be strengthened. This will also require investments in skills as well as increased research and management capacities. Moreover, investments in improved processing capacities (including canning and drying) and low energy cold chains will facilitate trade and reduce post-harvest losses of this highly nutritious food source. Investments and policies to improve the sustainable management and exploitation of marine and inland capture fisheries in Africa are needed, with a focus on sustainable fishing gear, and transparent and equitable conditions of access to offshore fisheries resources. The need for restoration of fishery habitats and breeding grounds is clearly established: Regeneration periods are vital to ensure fish populations grow and the size of the fish does not degenerate. Social protection measures for fishery communities can be (and have been) used to allow for off-season regeneration of the breeding areas.The aquaculture sector has significant but as yet largely untapped potential. It can be realized through additional investments in feeds and fish stocks, and environmental water management.

III) Institutional frameworks: Governance, market access, trade and continental and international cooperation

1. **Inclusive markets:** Investments and policies that advance the commercialization of small-scale producers and small businesses facilitate their participation in markets. Specialized farmers marketing organizations including cooperatives can provide support in this regard. In addition, contract farming should be promoted, provided that it is designed in such a way that contract security is assured for participants and producers receive a fair return for their products. A meta-analysis of contract farming programmes in 13 countries

indicates an increase of average farmers' income by about 38 percent (Ton et al., 2018). Public investment is needed in hard and soft market infrastructure to improve market access through constructing, modernizing and managing market centres, market shades and warehouses, and developing market information systems. In response to expanding urban markets, the food processing sector is rapidly becoming the main bridge or barrier between small-scale producers and domestic markets. Failure to competitively grow the sector will cut small-scale producers off domestic markets. On the other hand, a growing and competitive processing sector will be the main vehicle to integrate small-scale producers into the rapidly transforming food systems. This requires specific focus in policies dealing with skills development, financing, investment and technical innovation.

2. **Agri-food value chains:** Different investments, digital tools, regulations and policies will need to target the various actors in the value chain. In many contexts, investments in wholesale market infrastructures helps not only traders, but small-scale producers, food processors and retailers. Capacity building is required in particular in the area of logistics and retail. Overall, food safety regulations as well as quality grading and standardization need to be improved. Value chains in Africa (and internationally, especially for high value cash crops such as cocoa, coffee and nuts) from the small farm sector increasingly benefit from innovative digital tracking systems that facilitate control of social and ecological standards, and thereby offer more returns for such quality characteristics at farm levels. Modern digital tracking systems can not only serve exports internationally but all food products in taking African trade integration further, and especially so under COVID-19. Tapping the potential of inclusive markets for smallholders, agri-food value chains and intra-African trade requires massive investments in physical transport infrastructure such as roads and railways, estimated at US$ 35-47 billion per year (AfDB 2018).

3. **African Continental Free Trade Area (AfCFTA):** Effective and fast implementation of the AfCFTA would be a top priority in support of agricultural development. Intra-African agricultural trade could be boosted by 20-35 percent and strongest for meat and dairy products, sugar, beverages and tobacco, vegetables/fruit/nuts and rice (UNECA and AU, 2020). For the agriculture sector as a whole, the World Bank (2020b) forecasts an increase in intra-African imports of 72 percent by 2035. Such intra-African trade expansion can leverage regional differences in the competitiveness of African countries in key food value chains. To this end, trade standards need to be harmonized and regulatory barriers to trade within Africa reduced. The implementation of the AfCFTA is associated with substantial costs to facilitate the negotiation process and harmonize standards and trade rules across the continent. The African Union should be supported financially and through capacity building to support this process. Particular attention should be paid to the reduction of non-tariff barriers by supporting current efforts of non-tariff barrier-reporting by the African Union.

4. **Governance for agriculture and food security:** Many of the national agricultural and food security plans (CAADP National Agricultural Investment Plans) do not deal with food security per se and focus only on production. There is an opportunity to change that with clear strategies and investment priorities. Reforms in support of rule of law and strong enforcement at central and local government levels are key for improved agricultural productivity and food security. These reforms need to ensure that corruption is reduced and that women, youth and marginalized groups are well represented. Countries with better governance infrastructure produce more agricultural outputs, suggesting that investments in such infrastructure can improve agricultural productivity (Lio and Liu, 2008). Strengthening and mainstreaming the mutual accountability processes promoted under the African Union CAADP agenda, including the biennial review and agricultural joint sector reviews, are laudable building blocks. Enhancing peace and stability will also be essential for agricultural productivity, e.g. in the Sahel region. Finally, an enabling regulatory environment is needed to optimise the role of civil society and the corporate sector in making them drivers of agricultural development.

5. **Farmers' organisations:** Building effective farmers' organizations is an investment in institutional innovations. This is less of a task for governments and more one for international networks of farmers' organizations and civil society groups. There is real need and opportunity for farmers' organizations to fill the gap in service provision for farmers, including both technical and commercial services. To support and empower them to play this role more effectively is a most critical issue. That requires access to necessary organizational and business skills to operate effectively. In most African countries the staff of farmers' organization lack the right knowledge and resources to demonstrate sound practices to the member farmers and link them to higher value chain actors. Establishing and strengthening common interest groups and farmers cooperatives and unions would help to enhance productivity and commercialization.

6. **Private sector investments:** African agriculture is under-capitalized. Capital stock per agricultural worker is about US$ 3,000 compared to more than US$ 10000 in middle income countries. Capital investment levels in agriculture in Sub-Saharan Africa, even though they have almost tripled in comparison to the late 1990s, are still much below what is required to bring African agriculture near to its potential. Foreign direct investment in African food and agriculture was about US$ 1.5 to 2 billion per annum between 2003 and 2017 (Husman and Kubik 2019), while domestic investment was about US$ 20 billion. This needs to be addressed by facilitating increased investments especially by agricultural producers and businesses through better access to finance and lower costs of credit, as well as affordable insurance schemes to reduce risks. Property rights of small farms need to be secured to provide collateral and incentivise investment. Domestic and foreign investments will benefit from conducive regulatory and tax regimes that do not undermine local interests, including a supportive business environment, trade facilitation and local infrastructure.

7. **African and international policy initiatives.** The regional strategies and policies, i.e. the African Union Agenda 2063with the Malabo Declaration, and the African Development Bank's "Feed Africa" Strategy, inform national policy frameworks and investment plans. In addition to national initiatives, some national agricultural development programs have been converted into supranational programs in which some countries specialize in a particular target commodity or topic and thereby reduce duplication of efforts and costs.

8. **Development cooperation:** Official development assistance (ODA) from members of the Organisation for Economic Co-operation and Development (OECD) allocated to African agriculture recovered in recent years, growing to about US$ 4 billion in 2018. Agriculture ODA as a share of total OECD ODA rose to about 9 percent in 2018, reaching a level close to that in 1996. The German Government's initiative of ONE World – No Hunger with its Green Innovation Centers for the agriculture and food sector is a significant component. This level of commitment needs to be further expanded and combined with continued attention to aid effectiveness. And importantly, development assistance needs to be aligned with and supportive of the strategies referred to above for greater effectiveness. Any resulting programmes should be closely aligned with Africa's self-defined priorities, articulated in continental and national policy documents.

Ten Top priorities that boost agricultural growth and meet food systems needs

The investment and policy actions proposed above should not be viewed in isolation, but packages of them have big synergies. We also note that the above sets of eight systemic, eight sector-specific, and eight institutional investment proposals may seem a too large and diverse set for policy-makers that desire a focussed and limited set of priorities. Actually, considering them at country level would require strategic priorities and more detailed granularity of investment actions and policy reforms that hold promise not only individually but also foster the synergies among them, depending on country circumstances. In all investment priorities regional and international cooperation is essential.

To narrow down the **priorities** we considered as main criteria the expected contribution of investment and policy actions to the aim posed here, i.e. transforming Africa's agricultural production potentials into realities, actually securing its supply of food for affordable and healthy diets from sustainable use of resources.

1. Invest in young women and men, i.e. vocational training and extension services, to improve skills for all core and support professions along the entire value chain.
2. Invest in innovation and related agricultural research on crops, animal production, agro-forestry and fisheries.
3. Support the producer and local private sector-led development and adoption of environmentally sustainable small-scale irrigation, rural energy, digitalization and mechanization of production.
4. Implement sustainable land use, integrated, science-based agroforestry practices and incentive-based conservation, and agro-ecological approaches.
5. Invest in mobile connectivity of rural areas and across Africa as a perquisite for digital tools to be widely and effectively used in the food and agriculture sector.
6. Improve market access through rural infrastructure investments, and facilitate the participation of small-scale producers and small businesses in inclusive local and continental value chains, and the opportunities of the African Continental Free Trade Area.
7. Provide suitable frameworks and finance for the agro-processing sector, and invest in technological innovations to reduce food losses and waste, in particular on the farm and in the early stages of processing.
8. Improve the financial infrastructure and regulatory frameworks for agricultural banking to facilitate investments by small-scale producers and small businesses, including micro-finance.
9. Implement policy interventions that improve the business environment for agriculture, reduce corruption, build peace and stability among farmers and herders, and ensure strong representation of farmers' organizations in food and agriculture policy.
10. Align development support to Africa's own agricultural transformation agenda, at continental level, i.e. the African Union Agenda 2063 with the Malabo Declaration and at country levels, and sustain and expand development assistance in the above-mentioned priority areas for agriculture development and food security.

2 INTRODUCTION

The aim of this study is to identify how Africa may actually secure its supply of food for affordable and healthy diets from the sustainable use of its own resources. Intra-African and external food trade opportunities are considered too. The answer to this question can be approached through two interrelated pathways: (1) increasing the supply and distribution of sufficient and healthy foods and (2) increasing incomes to enable Africans to purchase such foods from within and outside of Africa.

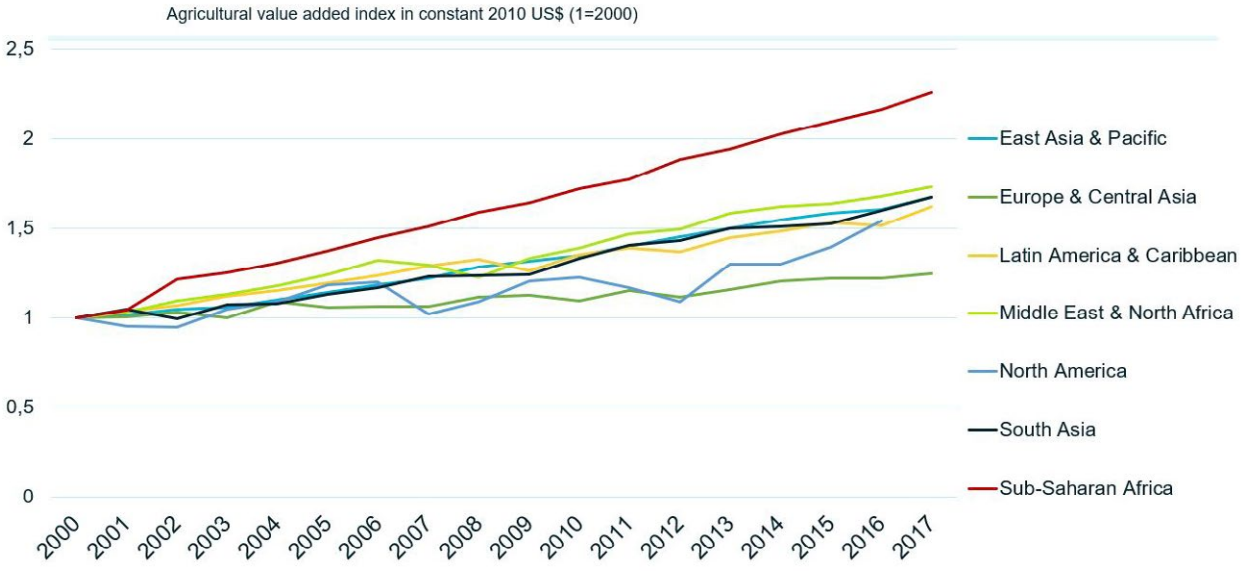
In the past two decades, attention to agriculture by many African governments and development partners and the private sector increased. Africa's agricultural sector growth accelerated and in the past two decades has been higher than in all other world regions (Figure 1).

While African agriculture shows accelerated growth, Africa imports large amounts of food, which add up to about US$ 60 billion per annum (UNCTAD, 2020). In net terms, cereals account for about US$ 25 billion per year, meat and dairy for about US$ 8 billion, the sugar sector US$ 4 billion and in the vegetable oil sector US$ 9 billion (Bouët, Odjo and Zaki 2020). This market, which is primarily urban, is an opportunity for African agriculture and food industries.

It is noted for some time that Africa's agriculture performs below its potentials. Lack of investment, institutional and governance deficiencies, and lack of supportive hard and soft infrastructures are mostly deemed the reasons for the gap between potentials and realities.

That there is still a lot of untapped potentials in African agriculture is indicated in a big-picture perspective. Comparing the African agricultural sector growth rate with Asia's or Latin America's suggests, that African agriculture grew faster than the other regions. But the sources of growth matter: African agriculture achieved only about 1 percent growth through innovations (i.e. total factor productivity growth), whereas Asia and Latin America achieve about 3 percent per annum through innovations (Fuglie and Rada 2013). The two percentage point difference is a sign of untapped African potentials. The good news is, these potentials can be tapped by suitable policy changes,

Figure 1: Agricultural Value added index in world regions



Source: Ousmane Badiane, 15th CAADP Partnership Platform, 11-14 June 2019 | Nairobi, Kenya

investments and innovations that are adapted to the local African and continental contexts, and these changes are already in progress.

The agricultural sector is at the heart of the economies of almost all African countries. Agriculture – here defined to include crop production, animal husbandry, fisheries and forestry – has the capacity to stimulate economic growth through rising rural incomes, enhance economic transformation in Africa, create jobs, increase government revenues, and ensure accelerated economic growth and development. Agricultural sector development remains an important driver of food security improvement, inclusive growth, and rural revitalization in Africa (IFPRI, 2019; World Bank et al., 2017). The important role of the agricultural sector in contributing to food security is reflected in its prioritization in the CAADP, an integral part of the NEPAD.

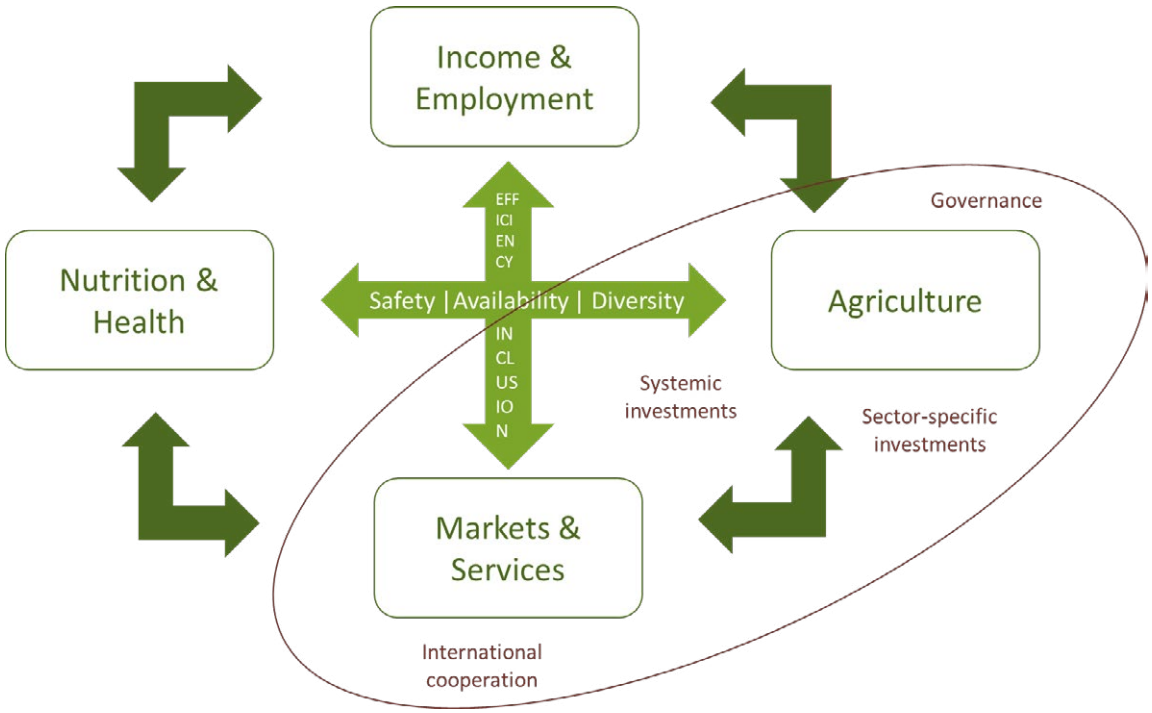
Improvements in productive and processing capacities would reduce poverty and improve food security by ensuring a sustainable supply of healthy and affordable food, generating export earnings and higher income for agricultural producers, increasing employment and income opportunities, and by creating linkages between agriculture and other sectors that drive the rural economy and provide capital and labour for growth in various sectors. Innovation would unlock potential to reduce malnutrition and reduce losses and waste.

Fast growing urban markets offer large commercial opportunities to Africa's about 60 million farms. The centre of gravity in Africa's food system moves to urban areas (AGRA, 2020).

The study is framed within an overall food systems approach (see Figure 2). It deals specifically with the components that relate to **agriculture** (How can Africa boost its supply of food products for a nutritious diet?) and related **markets** (How can domestically produced supplies be marketed and traded to improve food security at the continental level?).

Overarching, and surrounding Figure 2, are agricultural and environmental as well as macroeconomic framework conditions. Within this food systems framework, this study focusses mainly on **agricultural production and on market related linkages**. This entails, for example, paying attention to food supply and access to foods with diverse diets, quality and safety of foods, and production conditions. Markets and services are critical for delivering affordable and nutritious food. The attention to markets and trade is motivated by the heterogeneity of the African continent. Not all countries will be able to produce all

Figure 2: Food systems approach and focus of this study



Source: Adapted from von Braun (2017)

of their own food and will thus rely on imports for some food items, which entails the opportunities of comparative advantages guiding intra-African trade as envisioned by the African Continental Free Trade Area (AfCFTA), concluded under an agreement between African Union (AU) countries signed in March 2018. Trade is playing a growing role for tapping African agricultural potentials (Bouët et al., 2020). African agricultural exports showed an upward trend between 2003 and 2018, and diversification of export destinations, and intracontinental trade shows an expansion of the export shares of processed food products (Bouët et al 2020).

This study provides a structured review of recent state-of-the art literature with analyses to identify evidence-informed investment and policy priorities that could increase supply-side capacities and food security in Africa. Such an assessment depends on an understanding of the current food security situation in Africa and the key challenges that are hampering an adequate food supply and healthy and safe diets. This is discussed in **Chapter 3** which also looks ahead to assess how key trends are likely to shape future demands, such as changing diets, urbanization and population growth.

Chapter 4 deals with areas in which investments and policies are required to achieve a sustainable expansion and intensification of crop production, animal husbandry, (agro-)forestry, aquaculture and capture fisheries. The analysis focuses not only on improving yields and production volumes, but also on increasing the supply of food through a reduction in post-harvest losses, improvements in agro-processing and lowering the environmental footprint. The section pays particular attention to increasing supply while avoiding land degradation, adapting to climate change and sustainably using natural resources, as well as to opportunities to pursue agro-ecology approaches.

Specific investment and policy needs related to the different agricultural sub-sectors are addressed:

- How improved use of production inputs, mechanization, irrigation, digitalization, reductions in post-harvest losses and sustainable land management can raise the productivity of **crop production** within environmental limits.
- Opportunities to raise the productivity of the **livestock sector** through improved breeds, production systems, feed and veterinary services taking into consideration ecological sustainability aspects.
- How the supply of **fish products** could be enhanced through a sustainable exploitation of fish stocks, a sustainable expansion of aquaculture production and a more efficient processing to reduce losses.
- How to take advantage of **forestry** as a source of food either from existing forests or through agroforestry investments.

Chapter 5 assesses **systemic investments and policies** that cut across the different subsectors. The sub-sections discuss how to build the **skills** of agricultural producers and small businesses, actively engage the **youth**, expand the application of **digital** technologies, increase agricultural **research** investments, improve access to **finance and insurance**, promote the **electrification** in particular of rural areas, and make **markets and value chains** more inclusive for smallholders and small businesses.

The measures identified cannot be implemented in a vacuum, but will rely on conducive **governance** frameworks. This is the focus of **Chapter 6,** which assesses the elements of a supportive **policy environment** for food security, the role of **farmers' organisations**, how **land and water rights** can be strengthened, and how **women** can be empowered within the food system.

Chapter 7 deals with the role of **continental and international cooperation** to support Africa in its efforts to boost continental food supplies and ensure food security. Areas of cooperation discussed include effective targeting of **development assistance** for agriculture, attracting the kinds of domestic and foreign **private sector investments** that can help Africa feed itself, facilitating regional and international **trade**, and advancing related policy priorities in continental and international **policy processes and initiatives**.

3 CURRENT AND PROJECTED SUPPLY, DEMAND AND FOOD SECURITY SITUATION IN AFRICA

3.1 The political importance of food and nutrition security in Africa

A poor diet is the leading cause of mortality and morbidity in the world (Afshin et al., 2019). In Africa, the prevalence of undernourishment and food insecurity is particularly high. This has led to the explicit targeting and consideration of hunger and malnutrition in the continent in many policy frameworks. In those frameworks, food and nutrition security are consistently mentioned jointly.

At the international level, the development agenda and its Sustainable Development Goals (SDGs), especially SDG2, emphasize the notions of food and nutrition security and sustainable agriculture. The ambitious SDG Targets 2.1 and 2.2, to end hunger and all forms of malnutrition by 2030, are a recognized benchmark to assess national progress on food and nutrition security. Both the Global Nutrition Report (2020) and the Scaling Up Nutrition Movement in its strategy and Roadmap for 2016-2020, emphasize that nutrition matters for the global delivery of the SDGs. At their summit in Hamburg in 2017, the G20 committed to support Africa in its efforts to end hunger and malnutrition. The United Nations declared 2016-2025 a decade of concerted and sustained action on nutrition, through policies and programmes, following recommendations formulated at the Second International Conference on Nutrition (ICN2) in 2014 and given in Agenda 2030. Commitments taken at ICN2 were global in nature (eradicate hunger and malnutrition), later mirrored and given a time horizon in SDG2. In addition, during the 2012 World Health Assembly, African countries had committed to achieve a set of six nutrition targets for 2025. These targets now serve as an intermediary step to reaching SDG2, focusing on malnutrition.

At the continental level, the African Union's Agenda 2063 (AU, 2015b) reflects the common position of African governments in terms of targeted socio-economic development and transformation, and is an incentive for progress in the field of nutrition. The specific objectives of the Africa Regional Nutrition Strategy 2015-2025 are the same six objectives agreed in 2012 during the World Health Assembly. The next milestones for food and nutrition in Africa are naturally the SDG Targets 2.1 and 2.2. Several plans and initiatives explicitly or indirectly seek to fulfil these ambitious objectives and targets. Most notable is the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods (AU, 2014), which explicitly enshrined food and nutrition security as key components of the CAADP. The latter now includes common food and nutrition security indicators for all countries in its Results Framework, as part of the assessment of the countries' National Agricultural Investment Plan. The NEPAD also includes a Nutrition and Food Systems Strategic Plan and their related Implementation Plan (2019-2025). These are but the latest examples of the continent's commitment to nutrition and food security, following earlier declarations such as the African Union Declaration on Agriculture and Food Security in Maputo in 2003.

The programmes and policies mentioned above have led to some progress in the fight against food and nutrition insecurity. Yet, hunger still chronically affected around one in every five persons in Africa in 2019.[1] Malnutrition – an abnormal physiological condi-

1 Hunger or undernourishment, and its prevalence in a population, refers to the notion of insufficient food intake and a resulting deficiency in the dietary energy (calories consumed) necessary to live an active and healthy life. The FAO reports annually on the national prevalence of

tion caused by the deficient, excessive or imbalanced intake of dietary energy (carbohydrates, protein and fats) and/or nutrients (vitamins and minerals) – thus includes hunger but is an even more complex issue, with direct causes and consequences that are multiple and interlinked (Malabo Montpellier Panel, 2017). Clearly, the African agricultural sector must play a key role if the food security and nutrition targets are to be met, both because of its function in the supply of raw food products and because it still employs a large share of the African population. To realize its potential, the sector must aim beyond merely increasing production and productivity, to capture synergies (and reduce trade-offs) between nutrition, health and food production, including intersections with the fields of health, water and sanitation (Gerber et al., 2019). This would not only reduce food insecurity and poverty, but would also secure inclusiveness in the growth process, and make economies, communities and food systems more resilient (Malabo Montpellier Panel, 2017). In a context of rapid demographic growth, youth unemployment, urbanization and international pandemics, food system resilience is particularly relevant for Africa. Although the food system as a whole have been holding up during the global COVID-19 pandemic, there are serious concerns about what effects linked to the general economic slowdown - with knock-on effects for food and nutrition through prices, employment and poverty issues - might entail by the end of 2020 and beyond.[2]

3.2 Past and current trends in African food and nutrition security

The SDG Targets 2.1[3] and 2.2[4] are of relevance to any discussion on Africa's food and nutrition security. The prevalence of undernourishment (PoU) describes the proportion of the population that lacks enough dietary energy (SDG Indicator 2.1.1). The FIES captures the proportion of people who do not have access to nutritious and sufficient food and thus experience severe or moderate food insecurity (SDG Indicator 2.1.2). This section focuses on these two indicators, as the most direct indicators of hunger. Yet one should not forget that hunger is part of the more complex issue of malnutrition and should not be addressed in isolation. In that respect, SDG Indicator 2.2.1 relates to the prevalence of child stunting and SDG Indicator 2.2.2 comprises other indicators of malnutrition: the prevalence of wasting and overweight among children. On the other hand, the Global Hunger Index (GHI) compiles with equal weights the PoU, child mortality, and (equally weighted in a single measure of child undernutrition) child stunting and wasting. The GHI thus gathers into the one metric the notions of hunger and of malnutrition.

At the continental level, Africa has the highest prevalence of undernourishment (PoU), estimated at 19.1 percent for 2019, substantially higher than Asia and even Southern Asia, the second most affected region in the world at 13.4 percent (2019 estimate). Over the period 2005-2019, the level of PoU decreased until 2015 but slightly increased thereafter (Figure 3), bringing Africa further away from a steady world average. Moreover, due to population growth, the number of undernourished people in Africa has steadily increased between 2005 and 2019 (Table 1), from a share of 23.3 percent of the world's undernourished in 2005, up to a 36 percent share in 2019.

The prevalence of food insecurity in Africa has been increasing since 2014, the first year for which the FIES was computed (see Figure 4). A rising number of Africans are experiencing increasing difficulties in accessing enough food and of sufficient nutritional quality. The number of food insecure Africans is now 674.5 million, an increase of more than 140 million over the five year period (Table 2). This is calculated by combining those who are severely food insecure (roughly equivalent to those undernourished, i.e. 250.3 million in 2019, as per Table 1), with those who are moderately food insecure. The latter means that they face uncertainties regarding their ability to procure food and have had to compromise at times in

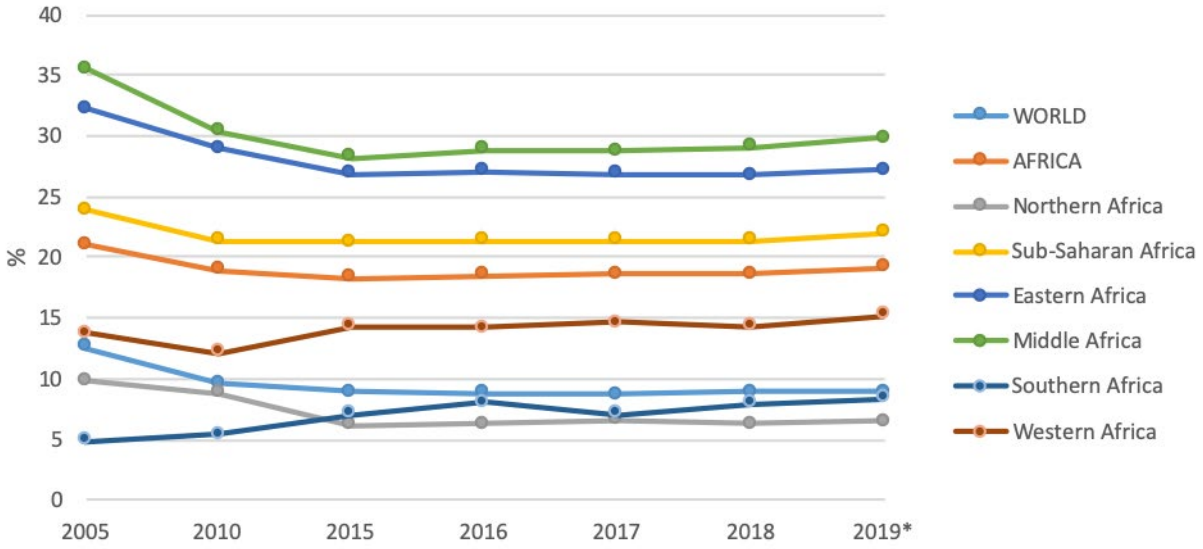
undernourishment (PoU) for most countries (FAO et al., 2019).

2 The Alliance for a Green Revolution in Africa (AGRA) issues regular situation reports on the COVID-19 pandemic and food security in Africa, e.g. https://agra.org/wp-content/uploads/2020/06/Covid19-SitRep-June-25-2020.pdf

3 SDG Target 2.1: By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food, all year round.

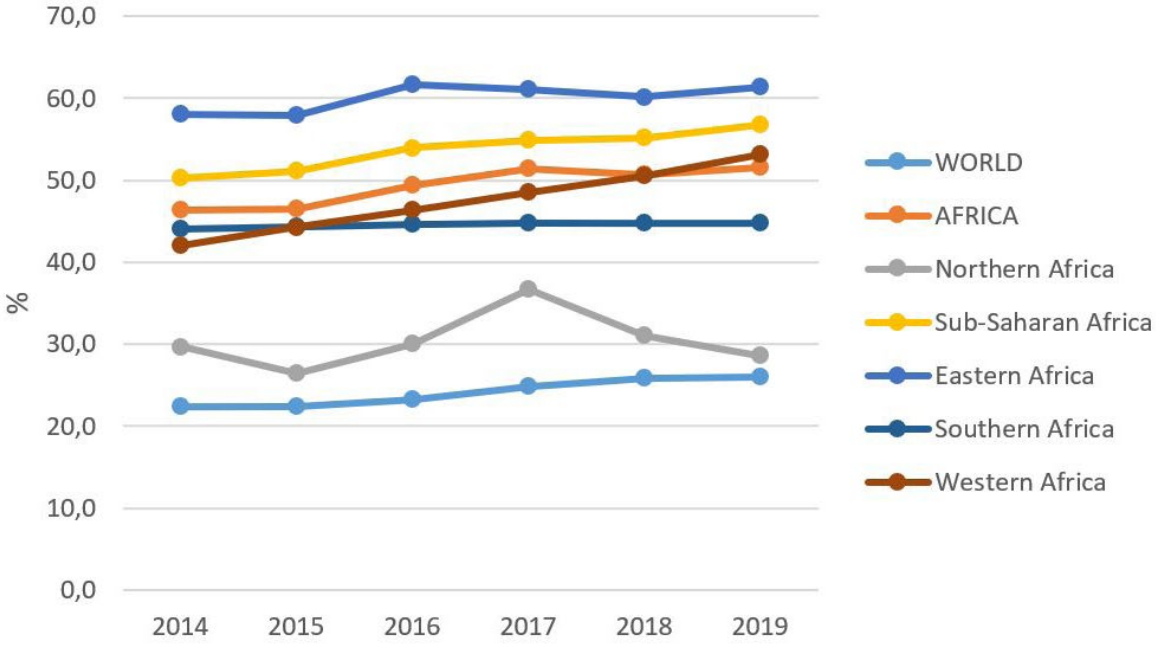
4 SDG Target 2.2: By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons. Retrieved from: https://unstats.un.org/sdgs/metadata/?Text=&Goal=2&Target

Figure 3: Prevalence of undernourishment (PoU) in Africa, 2005-2019



Note: * Projected values.
Source: Own design based on FAO et al. (2020).

Figure 4: Prevalence of moderate or severe food insecurity in Africa, 2014-2019



Note: FIES data for Middle Africa is not available.
Source: Own design based on FAO et al. (2020).

terms of the quantity and quality of food they consume, even if they have not necessarily suffered from hunger.

The indicators of malnutrition present a mixed picture of Africa compared to world averages. Aside from adult obesity, all African indicators show an improving situation in the past few years. Proportion of child overweight and low birthweight are especially favourable in Africa compared with global levels. The notable exception is the prevalence of child stunting: despite improvements between 2012 and 2018, the prevalence of stunting among African children (29.1 percent) remains much higher than the world average (21.3 percent) and highest among continental averages (FAO et al., 2020).

Inter-African comparisons at the regional level reveal some contrasting trends in terms of hunger, food insecurity and malnutrition indicators. In Southern and Western Africa, the prevalence of undernourishment has increased almost steadily since 2005 (Figure 3). In Northern Africa, the PoU decreased until 2015 but rose slightly thereafter. These three regions have the three lowest African PoUs in 2019, two of them below the world average. In contrast, Eastern and Middle

Table 1: Number of undernourished people in Africa, 2005–2019

NUMBER OF UNDERNOURISHED (MILLIONS)								
	2005	2010	2015	2016	2017	2018	2019*	2030**
WORLD	**825.6**	**668.2**	**653.3**	**657.6**	**653.2**	**678.1**	**687.8**	**841.4**
AFRICA	**192.6**	**196.1**	**216.9**	**224.9**	**231.7**	**236.8**	**250.3**	**433.2**
Northern Africa	18.3	17.8	13.8	14.4	15.5	15	15.6	21.4
Sub-Saharan Africa	174.3	178.3	203	210.5	216.3	221.8	234.7	411.8
Eastern Africa	95	98.1	104.9	108.4	110.4	112.9	117.9	191.6
Middle Africa	39.7	40	43.5	45.8	47.2	49.1	51.9	90.5
Southern Africa	2.7	3.2	4.4	5.1	4.5	5.2	5.6	11
Western Africa	36.9	37	50.3	51.2	54.2	54.7	59.4	118.8

Notes: * Projected values. ** The projections up to 2030 do not reflect the potential impact of the COVID-19 pandemic. For the 2030 projections: green = on track to achieve the 2030 target; yellow = some progress; red = no progress or worsening. See FAO et al. (2019), Box 2, Annexes 1B and 2 for a description of how the projections are made.
Source: extracted and compiled from FAO et al. (2020).

Table 2: Number of people experiencing moderate or severe food insecurity in Africa, measured with the FIES, 2014–2018

NUMBER OF PEOPLE (MILLIONS)						
	2014	2015	2016	2017	2018	2019
WORLD	**1633.5**	**1649.5**	**1735.2**	**1874.5**	**1969.6**	**2001.1**
AFRICA	**534.1**	**549.5**	**599.6**	**640.0**	**646.2**	**674.5**
Northern Africa	65.1	59.1	68.6	85.6	73.7	69.1
Sub-Saharan Africa	469.0	490.4	531.0	554.4	572.5	605.4
Eastern Africa	219.9	225.8	247.0	251.4	254.2	266.4
Middle Africa	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Southern Africa	27.4	28.0	28.5	29.1	29.4	29.8
Western Africa	144.0	155.7	167.6	180.2	192.6	208.1

Source: extracted and compiled from FAO et al. (2020).

Africa, after sharp decreases in PoU between 2005 and 2015, have since experienced slight increases and constitute the two regions most affected by undernourishment in the world. Accounting for population growth, Table 1 reveals that apart from Northern Africa, all regions have experienced a constant increase in the number of people suffering from undernourishment. Eastern Africa accounts for almost half of the continent's undernourished people, with almost 118 million people in 2019. Western Africa accounts for almost one-quarter, with 59 million in 2019; a shocking 60 percent increase in the number of undernourished people since 2005. By comparison, the increase in undernourished people across the whole of Sub-Saharan Africa over the same period is 34 percent.

In terms of experiencing food insecurity (Figure 4), the pattern in Northern Africa diverges from all other African regions: with a decrease, followed by an increase and then decrease, the prevalence level in 2019 is lower than it was in 2005. The rest of the continent, like the world, has experienced an increase in the prevalence of food insecurity, particularly sharp in Western Africa, the second most affected region behind Eastern Africa in relative terms. In 2019 over 266 million people in Eastern Africa experienced food insecurity and in Western Africa, over 208 million people (Table 2).

3.3 Successes in African agriculture and variability in food and nutrition security

The continental and regional figures discussed in the previous section hide much of the variability in food and nutrition security outcomes at the country level. It should however be stressed that certain countries and nutrition programmes in Africa have recorded great successes in the past few years. On the agricultural side, Huisman et al. (2016) examine country-specific trends in food production and food supply for ten African countries with contrasting social and agro-economic trajectories. They conclude that the oft-heard dual prospect that Africa will have to increase its import dependence and expand its area under cultivation to secure its food supply is not true. Rather, and despite high population growth, for the period 1990 to 2010 the average food supply per capita increased in Sub-Saharan Africa. Further, over 90 percent of food supply increases came from increased domestic production rather than imports, and intensification and yield growth were the key drivers of this increase, not expansion. Although replication of such successes in the future may be possible, there is no guarantee (Huisman et al., 2016). van Ittersum et al. (2016) focus on Africa's consumption of cereals and note that by 2050, demand will triple compared to 2005/2007, and thus its already strong dependence on cereal imports will likely increase. This is due both to population increase (multiplied by 2.5) and increased purchasing power. The authors are pessimistic that such an increase in cereal demand can be met by increased productivity (closing the famous yield gap), as meeting the demand locally would require "[…] other more complex and uncertain components of intensification […]" (van Ittersum et al., 2016, p. 1).

Large decreases in the prevalence of undernourishment also point to national successes. The following trends can be observed based on FAO data for PoU[5] and on data for potential drivers of PoU change, e.g. economic and structural change, demographic growth, human development, public expenditures in relevant fields such as health and agriculture, aid, capital investment of governance. Between 2000 and 2017, the majority of low and lower-middle income countries are among the best performers in reducing the PoU: Angola, Cameroon, Djibouti, Ethiopia and Senegal all decreased their PoU by more than 60 percent. A number of countries have successfully implemented programmes with positive effects on nutrition indicators. In Ethiopia, the programme Alive & Thrive increased exclusive breastfeeding and its early initiation, by 11 percent and 15 percent respectively. The introduction of orange-fleshed sweet potato significantly increased child vitamin A intake in Uganda and doubled Vitamin A intake in Mozambique. In just two years the Enhanced Homestead Food Production programme in Burkina Faso increased women's intake of meat (by 8 percent), poultry (by 85 percent) and fruits (by 16 percent). This resulted in a decrease in the proportion of underweight women and a reduction in anaemia in children by 9 percent and 5 percent for the age groups 3-6 months and 3-12 months respectively (Malabo Montpellier Panel, 2017).

The Global Hunger Index (GHI)[6], released annually since 2006, captures the calorific availability at the

5 Figures until 2018 only, thus subject to changes post 2020 revisions.

6 von Grebmer et al. (2019) present the evolution of the GHI since 2000.

level of the whole population of a country (the PoU), undernutrition in children below the age of five (a particularly vulnerable group), and the most critical outcome, child mortality, which combines these two factors. Furthermore, the GHI captures both chronic and acute undernutrition by using stunting and wasting (SDG Indicator 2.2.1 and part of Indicator 2.2.2) in its measure of undernutrition. As it directly highlights the changes to values over time, it allows the identification of success stories in Africa. Of the 42 African countries that participated over the period 2000 to 2019, Angola, Burkina Faso, Ethiopia, Malawi, Mali, Mozambique, Niger, Rwanda and Sierra Leone all managed to reduce their GHI by at least 20 points (the GHI is measured between 0 and 100 points), recording a >40 percent drop in their GHI in the process. Angola (-35 points), Rwanda (-27.5 points) and Ethiopia (-27 points) managed to decrease their GHI by the most points. Angola, (-54.2 percent), Ghana (-51.2 percent) and Senegal (-50.7 percent) have the best relative decreases in their GHI, more than halving their score.

On the other end of the food security spectrum in Africa, the Central African Republic is one of only two countries in the GHI to record an increase between 2000 and 2019 (from 50.7 to 53.6 points), ranking last among all GHI countries in 2019. This development is worrying because its score in 2010 was 42 points, which means that it progressed in the first decade of the century but then rapidly slipped to the worst position. Sub-Saharan African countries make up all but ten of the lowest rankings (from number 74 to 117) in 2019. These low GHI scores are driven by the worst undernourishment and child mortality figures in the world, with child stunting being only marginally second worst behind Southern Asia. Central African Republic, Chad, Madagascar and Zambia are among only five countries in the world classified as "alarming" or "extremely alarming" in the 2019 GHI (von Grebmer et al., 2019). Other African countries for which the GHI does not have full data, but of clear concern with respect to hunger and malnutrition, are Burundi, The Comoros, The Democratic Republic of Congo, Eritrea, Libya, Somalia and South Sudan (von Grebmer et al., 2019).

Rates of hunger and malnutrition are highly variable within any given country (von Grebmer et al., 2019). Data is thus critical to effective hunger and malnutrition reduction policy, yet is available for just 31 African countries.[7] The most unequal countries are identified by a comparison of the figures[8] for the lowest, the national average and the highest prevalence of child stunting within the countries. The following countries all display a highest prevalence more than twice as high as the lowest subnational prevalence: Tanzania (<15, >30, >50), Nigeria (<15, >30, >60), Rwanda (<20, >30, >50), Ethiopia (<15, >30, >40), Chad (<30, >30, >50), Niger (<20, >40, >50), The Democratic Republic of Congo (<20, >40, >50), and Burundi (<25, >50, >60) (interpreted from von Grebmer et al., 2019, p. 19).

Inequalities in nutrition across and within countries, the topic of the latest Global Nutrition Report (2020), arise "[…] from unjust systems and processes that structure everyday living conditions […]" (Global Nutrition Report, 2020, p. 21), affecting different population groups differently, e.g. along gender, age, ethnicity, political and ideological views, religion, or economic status. The Global Nutrition Report (2020), which covers more than 20 indicators, has made a tremendous effort to improve understanding of these issues. It provides data on global and national-level nutrition status and assesses countries' progress based on their likelihood of achieving the 2025 Nutrition Targets. It highlights Africa as the continent with the most critical overlaps in various dimensions of malnutrition: the majority of countries show combined critical levels of child stunting, anaemia among women of reproductive age, and overweight in adult women. Another large group of African countries are displaying both critical prevalence of child stunting and of anaemia in women of reproductive age, whilst Gabon, Ghana, Senegal (all countries who made good progress in reducing child stunting) as well as Morocco, Algeria and Tunisia have a combined critical prevalence of women overweight and anaemia (Global Nutrition Report, 2020, p. 40)[9].

7 von Grebmer et al. (2019) put forth that childhood stunting is a key indicator, as it can result from a wide range of factors— insufficient consumption of calories, insufficient consumption or absorption of micronutrients, or recurrent diseases that affect child growth. Further, it is not significantly affected by seasonal variations, unlike child wasting.

8 Although based on different definitions of subnational administrative units.

9 Another illustration of the multifaceted issue of malnutrition in Africa is provided by NEPAD (2019), showing various national nutrition indicators together with indicators of agricultural potential and food trade dependency.

Prevalence rates of child stunting across income groups within a given country can also illustrate the issue of nutrition inequality and inequity. For example, since 2000 the Global Nutrition Report (2020) reports widening gaps in the prevalence of child stunting between the richest and poorest wealth quintiles in Burundi, Lesotho and Nigeria, whereas this gap has been closing in Ghana. In Burundi, between 2000 and 2016 prevalence of child stunting in rich households reduced to 31.2 percent while it increased in the poorest households to 69.1 percent. In Nigeria, over the same period, it fell to 18.3 percent in rich households and rose to 62.8 percent in poor households (Global Nutrition Report, 2020). Such wealth inequality with respect to nutrition clearly points at issues of accessibility to sufficient and quality food.

Notwithstanding the worrying statistics presented above, the analysis of best African performers with respect to food security and nutrition conveys a strong message of hope. No country seems doomed to suffer malnutrition by its structure and endowments, rather the right mix of policies, of implementation actions and of institutions can guide a country on a positive path to food and nutrition security.

3.4 External trends influencing the food security situation

Reaching the 2025 or 2030 targets on food and nutrition will be a challenge in Africa, as in other parts of the world. Global threats to achieving the targets – conflicts, climate change and extreme weather events, and economic slowdowns – have been the main focus areas of recent FAO State of Food Security and Nutrition reports (FAO et al., 2019, 2018, 2017). We add to that list, in the context of Africa: population growth, urbanisation and change in dietary patterns.

The latest figures on the relationship between undernourishment and conflict in countries in Sub-Saharan Africa are provided in FAO et al. (2019): both the prevalence (PoU) and the number (NoU) of undernourished people increased much more sharply in conflict than non-conflict countries between 2015 and 2018: +12.2 percent versus +5.8 percent (PoU) and +21.6 percent versus +14.1 percent (NoU), respectively. Even more pronounced are the effects on the prevalence of undernutrition among children (FAO et al., 2017). This is of real concern as, over recent years, the number of violent conflicts across the globe is rising. As many conflicts are largely localised and internal, national prevalence figures on malnutrition mask the actual state of food insecurity and malnutrition among the local conflict-affected population (FAO et al., 2017). The impact pathways from conflict to food insecurity and malnutrition are often difficult to determine in specific cases, with for instance impacts occurring during the conflict or with a lag time. However, the impacts of direct conflict include forced population movements, the destruction of food stocks and productive assets and increased health complications, including death (Justino, 2012). Indirect impacts affect the economy, society and institutions more broadly, such as disruptions to food systems and markets and impacts on food accessibility through raised food prices or decreases in household purchasing power (FAO et al., 2017).

Climate change and increased frequency and magnitude of extreme weather events constitute another mega trend affecting Africa's food and nutrition security. In particular, the shorter-term variations largely associated with (long-term) climate change can be associated with changes in food and nutrition security and other indicators of individuals' everyday lives (UN, 2016). Such variations include temperature and rainfall variability and the frequency and magnitude of extreme weather events such as droughts, floods and storms. FAO et al. (2019) highlights the role of droughts in Sub-Saharan Africa between 2010 and 2018: in drought-sensitive countries, the PoU and NoU increased by 23.0 percent and 50.5 percent respectively; in other countries, the PoU decreased by 4.8 percent and the NoU increased by 19.7 percent. Of all extreme weather events, drought has the most impact on agriculture, accounting for 80 percent of total global damages and losses to the sector (FAO et al., 2018). Indeed, 70–80 percent of Africa's rural population is estimated to rely on dryland farming and pastoral rangeland systems, and are therefore particularly vulnerable to climate variations (Neely et al., 2009). The channels of impacts of climate variability and extremes on food and nutrition insecurity can be summarized as: a) a decrease in food availability, due to a fall in agricultural productivity and food production, b) a decrease in food accessibility, due to price effects (food price spikes and volatility) and agricultural income effects, both with follow-on effects on quantity, quality and diversity of food purchased and consumed, and c), a decrease in nutritional content,

due to a decrease in the quality and diversity of foods produced and consumed, as well as interactions with negative water and sanitation developments with follow-on effects for health (FAO et al., 2018).

Improving human well-being and food security largely depends on broad-based economic development (Nelson et al., 2009) and Africa in general has much progress to achieve in this area. In particular, its smallholder-dominated farming sector needs to be better connected to markets for the sector to contribute to broader economic growth. This points at the role of structural transformation in African agriculture and economies to achieve improved food security and nutrition (Malabo Montpellier Panel, 2017). Macro-economic effects on food and nutrition security are also evidenced by the strong relationship between commodity dependence and increased undernourishment during economic slowdowns (FAO et al., 2019). The same report shows that the effect of economic downturns on PoU is almost double the effect of either conflict or vulnerability to climate change, and that Africa has the largest number of countries where increases in undernourishment occurred when the economy stagnated or slowed down. Of the 19 countries classified as low-income countries where issues of poverty will become even more acute, 17 are in Africa. This underscores the importance of the accessibility dimension of food security, which suffers as a household's purchasing power decreases. Besides sound policy aiming for economic diversification, human capital accumulation and universal health care, all of which have the power to reduce economic vulnerability, key short-term buffers to protect household income include social protection programmes and safety nets, in the form of cash or in kind transfers, as well as public work programmes (FAO et al., 2019). Such programmes and actions are particularly important for the poorest households. Eliminating hunger and malnutrition is therefore also an economic decision. The cost of undernutrition in Africa is on average 11 percent of its annual gross domestic product (IFPRI, 2016), and estimates suggest that every dollar invested for improved nutrition generates US$ 16 in economic returns (IFPRI, 2015).

As discussed in the previous section, Huisman et al. (2016) show that agricultural output in Africa grew faster than the population over the 1990-2010 period. Thus, population growth in itself is not a de facto threat to food and nutrition security. Yet, a quick calculation based on the figures presented in Figure 3 and Table 1 show that for Africa as a whole and for each specific region, between 2015 and 2019 the annual rate of increase in the number of undernourished people was higher, by between 0.5 and 3 percentage points, than the annual rate of increase in the prevalence of undernourishment. This tends to show that, at least for some time periods, high rates of population growth can increase levels of food and nutrition insecurity. With Africa's large predicted demographic growth over the next decade (from 1.0 billion people in 2010 to 1.6 billion in 2030), this could equate to more malnutrition trouble for the continent. Even if food availability and agricultural production can keep up with population growth, accessibility might not.

Africa's middle-class and urban population is expanding, with adverse consequences for diets leading to increased prevalence of malnutrition in some countries (Popkin, 2003). Changing food systems (or environments) in urban settings can influence consumers' food choices and are associated with a nutrition transition towards highly processed, cheap and nutrient poor but fat-, sugar-, salt- and energy-rich products (Tschirley et al., 2015; WHO, 2016). New food retail experiences, such as the rise of supermarkets, play a role in this transition and its associated health outcomes (Demmler et al., 2017). The process of urbanisation itself, i.e. the fact of migrating from a rural area to an urban centre, has been shown to lead to a dietary transition (Cockx et al., 2018). Occupational change (especially moving out of farming) is an important channel of the dietary impacts of urbanization (Cockx et al., 2018), yet it remains unclear why this is the case. Also unclear is if and how regional food production influences (urban) diet transitions in Africa, and if the changing urban demand for food has impacts on the prospects of Africa feeding itself sustainably.

4 SUSTAINABLE EXPANSION AND INTENSIFICATION OF AGRICULTURAL PRODUCTION

In 2019, agriculture, forestry, and fishing together contributed US$ 310 billion to Sub-Saharan African GDP (World Bank, 2020b). This represents 15 percent of the region's overall GDP. The economic importance of the sector differs widely between countries, ranging from 2 percent in Botswana to 63 percent in Somalia. The sector is also an important source of self-and wage-employment, accounting for just over half of total employment in Sub-Saharan Africa (World Bank, 2020c). This section provides a detailed discussion of the constraints and opportunities in the different agricultural sub-sectors, including crop production, animal husbandry, fisheries and forestry to identify promising areas of investment and policy related to technological and institutional innovations that could boost supply-side capacities small-scale production systems.

4.1 Crop-related innovations

Crop production is still the single most important productive sector in most African countries, in terms of its share in gross domestic product and number of people it employs. Small farms continue to dominate production. About 70–80 percent of farms in Sub-Saharan Africa are smaller than 2 ha (Lowder et al., 2016), contributing around 30 percent of most food commodities (Herrero et al., 2017). If farms up to 20 ha are included among small farms, their share in the production of food commodities rises to 75 percent and of essential nutrients to over 80 percent (Herrero et al., 2017). Maize production takes up the largest share of the area under cultivation across Africa (14 percent in 2018), followed by sorghum, millet and cassava. In terms of production volumes cassava has the largest share, followed by sugarcane, maize and yams (Table 3).

African farmers are faced with a number of challenges, the most notable of which is low agricultural productivity. Many still lack access to high-quality production inputs, such as seeds and fertilizers, and the related knowledge to sustainably use these inputs to increase productivity in the long term. In addition, the African farm systems remain the least mechanized of all continents as a result of which labour produc-

Table 3: Top 10 crops by area and production volumes (2018)

AREA HARVESTED (HA)		PRODUCTION VOLUMES (TONNES)	
Top 10 crops	% of total area	Top 10 crops	% of total production
Maize	14	Cassava	19
Sorghum	11	Sugar cane	10
Millet	8	Maize	9
Cassava	7	Yams	8
Groundnuts, with shell	6	Rice, paddy	4
Rice, paddy	5	Sorghum	3
Cow peas, dry	4	Wheat	3
Wheat	4	Potatoes	3
Yams	3	Sweet potatoes	3
Cocoa, beans	3	Plantains and others	3

Source: FAOSTAT (FAO, 2020a)

tivity in this sector has largely stagnated over the years (Daum and Birner, 2020). Similarly, only about 6 percent of arable land is irrigated (Malabo Montpellier Panel, 2018a). Significant post-harvest losses, in particular on the farm and in the early stages of processing, further reduce the produce that is available for consumption (Houngbo, 2019). Moreover, in the absence of sustainable land management practices, soils are degrading over time, undermining the long-term sustainability and productivity of the crop sector. Finally, while many farmer organisations exist across the continent, they are often not heard in related policy processes. This section examines these different constraints in turn to identify the main bottlenecks and discuss high-potential areas for investment and policy to raise productivity and thereby increase crop-based food supplies.

4.1.1 Production inputs

Africa has experienced impressive agricultural growth in the past two decades, a dramatic contrast with preceding decades of stagnation (Badiane et al., 2014). A burgeoning middle class and growing urban markets present opportunities for local producers and processors. However, Africa's agricultural sector has yet to meet its potential to feed its population and contribute more fully to rural livelihoods and overall economic growth. The majority of agricultural output growth in Africa since the 1960s has been driven by land area expansion rather than by productivity increases, but growing population density makes further area expansion increasingly difficult and environmentally unsustainable (Chamberlin, 2018; Fuglie and Rada, 2013). In order to avoid encroachment into forests and marginal land and to feed its growing population, Africa will need to raise productivity to produce more on the same area.

Africa's farmers face multiple constraints to increasing productivity. Crop production is primarily rainfed, subject to weather variability and climate shocks, both of which are increasing in frequency and severity. Limited access to finance hampers farmers' ability to make productivity-raising investments. Poor quality transport and market infrastructure impedes farmers' access to markets and connections with other value chain actors. The lack of processing opportunities acts as a disincentive to increasing production and leads to considerable losses as poorer quality food that could be processed is wasted and seasonal produce gluts (such as with mangoes) reduce prices, leading to income losses and risk. Use of inputs — particularly fertiliser and improved seeds — is also low in Africa, despite their proven importance in increasing productivity both in Africa and elsewhere in the world (AGRA, 2019a; Evenson and Gollin, 2003; Maredia et al., 2000).

Modern inputs present great potential to raise crop productivity, and low input use hampers the ability of African countries to achieve their agricultural potential today and in the future, especially as the effects of climate change increase in severity. Low input use results from the absence of a system in which (i) public and private sector actors develop high quality seeds and fertiliser, and (ii) infrastructure, institutions and the regulatory environment create incentives for private entrepreneurs to invest in the capacity to source/produce inputs and distribute them to farmers at a reasonable cost. Countries must pursue policies and investments that strengthen science and technology platforms, create incentives for wider distribution and use of inputs, and prioritize the technologies with the highest potential for improving productivity.

This section briefly highlight the factors inhibiting the use and effectiveness of improved inputs in Africa before discussing priority investments and policy actions to expand input use and increase agricultural productivity.

Constraints to input use and efficiency

At a basic level, the high-risk environment in which most African smallholders operate disincentivises investment in inputs (Abate et al., 2020). This is particularly constraining in marginal areas with rainfed agriculture and shifting weather patterns, notably erratic rainfall. The lack of low interest credit options also prevents smallholders from using purchased inputs which require significant cash outlays at the beginning of an agricultural season. In addition, information asymmetries, and specifically the risk of counterfeit products resulting from regulatory failures and logistical issues, affects demand for both seeds and fertiliser (Abate et al., 2020; Christinck et al., 2018).

With regard to fertiliser, high costs and limited benefits combine to make fertiliser use unprofitable for many smallholders in Africa (Jayne and Rashid, 2013). Fertiliser costs are especially high in Africa, due to poor infrastructure which results in high costs for transport and distribution, among other factors.

At the same time, crop fertiliser response rates are often low, resulting from high soil acidity and low soil fertility levels. In addition, due to the limited availability of testing, farmers often have no way of knowing the optimal nutrient mix for a given plot (Abate et al., 2020). The right combination of inputs and management techniques is required to glean benefits from input use. For example, one study finds that in Ghana, fertiliser and other chemical inputs have little effect on farmers' economic efficiency; however, fertiliser increases efficiency when combined with mechanization (section 4.1.2), a labour-saving technology (Nin-Pratt and McBride, 2014).

Africa's seed industry is currently constrained by multiple factors, including barriers to the import and export of seed, financial and human resource barriers to establish seed companies, high seed production costs, marketing and distribution challenges including lack of required facilities, and limited demand for improved seeds (Juma, 2015). The ability of farmers to access improved seed is hampered by a lack of information on new varieties, mismatches in the supply and demand for varietal attributes such as food quality and suitability for low-input conditions, and slow release procedures (Christinck et al., 2018). Regarding the latter, legislative and regulatory delays can lead to especially long and costly processes for the approval of newly developed varieties (Falck-Zepeda and Zambrano, 2013; Spielman, 2020). Importantly, regulations addressing seed certification, quality checking and timely distribution in many countries do not align with traditional and widespread seed sharing practices, causing ambiguity and creating challenges in integrating existing practices with formal seed systems (Christinck et al., 2018; Spielman, 2020).

Priority areas for actions to increase improved input use and efficiency

Africa's average crop yields are far below those of other world regions, including other developing regions. Although there are many reasons for this and multiple constraints to be addressed, it is widely agreed that increasing agricultural productivity will require an increase in the use of improved seeds and fertiliser (The Montpellier Panel, 2013). Both agronomic and economic analyses have confirmed the key role played by improved inputs in enabling agricultural productivity growth and ultimately in reducing poverty (Sheahan and Barrett, 2017), and their potential to unleash further advancement. Mueller et al. (2012) find that even partially closing yield gaps in Sub-Saharan Africa would result in large productivity increases. They estimate that increased nutrient application would be largely sufficient to raise yields to 50 percent of attainable yields, resulting in production increases of 72.6 percent for maize and 66.8 percent for rice, compared to 2000 levels. Both increased nutrients and irrigation would be necessary to raise yields to 75 percent of attainable yields, enabling production increases of 152.6 percent and 143.8 percent for maize and rice, respectively.

The importance of nutrient application in increasing crop yields and ultimately improving food security is similarly underlined by Pradhan et al. (2015). They estimate that adequate nutrient application on rainfed cropland would allow the production of an additional 94.7 trillion kilocalories per year (kcal/year) in Western Africa, 71.6 trillion kcal/year in Eastern Africa, and 4.2 trillion kcal/year and 4.6 trillion kcal/year in Southern and Central Africa, respectively, compared to levels in the year 2000.[10] Large additional gains, reaching 560.0 trillion kcal/year and 280.9 trillion kcal/year in Western and Eastern Africa respectively – the two regions with the highest unmet nutrient needs – could be attained from combining adequate nutrients with soil management strategies to increase nutrient retention, improve drainage and increase soil workability. These production increases would require additional nutrient application, compared to 2010 levels, of 11.7 million tonnes per year of nitrogen fertilizer, 4.4 million tonnes per year of phosphate, and 9.2 million tonnes per year of potash over the continent as a whole (Pradhan et al., 2015).

Modern inputs can contribute to environmental sustainability in several ways, including by lessening the need for further area expansion; however, care must be taken to avoid the potential negative environmental impacts of increased input use as well. In addition, appropriate input use and the use of climate-smart technologies and practices will play an important role in helping African countries to respond to climate change. A simulation analysis by Wiebe et al. (2017) suggests that, at the continental level,

10 These increases correspond to 44 percent, 42 percent, 8 percent, and 14 percent of FAO total food supply estimates for the year 2000 for Western, Eastern, Southern and Central Africa, respectively (authors' calculations based on FAO (2020a).

climate change will cause a reduction in total food production of 4.9 percent by 2030 and 8.6 percent by 2050, compared to projected production levels in the absence of climate change. This relative decline is larger than that of the world as a whole, indicating that Africa will be hit relatively hard by climate change; the most severe production impacts are expected in Central and Northern Africa. Fruits and vegetables show the strongest effects, with projected production reductions of 7.6 and 13.1 percent in 2030 and 2050, respectively, followed by cereals and root and tubers. However, the impacts of climate change can be lessened through technologies including improved inputs. Rosegrant et al. (2014) simulated the effects of different crop and management technologies under climate change, finding that the use of nitrogen-efficient varieties could increase yields in Africa by 20.9 percent for rice, 7.9 percent for maize, and 4.4 percent for wheat in 2050 compared to projections without improved varieties. Yields could also be increased under climate change by the use of other types of improved varieties and management practices such as no-till farming, precision agriculture,[11] and integrated soil fertility management.[12] Seed development efforts should focus on heat- and drought-tolerant varieties as well as on maximizing crops' nutrition content per unit of water used (Renault and Wallender, 2000).

For the above to happen however, African countries need to find ways to nurture private sector led, input supply systems. Subsidies and other public policies to cut costs and ease access to inputs can only function as short term solutions. Long term, sustainable solutions need to address the institutional, regulatory and administrative constraints to the emergence of a critical mass of operators willing to make the necessary investment in logistics and networks to source/produce and distribute modern inputs. This includes smallholder friendly private sector based seeds systems production and distribution. In an analysis of over 20,000 households in six African countries, Sheahan and Barrett (2017) found that unobserved country factors explained nearly half of the variation in the use of fertiliser and chemical inputs at the farm level, underlining the importance of national policies and institutions in creating the conditions for robust input systems.

Governments and other actors can take several actions to increase the availability of inputs – improved seeds and fertilisers – in Africa. Robust science and technology systems are key both to increasing the supply of inputs and facilitating their adoption by farmers. Investment in agricultural research and development (R&D) is critical to enable the development or adaptation of locally appropriate improved varieties and other technologies. Research from Africa and other regions has demonstrated the high returns to investments in agricultural research (Fan, 2008; Fuglie and Rada, 2013). However, disseminating technologies to farmers and supporting their uptake is an equally critical area and one which has also been neglected. With many countries lacking strong extension systems, farmer organizations are good candidates to fill the gap to disseminate technologies to farmers; they should be supported in this role with training and tools to effectively interface with technology providers and member farmers. Farmer organizations can also facilitate the flow of information from farmers back to formal research systems to enhance farmer participation in the development and evaluation of new technologies (see section 6.2). National agricultural research systems should also focus more deliberately on creating products and services for acquisition and scaling up by domestic private sector enterprises. This requires an institutional environment that ensures strategic connection between public sector R&D institutions and the domestic agro-industrial sector such as to constitute a single innovation ecosystem (Badiane and Collins, 2020).

Strengthened science and technology systems which integrate public and private sector actors are prerequisites to increasing the availability, adoption and efficiency of improved inputs in Africa. Beyond this, additional policy initiatives and investments are required to address the constraints specific to different types of inputs. Policymakers need to facilitate the increased and effective use of fertilisers while safeguarding against the negative environmental impacts of overuse to ensure that the issues seen in other countries with higher application rates do not become a problem for African countries. Investments and policies should aim to increase the productivi-

11 Precision agriculture refers to practices and technologies that maximize the efficiency of inputs by applying them at the precise location, time and amount for optimal yield impacts (Kienzle, 2013).

12 Integrated soil fertility management is an approach that combines use of organic and inorganic fertilizer with management practices adapted to local conditions to enhance soil fertility (CCAFS, n.d.).

ty benefit of every unit of fertiliser applied to serve both environmental and economic objectives. Key investment areas to prioritize include increasing the availability of soil testing to enable farmers to select the appropriate nutrients for their fields (Abate et al., 2020). In recent years, investments in soil testing and mapping in Ethiopia, Ghana, Nigeria and Tanzania have allowed these countries to improve recommendations and develop blends best suited to local soil needs (AGRA, 2019a). Other investments in soil fertility will also help to increase the effectiveness and profitability of fertiliser. These include interventions to improve soil drainage, address soil acidity, and build soil organic matter, and must be informed by granular research on location-specific conditions (Jayne and Rashid, 2013).

In particular, agro-ecological and sustainable intensification approaches which seek to maximize the efficiency of input use while minimizing negative effects on the environment need to be further explored. One example is fertiliser micro-dosing, a precision agriculture practice in which small and more affordable amounts of fertiliser are applied to each plant, usually at sowing. The technique has shown promise in increasing yields even at low fertiliser application levels. Early interventions in micro-dosing allowed farmers in Mali, Burkina Faso and Niger to increase sorghum and millet yields by 44 to 120 percent, and provided better economic returns for farmers than fertiliser application at conventionally recommended rates (ICRISAT, 2009; Okebalama et al., 2017). However, farmers have found the technique to be labour-intensive, and overall adoption remains low. Further research is required on ways to alleviate labour constraints and maintain soil fertility, such as combining inorganic fertiliser micro-dosing with the use of organic fertiliser (Okebalama et al., 2017).

Fertiliser efficiency can be enhanced through complementary actions to improve soil fertility. Conservation agriculture, an approach that combines reduced or no tillage, permanent soil cover through retention of crop residues or cover crops, and crop rotation or intercropping, improves soil structure and fertility while maintaining or increasing crop yields (FAO, 2020b; The Montpellier Panel, 2014); it also contributes to climate resilience by improving soil moisture retention (Thierfelder et al., 2017). However, the practice also presents limitations and challenges. A large meta-analysis of studies in Africa suggested that conservation agriculture improved yields only when combined with herbicide use (Corbeels et al., 2020). Adoption of minimum tillage alone did not produce yield advantages, and adoption of the complete package of conservation agriculture practices may be challenging for smallholders due to competing uses of crop residues, e.g. as animal feed (Corbeels et al., 2020; Valbuena et al., 2012).

While ecological intensification practices contribute to environmental sustainability, they do not always raise yields, and practices are often not scaled up due to their high labour requirements and skills and knowledge needs (The Montpellier Panel, 2013). Skills development and training for farmers can enhance uptake; for example, training in fertiliser micro-dosing strongly increased adoption of the technique in Zimbabwe (Winter-Nelson et al., 2016). Further research on agro-ecological approaches is necessary to overcome constraints to increasing productivity and to enhance the efficiency of fertiliser and other inputs (Corbeels et al., 2020).

Lowering the cost of inputs such as fertiliser could do much to increase their use. Fertiliser costs in Africa are the highest in the world, resulting in part from the low quality of infrastructure which raises last-mile costs (Abate et al., 2020). Africa's fertiliser industry is unusual in that the continent exports the majority of the fertiliser and related raw materials it produces to other parts of the world, while the majority of fertiliser used by farmers is imported. This is due to poor infrastructure and other barriers to intra-regional trade, and the fact that fertiliser demand in most African countries remains low and dispersed compared to higher levels of demand in larger markets outside of the continent (AGRA, 2019a). Investments in infrastructure and efforts to build larger markets by facilitating intra-African trade, including by harmonizing product standards, would help to reduce costs and put fertiliser within the reach of more farmers. The demand for fertiliser could also be increased by lowering the risk of counterfeit or poor-quality products. Better design and enforcement of regulations to address substandard products are needed. Wider use of brands should be encouraged to incentivize producers to ensure the high quality of their products (AGRA, 2019a).

After partial withdrawals during the structural adjustment programme period, fertiliser subsidies have again become widespread in Africa in recent years. While subsidies show some benefits, these are

often small relative to the high costs of such programmes; for example, studies of Malawi's Farm Input Subsidy Programme have found that its effect on maize prices was minimal (Ricker-Gilbert et al., 2013) and that wealthier households benefitted more from the programme than poorer households (Lunduka et al., 2013). Many observers suggest that the costs of subsidy programmes would show greater returns if allocated to alternative uses such as agricultural research (Jayne and Rashid, 2013). In addition, subsidies can set back the development of fertiliser distribution systems if they do not allow a role for the private sector. In some cases, subsidies are not well targeted and may encourage inefficient overuse of fertiliser. Countries implementing fertiliser subsidies should ensure that they are targeted to households unable to purchase fertiliser without a subsidy and that they ensure a strong role for the private sector in fertiliser supply and distribution (AGRA, 2019a; Jayne and Rashid, 2013).

Increasing the availability and adoption of improved seeds and seedlings is particularly complex due to the mix of formal and informal seed dissemination models currently in practice. As part of their quality control systems, over 20 African countries have laws forbidding sale of unregistered seed, despite the ubiquity of farmer-to-farmer seed exchange. While quality control regimes have enabled the development of well-functioning improved seed markets in some cases, such as for hybrid maize in Kenya, in other cases their high costs and stringent requirements may discourage seed industry development, particularly where seed demand is dispersed or highly localized varieties are needed (Spielman, 2020). Given that the large majority of farmers rely mainly on informal sources for seed (McGuire and Sperling, 2016), efforts must be made to enhance the capacity of these systems to provide high-quality seed. This may include improving seed storage materials and techniques and improving farmers' incentives to supply quality seed to local markets (McGuire and Sperling, 2016).

In addition to supporting the quality of informal seed systems, policymakers and partners must seek avenues to promote the emergence of smallholder-based modern seed production and other plant multiplication systems such as micropropagation and tissue culture. Smallholder farmers can be key actors in formal seed systems, such as in Mali where farmer seed producer organizations supply nearly all certified seed (Christinck et al., 2018). In addition to producing certified seed in collaboration with national agricultural research systems, farmer cooperatives in Mali, Burkina Faso, Niger and Senegal often participate in varietal testing and facilitate participatory varietal selection, ensuring that farmers play a central role in informing the development of new varieties (Access to Seeds Foundation 2018). Governments and partners can support the development of smallholder seed producer organizations by facilitating access to affordable credit and providing capacity strengthening for both technical and business management skills (Neate and Guéi, 2010).

To decrease barriers to entry for seed producers, governments should consider adopting Quality Declared Seed systems (Christinck et al., 2018; Spielman, 2020). Such systems provides alternative standards which are less onerous than those of most formal seed quality systems and more attainable by potential smaller-scale seed producers which could otherwise be excluded from seed sectors, such as farmer organizations, large farms and non-governmental organizations (FAO, 2006). Quality Declared Seed systems such as that introduced in Uganda in 2018, show great potential to increase the supply of quality seeds, bridge informal and formal seed production and distribution sectors, and allow entry to new actors (Spielman, 2020).

Seed policy objectives should include regular varietal turnover to ensure continued yield gains and respond to emerging threats from pests and diseases. Policies to reduce the regulatory and time burden of variety registration and release, and to increase private sector access to public germplasm, can lessen barriers to the development of new varieties (Spielman and Smale, 2017). However, releasing new varieties is only part of the story. In the absence of explicit efforts to retire old varieties that have yield or pest related disadvantages as improved varieties are introduced, old varieties continue to be sold and used. Studies carried out by The African Seed Access Index found that the average age of marketed seed varieties often exceeds 15 years, for example in the cases of sorghum and cowpeas in Kenya, maize and groundnut in Madagascar, beans in Tanzania, and maize, rice, groundnut and millet in Senegal (Mabaya et al., 2017; Mabaya and Mugoya, 2017).

National seed systems should be flexible enough to incorporate multiple models of seed production and dissemination: decentralized, farmer organization-led approaches are potentially better suited for diverse

local crops with geographically diffused demand, while large seed companies may be more appropriate to produce seed for widely used varieties (Christinck et al., 2018). Community seedbanks have been successful in facilitating diverse agricultural production patterns and in preserving local varieties at risk of disappearance—thus also contributing to conservation efforts which ensure the diversity of genetic material available to breeders (Bioversity, 2017). Decentralized systems may offer advantages in terms of responding to local demand, and potentially in ensuring high quality seed. Studies by The African Seed Access Index found that counterfeit seed remains a major challenge for seed producers and farmers in 12 of 13 countries examined, with South Africa being the exception (Mabaya and Mugoya, 2017). Interviews conducted by Christinck et al. (2018) in Kenya and Mali suggest that fake or underperforming seed was a larger problem in Kenya than Mali, despite its better developed regulatory and quality control system. Among other factors, this could be related to the fact that seed supply chains in Mali tend to be short and localized, while those in Kenya are longer and more complex.

Investment and policy priorities

Increasing modern input use can produce immense gains, but requires addressing multiple constraints simultaneously to increase both the demand for and supply of inputs. Clear lessons that emerge from research on agricultural inputs include the primary importance of both investments in agricultural R&D and policy efforts to address the multiple constraints which hamper farmers' adoption of the outputs of agricultural research.

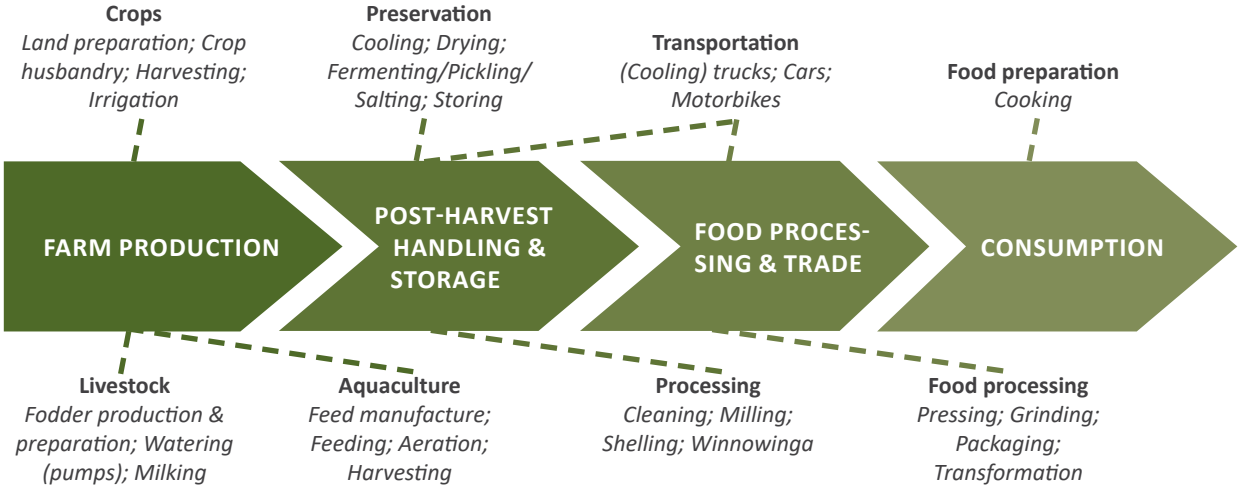
- **Adopt regulatory and administrative reforms to encourage the emergence of competitive private sector based modern input supply systems**, including participation of smallholder farmers in seed production and ensuring that input subsidies do not crowd out private sector actors.
- **Invest in infrastructure and services such as soil fertility testing and mapping, and initiate long-term efforts to improve soil fertility and boost returns to improved seeds and fertiliser**.
- **Address the high cost of fertiliser through better quality control, improvements in infrastructure and removal of regulatory barriers**, including enforcement of existing rules, to promote intra-regional trade in inputs; lowering the time and cost associated with releasing new crop varieties; and putting in place flexible seed quality systems which provide space for different types of operators, potentially including recognized Quality Declared Seed standards;
- **Mitigate constraints to the adoption of sustainable farming methods** to enhance long-term productivity and climate change adaptation through the effective use of inputs.

4.1.2 Mechanization along the value chain

Agricultural mechanization refers to the use of animal or mechanical power along agricultural value chains, comprising crops such as grain, legumes, fruits and vegetables as well as livestock and fish (see Figure 5). African agricultural value chains are the least mechanized in the world (Sims et al., 2016). In grain production, estimates show that less than 10 percent of farmers use tractors and around 15 percent of farmers use animals for land preparation, which is usually the first farming step to become mechanized. Mechanization levels down the value are equally low (Daum and Birner, 2020). According to the Malabo Montpellier Panel, low levels of mechanization are one of the "main constraints to increasing domestic food supplies in Africa" (Malabo Montpellier Panel, 2018b, p. 8).

Mechanization can affect food supply at several value chain steps. On the farm, low levels of mechanization can constrain yields (Adu-Baffour et al., 2019; Daum et al., 2020a). African farming systems are characterized by pronounced seasonal labour bottlenecks, which makes the timely completion of farm activities challenging without mechanization in some areas (Silva et al., 2019). Deviating from the optimal dates for these activities can lead to yield drops, which can be as high as one percent per day (Baudron et al.,

Figure 5: Entry points for mechanization along agricultural value chains



Source: Own compilation

2015). Labour bottlenecks are aggravated in countries experiencing agricultural intensification and rising rural wages (Berhane et al., 2017; Diao et al., 2014). Mechanization may also enhance yields by enabling better plant spacing and seedbed preparation and by reducing weed growth, among others (Daum and Birner, 2020). In Zambia, a study found that mechanization increase yields by around 25 percent (Adu-Baffour et al., 2019), and a study across eleven African countries found that tractor-use increases maize yields by around 0.5 tonnes per hectare (Kirui, 2019).

In addition to affecting yields, mechanization can also affect the amount of land cultivated. Using hand tools, farmers can often not cultivate all of their lands. In Zambia, tractors allow farmers to double the land size cultivated – land which they owned but had left fallow because of labour shortages (Adu-Baffour et al., 2019). A lack of mechanization can also cause crop damage and loss during harvesting. In Kenya, for example, around 95 percent of potato damage and losses are attributed to a lack of harvesting technology (Breuer et al., 2015). Lastly, food supply can be affected by a lack of irrigation technologies. Studies estimate that irrigation could increase agricultural production in Africa by 50 percent (You et al., 2011).

Beyond the farm, down the value chain, a lack of processing and preservation technologies can affect food supply by reducing the amount of already produced food. For example, a lack of processing technologies such as milling machines causes an estimated annual loss of one million tonnes of rice in Africa (Malabo Montpellier Panel, 2018b). A lack of preservation technologies such as dryers can cause considerable losses during postharvest handling (Salvatierra-Rojas et al., 2017) and a lack of proper storage can lead to storage losses and contamination with fungi such as aflatoxins (Williams et al., 2014). In dairy production, a lack of cooling technologies causes a milk loss of around 20-30 percent (Salvatierra Rojas et al., 2018). In addition to processing and preservation technologies, a lack of transportation technologies can affect food supply – by causing food losses but also by discouraging farmers to produce food for markets in the first place. It is important to note that some of the most nutritious foods (including fish, livestock products, fruit and vegetables), all of which are important to reduce malnutrition, in particular of children (Headey et al., 2018), are highly perishable and require care in transporting and storing to preserve their shelf-life.

There are also concerns related to mechanization. For example, critics argue that mechanization can cause soil erosion and trigger farmland expansion on the costs of forests and savannah, leading to a decline of biodiversity and contributing to climate change (Daum and Birner, 2020). Also, there are concerns that mechanization can induce structural transformation of the agricultural sector towards larger farms and concerns related to unemployment effects. Such concerns have to be taken seriously. However, such negative effects are not inherent to mechanization and can be avoided with sustainable mechanization strategies and accompanying policy efforts (Daum et al., 2020a; Daum and Birner, 2020). For example, soil erosion can be minimized with locally adapted Conservation

Agriculture and the effects of land expansion can be addressed with careful land-use planning (Daum and Birner, 2020). Similarly, scale appropriate mechanization, where "machines are adapted to farm size and not the opposite" (Baudron et al., 2015, p. 154) and institutional solutions for smallholder farmers can ensure that mechanization does not artificially trigger structural transformation. Regarding employment effects, research has shown that effects depend on the type of and the context in which mechanization unfolds (Binswanger, 1986). Irrigation, for example, often raises the demand for labour because yields increase. Importantly, in many situations, mechanization is merely an answer to a decline in labour availability, for example, due to rural-urban migration or because children go to school rather than working on the fields. However, when market forces are distorted, for example, when mechanization is artificially driven by large subsidies and not by rising labour costs, it can indeed cause job losses, thus such market distortions should be avoided.

While mechanization levels are low along African agricultural value chains on average, there are also examples of rapid mechanization in selected pockets of Africa (Malabo Montpellier Panel, 2018b). For example, there are parts of Ghana where up to 80 percent of farmers use machinery (Cossar, 2016) and Ethiopia has witnessed the emergence of a vibrant market for wheat combining (Berhane et al., 2017). In these areas, mechanization is driven by rising rural wages and enabled by service markets, which help to ensure that poorer farmers who cannot buy machinery can still benefit from mechanization (Berhane et al., 2017; Cossar, 2016; Diao et al., 2014). In crop production, the "rise of medium-scale farmers" (Jayne et al., 2019) who can afford to buy machinery and often serve smallholder farmers, and "Uber"-type digital services, which can reduce transaction costs (Daum et al., 2020b) offer new prospects for service markets. Another driver of mechanization are falling machinery prices due to increased price competition with manufacturers from India and China (Agyei-Holmes, 2016; Sims et al., 2016).

Mechanization technologies such as tractors, shelling machines, and dryers are embodied, private goods, thus mechanization can and should be driven by the private sector (Sunding and Zilberman, 2001). Public efforts to directly promote mechanization in Africa by supplying machinery have proven costly and mostly unsustainable (Daum and Birner, 2020, 2017; Pingali, 2007). As noted in one study, "where private markets do not evolve, public mechanization programs do typically not work either and where private markets do evolve, public programs may crowd out private companies" (Daum and Birner, 2020, p. 4). Yet, while there has been a growth of private-sector channels supplying mechanization in Africa (Diao et al., 2016), including both efforts by global machinery manufactures such as AGCO, John Deere, and Mahindra and a rise of local manufacturing of equipment, the evolution of such markets is often constrained by market failures and a lack of conducive framework conditions, which public policies have to address. Missing framework conditions revolve around a lack of knowledge and skills, limited access and high costs of finance, fiscal and trade policies hampering imports, a lack of applied research as well as erratic electricity supply, and a lack of standards and certification, hampering local manufacturers of machinery, among others (Daum and Birner, 2017; Diao et al., 2014; Sims et al., 2016).

Priority areas for action to promote mechanisation

Missing **knowledge and skills** hampers mechanization, and subsequently, food supply, on several fronts. For example, a lack of knowledge and skills on maintenance can lead to breakdowns and reduce the profitability of machinery (Houssou et al., 2013; Thoelen and Daum, 2019). In Ghana, around 50 percent of tractors breakdown more than three times a year because of careless operation and lack of maintenance (Aikins and Haruna, 2012) and most technicians are self-educated "roadside mechanics" (Daum, 2015). A lack of knowledge and skills on how to drive tractors with attachments can also lead to soil degradation, affecting yields (Daum et al., 2020a). Building sufficient knowledge and skills has been a key to mechanization in today's mechanized countries. In Germany, for example, public training caravans organized by the DEULA travelled across the country to train machinery operators, owners, and technicians, and vocational schools were set up (Daum et al., 2018). Such historical examples suggest that parts of the overall knowledge and skills needed can be provided by local extension networks (e.g. courses on machinery economics and maintenance). Many other aspects require long-term training, however, such as the training of mechanics, which may be best provided at vocational training centres combining "on-the-job"-training with

more formal education. Knowledge and skills are also needed for machinery production. While large tractors are likely to come mostly from outside Africa in the foreseeable future, attachments such as rippers and processing equipment such as maize shellers and forage choppers could be supplied by a well-trained force of local manufacturers.

Machinery is expensive and has a long depreciation period. Currently, access to **agricultural finance** is limited across most parts of Africa and hampered by a lack of financial literacy, lacking collaterals, and high production and market risks (Daum and Birner, 2017; Demeke et al., 2016; Ströh de Martinez et al., 2016). Moreover, even if accessible, the costs of financing machinery are prohibitively high – between 15-30 percent per annum – and the repayment schedules are too short – often a maximum of two years (Daum and Birner, 2017). Since public mechanization credit schemes have a track record of low repayment rates and high monitoring costs (Diao et al., 2016), policy action should rather focus on assisting the private sector to overcome market failures in credit and insurance markets. Such a strategy has been well documented as successful in several Asian countries and – unlike subsidies – does not distort markets (Diao et al., 2014). Smart subsidies may have a role to play, too, but truly smart subsidies are difficult to design. For development partners, supporting new ways of finance such as value chain finance, nucleus out-grower schemes, and direct supplier credits can be a promising area for action (Adu-Baffour et al., 2019; Ströh de Martinez et al., 2016).

In addition to improving knowledge and skills and funding, other measures are required to create a more **favourable environment that facilitates the provision and deployment of machinery.** Regarding fiscal and trade policies, governments canA reduce import duties on machinery and spare parts, which are often charged with particular high duties – up to 30 percent in various countries (Diao et al., 2016). In India and Bangladesh, for example, the uptake of mechanization increased rapidly once import restriction were reduced (Diao et al., 2016). Also, governments can ease custom processes and reduce exchange rate fluctuations. Governments can also support local manufacturers by ensuring reliable access to electricity, reducing duties on raw materials, and setting up standards and testing, among others. Local manufacturers are unlikely to produce large tractors in the foreseeable future – this is also not needed in today's globalized world – but they may have a comparative advantage to produce location-specific technologies such as tractor attachments and processing equipment, which also helps to create meaningful jobs in rural areas. The enabling environment should also cater for digital applications, such as Uber-type models whose success hinges on digital literacy and trust as well as connectivity, among others (Daum et al., 2020b). But the analogue infrastructure continues to be important: better rural roads, for example, facilitate service markets and the migration of machinery across agro-ecological zones.

Accompanying public measures are needed to **safeguard against some of the potential negative effects of mechanization**. For example, careful land-use planning and monitoring are needed to ensure that farm mechanization does not trigger deforestation and the conversion of savannah land. It is also important to ensure that mechanization does not exacerbate, in some places, existing gender inequalities. For this, gender awareness campaigns and programmes to support female mechanization groups and entrepreneurs may be useful. Supporting institutional solutions to make sure that smallholder farmers and other small-scale producers can benefit from mechanization, such as rental markets for tractor services and cooperative solutions for processing, will be key to avoid that mechanization leads to rising inequalities in land and wealth.

Additional investments in **public research on technical, agronomic, and economic aspects of mechanization** are also needed. This can help to ensure that mechanization unfolds in ways that are sustainable from a social, economic, and environmental perspective. Private actors can be support with public research such as basic research on engineering solutions adapted to local environments, country-wide soil maps, and household surveys on mechanization demand. There is also a need to address environmental concerns in mechanization. For example, applied research should focus on strategies for mechanized conservation agriculture, i.e. low-till options that protect soils and allow for efficient use of water, as well as the potentials of renewable energy powering mechanization along the value chain. Lastly, research is needed on institutional solutions such as (Uber-type) rental markets and co-operatives, which allow smallholder farmers to access agricultural machinery.

Investment and policy priorities

To tap the potentials of mechanization, public action should focus on the entire agricultural value chain ranging from land preparation towards post-harvest handling and food processing. This would act as a pull factor for increased production and productivity, and allow farmers and small businesses to add value to crops, while at the same time reducing food losses and waste.

- **Strengthen knowledge and skills.** These include capacities for the use and repair of agricultural machinery as well as the development and production of machines.
- **Improve financing and risk management of agricultural machinery.** Policies should create a conducive environment for private providers of credit and insurance.
- **Create a favourable business climate for local suppliers of machinery,** e.g. through fiscal and trade policy measures and investments in infrastructure.
- **Promote public research** to support an environmentally, socially and economically sustainable expansion of mechanization.

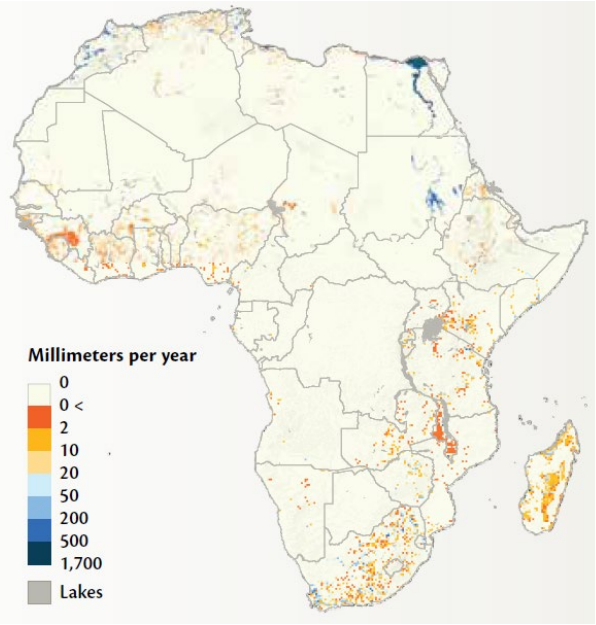
4.1.3 Irrigation

Rainfed agriculture makes up the majority of agricultural production in Africa. However, there is a growing trend towards expanding irrigated crop production across the continent. The major drivers behind the expansion of irrigated areas are their higher productivity, hence higher incomes, and stronger resilience to rainfall variability compared with rainfed crop production.

About 6 percent of Africa's cultivated land is irrigated, equalling about 17 million hectares (Figure 6), primarily in Egypt, Algeria, Morocco, South Africa and Sudan (AUDA-NEPAD, 2013). The extent of irrigated areas grew 1.5 percent annually between 1990 and 2015 (Malabo Montpellier Panel, 2018a). In fact, about 38 percent of the value of crop production in Africa comes from these irrigated areas (SAFI, 2018), i.e. gross revenues from irrigated crop production are ten times higher than from rainfed crop production, which underscores the importance of irrigation expansion for raising incomes. About 83 percent of these irrigated areas are small-scale, i.e. managed by individual smallholders or by local communities. The most widespread forms of small-scale irrigation are groundwater use by motor and treadle pumps, and surface water diversion to irrigation schemes of up to several hundred hectares (Lankford et al., 2016; Malabo Montpellier Panel, 2018a). In contrast, government organizations manage large-scale irrigation schemes, which typically exceed 1000 hectares (Malabo Montpelier Panel, 2018a). Rice, wheat, maize, sugarcane, cotton and fodder grasses are the highest consumers of irrigation water in Africa, followed by pulses, fruits, potatoes and a wide range of other crops, especially in arid Northern Africa (Siebert and Döll, 2010).

The potential to increase irrigation coverage in Africa is estimated at an additional 47 million hectares (Malabo Montpellier Panel, 2018a). This estimate is based on the availability of land and water resources. The biggest potential for irrigation expansion is in Sub-Saharan Africa (SSA), from the 7.7 million hectares in 2012 to 38 million hectares, particularly in

Figure 6: The extent of irrigated areas in Africa (2000), showing the amount of surface and groundwater used for irrigation (mm/year)



Source: Siebert and Döll (2010)

the Democratic Republic of the Congo, Angola and Mozambique (from 1 to 14 million hectares). According to Altchenko and Villholth (2015), groundwater resources could help increase the share of irrigated land to 20–49 percent of croplands in SSA, i.e. by an additional 19 to 103 million hectares, with particularly high potential in the Sahel region and Eastern Africa (Pavelic et al., 2013). In contrast to already emerging groundwater overuse in Northern Africa (Benfetta and Ouadja, 2020), where annual withdrawal of groundwater is three times higher than its annual recharge, in Sub-Saharan Africa only 17.5 percent of renewable groundwater is tapped annually (You et al., 2011).

The shortcoming of the above estimates of irrigation potential is that they are usually based on biophysical factors only, i.e. they define overall boundary conditions for irrigation potential in Africa according to soil conditions, water availability and irrigation water requirements based on cropping patterns and the climate. Often these figures do not take into account economic, social and institutional factors, or the impact of the application of different irrigation technologies, which are equally, if not more, important in determining Africa's actually achievable irrigation potential. You et al. (2011) consider both biophysical and socioeconomic factors, and find that Africa's expansion potential for small-scale irrigation, i.e. using small reservoirs and water harvesting, is 7.3 million hectares with an investment cost of US$ 37.9 billion and an internal average rate of return at 20 percent. On the other hand, the expansion potential for large-scale irrigation, i.e. dam-based surface irrigation, is estimated at 16.2 million hectares with investment costs of US$ 31.7 billion and an internal average rate of return at 6.6 percent[13] (You et al., 2011). These numbers also imply that economic profitability from investing in small-scale irrigation schemes can be three times higher than from investing in large-scale irrigation schemes. Accounting for economic costs too, the potential for irrigation expansion in Africa reaches 23.5 million hectares until 2060, of which 21.8 million hectares is in SSA. If socio-economic aspects are taken into account, the locations with the highest potential for irrigation expansion change, which according to You et al. (2011) are in the broader Sudano-Sahelian zone and the countries of Gulf of Guinea.

The caveat of You et al.'s (2011) projections is that they focus primarily on surface waters and do not fully capture the potential of utilizing groundwater aquifers. Unlike dam-based irrigation, use of groundwater for irrigation does not require massive infrastructural investments. Hence smallholder farmers can themselves, individually or through local collective action in a decentralized manner, expand the area under groundwater irrigation. This trend of smallholder-led irrigation expansion using groundwater in SSA is already evident (Villholth, 2013), facilitated by low-cost technologies (e.g. motor pumps, treadle pumps, watering cans) and drilling services. Irrigation potential also varies by irrigation technology used: Xie et al. (2014) project that the expansion potential in SSA for smallholder irrigation through motor pumps is 30 million hectares, through treadle pumps 24 million hectares, through small reservoirs 22 million hectares, and through communal river diversion 20 million hectares. Significant part of the irrigation potential through motor and treadle pumps relies on availability of groundwater, hence, overdraft of groundwater can undermine the long-term sustainability of newly irrigated areas. Thus, proper monitoring systems and regulations are required to ensure the sustainable use of groundwater (Xie et al., 2014).

Xie et al. (2014) project that exploiting the small-scale irrigation potential across SSA could result in additional net revenues of US$ 14-22 billion per year, directly benefitting between 113 and 369 million people. Although irrigation adoption can be a contributor to reducing poverty and enhancing food security, by itself it is not enough to eradicate poverty and undernourishment among smallholder farmers. Other accompanying inputs are required, such as the wider and sustainable use of productive seeds and fertilizers, mechanization, better access to markets, and other factors discussed in more details in other sections of this report. Indeed, Passarelli et al. (2018) find that the impact of irrigation adoption on household nutrition is context-specific: those households who adopted irrigation had higher incomes and dietary diversity than rainfed farmers, but other factors such as the gender of the household head and access to off-farm income strongly modulated the impact. In many parts of SSA it has been suggested that the adoption of irrigation is profitable only for cash crops and other higher value crops (Rosegrant et al., 2009). Yet You et al. (2011) project that a significant share of large-scale dam-

13 The dam capacity needed for 8.4 million hectares of this potential irrigation expansion already exists.

based irrigation expansion in SSA will be used to grow staple crops, whereas small-scale irrigation schemes will be used to grow primarily horticultural crops.

Numerous studies across Africa show that the key drivers of irrigation adoption by smallholder farmers are access to off-farm income, proximity to markets, access to irrigation equipment, access to credit, availability of reliable water sources, and secure land tenure (Balana et al., 2020; Burney and Naylor, 2012; Malabo Montpellier Panel, 2018a; Mango et al., 2018). When farmers lose access to any of these, they may also dis-adopt irrigation (Burney and Naylor, 2012).

Adoption of irrigation is shown to increase food security, e.g. in Benin, 60 percent of irrigation farmers were food secure compared to only 46 percent of rain-fed farmers (Nonvide, 2018). Adoption of small-scale irrigation increased net farm profits by 154 to 608 percent in Ghana (Balana et al., 2020). The adoption of treadle pump irrigation in Malawi increased net profits for rainfed farmers by between 1.5 and 6 times (Mangisoni, 2008). In Ethiopia, households using irrigation in crop production earned about US$ 150 more than those practicing rainfed crop production (Gebregziabher et al., 2014). Similarly, in Ethiopia, Bekele (forthcoming) found that privately managed pump-based irrigation schemes generated three times higher profitability per hectare than communally-managed canal irrigation schemes (US$ 1770 vs. US$ 570 per hectare). Access to small-scale irrigation has been estimated to almost double maize yields and triple paddy rice yields across SSA (Xi et al., 2014). The adoption of irrigation in dryland areas in Africa is projected to reduce Africa's food import dependency from 54 percent under the business-as-usual scenario to 17-40 percent (Xie et al., 2018). Lobell et al. (2009) found that in irrigated wheat, rice, and maize systems, crop yields were close to 80 percent of their potential, while in corresponding rainfed systems they reached only 50 percent of their potential. In this regard, it is clear that with changing climate and increasing rainfall variability, the benefits of irrigated crop production over rainfed crop production will only get amplified in the future (Malabo Montpellier Panel, 2018a).

Adoption of irrigation is an important climate change adaptation measure in many settings of rainfed farming across Africa (Mirzabaev et al., 2019). Climate change is projected to increase rainfall variability across the continent. Even in cases when overall rainfall amounts do not change or even increase, the changes in seasonal distribution of the rainfall and higher temperatures can create water shortages for crop growth during critical vegetation periods (Mirzabaev et al., 2019). The profitability of adopting irrigation in SSA can be even higher under climate change because of increased resilience to higher rainfall variability (Reichhuber et al., 2019). Irrigation expansion across SSA also needs to be accompanied with the adoption of more water efficient irrigation methods (e.g. drip or sprinkler irrigation instead of flooding-based or furrow irrigation).

It does not come as a surprise then that irrigation expansion is a key element of the NEPAD's CAADP (You et al. 2011). There are significant opportunities for technological and institutional innovations, as well as for enabling policies to promote environmentally sustainable and economically profitable irrigation expansion in Africa. Despite these irrigation potentials, the adoption of irrigation by resource poor smallholder farmers, and especially by female farmers, will be constrained without equitable access to irrigation technologies (Lefore et al., 2019). Innovative technologies include sprinkler and drip irrigation, micro-irrigation, use of solar panels for pumping groundwater for irrigation, and use of soil sensors for irrigation timing (Malabo Montpellier Panel, 2018a). From a policy perspective, the Malabo-Montpellier Panel suggested elevating irrigation expansion to a top policy priority in Africa, specifically by creating dedicated government organizations responsible for irrigation expansion (Malabo Montpellier Panel, 2018a). Moreover, smart water pricing policies to avoid excessive and unsustainable water use need to accompany the promotion of irrigation technologies. Mainstreaming irrigation into agricultural policies requires planning and an allocation of funds for the regular maintenance and cleaning of centralized irrigation and drainage systems (e.g. using revenues from water fees and taxes), as well as putting in place of mechanisms for collective action and cost-sharing for these costs within community-managed irrigation schemes.

Facilitating private sector initiatives for the development and spread of locally suited irrigation technologies and tools can become a key promoter of irrigation expansion, particularly decentralized small-scale groundwater based irrigation schemes. The development of such local small-scale irrigation schemes can be accelerated by pooling the resources of farmers through community collective action. Government can

play a crucial role by facilitating such collective action, and by supporting the local private sector through fiscal and import tariff incentives, and access to soft credit.

The majority of Africa's surface waters are transboundary. In fact, Africa's 80 water basins extend to 60 percent of its land area, often crossing several countries (Mirzabaev et al., 2019). Hence, sustainable irrigation management and expansion also requires proper dialogue, negotiations and decision-making for sustainable governance of these transboundary water resources, both in terms of quantity of water allocations and quality of water. ZEF's research in the Nile and Olifants river basins in Africa show that improving the governance of transboundary water resources would involve raising awareness of the benefits of cooperation, involving all stakeholders in planning processes (from the water, energy and agricultural sectors), and creating institutional frameworks to support transboundary collaboration (Mirzabaev et al., 2019; Paulos, 2019). Moreover, these shared water resources are also key for the maintenance of natural ecosystems and biodiversity (Mirzabaev et al., 2019). Hence, planning of future irrigation systems also needs to take into account the use of water for maintaining ecosystem functions, which are often essential for food production and for the food security of Africa's rural population.

Investment and policy priorities

- Promote supply chains and distribution networks for affordable pumps and their spare parts, water-efficient irrigation technologies (e.g. sprinkler, drip) and equipment.
- Improve access to finance for smallholder adoption of irrigation technologies.
- Strengthen the monitoring of water use through water accounting and aquifer auditing.
- Promote water saving irrigation technologies, including through water use pricing.
- Train and build the capacity of water governance institutions, including at community, national and transboundary levels.

4.1.4 Reducing food losses

Food loss and waste are global issues that have consequences on food security. In Sub-Saharan Africa, food loss has a major impact on the economy, the environment and livelihoods (Dongyu, 2019). In lower-income countries and in Sub-Saharan Africa specifically, most food loss occurs on field and post-harvest. In Sub-Saharan Africa, about 13.5 percent of all grain crops and up to 50 percent of all fruits and vegetables are lost post-harvest (Houngbo, 2019), ranging from 28 to 42 percent for cassava, 19 to 42 percent for yams and 7 to 44 percent for sweet potatoes (Affognon et al., 2015).

Food loss is defined as the loss of food at the beginning of the supply chain, during the farm and wholesale stages. Food waste occurs later in the supply chain at retail and consumer levels (Flor, 2019). While food waste is also an important issue, this section will focus on food loss, as it is most common in Africa and more relevant from a policy standpoint. Many key constraints prevent the reduction of food loss and subsequently food security. General drivers of food loss include unfavourable climatic conditions; improper post-harvest handling; and lack of economic incentive, data, education, technology, infrastructure, affordable financing and market access (The Pontifical Academy of Science, 2019). A significant factor is also a lack of refrigeration in the cold chain, which is estimated to cause nearly two-thirds of global food loss (Fay, 2019).

Several growth potentials exist for the reduction of post-harvest losses and therefore food security. Interventions early-on in the supply chain that reduce on-farm losses can strongly improve food security (Dongyu, 2019). By simply reducing grain loss in Sub-Saharan Africa, US$ 4 billion per year could be saved and the annual caloric requirements of more than 48 million people met (Houngbo, 2019). To achieve such food security gains, policy and private initiatives, guided by a systematic approach, are necessary.

Reducing post-harvest losses is possible by improving farmers' and other small scale producers' access to markets and increasing their capacity to store

and process agricultural produce to create a more integrated food supply chain. In addition, lowering the costs of transportation and distribution leads to fewer post-harvest losses (Vos, 2019).

The private sector in Africa offers a lot of potential to create agricultural transformation in Africa and therefore reduce food loss (Kibaara, 2019). Small and medium-sized enterprises (SMEs) in Tanzania, for example, play a key role in enabling the access of smallholder farmers to appropriate technologies through manufacturing, distribution, operation and maintenance, and hire services. SMEs also play a significant role in training and offering extension services to farmers on technologies and practices for food loss reduction (Mbaabu and Alela, 2019). Technologically empowered SMEs, through the use and adoption of advanced technology, would directly contribute to an 84 percent reduction and indirectly contribute to a 30 percent reduction in food loss in Sub-Saharan Africa (Hatibu, 2019). Additionally, the possibility for innovation via start-ups exists (The Pontificial Academy of Science, 2019).

Economic reasons contribute to food loss. If market prices are low, farmers may not market all of their produce or harvest everything because it is not profitable (Vos, 2019). In addition, there is evidence that when more valuable crops are part of the second planting of a season, farmers improperly process the initial crop due to lack of economic incentive, which leads to loss (Goldsmith et al., 2015). Furthermore, farmers may not often perceive the expected returns of improving harvest and post-harvest handling practices as being worth the investment (Vos, 2019). Even despite knowing the benefits, there is still little widespread adoption of improved practices among farmers and other supply chain actors (Vos, 2019). Lack of market access is particularly significant in Sub-Saharan Africa. An estimated one-third of the population lives at least five hours away from the nearest market town of 5,000 people, which limits the amount of food that can be transported and contributes to food loss, particularly when roads are impassable (Houngbo, 2019).

Lack of data on the driving factors and the impacts of various measures on reducing food loss hinders the prevention of food loss. Most evidence focuses on technical efficacy as opposed to the social, economic and environmental outcomes of post-harvest loss reduction interventions (Dongyu, 2019). There is also still little understanding on how viable it is to reduce food loss, and on the effect of training, finance policy or infrastructure interventions aimed at reducing post-harvest losses (Dongyu, 2019).

Quality losses tend to be greater than quantity losses. This poses an economic issue to farmers and a food safety issue to the poor. A loss in quality forces farmers to sell their goods for cheaper (Vos, 2019). When food spoils, instead of being thrown away, it can then end up with the poor and lead to food safety concerns (Hatibu, 2019). In an IMPACT-SIMM simulation, it was shown that eliminating post-harvest losses for vegetables in Senegal would increase the total value of supply by US$ 72 million and reduce imports by 127,000 tonnes (Bèye and Komarek, forthcoming). Another key constraint is the use of food after its production. Little food, outside of Africa's cities, is actually thrown away and wasted. Instead, it is often reused in other ways, such as for feeding livestock or turning into compost (Vos, 2019).

The solutions to food loss remain poorly researched and are perhaps ineffective in increasing food security. Reduction of losses is not free of charge and requires investments that need to follow cost effectiveness and optimality criteria, just like any investment. The limited evidence shows that investments in food loss reduction are less cost-effective than investing in agricultural research or input system improvements to reduce yield gaps (FAO, 2019a). A study by Rosegrant et al. (2016) shows that reducing post-harvest losses by 10 percent in lower-income countries by improving electricity, paved roads, and rail and road capacity would require US$ 203 billion. Such a scenario would have a benefit cost ratio of 11 and lead to a 15.8 percent reduction in the population at risk of hunger and a 4.7 percent reduction of the number of malnourished children in Sub-Saharan Africa in 2050. However, investing in agricultural research would instead require a cost of US$ 66 billion and would have greater impacts on food security. With a benefit cost ratio of 32, this alternative scenario would lead to a 21.2 percent reduction in the population at risk of hunger and a 6.9 percent reduction in the number of malnourished children (Rosegrant et al., 2016).

A study by Bahadur KC et al (2016) shows that increasing the use of agricultural machinery up to 95 percent of the level of the top performing country in the low-income category would reduce food loss by 42.3 percent. The lower-middle-income category would see a food loss reduction of 23.8 percent. Per-

forming a similar improvement in roads would show a respective 6.9 percent and 8.6 percent reduction in food loss in the low-income and lower-middle-income categories. Investing in telecommunications infrastructure would contribute a 7.4 percent and 19 percent reduction in food loss in low income and lower-middle income countries, respectively (Bahadur KC et al., 2016).

Food loss and waste also accounts for a significant share of greenhouse gas emissions and must therefore be factored into climate negotiations (The Pontificial Academy of Science, 2019). Policies designed to reduce food loss must also coincide with related policies in agriculture, trade, energy and infrastructure, among others (Hatibu, 2019).

Investment and policy priorities

In order to come up with a policy framework to combat food loss, it first becomes essential to identify at which point to focus interventions in the supply chain. This is especially critical considering that there is a lack of evidence on the effectiveness of loss reduction interventions, particularly concerning key crops in Sub-Saharan Africa. As a first step more research is needed to gauge how much food is lost post-harvest (Dongyu, 2019).

It is recommended to pursue interventions that reduce food loss earlier in the supply chain in Sub-Saharan Africa, at the farm level and at the early processing stages (Dongyu, 2019). A holistic sectors approach is needed to combat systemic indirect causes of food loss (Fay, 2019) and should be integrated into broader food and agricultural policies as opposed to specific targeting of food loss reduction (Vos, 2019). It therefore becomes necessary to invest in value and supply chain infrastructure, to create incentives for the private sector to act and pursue targeted interventions (Dongyu, 2019).

- Implement on-farm practices and collaborations along value chains to reduce post-harvest losses during production and storage.
- Promote proved low-cost storage solutions such as hermetic bags for grains and reusable plastic crates for the transport of fresh produce.
- Stimulate the development of aggregation centres for produce to facilitate food processing plant establishment.
- Develop processing technologies to extend the shelf-life of foods and aid in the wider distribution of nutritious foods year-round
- Form public-private partnerships and develop national strategies for reducing food loss and waste.
- Scale up financing for programmes, technologies and enterprises that prevent and reduce loss, including a range of food processing techniques;
- Obtain sound data and research on the economic and environmental effects of proposed policy initiatives (Kibaara, 2019).

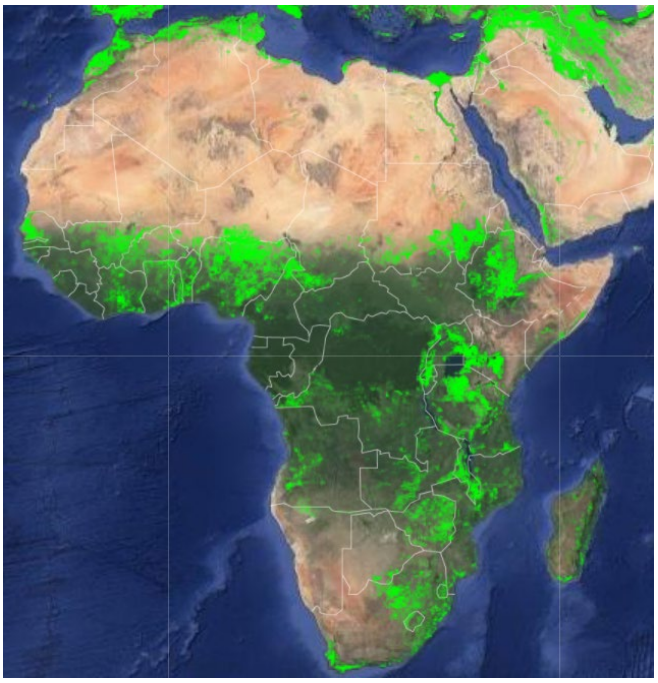
4.1.5 Land use change, sustainable land management and climate resilience

The current extent of croplands in Africa is estimated at around 278 million hectares and the extent of pastures 860 million hectares (FAO, 2020a). In terms of area, the major share of the croplands is located across the Sahelo-Sudanian zone, along the eastern coast of Africa from Tanzania to Southern Africa, and in northern Africa. Most irrigated croplands with higher monetary value of crop production per hectare are located in northern African countries and South Africa (Figure 7). The pastures[14] are spread across the continent except the Sahara Desert and the dense tropical forests of Central Africa (Figure 8).

Land use and land cover changes between 1990 and 2017 in Africa indicate marked trends (Figure 9). During this period, the extent of croplands increased by 37 percent, from 203 to 278 million hectares. This came primarily at the expense of forests (including woodlands and shrublands) and grasslands. Forest cover reduced by 12 percent, i.e. from 705 to 624

14 Land used permanently (five years or more) to grow herbaceous forage crops through cultivation or naturally (wild prairie or grazing land).

Figure 7: The extent of croplands in Africa in 2015 (in bright green)



Source: Global Food Security Analysis-Support Data at 30 Meters (GFSAD30) Project (Xiong et al., 2017b, 2017a)

Figure 8: The extent of pastures in Africa in 2015

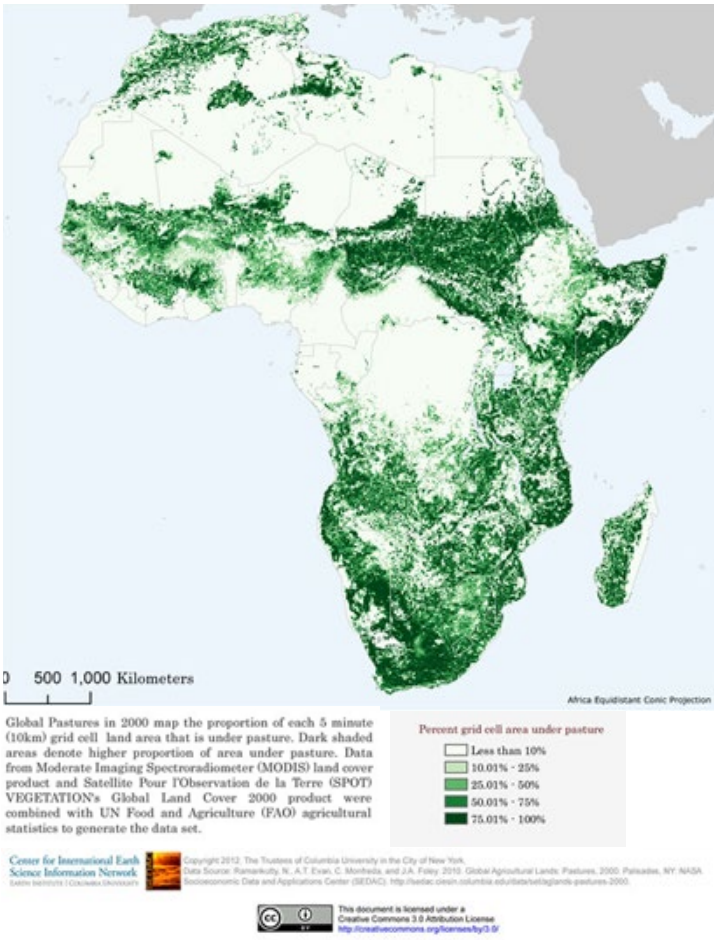
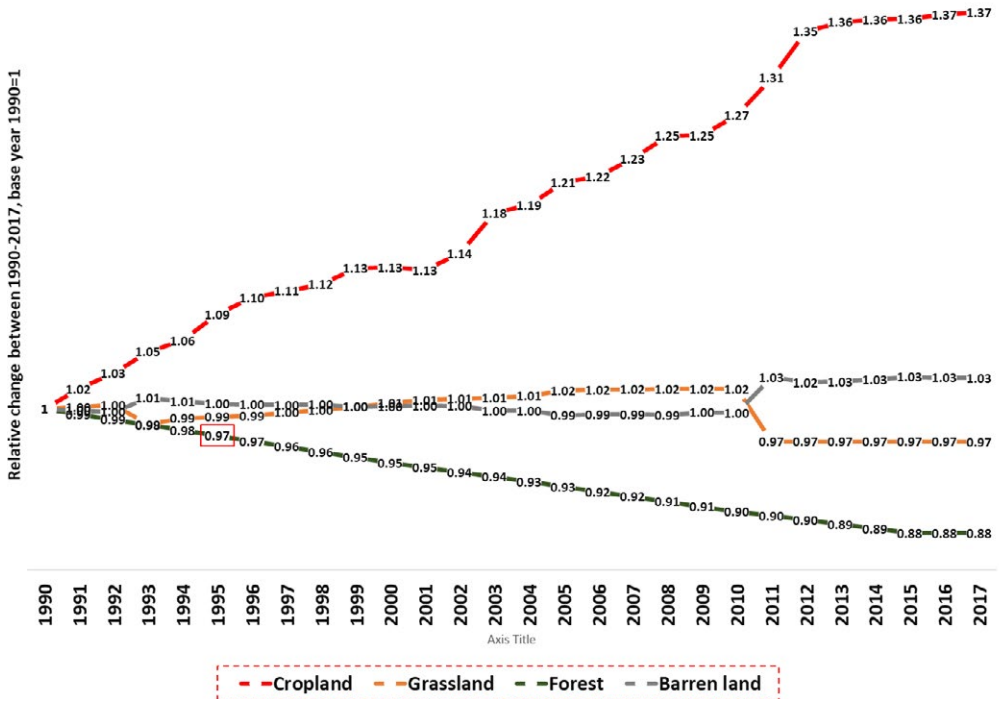


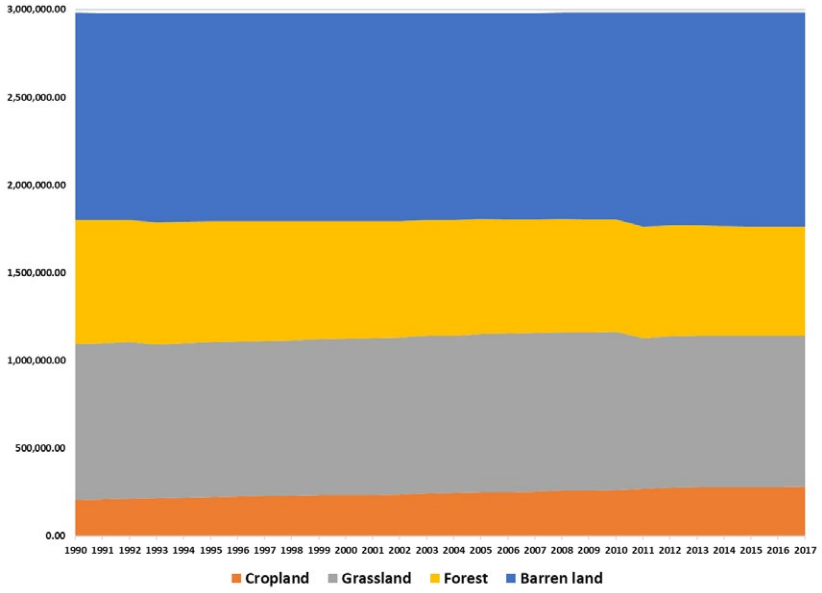
Figure 9: Inter-annual changes of LULC types. 1990 is taken as the base year.



Source: FAOSTAT

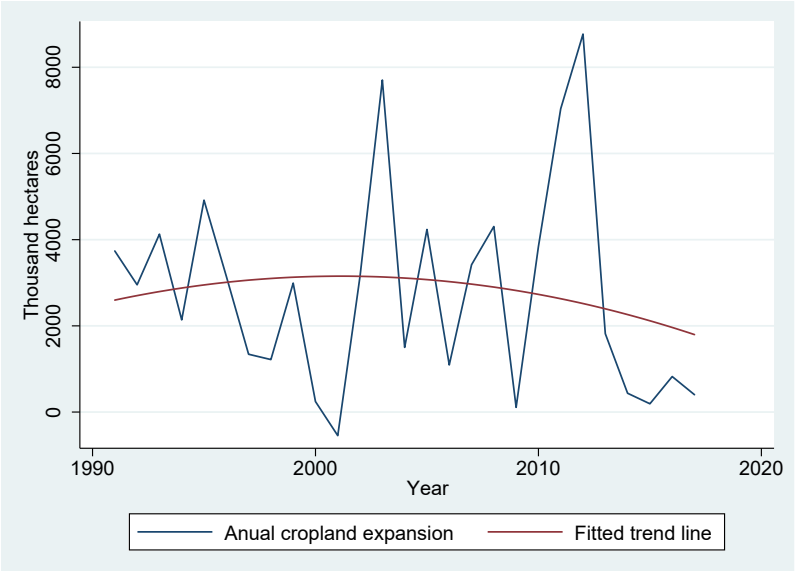
million hectares. Often, this deforestation was not the result of a direct conversion of forests to croplands, rather there is a land use and land cover (LULC) change trajectory wherein forests are first converted to woodlands, then to shrublands, then to grasslands and croplands. Strong reliance on biomass for energy is a major driver of deforestation, in addition to cropland conversion. Low livestock productivity is a major reason spurring grassland conversion to croplands (Nkonya et al., 2016).

Figure 10: The change of relative shares of land use and land cover types in Africa over time



Source: FAOSTAT

Figure 11: Evolution of annual cropland expansion in Africa



Source: Representation based on FAOSTAT data

Although these are relatively large changes for croplands and forests, at the continent level the overall LULC shares experienced only small changes during this period because of little overall net change in the areas of grasslands and barren lands, the two biggest LULCs (Figure 10). Although the pace of cropland expansion was historically high, on average 1 percent cropland expansion per year since the 1960s, since 1990 there is a declining trend in cropland expansion suggesting the rate of cropland expansion in Africa may decline further and more rapidly (Figure 11).

Earlier estimates of potentially available cropland in Africa ranged between 400 to 800 million hectares (cf. Chamberlin et al., 2014 for a review). Many such studies were based only on biophysical potential, without taking into account socio-economic factors. However, by taking into account some socio-economic factors, such as market access, Deininger et al. (2011) pointed at the expansion potential of 198-446 million hectares, i.e. still practically doubling or tripling from the current levels. A more detailed analysis by Chamberlin et al. (2014), who control for a larger number of socio-economic factors such as the cost of land conversion and profitability of crop production, concludes that from 80 to 242 million hectares could be converted to croplands under medium input use, and from 167 to 383 million hectares under high-input commercial farming. However, Chamberlin et al. (2014) also show that these estimates may be pointing at the upper bounds of cropland expansion potential.

The actual area by which croplands would expand is likely to be lower than these estimates if production uncertainties and other constraining factors, such as endemic diseases burden, conflicts and insecurity, are taken into account. Based on these earlier studies and a trend line analysis of cropland expansion time series in Africa, cropland expansion in Africa during the next 30 years till 2050 is not likely to exceed 50-60 million hectares, even if we assume no further decline of the annual expansion rate and continued cropland expansion at trend line values of about two million hectares per year. This expansion will amount to bringing the extent of croplands in Africa to about

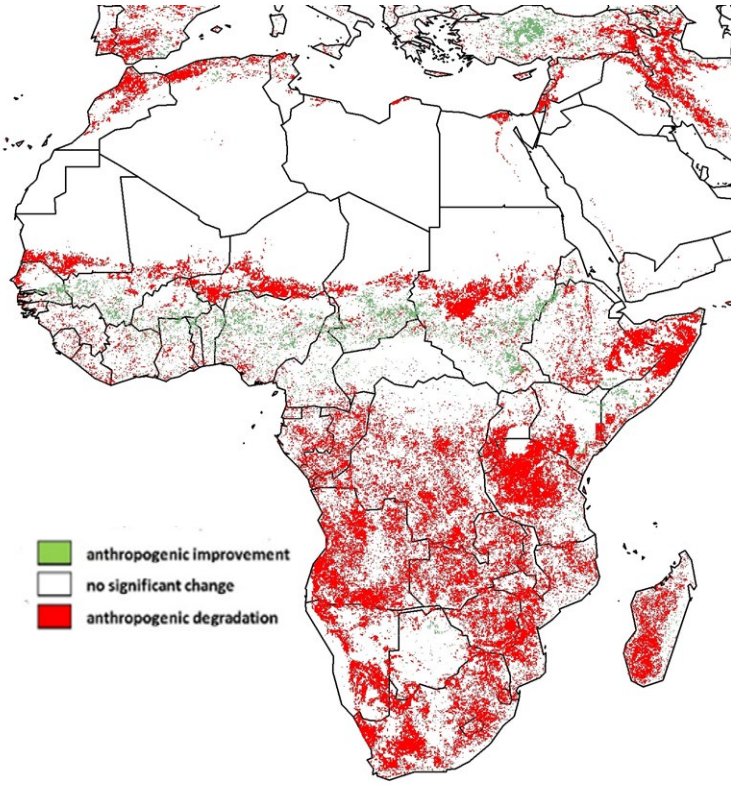
330-340 million hectares by 2050. Considering that the population in Africa is projected to double from the current 1.2 billion to 2.4 billion people by 2050, per capita cropland availability will decline even with this projected expansion.

Moreover, two emerging factors, continued cropland degradation and climate change, are likely to further reduce the potential area of actual cropland in Africa. Soil erosion, secondary salinization, soil nutrient mining and other forms of land degradation are degrading existing cropland areas across Africa (Nkonya et al., 2016) (Figure 12). Nkonya et al. (2016) estimate that the annual costs of land degradation in SSA is US$ 58 billion through land use and land cover changes and another US$ 3.3 billion through cropland and pasture degradation. More than half of these costs are associated with losses in non-provisioning ecosystem services, primarily in losses of carbon sequestration potential, thus contributing to global warming (Nkonya et al., 2016). Moreover, climate change is predicted to reduce the biophysical potential of suitability for crop production in many parts of Africa (e.g. Chemura et al., (2020); Mirzabaev et al. (2019)). Addressing land degradation through sustainable land management is also a major form of climate change adaptation on the continent (Mirzabaev et al., 2019; Olsson et al., 2019). Such sustainable land management measures such as rainwater harvesting, rotational grazing, crop diversification and diversified crop rotations including legumes, application of conservation agriculture practices, inter alia, can contribute to climate change adaptation, carbon sequestration and biodiversity protection (Reichhuber et al., 2019).

In view of these facts, the widespread belief that Africa has abundant unutilized land which can be converted to croplands does not stand up to scrutiny in view of these facts. More than half of the land suitable for cropland expansion in Africa are currently forests, the destruction of which would imply major environmental damages (se also section 4.4). Moreover, large swathes of these areas have low access to markets and infrastructure hence considerable investments would be required before it would become economically profitable to turn them into croplands (Chamberlin et al., 2014). Other seemingly unused areas are used for grazing.

Furthermore, even with these projected possibilities of increasing cropland, much of this expansion potential is concentrated in a few African countries,

Figure 12: The extent of land degradation and improvement in Africa



Source: Le et al. (2016)

specifically Sudan, Madagascar, Democratic Republic of the Congo, Mozambique, Angola, Republic of the Congo, Central African Republic, Ethiopia and Zambia. Expansion of croplands in these countries does not necessarily imply higher food production or improved food security in the remaining African countries where there may be no potential for cropland expansion.

The key conclusion is that ensuring future food security in Africa is not possible by cropland expansion, but would primarily rely on intensification of agriculture, increasing crop yields and raising livestock productivity. At the same time, the further expansion of croplands will still occur in many places across the continent, as it did elsewhere in the world, even in countries with strong growth in agricultural productivity e.g. Brazil, Indonesia. The expansion of croplands in Africa will make particular economic sense in the Democratic Republic of the Congo, Central African Republic, Republic of the Congo, Cameroon and Angola (all in Central Africa), in Mozambique and Madagascar (in Southern Africa), in Tanzania and Sudan (in Eastern Africa), and in Côte d'Ivoire and Guinea (in Western

Africa) (Chamberlin et al., 2014). Depending on the location, projections for the crops to be grown in new croplands are wheat, rice, maize, sorghum, banana, soybean, coffee, cotton and barley (Chamberlin et al., 2014). A major challenge in this expansion of croplands is the mitigation of trade-offs between environmental degradation and increased food production.

Similarly, grasslands have experienced large-scale degradation across Africa since the 1980s. According to Le et al. (2016), 40 percent of grasslands in SSA and 52 percent of grasslands in North Africa experienced degradation trends between the 1980s and 2000s, making the level of vegetation loss in grasslands the highest among all LULCs in Africa. Sustainable grassland management can help meet the growing demand for livestock and dairy products, but this would require increasing public budget allocations to livestock production (Nkonya et al., 2016).

It is therefore essential to address the growing problem of land degradation in Africa. The key drivers of land degradation across the continent are population growth leading to increased demand for food and fuelwood, poor agro-sylvo-pastoral practices such as the slash-and-burn system, land tenure insecurity, lack of access to markets, extension services, and credit (Gebreselassie et al., 2016; Moussa et al., 2016; Nkonya et al., 2016; Sow et al., 2016). Low productivity associated with subsistence farming caused soil fertility mining and soil degradation in many parts of the continent. This also brought about an expansion of cropping to marginal lands with fragile soils (Ogunlela and Ogungbila, 2006), leading to new cycles of land degradation, and exacerbating conflict dynamics such as intense competition over land and water resources between pastoralists and sedentary farmers. The economic and social returns from sustainable land management in Africa are high. Nkonya et al. (2016) estimate that every US dollar invested into land restoration and rehabilitation in Africa yields between three and five dollars of returns within a 30-year period. The amount of investments required during this 30-year period to fully restore all lands degraded between 2001 and 2009 in SSA was estimated to equal US$ 759 billion, i.e. about US$ 25 billion. Correspondingly, if no action is taken to restore these degraded lands, the total economic value of lost ecosystem services during this 30-year period can reach US$ 3.181 billion (Nkonya et al., 2016). There are numerous sustainable land management technologies available (both for croplands and rangelands), but their adoption remains low and needs to be dramatically increased for the sustainability of food production in the continent. Policy options that can help to boost sustainable land management adoption include instituting payments for ecosystem services, and improving land tenure security, access to markets and access to credit (see also sections 5.5,5.7 and 6.3).

Investment and policy priorities

Numerous policy approaches and investments are required for the sustainable management of various land types in Africa, both to increase food production and to maintain their environmental services:

- Strengthen land tenure security.
- Improve access to markets via investment in infrastructure.
- Promote large-scale adoption of sustainable land management practices (for croplands, pastures and forests) to avoid land degradation, and simultaneously adapt to and mitigate climate change, including through community participation.
- Facilitate the development of payments for land ecosystem services.
- Strengthen environmental legislation, monitoring and enforcement.

4.2 Animal husbandry

Africa's food system has been transforming over the last decade, sparked by prolonged economic and population growth, urbanization, and shifting dietary preferences and habits. Rising demand for animal-sourced foods, such as dairy, eggs, and (processed) meat, has been driven by a growing middle class across the continent. Although most African countries are still heavily import-dependent, domestic livestock sectors have been growing steadily to meet demand. Yet, consumption of these products is uneven

across the continent and relatively low among some groups of people. These foods are essential sources of nutrient-rich foods for children.

Livestock systems support diverse functions in the well-being of producers, including health and nutrition, employment, income, asset store and generation, draught power, transport, soil nutrient supply, social security, and insurance. At the same time, the predicted increase in demand for animal-sourced foods from US$ 51 billion in 2007 to more than US$ 151 billion annually by 2050 creates significant opportunities for the sector and for African countries to improve their trade balances (AU, 2015). Within this, beef and milk will be the largest markets by value for animal proteins in 2050, valued at US$ 46.6 billion and US$ 43.5 billion respectively. Although mutton and poultry grow significantly too, they will each only represent a market value about half of those for beef and milk (Pica-Ciamarra et al., 2013). By investing in appropriate institutions and policies, programmes and value chains, African governments can ensure that they increase productivity within livestock sectors to meet demand, thereby capturing the benefits sustainably and in an inclusive manner.

4.2.1 Production systems

Africa is a livestock-rich continent representing about one-third of the world's livestock population (AU, 2015). Its production occurs across a wide range of heterogeneous production systems: pastoral systems, mixed crop-livestock systems, and commercial livestock systems, each with their distinct characteristics, challenges, and opportunities.

Pastoral systems

Pastoralism is an extensive livestock production system, characterized by mobility and shared use of natural resources, both of which are key strategies to manage environmental variability and shocks (FAO, n.d.). Pastoralism is one of the most viable livelihood options in Africa's drylands (FAO, n.d.), and is the primary livelihood of an estimated 268 million people who mainly produce camels, cattle, sheep and goats that can easily digest forage (FAO, 2018a). Approximately 43 percent of Africa's land mass is conducive for pastoralism (FAO, 2018a) and the highest concentration of pastoralists within SSA is located in Sudan, Somalia and Ethiopia (Jenet et al., 2016).

Mixed crop-livestock systems

Mixed crop-livestock systems, in which crops and livestock are produced on the same land, are central to smallholder production in most of SSA (Thornton et al., 2018). Mixed systems are primarily rainfed, and predominantly subsistence-oriented and crop-dominated (Thornton and Herrero, 2015), with livestock also contributing to cropping with manure and traction services. In the Intergovernmental Authority on Development (IGAD) region[15], mixed systems account for nearly 40 percent of all livestock farming, and produce 35 percent of total beef, 30 percent of goat meat, 29 percent of mutton, and 16 percent of cattle milk outputs (Guthiga et al., 2019).

Commercial livestock production systems

Commercial systems produce livestock purely for income-generating purposes (Otte and Chilonda, 2002). They are less labour-intensive and focus on optimizing the value chain for maximum returns, by concentrating the availability of inputs such as land, feed and water. Overall, the number of commercial livestock enterprises across Africa is still small, but it is growing. Although the majority of commercial systems produce ruminants on ranches across most of SSA, commercial poultry farms are rapidly increasing in number to meet the growing demand for livestock products. This is true especially for Southern Africa, where most of the poultry originates in one of three vertically integrated companies, and in Nigeria, where commercial entities produce 21 percent of the total chicken output (FAO, 2018b).

4.2.2 Production and consumption trends

The growing popularity of livestock production is evident in the expansion of livestock units (LSU) per hectare, which is an indicator of total livestock density, presenting an aggregated measure of livestock including cattle, buffalo, sheep, goats, and equines. One LSU is the grazing equivalent of one adult dairy cow producing 3,000 kg of milk annually (Eurostat, 2020). Across Africa, the average LSU/ha rose from 0.16 in 1990 to 0.28 in 2017, with the highest concentration of animals in Eastern Africa and most significant growth taking place in Central Africa, albeit from a very low base. This growth in livestock production is set to continue. The latest Agricultural Outlook pro-

15 IGAD comprises Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, and Uganda.

duced by the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) covering 2020-2029 expects that livestock production in SSA will expand by 25 percent over the next ten years, with the fastest increases coming from poultry and milk production (OECD and FAO, 2020).

However, domestic production in many African countries does not currently meet the demand for livestock products, resulting in substantial net imports of animal products and animal feed. Without significant investments across the value chain, Africa's livestock will remain uncompetitive in the global market and countries will continue to be a net importers of livestock products. Imports are projected to account for 10 to 20 percent of beef, pork, poultry and milk – and 12 to 15 percent of livestock products consumed in Africa between 2030 and 2050 (World Bank and FAO, 2014).

Milk

Total milk production in Africa more than doubled between 1990 and 2018, from about 22 million to 47 million tonnes (Mattiello et al., 2017). Approximately half of the total milk is produced in just six countries: Egypt, Kenya, Sudan, Algeria, and Ethiopia, and South Africa (Mattiello et al., 2017), and more than 70 percent of total milk produced is either consumed on the farm or distributed via informal markets. Only 15 percent is processed into fresh products such as cheese, pasteurized milk, yogurt, or butter (Ndambi et al., 2019). By 2030, milk production in SSA (not all of Africa) is expected to grow to 27 million tonnes (Seré, 2020).

Over the period 1990 to 2013, average per capita milk consumption in Africa increased from around 37 kg to 44 kg (Ritchie and Roser, 2017), although this varies greatly between and within countries (Muriuki, 2011). Currently, per capita milk consumption across Africa is significantly higher than production contributing to a large import bill. For instance, between 2015-2017, Western Africa imported over 2 billion tonnes of milk equivalents per year, costing the region US$ 805 million (FAO, 2020a). Over 2016-2018, domestic production in Côte d'Ivoire, Senegal and Ghana was a small fraction of total consumption, importing 565, 426 and 375 percent respectively of domestic production from Europe (Eurostat, 2020; FAO, 2020a). With projections of average per capita milk consumption on the continent expected to rise to 64 litres per annum by 2050 (Pica-Ciamarra et al., 2013), the urgency of investing in the dairy sector becomes clear. However, consumption will be concentrated in Eastern Africa/IGAD and Northern Africa, consuming over 70 percent of all milk in Africa. Thus, the sector will benefit from greater intra-African agricultural trade brought about by regional trade integration and through the African Continental Free Trade Area (AfCFTA).

Meat

Over the same period, 1990-2018, total meat production in Africa—including beef, poultry, mutton, goat, pork, and wild game—more than doubled from almost 9 million tonnes to 20 million tonnes (Ritchie and Roser, 2017). Northern Africa produced more than a quarter of this, 5.4 million tonnes, the highest among Africa's sub-regions (Ritchie and Roser, 2017). By 2030, it is expected that SSA will produce nearly 17 million tonnes (Seré, 2020), largely from an increase in herd size. Within total meat production, poultry meat trebled to 6 million tonnes between 2000 and 2018, nearly a third of which came from South Africa's commercial broiler industry alone, making it to the largest producer on the continent (Ritchie and Roser, 2017; Samboko et al., 2018). This trend is expected to continue over the next decade, particularly in Zambia and South Africa, whose combined share of global production will rise from 1 percent to 14 percent by 2029, underpinned by greater feed intensity (output per unit of feed consumed) (OECD and FAO, 2020).

Despite significant growth in meat production, consumption has remained stagnant across the continent since 1990, except in southern Africa. South Africa is currently the largest poultry consumer in this region, with consumption having increased from 23 kg per capita in 2003 to nearly 40 kg per capita in 2015 (Ncube, 2018). However, South(ern) Africa is an extreme outlier on meat consumption, with other regions consuming as little as 10.8 kg per capita in 2013 (FAO, 2020a). It is envisaged that average per capita annual meat consumption across Africa will grow from 19 kg per capita in 2013 to 26 kg per capita in 2050, aggregated to 35 million tonnes (FAO, 2019b; Pica-Ciamarra et al., 2014; Ritchie and Roser, 2017).

Eggs

Total egg production in Africa more than doubled from 1.4 million to 3 million tonnes between 1990 and

2018. Nigeria is the largest single producer of eggs across the continent, with almost 500,000 tonnes of eggs in 2018 (Ritchie and Roser, 2017; Sahel Capital, 2015). Growth in production in Northern and Southern Africa more than doubled while the rest of the regions had more modest growth (Ritchie and Roser, 2017). However, when compared to other developing regions, Africa's total egg production is still meagre: in 2018, the continent produced over 3 million tonnes while just India produced over 5 million (Ritchie and Roser, 2017). This is an outcome of small flock sizes, ranging between 5 to 20 birds, and low productivity of just 30 to 80 eggs per hen per year in unimproved systems (Morris et al., 2018). Compared to other regions, egg consumption is also low. In 2013, average annual per capita egg consumption in Africa was 38 eggs, in contrast to 86 and 134 eggs in Western Europe and Asia, respectively. While Kenyans consume an average of about 45 eggs per year (FAO, 2018b), in Burundi, Chad, Niger and Rwanda, annual per capita consumption is as low as 6 eggs per year (Ritchie and Roser, 2017).

Despite some growth in production and productivity, studies suggest that under current trends Africa is unlikely to meet projected demand in the foreseeable future. Targeted investments in raising productivity sustainably will ensure that the sector continues to provide food and nutrition, generate employment and income, especially for women and young people, and support the vast array of socio-economic and environmental functions.

4.2.3 Improving productivity of animal husbandry practices in Africa

Livestock productivity in Africa, measured in terms of yield per animal, is below other lower-income regions, and much lower than industrialized countries. Growth in herd and flock size rather than yield increases have, to date, driven increases in livestock production. Feed (availability and quality), diseases and parasites, genetic composition, animal health services, access to markets, as well as extreme weather events affect the productivity of livestock. Consequently, raising productivity sustainably requires the participation of a wide range of actors such as research organizations, policymakers, feed and forage farmers, veterinarian services, local agro-dealers, and equipment providers, among others.

Breeding

Africa has a very diverse stock of livestock that are well adapted to the harsh conditions under which they live (Kim et al., 2017), including the diseases to which they are exposed (Murray et al., 1981). The genetic diversity represented within Africa's indigenous breeds in itself offers a unique resource to meet increased demand and tackle forthcoming challenges such as climate change (Mwai et al., 2015). At the same time, with careful breeding, it is possible to raise productivity; increase fertility and reduce the need for a large breeding stock; accelerate the rate at which new and stable breeds are developed; and reduce susceptibility to diseases and a changing climate, all the while maintaining livestock's adaptability to local conditions and prevailing husbandry practices. Breeding can also be beneficial for environmental outcomes, as greater productivity can reduce the number of animals kept, with positive implications for land use. Ruminal microflora can also be altered using breeding applications to reduce methane production (Cassandro, 2020).

Despite the potential benefits, there are few examples of systematic and sustainable breeding programmes in Africa. The heterogeneity of livestock systems and farm sizes as well as the cost of services hinder the uptake of breeding programmes, as do management practices, and needs and preferences of livestock keepers. However, investments in policy and institutional support, research, infrastructure and extension service capacity, would foster greater uptake of systemic breeding and breeding programmes (Marshall et al., 2019).

By using a variety of technologies such as juvenile in-vitro fertilization and egg transfers, artificial insemination, and semen sexing, livestock keepers can have access to better genetic material and systematically improve the genetic composition of the herd (Enahoro et al., 2019). Since introduced and crossed breeds tend to require greater management of feed, healthcare and shelter to thrive, they dominate commercial and mixed intensive systems. Accordingly, indigenous breeds tend to dominate agro-pastoral and extensive systems (Marshall, 2014). Aligning the breed type to its local environment and conditions is crucial to achieve beneficial impacts quickly and efficiently (Marshall, 2014).

Artificial insemination

The relative potential of artificial insemination has remained generally un- or underexploited across Africa and is mainly used for exploratory purposes by re-

search institutions or with the support of government subsidies. A few African countries have taken the technology to the field, but mostly to upgrade indigenous stock and to enable a limited number of commercial farmers to keep exotic dairy cattle breeds (Agriculture for Impact, n.d.). To maximize calving, procedures such as estrus synchronization, detection of reproductive disorders and pregnancy testing require skilled technicians and sophisticated technology coupled with extensive training and experience. Equally, the procurement, storage and transport of semen for prolonged periods and over long distances requires specific skills and appropriate equipment such as liquid nitrogen tanks. The International Atomic Energy Agency and the Nuclear Techniques Division at FAO have implemented several technical cooperation projects across the African continent to improve livestock production and reproduction through capacity enhancing, strengthening operational and regulatory frameworks, and providing physical infrastructure (FAO and IAEA, 2017a). Through this initiative, the Bambui Cattle Centre in Cameroon was able to develop a chilled semen processing methodology using egg-yolk and coconut water in which sperm can survive for up to seven days (FAO and IAEA, 2017b). **Scaling up simple solutions using locally available materials appropriate for the context offer an ideal investment opportunity for easing the uptake of artificial insemination.**

Moreover, by providing artificial insemination services alongside dairy cooperatives, farmers can benefit from negotiated rates and shared costs, rather than shouldering the individual costs of private agents (Omondi et al., 2017). Similarly, farmer cooperatives and community-based breeding programmes (CBBPs) where bulls, rams or bucks are shared, have also proven successful. CBBPs are ideal for locations where extension services and infrastructure is weak but where existing social ties within communities of livestock producers is healthy. Although CBBPs also require continuous technical and financial support, by providing a supportive enabling environment such as subsidies and access to credit, local government involvement can ensure longevity in CBBPs (Mueller et al., 2015). Scaling out successful models of CBBPs can provide a return to investment of up to US$ 5.1 per US$ 1 invested (Haile et al., 2019).

Record-keeping and sharing

Livestock producers have long practiced selective breeding strategies, not only to increase productivity but also for characteristics such as size, colour, shape of horns, the taste and quality of meat, or the number and quality of eggs (Conway et al., 2019). However, without accurate and regularly updated data, it is difficult to identify which breed compositions are most suitable to what conditions (agro-ecological zones, production and feeding systems). These constraints are particularly acute where herds are small, with low access to inputs, and lack of appropriate management of mating. Consequently, farmers may not achieve the desired outcomes and prefer to work with indigenous breeds (Enahoro et al., 2019). New genomic tools and digital technologies play an important role to reduce cost and simplify the analysis, recording, storage, and management of livestock genomic and phenotypic data (Mrode et al., 2020).

Several projects have been initiated across the continent to retrospectively identify the genetic composition of local cattle stocks. By reverse-engineering the genotypes, experts are able to generate an estimate of ancestral breed composition of each animal. Combining this information with the environments in which the animals operate optimally, future livestock programmes can be tailored to suit both the animals and their environment. For example, in Kenya, the Dairy Genetics East Africa project implemented by the International Livestock Research Institute, the University of New England, and PICOTEAM Ltd., showed that animals with less than 50 percent share of exotic breed perform best in smallholder farms while those with a higher mix of exotic breeds require high input environments to succeed. Several other programmes are applying a variety of mapping technologies to identify matches between breeds, their local environments and purposes (Marshall et al., 2019). Results from each of these studies are being applied to improve decision-making at both the farm-level and the national policy level.

Opportunities for investments in breeding

Animal science, breeding, and genetics research capacities across the continent need strengthening to equip African institutions and researchers with the practical skills needed to understand livestock population genomics and improve breeding techniques for a greater productivity of African livestock. This includes the need to develop a better understanding of the adaptive ability of livestock in the context of climate change, for preserving the genetic resources of indig-

enous breeds, and for sustainable livestock management practices (Mwai et al., 2015).

Since 2000, the International Livestock Research Institute has been running several training courses on animal sciences, breeding and genetics. For example, in 2019, the Institute and the Swedish University of Agricultural Sciences hosted a one-week workshop for African researchers to equip them with knowledge on improving the productivity of African livestock, including dairy cattle. Twenty-six researchers from 14 African countries took part in training on current genomic data tools, methods, and trends and their application in Africa (Patel, 2019).

The transfer of these skills and knowledge to livestock producers through appropriate reform and retraining of extension service providers – including community based animal health workers (CAHWs) – is urgently required. This is particularly important as the traditional distinction between crop farmers and livestock keepers is gradually fading and livestock producers increasingly request information on production methods, including breeding, animal health and feed (Morton and Matthewman, 1996). In addition to enhancing capacities among livestock producers themselves, there is a need for more training of professional extension agents and CAHWs to deliver much-needed advice and guidance. This in turn will require a review of policies, investments in higher-level education in veterinary and animal sciences and a legal recognition of CAHWs. In addition to national or regional governments, other stakeholders such as NGOs, cooperatives, universities, or national agriculture research institutes as well as the private sector could provide comprehensive extension services. For example, in India a system of dairy cooperatives, which reaches from village-level primary societies to a national federation, provides some extension services (Punjabi, 2009).

While commercial breeders may afford the opportunities to do this with private capital, investing in national research and breeding programmes – like South Africa's Kaonafatso ya Dikgomo (KyD) programme – will ensure that new genetic materials are also available to small and emerging producers (van Marle-Köster and Visser, 2018). The programme, which was initiated by the Agricultural Research Council in 2007, fosters the adoption of breeding and improvement approaches, combined with better information recording among emerging and small livestock producers. Farmers are trained on breeding and animal health as well as recording information such as birth, weaning weight, and weights at 12 and 18 months. This information is then transferred to the national database on animal improvement, Integrated Registration and Genetic Information System, for analysis to enable farmers to make selection and culling decisions. The programme provides additional services through a mobile laboratory such as bull fertility tests, synchronization of cows, artificial insemination, embryo transfer and pregnancy tests (ARC-Animal Production Institute, n.d.). By 2014, over 8,000 producers had benefitted from the programme (ARC, 2014). It has resulted in higher calving rates and growth in herd sizes, and, by promoting the use of more lucrative market channels, offtake rates increased by 16 percent (Ngarava et al., 2019, 2018).

It is essential that breeding programmes are reflective of the different objectives of the actors in the value chain (van Marle-Köster and Visser, 2018). Setting breeding objectives at the outset is critical to ensure long-term success and sustainability. Criteria such as farmers' motivation, livelihoods, genetic value of outcome population, prospective markets, logistic feasibility as well as political will and support will ensure that breeding programmes deliver the desired outcomes in the long-term. While farmer workshops can help to identify the goals of producers entering breeding programmes, incentives such as training opportunities, promotion of products, access to markets and feedback of processed data strengthen the quality of participation (Mueller et al., 2015).

Breeding programmes must also consider the socio-economic impacts of changing the type of breeds raised at household level and beyond. This is pertinent where breeding leads to a shift from low-input, low-output to high-input, high-output herds. Given the wide range of roles that livestock fulfil – especially within agro-pastoral and pastoral communities – changes in breeds can have an impact on the use and control of resources within households, complicate access to markets, and can result in the loss of some of the multi-functionality of livestock, including a reduction in the assets available for use as risk management (Marshall, 2014). Therefore implementing and expanding breeding programmes must be embedded within the context of addressing other socio-economic factors such as access to land and capital.

Feed

While progress is being made across the African continent in improving feed for livestock, the availability of reasonably priced, high-quality and nutritious feed remains a major challenge to raising livestock productivity.

There are several types and sources of feed and fodder, such as tree fodder, shrubs, grasses, and crop residues, as well as commercial supplies such as agro-industrial by-products, cultivated fodders, oilseed cakes, and permanent crops. Crop residue blocs can be further modified by adding water, salt, and urea to improve their digestibility and nutrient value (Enahoro et al., 2019). Despite the diversity, much of Africa's livestock production is highly reliant on rainfed fodder (pasture). As a result, producers experience seasonal fluctuations in the volume and quality of available fodder, making them vulnerable to a changing climate and affecting the health of their animals. For instance, in areas where the seasons are distinctly wet or dry, the quality of pasture declines significantly during dry seasons, as does the productivity of livestock. Conversely, in the absence of alternatives or incentives, grazing land is converted into arable land, even where marginal, and the remaining pastures are often of poor quality. Combined with growing livestock populations, reduced seasonal mobility and insecure land tenure – all contributing to overgrazing – Africa's grasslands are facing severe degradation. Estimates show that 18.5 percent of SSA's grazing area is degraded (Kwon et al., 2016) (see also section 4.1.5). The restoration of the quality of pastures and increased sequestration of soil organic carbon can reduce the negative impact of livestock on grassland (FAO, 2018c).

Currently, the high cost of imported feed prices African livestock products out of international markets. Imported commercial concentrate feeds are rarely tailored to local needs and contribute to the high cost of production – sometimes as high as 65 percent of production costs (FAO and IGAD, 2019). Although the production of compound feed produced in Africa grew by 156 percent between 2013 and 2017 to 39.14 million tonnes (Cadiou, 2018), this represents just 1 percent of global animal feed output (Iwuoha, 2013). In Kenya, Uganda and Tanzania, the combined shortfall of locally produced animal feed in 2014 stood at 5.3 million tonnes (Kilimo Trust, 2017). Commercializing the production of the feed industry will underpin a growing livestock sector and to reduce the cost burden to livestock producers. It is also a means to engage young entrepreneurs in the livestock sector and to capture a larger market share from global trade in livestock feeds, valued at over US$ 400 billion per year (Iwuoha, 2013).

For Africa's livestock sector to thrive, feed must be available around the year, produced by effective feed and forage value chains. The choice of feed is contextual, contingent on biophysical, socioeconomic, and policy environments. For instance, in dry regions, transhumance or supplementary feeding with concentrates of phosphate, calcium, and trace minerals can help to overcome seasonal weight loss. Introduction of Faidherbia albida – a leguminous tree – into mixed systems can provide nutrition during extended dry periods. The tree is unique in that its leaves grow during the dry season and shed during wet seasons, providing critical fodder during periods of drought (World Agroforestry Centre, n.d.).

The last few decades have also seen vigorous promotion of fodder trees and shrubs—both indigenous and exotic, such as Calliandra calothyrsus, Sesbania sesban, Gliricidia sepium, and Leucaena leucocephala (Franzel and Wambugu, 2007). Not only do these provide highly nutritious leaves for livestock consumption, they also grow fast and fix nitrogen in the soil, thus improving fertility of the land on which they are grown. Within two years of planting Calliandra calothyrsus in East Africa, its use as a substitute for concentrates (animal feeds rich in energy and protein but low in fibre) to feed dairy cows led to an increase in milk production and corresponding income of US$ 62 to US$ 122 per year in 2003 (Franzel and Wambugu, 2007). Leaves from Calliandra calothyrsus can also replace soybean in the diets of goats raised for meat (Ebong et al., 1999).

Fostering a viable commercial feed and forage subsidiary value chain – involving forage seed producers, marketers and distributors, millers, and transporters – is critical to supply both wet and dry season feed, increase productivity, and thus reduce overall production costs. On the one hand, dedicating land to the production of fodder requires secure land tenure, time, financial and labour investment and a reliable supply of water – all of which come at a great opportunity cost to small producers. On the other hand, smallholder farmers producing forage can also benefit from an additional source of income. Providing a market for feed and forage producers to sell directly to

livestock producers creates a sustainable value chain partnership.

The International Center for Tropical Agriculture (CIAT) has developed new varieties of Brachiara and Panicum, two local grass species, to provide higher land and animal productivity. The grasses are high-yielding, adaptable to poor soils, drought and flood resistant, and more palatable and nutritious (Odhiambo, 2016). Preliminary data from Brachiara test plots in Kenya showed an increase in milk yields by 15 to 40 percent and an average of 36 percent in Rwanda. In addition, cattle fed on Brachiara instead of elephant grass in Rwanda benefited from a daily increase in average body weight of 205 grams over a 12-week period (Ghimire et al., 2015; Gonzáles et al., 2016).

While these grasses have been extremely successful in South America, particularly in Brazil, they have yet to achieve meaningful scale in Africa. To exploit their potential to address the challenge of livestock feed scarcity in Africa, it is necessary to invest in **developing a sustainable seed production system for affordable seeds**; **information and awareness campaigns** in partnership with extension and advisory services; subsidizing the initial cost of production including for fertilizer, watering infrastructure and labour or mechanization for harvesting; and addressing uncertainties of land tenure (Tesfai et al., 2019).

Animal health

Disease and poor health are another main reason for low productivity in Africa's livestock sector. Lack of access to good quality veterinary care, including limited diagnostic infrastructure, and poor extension services, particularly in rural areas, underlie the high prevalence of disease (Enahoro et al., 2019). Although the disease burden has been falling in SSA, it still remains higher than in Asia and the burden of zoonoses is twice as high (FAO, 2019b). Neglected zoonotic diseases are particularly persistent in poor, rural and semi-urban slums, particularly in lower-income countries (King, 2011). Progress made on disease eradication is also likely to be undermined by climate change, which will impact vegetation and rainfall patterns and affect the dynamics of disease type, incidence, spread, and interactions in African livestock (Enahoro et al., 2019). Livestock trade – which increasingly also takes place in peri-urban and urban areas – and mobility further speed up the spread of animal and zoonotic diseases (Apolloni et al., 2018).

Diseases such as animal trypanosomiasis, bovine pneumonia, and East Coast fever kill thousands of livestock in Africa each year and reduce overall productivity among the surviving herds (Enahoro et al., 2019). Costs of diseases are further aggravated by the cost of treatments, loss of fertility, newborn diseases, and mortality and loss of weight among the survivors. Furthermore, zoonotic diseases, which are transmitted from animals to humans, reduce human health and capacity, together inflicting a serious burden on economic growth. For instance, the cost of bovine tuberculosis in animals and humans to Nigeria in 2016 totalled US$ 9.6 billion, equal to approximately 0.9 percent of national GDP (FAO, 2018d).

In the context of limited resources, interventions must be prioritized and targeted to areas where the potential benefits are the greatest. For instance, although managing trypanosomiasis in Eastern Africa can be extremely advantageous, the benefits vary greatly by geography. In economic terms, the region can accrue benefits of as much as US$ 2.5 billion over 20 years, ranging from US$ 500 per km2 in some areas, to as much as US$ 10,000 in others. Ethiopia's high animal density and use of animal traction, places it at the forefront of potential benefits accrued from trypanosomiasis interventions (Shaw et al., 2014).

Nevertheless, addressing the challenges of animal health in Africa requires comprehensive and integrated packages of interventions, including data collection and transmission, reform of the veterinarian value chain from diagnostics to supply of veterinary products, veterinary drugs use and control and the use of traditional herbs and medicines. Strengthening surveillance, early warning systems, and epidemiology work particularly for new and emerging diseases is of critical importance. Digital tools can be particularly helpful to enhance timeliness and increase geographical coverage for effective implementation. Successful animal health programmes also demand well-coordinated institutions and policy frameworks.

Ethiopia is one of the continental front runners in developing a robust institutional framework for animal health. Since the 1960s, the country has gradually invested in building its disease surveillance, investigation, and diagnostic capacities, as well as vaccine production and dissemination – both by state and private players. The National Veterinary Institute

achieved internationally recognized certification for the production and distribution of vaccines in 2005 (National Veterinary Institute, n.d.). By 2020, NVI was producing approximately 200 million doses for 20 different vaccines for domestic use and export to up to 26 African countries (National Veterinary Institute, n.d.). South Africa, Uganda and Senegal are also important regional players with strong institutional frameworks for animal health (Malabo Montpellier Panel, 2020).

Several African laboratories, including in Ethiopia, Kenya, Morocco, Senegal and South Africa, are working to produce vaccines for zoonoses and other livestock diseases. However, some are working with outdated technology and under inadequate standards. Technology such as diagnostic tools and vaccinations must be appropriate for the specific contexts and easy to use (Enahoro et al., 2019). Poor vaccination storage and delivery systems lead to further limitations in access and availability for livestock keepers (AU, 2013). Where multiple doses are required, livestock producers often cannot afford or do not have the appropriate storage facilities for additional doses. Moreover, where vaccinations may be available, they are not always administered correctly or consistently, risking the overall success of vaccination programmes. It is essential to develop and disseminate single-dose vaccines that remain stable at higher temperatures (thermostability) for longer. This ensures that they can be transported to, and stored safely in remote communities where access to refrigeration may be limited (Acosta et al., 2019). The Global Alliance for Livestock Veterinary Medicines (GALVmed) deploys the latest scientific knowledge to produce and market vaccines, medicines and diagnostics for livestock producers. Once mainstreamed, private vaccine manufacturers are introduced to scale production and accessibility. Since 2008, GALVmed has raised over US$ 100 million from the Bill & Melinda Gates Foundation and the UK Government's Department for International Development (DfID) to seek solutions for 17 neglected livestock diseases (GALVmed, n.d.).

Various public-private partnerships have also been formed across the continent, drawing upon the expertise and strengths of each sector to deliver effective vaccination campaigns (OIE, 2019). Public-private partnerships can streamline vaccination supply chains by driving innovation, and supporting their registration, commercialization, and distribution—eventually leading to reduced costs and greater availability (Acosta et al., 2019; IDRC, 2020). Fostering local SMEs to produce vaccines and to participate in the delivery system extends the coverage and diversity of services provided by state and other large players.

Once produced, it is important to disseminate vaccinations in a timely and cost-effective manner. In Mali, Tunisia and Senegal, incentives such as tax exemptions and subsidies on vaccinations have been introduced for private veterinary professionals to provide services in remote areas and to preserve the competitiveness of livestock products (République de Mali, 2013). In Ethiopia, the deployment of CAHWs has been a successful approach. As the first point of contact for livestock keepers, CAHWs provide more effective disease surveillance and data collection—an indispensable service for timely detection of any outbreak and supervision of implementation of control measures (OECD, 2012). In addition, even with low levels of formal education, CAHWs can be trained to administer vaccinations. Partnering networks of CAHWs with private suppliers of veterinarian products ensures that vaccinations reach remote areas in a cost-effective manner.

To protect national herds effectively, vaccination programmes must be extended to nomadic pastoralists too. For these communities, water access points, markets and traders provide key connections for delivering livestock disease control interventions (Atherstone et al., 2019; FAO and IGAD, 2019). In Chad, a successful joint human and livestock vaccination campaign optimized visits by professionals from both disciplines to nomadic communities, thereby sharing costs and infrastructure between them. The campaign was implemented by the Chadian Ministries of Health and of Livestock Production, in partnership with local private health and veterinary providers. It successfully vaccinated 149,255 livestock against anthrax, pasteurellosis, blackleg, and contagious bovine pleuropneumonia, 4,653 children against diphtheria, whooping cough (pertussis), tetanus, and polio, and 7,703 women against tetanus (Schelling et al., 2007).

Finally, new digital solutions that combine geographic information systems (GIS), spatial analysis, and performance monitoring systems can further transform the management of livestock health. Mobile phones can facilitate the collection of health data in a timely manner and broadcast advice and information at low cost across countries (Enahoro et al., 2019).

Preventing the occurrence and spread of diseases is vital to reduce the costs to human health and losses incurred by livestock keepers and to raise animal pro-

ductivity. However, some losses may be unavoidable. In these cases, compensation and insurance schemes can be considered, as have been applied in Australia, Canada, Germany, the Netherlands, and Viet Nam. For animals that survive, ensuring that the markets are accessible and provide a fair price for the produce is key to supporting livestock-based livelihoods to recover their productive capacity post-disaster.

Investment and policy priorities

Africa is a livestock-rich continent. However, domestic production in many African countries does not currently meet the demand for livestock products, resulting in substantial net imports of animal products. Investments in breeding and genetics, feed availability and quality, and health will contribute towards the reduction of Africa's import bill and benefit from the potential of inclusive growth that the sector can offer. In particular, commercializing the feed industry by investing in feed and forage value chains will underpin a growing livestock sector and reduce the cost burden to livestock producers. In addition, investments in national and private research, breeding and genetics capacities combined with upgrading extension service provision will ensure that new technologies and solutions are available to small and emerging producers. Finally, reforming the veterinary sector by scaling up and out public-private partnerships and the role of the private sector will provide critical support to vaccination programmes, particularly in remote areas.

Key areas for policy and investments include:

- Greater financial and technical support to national and commercial livestock **research programmes, investments in data collection, data collection systems, and analytical capacities** across the continent to ensure the evidence-based design of policies and regulations.
- **Strengthen animal science, breeding, and genetics research capacities across the continent** to equip African institutions and researchers with the practical skills needed to understand livestock population genomics and improve breeding techniques for a greater productivity of African livestock.
- **Finance common goods** such as animal health, animal improvement, and research to create a strong foundation upon which both market-oriented and subsistence livestock sectors can prosper. **Financial services** must be (re-)designed to cater for the unique circumstances of livestock producers, such as the need for different loan sizes and duration of borrowing, alternative forms of collateral, seasonality of production, and other inherent risks.
- **Reasonably priced, high quality, nutritious feed** is required to increase livestock productivity. Commercializing the production of the feed industry will underpin a growing livestock sector and reduce the cost burden to livestock producers. Fostering a viable commercial feed and forage subsidiary value chain — involving forage seed producers, marketers and distributors, millers, and transporters — is critical to supply both wet and dry season feed, increase productivity, and thus reduce overall production costs.
- **Transfer skills and knowledge to livestock producers** through appropriate reform and retraining of extension service providers – including community based animal health workers (CAHWs). In addition to enhancing capacities among livestock producers themselves, further training of professional extension agents and CAHWs to deliver much-needed advice and guidance.

4.3 Capture fisheries and aquaculture

The fisheries sector plays an essential social, nutritional, economic, and environmental role for the African continent, significantly contributing to food security and poverty reduction, especially for coastal populations. Indeed, fish is the most important source of animal protein in most African countries (Bjørndal et al., 2016) particularly in riparian communities along major rivers, lakes and the ocean. On average per capita fish consumption is 9.9 kg in Africa[16] while the world average per capita fish consumption is estimated to be

16 Actual consumption levels are likely to be higher when taking into account the under-recorded contribution of subsistence fisheries, some small-scale fisheries and informal cross-border trade (FAO, 2020c).

about 20.3 kg, however this hides intra-regional and intra-country differences (in 2017) (FAO, 2020c). The top eight fish consuming countries in Africa are spread across the per capita consumption range. Ghana and Senegal consume more than 20 kg per capita a year; Cameroon, Côte d'Ivoire, and Uganda are in the 10 to 13 kg range; and finally, three populous but relatively low-level consumers are the Democratic Republic of the Congo, Nigeria, and Tanzania, all in the low per capita consumption range of 5 to 8 kg. By global standards these countries have a relatively low per capita fish consumption, however low consumption of other animal proteins means that fish makes up over 30 percent of the total. Even these small amounts of fish provide essential vitamins, minerals, and fats in otherwise nutrient-poor diets.

Within countries, low to middle income communities, and especially children and lactating women, depend on fish for proteins and micronutrients. However, fish and seafood do not only provide protein, but are also an important source of long-chain omega-3 fatty acids, which are important for healthy brain development in children. Experts agree that fish consumption, particularly oily fish, is essential for an optimal development of a child's brain and neural system. It is therefore particularly important to include fish in the diets of pregnant and breastfeeding women and in the diets of children, particularly during the first two years of life (the 1,000 day window). Strong evidence also underlines how consumption of oily fish lowers the risk of coronary heart disease (Bodiguel et al., 2016).

Africa has a high prevalence of malnutrition and anaemia, with young children and reproduction women vulnerable to deficiency in proteins, Vitamin A, iodine and iron, which are present in fish and other aquatic products (Chan et al., 2019; Petry et al., 2019). Central and Eastern Africa have the highest prevalence of undernourishment and low overall fish and animal meat intake, with fish accounting for 26 and 15 percent of animal protein respectively (Chan et al., 2019). However, most of the major lakes and river are located in these regions, hence the "Great lake region", which can be harnessed by communities for freshwater fish and aquaculture production. Fish plays the most important role as a source of protein in Western African where about a third of animal protein come from fish (Chan et al., 2019) and in some countries, such as the Gambia, Ghana and Sierra Leone, the share is 50 percent or more (FAO, 2020c).

In Africa, absolute levels of fish consumption remain low (9.9 kg per capita in 2015), compared with others regions. Fish consumption in Africa ranges from about 14 kg per capita in Western Africa to a mere 5 kg per capita in Eastern Africa (FAO, 2018e). Major growth was observed in North Africa (from 2.8 to 13.9 kg between 1961 and 2015), while per capita fish consumption has remained static or decreased in many other countries in Sub-Saharan Africa (FAO, 2018e). The low fish consumption is a result of a number of interconnected factors, including population growth that exceeds growth in food fish supply; limitations in the expansion of fish production because of pressure on capture fisheries resources and a poorly developed aquaculture sector; low income levels; inadequate storage and processing infrastructure; and a lack of marketing and distribution channels that are necessary to commercialize fish products beyond the localities where they are captured or farmed.

Fisheries and aquaculture currently contribute about US$ 24 billion (or 1.4 percent) of African GDP, the largest share of which is generated by the capture fisheries sector (US$ 21 billion) (AU-IBAR, 2019). Africa's fishing sector provides employment to approximately 13 million people with 58 percent in the fishing and 42 percent in the processing sector (AU, 2018). While men mainly occupy the fishing jobs, women carry out 59 percent of the processing work. According to the World Bank, employment multiplier effects are remarkable in the sector: every fisher job generates 1.04 additional onshore-jobs in Mauritania, while this ratio reaches 3.15 in Guinea, illustrating the potential for further job creation through value chain development. This situation is almost the same for all coastal countries in the continent (World Bank, 2015).

Though increasing, the demand for fish in Africa is limited by its supply sourced from overexploited natural resources and low productivity aquaculture. Growth in population and urbanization are the major drivers of the increase in fish demand (Thurstan and Roberts, 2014). Urbanization has generated a middle-income class with new consumption patterns: preferring healthy diets derived from aquatic products (fish). Intra-continental trade in fish in Africa services mainly landlocked countries, which tend to import from their neighbours, the fish largely produced by artisans with a low level of quality often characterised by a lack of proper conservation. The increasing demand for fish has also resulted in the import of seafood

products, much of it from Asia. This low value imported fish mainly targets low-income earners (Tran et al., 2019). However, such imports are threatening efforts to promote small-scale fish production. As a result, fishers are adopting low-cost but efficient technologies that generate competitive products (Tran et al., 2019). Nevertheless, Africa is expected to remain a net importer of fish in the coming decades, with half of its consumption predicted to be imported by 2050 (Chan et al., 2019).

Production of capture fisheries is expected to remain almost constant up until 2050, whereas aquaculture production will remain well below that of capture fisheries (Chan et al., 2019). Reflecting the different growth trajectories, aquaculture's share of total African fisheries production is likely to increase gradually from 17 percent in 2015 to 24 percent in 2050, with a 2 percent average annual growth rate between 2015 and 2030. With slow growth of capture fisheries and relatively slow growth of aquaculture, and even assuming per capita fish consumption gradually declines from 10 kg in 2015 to 8.5 kg in 2030, then to 7.7 kg in 2050, more imported fish will be needed to sustain domestic consumption (Chan et al., 2019).[17]

4.3.1 Ocean and inland fisheries

Over half of Africa's countries have a coastline and correspondingly, territorial waters and an exclusive economic zone (EEZ) extending 200 nautical miles out to sea. Most of Africa's countries have extensive inland waters, including rivers such as the Nile, Congo, Zambezi, Niger, lakes such as the Victoria, Tanganyika, Nyassa, Volta, Kivu, Kainji, and streams and ponds, swamps, mangroves, salt marshes and coastal lagoons, as well as reservoirs. These marine and inland waters contain a very high diversity of aquatic species. Marine and inland fisheries provide both direct and indirect employment and income to several million people in Africa. A recent estimate of employment and income for seven major river basins found that in Western and Central Africa alone, fresh water fisheries provide livelihoods to more than 227,000 full-time fishers and yield an annual catch of about 570,000 tonnes with a first-sale value of US$ 295 million[18].

As mentioned above, fish production in Africa is essentially led by the marine and inland capture fisheries. The total production volume was estimated at roughly 12 million tonnes in 2018 and is expected to remain fairly constant up until 2063 caused by inter alia, overfishing, overcapacity, and poor governance (AU-IBAR, 2019). Of the US$ 21 billion total gross value-added of the capture fisheries, marine artisanal fisheries contribute the most at US$ 8.1 billion, followed by marine industrial fisheries and inland fisheries at US$ 6.8 billion and 6.3 billion respectively as of 2018 (AU-IBAR, 2019). It is important to note that captures from marine fisheries almost stagnated since the year 2000 while inland captures increased moderately, showing the potential of the subsector in Africa if proper development strategies are adopted.

Constraints affecting supply-side capacities in ocean and freshwater fisheries

Several global level challenges are of concern. The effects of climate change are causing rising sea temperatures, non-stability of the weather conditions for fishers, migration of fish to cooler waters away from the equator, and reduction of fish size and quality. The global pandemic of COVID-19 has deepened the challenges that threaten the African fishing sector. Sanitary measures taken by governments across the globe to stop the rapid spread of the disease have affected the fishing sector, e.g. countries' lockdowns have limited the international transportation and trade of many commodities, including fish products.

At the national and regional level, activities related to sectors like agriculture, hydropower development, and navigation impact fisheries.[19] The depletion of most target species due to overfishing has become a serious constraint for fishers[20]: According to FAO (2020c), most fish species are fully or overexploited

17 Under the Business-as-usual scenario, and despite a projected production of 11.5 million tonnes by 2030 and 12.1 million tonnes by 2050, Africa will have a trade deficit of 5.0 million tonnes by 2030 and 10.6 million tonnes by 2050. The expected rapid population growth weighs heavily on the future of per capita consumption. Simply to reduce its dependence on fish import, even with declining per capita fish consumption, Africa will need an additional 10.6 million tonnes from aquaculture by 2050.

18 6th meeting of ACP Ministers in charge of Fisheries and Aquaculture APIA, SAMOA, 2019: Inland fisheries for economic transformation.

19 6th meeting of ACP Ministers in charge of Fisheries and Aquaculture APIA, SAMOA, 2019: Inland fisheries for economic transformation.

20 These constraints are well analysed with detailed measures to be taken by the African Union, the RECs and RFBs.

leading to the scarcity of several high value species that have become rare in African local markets.

The most significant constraints that affect the fisheries supply-side in Africa relate to the artisanal subsector with poor or low quality fishing materials. The materials used for fisheries in Africa remain poor compared to the development and availability of new technologies. Indeed, the type of fishing gears used by artisans do not favour an optimization of production[21]. With most fishers classified among the most vulnerable population, the initial investment for fishing activities remains a serious issue. The lack of a strong financial institution to support fishers plays a key role in this situation (Horemans and Kébé, 2006). Poor or inappropriate governance has plagued the fisheries sector: the late adoption of sustainable fisheries management plans has put the sector in a situation whereby the revival of marine and inland fisheries capacities is a priority.

In general, access rights are framed for industrial fishing; by annual plans defining the potential and the corresponding fishing effort allowed. Countries have licensing systems for national industrial fisheries and fishing agreements with regions and countries allowing them to access their EEZs. Regarding artisanal fisheries, access is open, often free, and unregulated. Illegal, unreported and unregulated fishing remains a scourge for Africa's waters (Agnew et al., 2009).

Innovations in capture fisheries

Fishing gear and fiberglass canoes

Technological innovation is key to deal with most of the constraints related to the fisheries supply-side in Africa. For instance, the improvement of fishing gear is highly necessary to take full benefit from fish resources at a sustainable level. Possible technological innovations should be mostly oriented to the artisanal fisheries, characterized by its outdated tools.

The renewal of pirogue fleets with the introduction of fiberglass canoes in all countries is both a strategy of adaptation and mitigation to climate change. Fiberglass canoes, which are inexpensive and easy to repair, can increase the volume of output and time on the water (reduced fuel consumption). Therefore, the use of such improved vessels can lead to an increase in fishing capacity. In addition, the promotion of fiberglass canoes contributes to the protection of forests, especially in Africa where the production of dugout canoes and other such traditional vessels leads to the felling of trees.

Clean technologies to reduce fossil fuel consumption

The adoption of clean technologies to reduce fuel consumption in the fishing sector is becoming more and more crucial for the effectiveness of sustainable fisheries management plans in Africa. Because Africa contributes the smallest amount to global greenhouse gas emissions, emphasis is often placed on adaptation rather than mitigation strategies. However, it is important to highlight Africa's significant capacity for carbon sequestration thanks to its vast forests, mangroves, seagrass beds and mudflats, which are real carbon sinks (Laffoley and Grimsditch, 2009). The rise of oil exploration in most of the African coastal countries accompanied by the effects of climate change is causing a serious dilemma to the implementation of an effective and practical fisheries management, especially considering the high economic returns expected from other marine activities too (navigation, hydropower development etc.).

The amount of fuel used to catch and land a tonne of fish varies greatly with the type of fishing gear and methods used as well as the fish resource, including the distance to the fishing ground (Muir, 2015). In this regard, the African Union advocates for the promotion of a scientific-based approach in collaboration with university and research institutes specialized in environmental and water resources management. Moreover, except for non-motorized vessels, fuel represents a significant input cost in most fishing operations, across all scales of output.

Overall, the largest share of energy use in the fisheries sector is required for processing, transport and storage. One of the key implications of inefficient processing technologies and storage facilities – bad handling and non-hygienic treatment – is the high level of post-harvest losses (AU-IBAR, 2019).

Post-harvest and value addition technologies

Fish products are highly perishable and thus require sound infrastructure for their conservation. Post-harvest losses are one of the critical challenges that face both inland and marine fisheries in Africa. The COVID-19 outbreak has exposed the weakness of most countries in finding alternative markets for export commodities. The development of a value chain with an integrated cold chain for conservation is a must for Africa's fisheries. The African Union's Blue Economy Strategy proposes investment in and acceleration of the development of

21 This idea is supported by the AU Blue Economy document which highlights investment for the improvement of fishing technologies.

fisheries and aqua fish processing and storage capacities; support to research on processing technologies and value addition; inclusion of post-harvest actors in decision-making processes; improvement of cold chain infrastructure through solar generated ice plants; improvement of transport infrastructure (roads, railway and air); and capacity building to actors involved in value addition (AU-IBAR, 2019).

Most African countries still export raw, unprocessed products, meaning a loss in export revenues. Investments in value-added products would enable optimum gains from aquatic products and create needed employment and earnings from foreign currency. Therefore, there is a need to transfer appropriate technology to member states to meet processing, packaging, and marketing requirements (AU-IBAR, 2019).

Marketing

To increase the economic impact of fishing activities to fishers and processors, the marketing style must be more adaptive and advanced to revive or promote the image of African fish products. Several regional fisheries organizations and the African Union recommend the development of group action through regional labelling. In most African countries, the artisanal sector is trying to adapt to the development of the international fish trade where high quality and food safety is very important. One strategy is the regional labelling of fish products and effective application of sanitary and phytosanitary standards.

Investment and policy priorities

More effective planning for fisheries governance, including investment in improved valuation and assessment methods, and development of approaches to manage waters across sectors and scales. Develop, promote, and support standardized methods for the assessment of fisheries harvest including data collection, database management, and data sharing. Develop novel approaches to collect fisheries data, e.g., remote sensing of habitat types and population densities linked to fish production models through collaboration and adoption of new technology development (AU-IBAR, 2019).

Mobilize resources for research and improve capacity of fisheries researchers to undertake research to support marine fisheries management, and build an integrated research programme in fisheries, biology, ecology, economics, socio-economics and humanities for the rational management of inland fisheries.

Integrate local knowledge into the management of fisheries and build a process of integrating local knowledge into fisheries management policies. A more participative approach should engage other users of the sea and freshwater resources to participate in national and international fora that address fish resource issues, conflicts, and synergies.

Focus on the use of proper technologies and fishing gear in a context of transparent and equitable conditions of access, giving priority to the supply of African markets.

Invest to develop fisheries processing and storage capacities to reduce post-harvest losses by improving cold chain infrastructure using renewable energy such as solar generated ice plants.

4.3.2 Aquaculture

Aquaculture provides an alternative aquatic food source to supplement stagnating and over-exploited marine and inland fisheries (FAO, 2020c). Africa produced 2,196,000 tonnes of live aquaculture products (finfish, shellfish and aquatic plants) in 2018, supplementing household food and nutrition security, and providing income and employment (FAO, 2020c, 2017a; Halwart, 2020; Jamu and Ayinla, 2003). Inland aquaculture (freshwater based) is most preferred in Africa, practised in earthen ponds, raceway tanks, above ground tanks and cages; raising finfish especially tilapia, catfish and carps (FAO, 2020c). The two other forms of aquaculture include coastal aquaculture – practised along the coast – that raises crustaceans (shrimp), finfish, molluscs and seaweeds, and mariculture – practised in the open ocean or using seawater – for raising aquatic products in marine water (FAO, 2020c).

Despite its low production relative to capture fisheries, aquaculture in Africa accounts for 17.9 percent of total fish production and is valued at US$ 2.77 billion (AU-IBAR, 2019; FAO, 2020c). Production in Africa increased by 19 percent from 2015 to 2018, mainly due to enabling policies and technological advances

(FAO, 2020c). Egypt is the leading African aquaculture producer, farmed in the River Nile, accounting for 71.1 percent of regional production (FAO, 2020c). African countries are investing in aquaculture to reduce their reliance on fish imports as seen in Ghana, Nigeria, Uganda and Zambia (Adeleke et al., 2020; Kaminski et al., 2018; Ragasa et al., 2018a). Their governments embrace the "Blue Revolution" or Blue Economy Strategy that promotes a private sector led sustainable aquaculture sector while targeting profitable farmed tilapia and catfish industries. These countries are focusing on advancing seed and feed technology using locally available materials to increase aquaculture productivity.

Production systems

Aquaculture in Africa is characterized by three major production (management) systems: extensive, semi-intensive and large-scale (Brummett et al., 2008). It is mainly practised in three culture systems: ponds (>80 percent), cages (>10 percent) and tanks or raceways (<5 percent) for seed and food production (Jamu and Ayinla, 2003). Seed producers use a combination of culture systems depending on the scale of production and type of species raised. In rural areas, integrated aquaculture systems are usually practiced under the mixed farm model for the purpose of enhancing household food security and nutrition. Smallholder farmers comprise over 70-80 percent of the producers in Sub-Saharan (Lowder et al., 2016), and are mostly vulnerable to food and nutrition insecurity, poverty and the effects of environmental degradation. Women and youth contribute about 80 percent of the labour but lack access or an equal share to the available limited resources (finance, land and water), and hence can be considered vulnerable and marginalised (Nagoli et al., 2009; Njarui et al., 2012).

Extensive systems are commonly practised by small-scale subsistence farmers resident in rural areas. Farmers access seed from the wild environment and raise it in earthen ponds (100-200m2) using organic manure (10 kg per 100 m2), with yields of about 500 kg per hectare for home consumption. These farmers are challenged with low productivity, high post-harvest losses, poor market strategies, limited access to knowledge and skills, poverty, often limited access to water resources, and finally, by climate change to fully harness the opportunities in aquaculture (Aanyu et al., 2020; Brummett et al., 2008; Kabirizi et al., 2012; Stutzman et al., 2017).

Semi-intensive systems are used by commercial aquaculture producers using feeds in land-based and water-based culture systems (ponds, tanks and cages) to produce aquatic products for food and income. Supplementary feeding improves yields which range from five to 40 tonnes per hectare in ponds with water exchange of 3600 litres/kg and biofloc technology (Brummett et al., 2008). Most hatcheries have adopted this system despite experiencing low survivals, which in catfish seed production range from 10 to 40 percent (Walakira et al., 2014; Wamala et al., 2018). Furthermore, some farmers obtain seed from natural water. For example, farmers involved in the mariculture of seabream, seabass, mullets and eels access seed from the Mediterranean Sea and are reported to contribute to the decline of wild stocks (Cai et al., 2017; GAFRD, 2014).

Large-scale intensive systems are characterised by huge investments to produce more than 1,000 tonnes of aquatic products per year per farm. Cage farming is a highly efficient technology adopted in Africa to meet the increasing demand for fish in the region. Land-locked countries, for example, Uganda, Zambia and Zimbabwe have increased aquaculture production through cage farming (Reilly, 2018). Farmers, however, are challenged, with a) access to good quality seed and feed, b) availability of production inputs for example, equipment, c) lack of local expertise to operate intensive systems, and d) absence or unclear policies or frameworks for the aquaculture industry in Africa (Halwart and Moehl, 2004).

Key constraints that hinder production

Access to technology or innovations that improve the efficiency and profitability of aquaculture production, access to water and financial resources, and enabling policies are the key drivers of aquaculture growth in Africa (Brummett et al., 2008; Chan et al., 2019; Jamu and Ayinla, 2003). Yet although Africa has sufficient resources to improve and increase aquaculture production using sustainable technologies or innovations, aquaculture will only improve if the seed and feed problem is addressed to meet the future demands of its growing population, which is expected to double by 2050 (FAO, 2020c; Jamu and Ayinla, 2003; Lind et al., 2012; Mbengue, 2018).

The majority of small-scale producers in Africa access poor quality **seed** from natural waters or uncertified hatcheries and produce low yields in

Table 4: Prediction of fish production, seed and feed requirement

	YEAR							
	2015	2020	2025	2030	2035	2040	2045	2050
Aquaculture (Million tonnes)	1.82	2.11	2.31	2.44	2.57	2.68	2.77	2.86
Per capita consumption (kg/person/year)	10	9.5	8.9	8.5	8.0	7.7	7.7	7.7
Estimated seed required, stocked at 2 g (billion)	910	1055	1155	1220	1285	1340	1385	1430
Feed required at FCR 1.3 (million tonnes)	2.37	2.74	3.00	3.17	3.34	3.48	3.60	3.72

Source: Chan et al. (2019)

ponds, of less than 0.6 tonnes per hectare (Jamu and Ayinla, 2003). Through support from FAO, ICLARM-BMZ/GIZ and USAID, these farmers doubled their efficiency and profitability, increasing production to 2-35 tonnes per hectare when using good quality seed and feed, and water exchange (Brummett and Noble, 1995; Isyagi et al., 2009). However, demand for good quality seed is expected to increase by 26 percent in 2050 (Table 4) to meet the availing per capita fish consumption (Chan et al., 2019; Mbengue, 2018). Most production will likely come from large-scale farmers who also demand good quality seed that a) grows faster with high survival rates and good yield, b) is disease-free or resistant to pathogens, c) has good economic returns, d) is easy to grow in any culture system, and e) is resilient to climate extremities.

Africa has a rich diversity of **native aquatic resources**, which research efforts aim to use to improve food security and nutrition (Lind et al., 2012). However, the key challenge facing governments is to develop policies that embrace aquaculture to help reduce poverty and food insecurity, and conserve aquatic biodiversity. Utilisation of aquatic genetic resources for long-term aquaculture development should adopt strategies for zoning, environmental risk analysis and molecular characterization techniques that maintain natural biodiversity, ecosystem services and a genetic material source for future breeding programmes (Lind et al., 2012). It is also important for governments to prioritise breeding improvement programmes that strengthen local capacity expertise for sustainability purposes.

Accordingly, genetic improvement programmes for Africa should follow an approach given by Lind et al., (2012): a) minimize the spread of escapees by creating species-specific aquaculture 'zones', and by demonstrating productivity gains over local strains, b) evaluate the production systems required to raise these genetically improved aquaculture seed, c) increase the benefits of improved genetic resources but ensure that these technologies are affordable to producers in Africa, and d) safeguard and ensure royalties for communities who have maintained these genetic resources for generations. To reduce any threats from aquaculture species the programme should have a transparent and participatory environmental audit and a mitigation and management strategy.

Disease outbreaks are increasingly as the aquaculture industry expands and intensifies. For example, the existence of the novel Tilapia Lake Virus and Infectious Spleen and Kidney Necrosis Virus reported in Ghana, Egypt and Uganda causes mortalities in aquaculture production systems (Al-Hussinee et al., 2019; Hounmanou et al., 2018; Ramirez et al., 2018). Comprehensive research is therefore required to understand the epidemiology of diseases or pathogens affecting aquaculture systems. This will inform or guide policy to establish effective biosecurity measures at the continental, regional, national and farm levels. Capacity to diagnose and control diseases needs to be strengthened through effective networks.

Therefore, scientifically sustained support for effective utilisation of quality aquatic genetics can be a game changer in the seed production industry. Public hatcheries should concentrate on brood-stock

development programmes, which will ensure maintenance of quality seed and conservation of biodiversity. Governments (member states and Regional Economic Communities), development partners, CGIAR centres (e.g. WorldFish) and civil society organisations will be instrumental in developing effective plans, policies and guidelines for the seed production industry and strengthening genetic resources management. The private sector is the transformational engine for this industry that can ensure multiplication and quick access to affordable seed, thereby creating employment especially for women and youth. Strengthening the capacity of key stakeholders (i.e. researchers/scientists, planners, producers, genetic resource custodians and the private sector) will ensure sustainable utilisation of aquatic resources for aquaculture seed.

Quality feeds (aqua-feeds) for aquaculture production are very important drivers for the sector. Feeds account for 50 to 70 percent of the cost of production, and over 60 percent of aqua-feed is imported (Aanyu et al., 2020; Cai et al., 2017). The rapid growth of aquaculture in Africa has renewed interest from governments to invest in feed development and its management; thereby, promoting an import-substitution strategy. Though the aqua-feed industry is well-established in Egypt, Nigeria and Zambia where aquaculture production has grown significantly, it is still challenged with a lack of farmers' records and other information for planning purposes. Africa's aqua-feed industry comprises a majority of small-scale feed manufacturers and a few industrial scale producers like Aller Aqua, Skretting and Ugachick Ltd (Agboola et al., 2019). The industrial scale producers are mostly foreign investments that rely on imported inputs and have a large labour force estimated at 70-120 persons per producer.

Wild fish are caught, processed and used as fishmeal as protein ingredients for aquatic feeds. Expensive, such fishmeal is used for human consumption and livestock feed too (de Silva and Anderson, 1995). Use of fishmeal is however not sustainable as the practise contributes to the decline of natural fish stocks. Consequently, global research is currently directed towards finding a replacement for fishmeal with low cost plant protein materials like soybean (FAO, 2016a). However, plant utilization is also constrained by the prevalence of anti-nutritional factors, availability of adequate local plant material, and competition for human consumption and other livestock feed (Francis et al., 2001; Hertrampf and Piedad-Pascual, 2012; Jobling, 2016). Several industrial feed producers in Africa, for example in Egypt, import ingredients to produce enough feed for the industry, however reliance on imports directly increases feed prices and minimize profits (Agboola et al., 2019; Cai et al., 2017). Therefore, it would be economical to develop or adopt a scheme that involves out-growers of these plant ingredients to ensure a continuous supply to reduce the price of aqua-feed in Africa. Most farmers have inadequate skills and knowledge to manage and understand the environmental impact of aqua-feeds in Africa. The water environment may be polluted (eutrophication) if low quality feed and poor management practices are applied (Musinguzi et al. 2019). Furthermore, poor storage of feeds may increase the risks of aflatoxin contamination thereby presenting health concerns for consumers (Namulawa et al., 2020).

Investment and policy priorities

The lack of legislation on aquaculture in some countries deters aquaculture development in Africa. Yet there are already continental, regional and national policies and legal frameworks for sustainable aquaculture development. Existing gaps in quantitative information affects decision-making and formulation of national and regional policies for aquaculture development. The aquaculture industry is presently guided by the following policy frameworks: United Nations Sustainable Development Goals (1, 2, 5, 8, 9, 10, 12, 13 and 14); FAO Code of Conduct of Responsible Fisheries; the CAADP pillars 1 to 4; the Science Agenda for Agriculture in Africa; Aspiration One of Agenda 2063; Pan-African Fisheries and Aquaculture Policy Framework and Reform Strategy 2014; the Africa Blue Economy Strategy; the African Continental Free Trade agreement; and The Regional Frameworks On Environmental Management For Sustainable Aquaculture Development In Africa. Therefore, there is need for member states to adopt or review, develop and streamline their aquaculture policies in compliance with existing policies.

For meaningful economic and transformational growth in Africa through Aquaculture development, member states can prioritize, embrace and implement the following policies/strategies:

Implement the Pan-African Fisheries and Aquaculture Policy Framework and Reform Strategy, especially policy area 1 on conservation and sustainable resource use; policy area 3 on sustainable aquaculture development; policy area 4 on responsible and equitable fish trade and marketing; policy area 6 on awareness enhancing and human-capacity development; and policy area 8 on cross-cutting issues, especially strengthening resilience and reducing vulnerabilities to climate change in African aquaculture, streamlining knowledge-based gender and youth considerations in policies, laws and plans, and promoting private sector investments and financing mechanisms for aquaculture in Africa to improve performance of SMEs in aquaculture value chains. The Policy Framework and Reform Strategy is complemented by **The Regional Frameworks on Environmental Management for Sustainable Aquaculture Development in Africa,** and supported by the public and private sector.

Implement The Africa Blue Economy Strategy, which guides development of an inclusive and sustainable blue economy that can contributes to continental transformation and growth through biotechnology, environmental sustainability, and tourism. Relevant targets and actions for aquaculture development include: thematic area 1 on fisheries, aquaculture, conservation and sustainable aquatic ecosystems in the context of Africa Blue Economy, and thematic area 5 on policies, institutions and governance, employment, job creation and poverty eradication, innovative financing in the context of Africa Blue Economy.

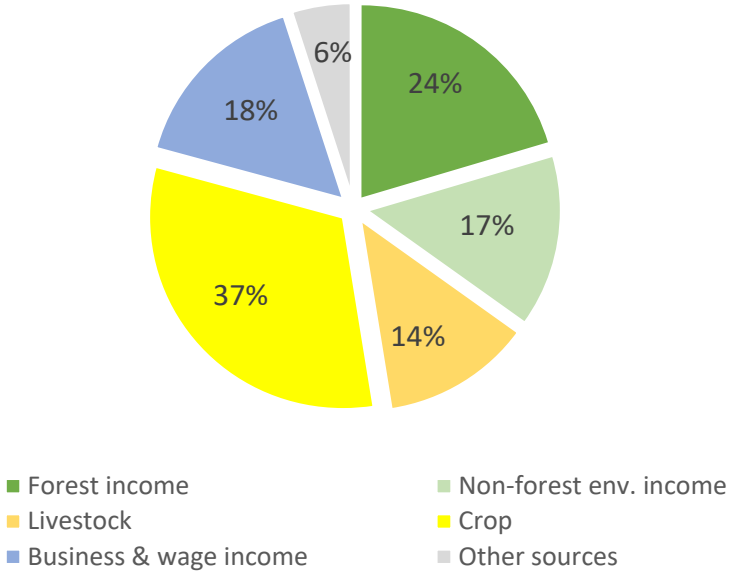
Focus on aquaculture within the African Continental Free Trade Agreement, which aims to create a continent-wide market, competitively integrate it into the global economy, reduce poverty, and promote inclusion by boosting intraregional trade in a bid to reduce the trade costs of aquaculture products. Importantly, it facilitates women to lower the gender wage gap, and assists workers by increasing decent employment opportunities.

Develop processing techniques and capacity to extend the shelf-life of fish products and facilitate greater access to fish, especially for children and their mothers.

4.4 (Agro-)Forestry

Forests provide direct and indirect benefits to human beings around the globe (Angelsen et al., 2014; Paumgarten, 2005). Particularly in Africa where the majority of the population (59 percent) lives in rural areas (World Bank, 2020d), people derive a substantial share of their livelihood from forests directly. According to data from the Poverty and Environment Network (PEN)[22], forest and environmental products and services contribute on average with over 40 percent to the total annual income of selected rural households in nine African countries. Forests alone represent the second most important source of household income after crop production in the African PEN subsample (Figure 13). Case study evidence further suggests that some African communities derive more than 30

Figure 13: Share of annual household income of African households (n=12585)



Source: PEN (2016)

22 The PEN data set covers selected rural areas in Burkina Faso, Cameroon, DRC, Ethiopia, Ghana, Malawi, Senegal, Uganda, and Zambia: www2.cifor.org/pen/

percent of their annual household income from direct forest uses (Appiah et al., 2009; Babulo et al., 2008; Gatiso and Wossen, 2015; Tieguhong and Nkamgnia, 2012). Forests support livelihoods in Africa by directly enabling local communities to meet their basic needs in terms of timber, fibre, firewood, medicinal plants, wild food (wild fruits, vegetables, meat, etc.). Particularly for poorer households, wild food is the main source of nutrition and protein, and plays a crucial role in improving the nutritional quality of their diets. For example, bush-meat contributes between 20 to 90 percent of the animal protein obtained by rural households in Western Africa (ACET, 2014).

African rural households use forest resources not only for subsistence, but also as a source of cash income (Endamana et al., 2016). As such, access to forest resources contributes to food and nutrition security, education, and health by means of covering related household expenditures (Lowore, 2020). Forests also play an irreplaceable role as safety nets for poor forest dependent households in times of shocks, such as crop failure, diseases, natural and man-made calamities, and climate change impacts. These shocks create income gaps that rural households can temporarily overcome by turning to forests resource (Wunder et al., 2014).

Forests also offer indirect benefits to African households and beyond by sequestering CO2 and reducing the effect of global warming and climate change (Bernal et al., 2018). Forests maintain watershed services and provide erosion and flood control, and habitat for endemic biodiversity (Kaiser and Roumasset, 2002). Moreover, forests deliver essential ecosystem services that are required for sustainable food production by regulating water and nutrient cycles (Reed et al., 2017; Watson et al., 2018).

4.4.1 Challenges to the African forest sector

Forest resources in Africa are under significant deforestation pressure, putting the livelihoods of forest dependent communities at risk. Aleman et al. (2018) estimated that tropical Africa lost 27 percent of its forests since 1900 with peak rates of forest loss (83-93 percent) in Eastern and Western African countries. The forest sector in Africa faces a multitude of challenges. First, high levels of forest product dependency, especially firewood, among both urban and rural African households exert direct pressure on forests (Chirwa and Adeyemi, 2019; Fisher, 2010). Second, population growth coupled with low agricultural productivity in many segments of African agriculture increases the pressure on forest via the expansion of crop and grazing land into natural forest landscapes (Curtis et al., 2018; Fisher, 2010). Thirdly, high demand for timber products in Africa and beyond (particularly from China) leads to forest degradation by way of unsustainable and often illegal logging practices (Lukumbuzya and Sianga, 2017). Africa's frantic push for development through foreign direct investment for resource extraction and infrastructure expansion tends to accelerate forest degradation and deforestation in many African regions (Assa, 2018). Finally, African forest managers and related policy sectors often lack managerial capacity, training, and resources to respond effectively to these pressures (Atyi, 2018; Connolly, 2006).

Forest degradation adversely affects the food security of forest dependent households both directly and indirectly. On the one hand, forest degradation affects food security directly by reducing wild food and forest-based income of households. On the other hand, it indirectly affects food security by increasing the time required to collect forest products, which reduces labour availability for agricultural production (Sola et al., 2016), education (Levison et al., 2018) and childcare. For around 53 percent of rural African households, wood is the main source of energy for cooking (Jin et al., 2017). In a case study on Uganda, for example, people were found to spend four to six hours per day travelling 8 to 12 km to collect firewood (Agea et al., 2010). Nonetheless, there is limited empirical research that rigorously examines the trade-off between forest product collection and agricultural production (Sola et al., 2016).

4.4.2 Towards enhancing the contribution of African forests to food security

Forest sector investments and innovations must be coherently aligned with interventions in other sectors in order to effectively improve food security and reduce the loss and degradation of African forests.

Clearly, productivity enhancing agricultural technologies improve the ability of farm-households to meet basic needs and can alleviate pressure on forest resources. The latter, however, hinges on public investments that simultaneously boost the effectiveness of

forest management and conservation policy implementation, while providing social safeguards for the marginalized forest-dependent rural population.

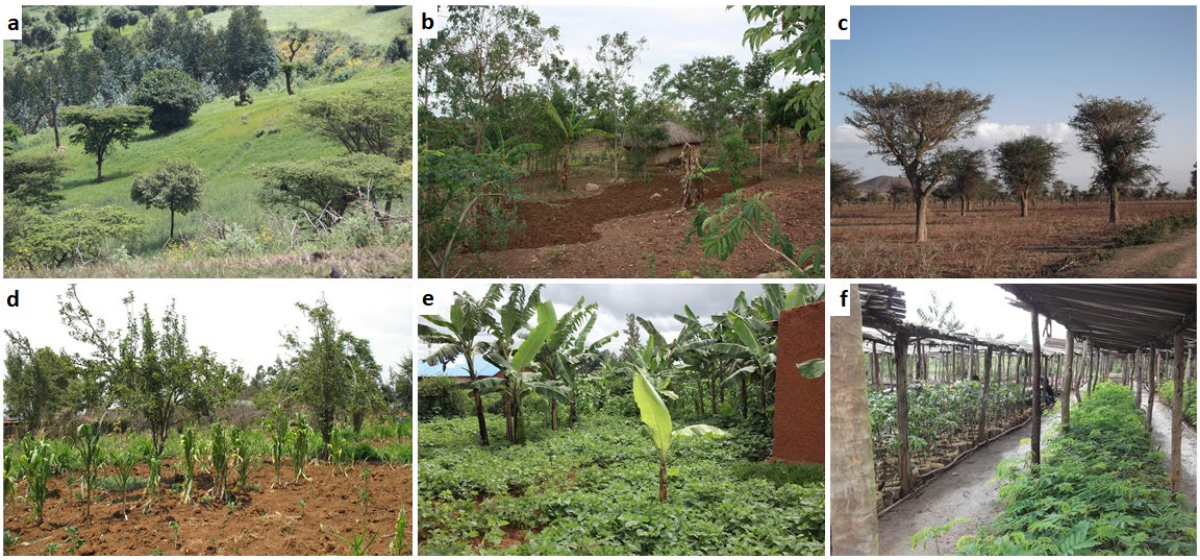
Win-win outcomes for people and natural resources can also be expected from well-targeted investments in alternative energy sources and more efficient energy uses. The costs of promoting improved cooking-stoves, for example, have been estimated to lie in the range of 0.17 to 3.2 EUR per household (Jeuland and Pattanayak, 2012). Well-targeted reforestation and afforestation efforts, including agroforestry (see below) can increase the supply of feedstock to substitute critical forest products (e.g. firewood) and minimize conflicts of use with agriculture and livestock production.

In many local contexts, the value of forests for people and the environment could be leveraged and poverty-environment trade-offs minimized by transitioning from traditional "fence-and-fine" conservation to collective natural resource management (Persha et al., 2011). Community-based resource management has several potential advantages. For example, it can reduce the costs of public forest management and encourage more sustainable use of forest resources as more forest use and access rights are transferred to the community level. However, building a systematic evidence base for what works and what does not in protecting African forests is a major future research challenge (Börner et al., 2020). Finally, to avert deforestation and thereby reduce its adverse impact on food security, governments should also consider implementing a mix of policies which combine strengthening forest law enforcement and introducing market-based instruments (e.g. payment for ecosystem services) (Busch and Ferretti-Gallon, 2017). A recent evaluation of a forest conservation initiative in Uganda estimated that the benefits of paying for forest conservation can exceed the costs by a factor of up to 2.4 (Jayachandran et al., 2017).

4.4.3 Agroforestry: The best of two worlds?

An important component of strategies to protect forests can be the establishment of alternative sources for frequently used forest products. Many ecosystem products and services that are traditionally derived from natural forests can also be generated on farms. Agroforestry systems integrate field crop production or animal husbandry with cultivated (or naturally occurring) trees or shrubs, aiming to achieve synergies between perennial and annual elements of cropping systems (Nair, 1993). Abundant evidence has been presented on situations where agroforestry systems have not only reduced pressure on forests, but also generated considerable benefits to farmers (Figure 14). The introduction of 'fertilizer trees', such as Faidherbia albida, can boost crop production (Garrity et al., 2010), fodder shrubs can act as a valuable source of protein for livestock (Vandermeulen et al.,

Figure 14: Agroforestry systems of Africa



Notes: a) Acacias and fruit trees in a cereal field in Ethiopia; b) Fruit and timber trees around a homestead in Western Kenya; c) Acacias in a harvested cereal field in Ethiopia; d) temperate fruit trees on a farm in the Kenyan Highlands; e) home garden in Rwanda; f) tree nursery for agroforestry species in Rwanda.

2018), and multi-layered home gardens can fulfil the nutritional needs of cash-constrained households (Whitney et al., 2017). Where timber and fuel wood can be produced in on-farm woodlots (Toth et al., 2019), forest resources can be spared and, in many cases, farmers' workload can be reduced.

Besides the direct provision of concrete products, trees on farms can supply additional ecosystem services, such as regulation of nutrient and water cycles, habitat for wild species, soil conservation, pollination, pest suppression and others (Kuyah et al., 2017). In a recent meta-analysis on ecosystem services provided by agroforestry in Sub-Saharan Africa, Kuyah et al. (2019) summarized the results of 126 peer-reviewed studies. In most of the cases covered by their review, agroforestry systems achieved higher crop yields and were more effective at providing soil fertility, erosion control and water regulation than cropping systems without trees. In terms of climate change mitigation, agroforestry systems were shown to store considerably more carbon than treeless systems (Luedeling et al., 2011; Montagnini and Nair, 2004). The mitigation effect of agroforestry is substantially enhanced wherever trees on farms contribute to the preservation of natural forests. Research has also highlighted the ability of agroforestry systems to support adaptation to climate change, e.g. by reducing windspeed and evapotranspiration in crop fields, by diversifying farmers' income sources, allowing them to accrue savings and by reducing the impacts of extreme weather events such as heavy rains or droughts (Thorlakson and Neufeldt, 2012).

Since tree-based agricultural systems can potentially achieve benefits to food security, adaptation and mitigation (Mbow et al., 2014), agroforestry has been labelled a potential 'triple-win' system (Bryan et al., 2013). This potential has recently been highlighted in the Special Report on Climate Change and Land commissioned by the Intergovernmental Panel on Climate Change (IPCC), which highlighted agroforestry as one of the most promising land-based options to address both climate change and land degradation (Shukla et al., 2019). On a global scale, the IPCC authors found that agroforestry has the potential to sequester more than 3 Gt CO2-eq per year, provide adaptation benefits to more than 25 million people, combat desertification and land degradation on more than 3 million km3 and strengthen the food security of 100 million people. Compared to other land use options, costs of achieving climate and conservation objectives with agroforestry were estimated to be relatively low.

While agroforestry may produce benefits in many settings, not every combination of trees and crops or livestock will produce net benefits in every location (Coe et al., 2014). One of the critical challenges in agroforestry research has therefore been the identification of tree-crop-animal combinations that work, and the design of locally adapted agroforestry options. This challenge has been substantial, since robust empirical testing of tree-based systems is a time-consuming and resource-intensive endeavour. The development of reliable models to predict the performance of agroforestry systems in new settings has been hampered by the need to capture the complex interactions between trees and crops (or animals) above and below the ground (Luedeling and Shepherd, 2016). Accurate quantitative description of these interactions has required collecting a large amount of data, and the resulting models have often not performed particularly well. It thus remains difficult to predict what agroforestry options will work where and for whom, which substantially complicates dissemination. The generally low investment in agroforestry research, compared to research on systems based on a single crop or animal species, contributes to the persistence of critical knowledge gaps.

4.4.4 Barriers to agroforestry adoption

Despite the promises of agroforestry to bring about major improvements in rural livelihoods, the adoption of tree-based options has often fallen short of expectations. Barriers to the adoption of agroforestry can be associated with characteristics of the innovation, the target population and the institutional setting (Table 5).

In comparison to simpler interventions, such as new crop varieties, agroforestry innovations are relatively complex, requiring the management of at least two species and their interactions. In most cases, agroforestry options only generate profits after several years, when trees have matured, rather than producing immediate returns. This is particularly problematic where establishing such new practices requires initial investments in terms of capital, labour or land that could otherwise be used to produce annual crops (Do et al., 2020). A major difficulty for farmers is that many innovations cannot easily be tested. For instance, a new type of fertilizer can be applied for one year and

Table 5: Adoption barriers of agroforestry systems

CHARACTERISTICS OF		
AGROFORESTRY INTERVENTIONS	TARGET POPULATIONS	INSTITUTIONAL SETTINGS
• complex • long lead time before returns are accrued • often require initial investments (capital, land, labour) • not easily testable	• conservative (sceptical of innovations) • risk-averse • resource-constrained • high time-preference (unwillingness or inability to wait for future profits)	• institutional divide between agriculture and forest • agroforestry not adequately represented in government, research or education • insecure land tenure • tree tenure or use regulations • inadequate seed/seedling systems • access to information • access to input and output markets

quickly abandoned if results are not satisfactory. But experimentation to decide whether an innovation based on long-lived perennials ultimately produces benefits, requires a much greater effort by farmers that many may not be willing to invest. Such efforts are needed, however, because it is often quite unclear, if a particular agroforestry intervention will actually benefit farmers, when considering their specific constraints regarding labour, capital, market access etc.

Characteristics of the target populations also determine whether particular practices are likely to be adopted. Ideally, farmers must be open to experiment with new practices. Cash-constrained farmers without access to credit may not be able to afford taking land out of their traditional cropping system for several years in order to establish trees even if they will eventually generate profits. Similarly, complex agroforestry interventions may fail where farmers lack management skills and lack access to capacity building opportunities.

In many rural African settings (and elsewhere; Simelton et al. (2017)), institutional factors represent major adoption barriers for agroforestry. Often administration and legal frameworks as well as research and extension services for agriculture and forestry are separately organized with little or no interaction and conflicting objectives. As agroforestry systems sit between these two sectors, they often do not receive adequate support from either side. Countries like Malawi, Rwanda or Kenya have recently addressed this issue by developing agroforestry-specific policies.

Insecure land tenure is another major obstacle to agroforestry adoption (Unruh, 2008). Millions of African farmers lack secure property rights for their land, which limits the attractiveness of long-term investments in agroforestry. Agroforestry faces particular challenges where governments have implemented specific rules to regulate tree tenure (Fortman, 1985). Especially in regions where trees are scarce, the cutting of trees is often prohibited, or farmers face other restrictions on tree use, even if these trees grow on their own land. Such rules discourage the addition of trees to agricultural systems. Further institutional constraints are related to farmers' access to high-quality tree seeds and seedlings (Lillesø et al., 2018), as well as, in many cases, access to relevant markets for inputs for and outputs from novel agroforestry systems.

4.4.5 Priority areas for action to expand agroforestry

Since a conducive institutional environment is critical for agroforestry adoption and dissemination, African governments interested in promoting agroforestry need to examine their land use rules and regulations through an agroforestry lens. This may require setting up inter-departmental task forces to ensure that policies support rather than impede agriculture with trees (Bartlett, 2020). Institutional barriers to adoption that may need to be addressed at government level are insecure land tenure, restrictions in the use of trees on farms, and other regulations that stand in the way of mixed cropping systems with trees. Investment needs for creating a favourable institutional environment are low, if such initiatives are initiated

and driven internally by governments. Efforts by external actors to overcome institutional barriers often fail and new ways of mobilizing political support may have to be explored.

Governments, international organizations, and development cooperation may also play a role in building and strengthening the capacity of farmers as well as researchers to develop, implement, evaluate, and refine agroforestry options. Due to the heterogeneity of African farming landscapes and the varied features and demands of agroforestry practices, upscaling of agricultural systems with trees requires continuous evaluation of what works and what does not in order to inform the development of creative solutions (Bartlett, 2019). Intensified impact monitoring and the learning of ensuing lessons will require a greater community of practice than exists at present. Such a community could be fostered by establishing agroforestry firmly in the curricula of agricultural universities, as well as through the design of agroforestry-focused training and extension programmes for farmers. The seeds of such capacity-strengthening initiatives could be sown by establishing appropriate curricula in selected universities, which would require modest investments or may even happen without external support. If such programs are perceived as successful by others, and possibly continue being supported by seed funds, widespread adoption in other institutions of higher education may follow. Directly reaching millions of farmers with appropriate training programs, on the other hand, would require large efforts that, given the low capacity of many national extension system, may have to be undertaken by non-governmental development agencies.

Despite decades of agroforestry research, there is still a shortage of reliable tools to predict the impacts of adopting a particular practice on farming households and landscapes (Bartlett, 2019). While some process-based models have been put forward (Luedeling et al., 2014; Smethurst et al., 2017; Van Noordwijk and Lusiana, 1999), modelling efforts have struggled with system complexity and have typically remained limited to capturing the biophysical dimensions of selected tree-crop combinations. This limitation remains a major obstacle to ex-ante impact assessments, because whether a certain agroforestry practice works well for a given household often depends strongly on labour availability, and access to markets, credit information and inputs. Practices must be compatible with local customs and traditions, and generate economic profits as well as other valued outcomes. Whether a technology is promising in these regards can vary at fine scales that current impact assessment tools are often too crude to capture. Improved methodologies to forecast the impacts of agroforestry adoption decisions, which should consider making use of nuanced expert knowledge and inputs from farmers (Dumont et al., 2019), are an urgent development need (Luedeling and Shepherd, 2016). Efforts to develop such methods are underway, e.g. at World Agroforestry or within the Water, Land and Ecosystem program of the Consultative Group on International Agricultural Research (CGIAR). What is needed is a sizeable investment (in the order of 10 million Euros) to support the development and refinement of methodologies that can credibly support decisions on agroforestry adoption in complex environments, acknowledging that such decisions need to keep multiple, often competing objectives in mind and are taken under considerable risks and uncertainties.

Much of the potential benefit of integrating trees into agricultural systems remains untapped. Most agroforestry literature to date has revolved around relatively simple combinations of cereals with trees grown for timber or fuel wood, or the improving of production of staple crops (Coe et al., 2014). While such outputs contribute to directly meeting basic household demands, it seems unlikely that, from an economic perspective, such systems are the best that agroforestry can deliver. Where appropriate output markets exist or can be established, the inclusion of fruit trees, vegetables, herbs or other high-value products promise much greater returns than traditional low-value products. Especially for land-constrained farmers, transitioning towards higher-value commodities may be a prerequisite to escaping the poverty trap of shrinking farm sizes faced by many African farmers. The design of high-value agroforestry options that work for smallholder farmers will require collaborative research efforts that should not only involve staple crop researchers and foresters, but also tap into the knowledge of horticultural scientists, drawing lessons from multi-layered home gardens, where farmers have long been experimenting with a wide range of tree-crop combinations. Systematic efforts to find and develop such innovative systems may require substantial investments in on-station experiments or large coordinated on-farm trials. Farmers could be incentiv-

ized to participate in such trials, or even conduct their own experiments, with experiences shared amongst themselves, as well as with research and development organizations. An inclusive approach would strengthen buy-in and accelerate progress. Such large-scale experimentation in agroforestry might require tens to hundreds of millions of Euros to get started, but it would have a fair chance of making small-scale agriculture more resilient and strengthening the livelihoods of Africa's farmers.

Investment and policy priorities

- **Facilitate alignment of sectoral policies affecting forestry and agricultural land uses** towards encouraging agroforestry practices and incentive-based conservation.
- **Improve efficiency of forest biomass uses**, especially for energy, and **promote alternative clean energy supply** for forest dependent rural households.
- **Promote high-frequency and high-resolution monitoring (including digital community-based approaches) of tree cover and wildlife dynamics**.
- Build capacities to **improve the effectiveness of land and forest use regulations** including social safeguards for marginalized rural households in customary land tenure systems.
- Support the development of science-based tools to **assess potential economic, social, and environmental impacts of adopting agroforestry innovations** at landscape scale.

5 SYSTEMIC INVESTMENTS FOR SUSTAINABILITY

Agricultural development needs not just specific investments such as in crops, animal production, and processing, but investments in the agricultural system. Systems investments create synergies and economies of scale across the entire sector.

Chapter 5 touched on specific **skills** needed to raise productivity in the different sub-sectors, including farming, forestry, livestock and fisheries. This section elaborates on the broader institutional dimensions of skill development, with a focus on strengthening vocational education and agricultural extension services. Skill development, along with other measures, will also be essential to engage the **youth** in food production and thereby provide them with access to remunerative income and employment opportunities.

To support the youth and agricultural actors more generally, four additional areas for systemic investments and policy initiatives are discussed in this section: (1) how **digitalization** could play a more prominent role in transforming agricultural value chains and thereby boost supply-side capacities, (2) how to strengthen **research partnerships** to stimulate and scale innovations in food and agriculture, (3) how to improve access to **finance** for agricultural producers and SMEs to enable them to make the necessary investments to increase production and mitigate risks , and (4) how to harness the potential of innovative off-grid **energy** solutions to reach currently underserved areas.

The final section discusses the importance of well-functioning **markets** so that food products actually reach African consumers while ensuring fair prizes for producers and small business that enable them to meet their own food requirements and generate income and employment. This requires actions at two levels. First, markets need to be inclusive of small-scale producers and small business, which, among other measures, will require investments and policies to raise the level of commercialization and competitiveness of smaller actors. Second, value chains need to function well so as to increase transparency, efficiency and fairness.

5.1 Skill development and agricultural extension

5.1.1 Skills development for value chain actors in African agriculture

The agricultural sector employs a vast proportion of the labour force in many African countries, yet it is not yet sufficiently professionalized to realize its potential for food security, poverty alleviation, and economic growth (Rangarajan and Chitja, 2020). For too long, African small-scale agriculture has been characterized by its lack of improved production methods and low productivity, making it an unattractive sector to work in. Designing policies and programmes to achieve a higher, more stable and sustainable food supply has become ever more complex. Innovations (technological, policy and institutional), requiring increased public and private investments alongside an effective and efficient dissemination and extension system, are critical for progress.

Skills and knowledge are themselves key inputs for agricultural productivity and a precondition for the effective and efficient management of soil and land, livestock and fisheries. Formal vocational training and skills development are needed to transform farmers and other small-scale producers into skilled entrepreneurs who can increase their level of productivity and income, and run their farms or businesses as productive and sustainable economic enterprises that compete in domestic and international markets (Carson, 2018; Kahan, 2013; Kahan and Worth, 2015; Reardon et al., 2019). Nevertheless, certain traditional agricultural knowledge and methods that have shown their own merits can be complimentary and must not be discarded (Briggs and Moyo, 2012; Ezeanya-Esiobu, 2019).

The impact of training and skills development extends beyond the individual level. For example, in the agri-food sector, higher productivity can lead to an increased supply of food, and lower prices due to larger production volumes (SDC, 2019, 2013). Furthermore, training and skills on specific topics such as post-harvest handling may lead to improved food quality and less waste, and more efficient use of resources (SDC, 2019). In turn, these outcomes affect the food security of a country. Along with higher incomes in the agri-food and allied sectors, this would lead to better nutrition and in the long-run even higher productivity (FAO, 2019). Cross-country variations in agricultural productivity are mostly related to differences in Total Factor Productivity (TFP)[23]– difference in TFP accounts for 50 percent of the productivity difference – the importance of skills is too large to be ignored (Cai, 2011). Evidence specifically shows that the differences in farmers' skills accounts for about 30 percent of the variation in agricultural productivity (Cai, 2011). Other research shows that cognitive, noncognitive, and technical skills explain up to 17 percent of the variation in yields (Laajaj and Macours, 2017). Gollin et al. (2014) show that productivity differences become smaller when accounting for observed human capital differences. A well-developed curriculum for agricultural technical and vocational education and training (TEVET) based on the current needs of the agri-food sector, therefore, can provide a boost to the whole economy.

Recent estimates from the International Labour Organization show that about 44 percent and 16 percent of the youth (ages 15-24) in northern Africa and Sub-Saharan Africa, respectively, are not in employment, education or training – that is, are classified as "idle" youth (ILO, 2020). It is expected that the COVID-19 pandemic will lead to a rise in these shares. Idle young people are unable to develop the skills needed in the labour market, which reduces their future employment prospects and limits their countries from achieving sustained economic growth (ILO, 2019; O'Higgins, 2017; World Bank et al., 2017). Further, statistics show that an overwhelming majority (95 percent) of the youth in employment in SSA in 2016 worked in the informal sector because of a lack of opportunities in the formal economy (ILO, 2020). Informal jobs (such as contributing to family work) are associated with vulnerability characterized by income instability and limited social security coverage (Elder and Kring, 2016). To keep pace with the growing working-age population, Africa requires some 18-22 million new jobs annually (Africa Growth Initiative, 2019; ILO, 2019; IMF, 2020).

The public sector does not provide adequate (agricultural) TVET across Africa. The TVET sector is grossly inadequate, and agricultural TVET is even worse in the countries where it is needed the most (Haseloff et al., 2017). There are still far too few training opportunities for young people. Vocational training institutes in many African countries have suffered from many years of neglect, having been poorly equipped with physical, human, and financial resources (Haseloff et al., 2017). In countries where some training is available, it often lacks practical relevance to labour market needs and does not match the needs of the private sector, and it also focusses mainly (if not solely) on technical (hard) skills (Chong, 2014; Eicker et al., 2017; Kosec and Ragasa, 2019). The curriculum in many such institutions is outdated (Haseloff et al., 2017; Janoski et al., 2014). The low social status of crafts and trades poses another challenge in promoting TVET (Chong, 2014; Ute et al., 2014). Furthermore, infrastructure and equipment are extremely insufficient (Li et al., 2016). The low quality of teaching in many institutions is also of major concern — most of the teaching and instructing staff do not have the requisite combination of academic competencies alongside technical qualifications and industry experience (Eicker et al., 2017; Ismail et al., 2018; Koobonye, 2020). In the absence of agricultural TVET, extension service providers have been filling the void, albeit with mostly disappointing results.

Skill gaps and training opportunity needs of various agri-food value chain actors

Most smallholder farmers, small-scale producers and other value chain actors across Africa are poorly educated and ill-trained, lacking the capacity to expand their small-scale operations (Babu et al., 2016). Though the innovation and entrepreneurial capacities of agri-food actors has risen (Tambo, 2018; Tambo and Wünscher, 2015), a critical mass of actors is yet to be reached and cannot overly substitute for the inherent weakness of formal skills and knowledge acquisition systems. Therefore a range of skills are needed:

23 TFP growth measures the contribution of innovation to overall growth: TFP increases when more output is produced from a constant amount of inputs.

- At the production level of the value chain, technical skills such as land preparation methods, proper use of inputs (seeds, fertilizers) and machinery, crop and soil management, and postharvest handling and storage (Mabaya and Cramer, 2014).
- Processing skills for transforming raw products into shelf-stable products that preserve the nutritional content of foods, smooth seasonal availabilities and enable wider distribution of foods while at the same time reducing food waste (IAP, 2019).
- Management skills that help value chain actors efficiently manage their physical, financial, and human capital resources, thereby boosting production quantities. With proper management skills, value chain actors have the capacity to identify and exploit opportunities, improve their operations, and respond quickly to market shifts (Reardon et al., 2019).
- Entrepreneurial and business skills to increase the profitability of enterprises (Zumkella, 2011). These skills are often important for input and output market participation, and for engaging with other value chain actors (for example, through contract farming) (Rao, 2012).

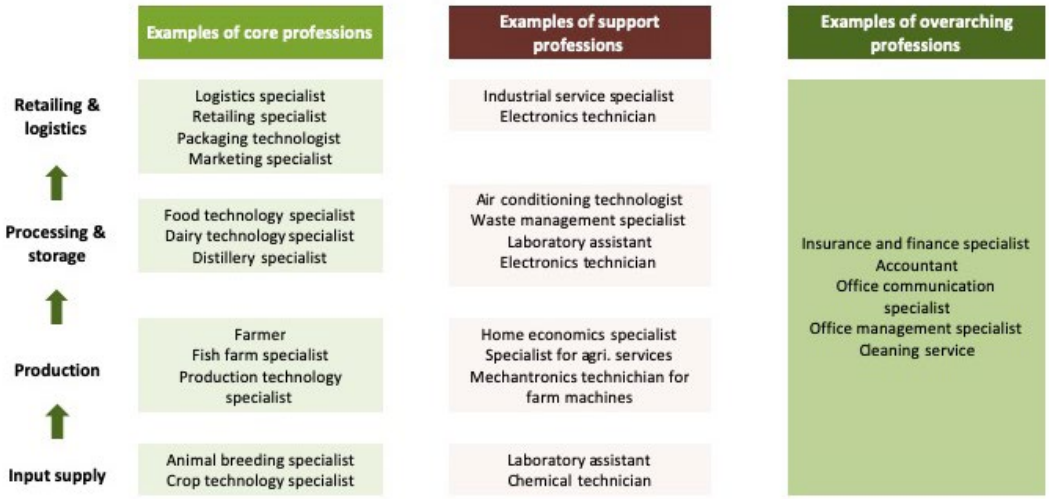
The expansion of small-scale production systems into agro-enterprises hinges on increases in both technical and entrepreneurial capacity (Yumkella, 2011).

Collaboration between public and private organizations and universities can provide suitable training to farmers and farm workers and nurture rural development practitioners. One such example is Songhai – which has a dense network of more than 40 stakeholders – providing agricultural TVET (initially in Benin) in 15 African countries. The training offered encompasses practical and entrepreneurial curricula and covers a wide range of topics such as production, agricultural entrepreneurship, and sustainable agricultural practices. Besides setting up model farms, the centres have been successful because of the cascading information transfer and teaching system that creates a large number of farmer resource persons (McNamara et al., 2016).

Although most agricultural TVET primarily focus at the level of the farm and basic processing, a much broader set of skills is required to transform the agricultural sector in Africa. The relevant professions can be grouped into three categories (Figure 15):

1. **Core professions** include those directly related to the agricultural value chain. The degree of specialization varies because innovations and the introduction of new technologies may require highly specialized and skilled labour beyond the production level – for example, input production (seeds, fingerlings, fertilizer mixing), processing and storage technologies, logistics, retailing.
2. **Support professions,** required to ensure the functioning of the core professions at different stages of the agricultural value chain — for example, electricians and machine technicians to install, repair and service farm machines and other technologies at the production, processing, storage and transport stages of the value chain.
3. **Cross-sectoral professions,** required to ensure the functioning of the value chain as a whole, though

Figure 15: Professions along the agricultural value chain



Source: Kirui and Kozicka (2018)

not directly related to the agricultural sector — for example, finance, accounting, insurance, and communication specialists.

Besides technical (hard) skills, there is growing recognition of the value of soft skills to employee productivity. The development of soft skills (mix of skills, attitudes, behaviours, personal qualities and mindsets that individuals use to be successful across different situations in work and life) is deeply intertwined with academic and technical skill development (Ignatowski, 2017; Palmer, 2020). Lippman et al. (2015) broadly classify soft skills into five sets; positive self-concept, self-control, communication, social skills and higher-order thinking (which includes problem-solving, critical thinking and decision-making). Though these soft skills are increasingly seen to benefit youth in all domains of life, these skills are poorly understood, not well assessed, and too often overlooked in policy and institutional contexts, including education, training and at the workplace (Palmer, 2020).

Africa does not need to reinvent the wheel but can learn from models that have worked elsewhere – such as the German dual system. The success of this dual system has been credited to its broad qualification structure that offers high-quality education and viable employment prospects for youth, coupled with a high degree of engagement of all stakeholders, a well-financed and balanced structure via the private and public sectors, and well-developed and institutionalized capacities (Kirui and Kozicka, 2018).

Costs-benefit projections of technical and vocational education and training

Different stakeholders (government agencies, private firms, development partners, NGOs and the trainees) can share the costs of TVET and apprenticeship programmes. Broadly, the costs include: costs for training and instruction personnel, costs for infrastructure (such as machinery, appliances, training premises), costs for supplies (such as books, audio-visual materials, software), recruitment and administrative costs, wages of trainees/apprentices (such as compensation for food, travel costs or living expenditures), and contingencies costs (such as duties and taxes, social insurance).

The benefits are manifold. For example, a firm would benefit from trainees that are able to perform skilled tasks because they would incur lower labour costs than if they had to employ skilled workers. Similarly, trainees performing unskilled tasks would likely be less costly than employing unskilled workers. Other (non-monetized) benefits to firms include: the ability to directly influence teaching and learning programmes to suit their skills' needs and ensure a steady supply of appropriately skilled employees; a reduction in future costs of recruitment, induction and in-house training; and the possibility of capacity building and job enhancement for firm employees assigned to act as coaches/mentors. Despite these benefits, some firms have shown unwillingness to invest in training and apprenticeships because of the fear of worker turnover – namely, that trained workers could be poached by competing firms (Mohrenweiser et al., 2019; Stockinger and Zwick, 2017). However, several studies have shown that the overall importance of poaching on expected returns to apprenticeship training and firms' training decisions seems to be negligible and that the "option value" of having extra well-trained workers with a range of skills far outweighs the consequences of poaching (Bornemann, 2006; Lerman, 2019).

Data providing the costs per person for a typical TVET in Africa is scanty. Available estimates show that the total annual costs range from US$ 204 for apprenticeships to US$ 1,704 for the most expensive private TVET in Kenya lasting two-three years. The median cost in Uganda for a three-year training is estimated at US$ 444 while in Ghana and Mozambique the total costs are estimated to be about US$ 1,500 – which is about three to four times the cost of secondary education (Adams et al., 2009; Fox et al., 2012).

Targeting training to the various categories of smallholders is also important. Though the number of medium-size farms is rising, the biggest growth driver will be increases in the productivity of small-scale producers. Africa has about 51 million farms of which 80 percent (or 41 million) are smaller than two hectares in size, their numbers still increasing in most countries (Lowder et al., 2016). Furthermore, Africa's smallholders are diverse and face varying livelihood prospects depending on their own assets and aspirations, as well as their local, regional and country contexts. Hazell and Rahman (2014) propose classifying smallholders into three groups: (i) commercial smallholder farmers – successfully linked to value chains, running their farms on a business basis; (ii) small farmers in transition – favourable non-farm opportunities, obtaining much of their income from non-farm sources; and (iii)

subsistence-oriented small farmers – marginalized for a variety of reasons that are hard to change, such as ethnicity, ill-health, age, or remote location with limited agricultural potential. The priority of TVET should be commercial farmers and smallholders in transition because the returns to training would be higher.

In addition to formal education and training, information and communications technologies (ICTs) – including radio, television, DVDs etc. – have been advanced as a means for increasing opportunities for lifelong learning (Kanwar et al., 2019). However, the integration of these technologies into TVET systems in many parts of the world remains marginal (Latchem, 2017). ICTs can be applied in TVET for administrative purposes, communication, teaching and learning, curriculum development and assessment, career education and guidance, labour market information, and job placement (Chinien, 2003). TVET teachers should also be trained to use ICTs to effectively harness their deliver skills (Kanwar et al., 2019).

Agricultural innovations, Total Factor Productivity and Green Innovation Centres

At an aggregate global level, innovations have become increasingly important for improved food security (Fuglie and Rada, 2013; von Braun, 2018). Innovations that impact the entire economic, social and food system context have huge positive effects in reducing hunger (Adenle et al., 2019; Ganguly et al., 2017; Gollin et al., 2014; Sayer and Cassman, 2013; von Braun, 2018). The sources of growth of food availability are one important component of food security. Specifically, agricultural innovations – which can be encouraged by platforms that connect bottom up producer-led innovations with more top down science-based innovations – are central to a sustainable increase in productivity to ensure food security while maintaining environmental quality and resources.

Total Factor Productivity – also called multi-factor productivity – measures the total resource cost of producing economic outputs (Fuglie and Rada; 2013). It takes into account the contributions of all inputs to production – land, labour, capital, and materials (inputs) (Fuglie and Rada; 2013; Hoang and Coelli, 2011; Lusigi and Thirtle; 1997). Agricultural TFP is usually measured as the ratio of aggregate agricultural output (crops, livestock, and fisheries) to aggregate inputs (land, labour, capital, and materials) (Gavian and Ehui, 1999; Sheng et al., 2020). TFP, thus, reflects improvements in the efficiency of aggregate bundles of inputs and is closely associated with technological change (Shen et al., 2019). In principle, increasing the efficiency of agricultural production — getting more output from the same amount of resources — is critical for improving food security (Gavian and Ehui, 1999; Hoang and Coelli, 2011; Lusigi and Thirtle, 1997; Shen et al., 2019; Sheng et al., 2020).

At the global level, innovation currently contributes about three-quarters of agricultural TFP growth while resource expansion and input intensification – which contributed a larger share in the previous decades – have scaled back (Fuglie and Rada, 2013). However, this contribution shrinks to just about a third in SSA (Fuglie and Rada, 2013). SSA continues to struggle to achieve sustained, long-term productivity growth in agriculture, as compared to the rest of the world. Over the last two decades the region averaged around one percent annual TFP growth (Block, 2016; Gollin et al., 2014; Villoria, 2019). Recent studies show that farmers are active experimenters who continuously generate remarkable and locally adapted innovations (Tambo, 2018; Tambo and Wünscher, 2015).

Bottom-up innovations and science-based top-down innovations need to be connected in new and more effective ways. A means for this are innovation platforms or innovation centres in which researchers and producers meet and jointly identify opportunities. The "Green Innovation Centres for the Agriculture and Food Sector"[24] (GIC) project initiated by the German Government, at the heart of the ONE World–No Hunger initiative, has founded 14 centres in 14 African countries. These serve as trial and demonstration sites and also form a basis for the development of synergies between local bottom-up and national and international top-down innovations by actors and research communities, respectively. It is important to sustain the Green Innovation Centres in the longer run because agricultural development takes time. Moreover, promotion of more innovations in different value chains and the inclusion of more actors is required. Vocational training can support this. Stimulation of farmers' innovative behaviour by providing appropriate incentives, and incorporation of local knowledge into more institutionalized research frameworks and extension services are both required. It would be

24 www.giz.de/en/worldwide/32209.html

fair and efficient to include a strong focus on women farmers too.

5.1.2 Agricultural extension provision for agri-food value chain actors

Traditional agricultural extension approaches are face-to-face, through an extension officer visiting a farmer or a group of farmers (Buadi et al., 2013; Hall and Kuiper, 1998; Lukkainen, 2012). The aim is to provide adequate and timely access by farmers to relevant advice, to nudge farmers to adopt innovations and new technologies (like improved seeds and better agronomic practices) and to aid the dissemination of research results and innovations to farmers and industry (Danso-Abbeam et al., 2018; Lukkainen, 2012; Maiangwa et al., 2011; Sigei, 2014). Thus agricultural extension programmes have been the main conduit for disseminating information on farm technologies, supporting adult learning in rural areas, and assisting farmers to develop their on-farm technical and managerial skills. Extension programmes are expected to help increase farm productivity, farm revenue, reduce poverty and minimize food insecurity. However this longstanding approach has been significantly hampered by many challenges including insufficient funding, limited involvement of farmers and the local population, and poor linkages with research and other stakeholders (McLeod Rivera and Qamar, 2003; Norton and Alwang, 2020).

One of the biggest problems bedevilling the organization of agricultural extension in many African countries is the lack of a proper and comprehensive legal and policy framework for providing services. The absence of policy has rendered the extension systems in many countries ineffective (Akiyama et al., 2003). A comprehensive agricultural extension policy ought to provide coordination among research, education, input supply, and credit, processing and marketing systems (Jones, 2013). Such a policy should also clarify the goals and mission of agricultural extension agents and their clientele. Besides, it should highlight the relevant guidelines and programmatic areas to be addressed. The most recent published study that surveyed 27 countries in SSA found that only Botswana, Kenya, Malawi and Uganda have legislated agricultural extension policy and a host of other countries (22 countries) have developed a provisional extension policy (Jones, 2013; Oladele, 2011). Although extension policy should be developed through multi-stakeholder processes, in practice government decrees and proclamations (which do not go through the process of consultation and do not involve various stakeholders and beneficiaries) are more often than not the norm. A review of existing literature and country reports

Table 6: Extension models practiced in different countries in Africa

EXTENSION MODEL	COUNTRIES
Farmer Field School	Angola, Benin, Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Malawi, Mali, Mozambique, Nigeria, Rwanda, Senegal, Tanzania, Uganda, Zambia, Swaziland
Pluralistic Extension System	Côte d'Ivoire, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Senegal, Lesotho, Sierra Leone, Liberia, Guinea
Ministry-based Extension System	Madagascar, Mauritius, Namibia, South Africa, Sierra Leone, Zimbabwe
Participatory Demonstration and Training Extension / Participatory Extension System	Benin, Ethiopia, Mali, Zambia, Swaziland
Training & Visit (Modified) System	Mali, Madagascar, Mauritius
Unified Agricultural Extension System	Nigeria, Lesotho
University-based Extension System	Tanzania, South Africa
National Agricultural Advisory Services	Uganda
Commodity-based Extension Services	Madagascar, Mauritius, Namibia, South Africa
Community Extension	Mauritius, Namibia, South Africa, Zimbabwe
Cyber Extension system	South Africa
Private Companies / Commercial Extension System	Sierra Leone, Zimbabwe
Farming Systems' Approach	Botswana

Source: Author's compilation from review of several literature and country reports.

shows that a variety of extension and advisory models are currently practiced in Africa (Table 6). Common extension models include Farmer Field Schools, pluralistic extension system, ministry-based extension system, commodity-based extension services, community extension system, and participatory extension (and training) system.

The emergence and potential of e-extension services

Information and communication technologies (ICT) have emerged as a promising alternative to face-to-face extension approaches. ICTs range in cost from cheap to expensive, and have the ability to deliver timely, relevant, and actionable information to farmers even in remote locations and to diverse populations. The key ICT technologies and tools which can be utilized to provide various extension services include radio, television and video, and feature and smart devices (e.g. tablets and mobile phones) and computers, the latter all requiring internet (see Omoregbee et al. (2016) and Vignare (2013) for a review).

The appropriateness of various ICTs as well as the capacity of farmers to leverage them needs addressing through literacy programmes. Other aspects such as accessibility of these tools in rural and remote areas, effectiveness (reconciling costs versus benefits), and gender sensitivity must also be addressed. As telecommunications services are the bedrock of ICTs, their availability in rural areas is required. The success of e-extension will therefore depend on addressing connectivity constraints, especially telecommunications and energy (electricity) challenges. In practice, the use of ICT for agricultural extension should be started at locations which already have the necessary infrastructure (Omoregbee et al., 2016)

Investment and policy priorities

The following are important policy and investment priorities for **skill development**:

- **Revamp existing training institutions and systematically expand relevant training opportunities.** Revise and tailor the curriculum offered in these institutions to meet the needs and demands of the agri-food sector, to contribute to growth and sustainable development.
- **Identify significant value chains** – that employ many people and generate significant incomes, based on present and future national labour market priorities and in partnership with multiple stakeholders – **and develop curricula for the various actors engaged in these chains**.
- **Adopt the use of emerging innovative modes of delivering training, such as the use of ICTs, and practical learning that links theory and everyday examples.** Policy makers and practitioners should review, adapt and replicate innovative community-based models for effective use in TVET.
- **Borrow and adopt successful models from other regions** – such as the German dual system – **to strengthen the (agricultural) TVET system.**
- **Increase and sustain investments like the Green Innovation Centres, because agricultural development takes time.** In this regard, regular scouting for bottom-up producer innovators is necessary, as is their acknowledgement and encouragement through innovation contests.

Regarding **extension services**, priorities would include:

- **Policy reforms to bring about new strategies to improve the public delivery of extension and advisory services**. For instance, ICTs present opportunities to reengineer the delivery of extension and advisory services – e-learning and e-extension – in a cost effective and timely manner. Building the human capacity of producers first requires building capacity among extension educators.
- **Address challenges related to infrastructure (such as electricity, and mobile network and roads) and literacy concurrently.**
- **Move agricultural extension to the next level, by periodical review of extension policy, enhanced policy dialogue, building of partnerships, and better coordination with all relevant stakeholders.** Extension systems must continually be responsive to the shifts in the agricultural sector.

5.2 Youth engagement

Labour is an essential factor of production in the agricultural sector – crops, animal husbandry, fisheries and forestry – and even though its contribution to sectoral output has, globally, been decreasing over time (Gong, 2020), it still plays an important role in Africa where the sector remains highly labour-intensive. However, labour productivity, measured as value added per worker, is usually much higher in non-agricultural sectors than in agricultural sectors, – on average three times higher, even higher in lower-income countries (Gollin et al., 2014). More recent literature shows that rather than a manifestation of causal impacts and the underlying labour market frictions, the productivity gap reflects worker selection, meaning that workers of lower ability and skill are concentrated in agriculture while workers with higher ability and skill move out of agriculture (Hicks et al., 2017).

Previous research has also shown that young people with higher human capital, measured either by educational attainment or cognitive abilities, are more likely to out-migrate from rural areas and, subsequently, work in the non-agricultural sector (Beegle et al., 2010; Miguel and Hamory, 2009; Young, 2013). In addition, it is asserted that various constraints, discussed below, to which young people are exposed, push them out of agriculture (Bezu and Holden, 2014) or that, simply, young people are not interested in agriculture anymore because of negative perceptions of the agricultural work (OECD, 2017). These considerations have sparked a debate on the changing age structure of the agricultural workforce in Africa and the need to attract more youth to agriculture in order to promote sufficient food production for the growing population (see the discussion in Jayne et al. (2017)).

To clarify this issue, two points need to be discussed. First, the actual extent of the shift of the young workforce out of agriculture; second, the potential implications of such a shift for agricultural productivity and output. Regarding the former, data-based evidence suggests a much more nuanced picture. Indeed, in most African countries, the share of employment in agriculture has declined over the last decades even if the rate of the decline has largely varied between countries (with the exception of Nigeria where it has actually increased (Yeboah and Jayne, 2018). This pattern of labour reallocation is in line with the discussion on structural transformation which is considered a feature of economic development and a driver of overall rise in productivity and poverty reduction, from both theoretical (see Lewis (1954) and later developments) and empirical perspective (Christiaensen and Martin, 2018; Timmer, 2009), also in case of Africa (Diao et al., 2017).

On the other hand, the absolute number of working-age persons (also youth) employed in agriculture has been on the rise in Africa (Yeboah and Jane, 2018), in line with its demographic structure and population

Table 7: Youth (15-24 years) share of potential labour force (15+ years)

	YOUTH SHARE (%)		HISTORICAL PEAK SHARE	
	2019	2050	%	YEAR
World	21.0	17.4	29.7	1975
Developing countries	22.8	18.3	33.0	1975
Sub-Saharan Africa	34.4	28.2	36.0	2002
Eastern Africa	35.7	27.1	37.2	2004
Western Africa	34.6	29.6	35.8	2000
Middle Africa	35.5	30.3	36.1	2005
Southern Africa	24.3	19.3	33.0	1977
excluding South Africa	29.9	22.2	37.5	2000
Northern Africa and Western Asia	23.9	19.0	33.8	1978
Central and Southern Asia	25.2	17.3	32.8	1977
Eastern and South-eastern Asia	16.3	12.8	31.9	1973
Latin America and the Caribbean	22.0	14.8	33.5	1976

Calculations based on World Population Prospects 2019 data from UNDESA. Table adapted from Thurlow (2015) and updated using most recent population data. 2050 projections based on the medium fertility variant.
Notes: Potential labour force measures as the population aged 15 years and older.
Source: Kubik (2020).

growth. With 62 percent of the population below the age of 25 in 2019, Africa has the youngest population in the world. It is also the only region in the world where projections indicate the youth population will continue to grow and will more than double by 2050 (UNDESA, 2019). On the other hand, the share of youth, defined as those between 15 and 24 years[25], in the potential labour force in Sub-Saharan Africa has already started declining, albeit very slowly (Table 7), suggesting that the youth bulge is already receding (Thurlow, 2015). The adult working-age population (25 to 64) is the fastest growing population group in the region, expected to grow from 35% in 2019 to 43% in 2050 (UNDESA, 2019). The fact that the working-age population is expected to grow faster than any other age group creates potential for demographic dividend[26] and presents opportunities for economic growth and structural transformation.

It is therefore not surprising that agriculture continues to be the largest employer for young people in many African countries, be it by necessity or by choice. In the context where the number of new entrants into the labour market every year is still very high – around 10 million every year (Maïga et al., 2015) – while the number of new jobs created outside of agriculture is still very low (Yeboah and Jayne, 2018), agriculture absorbs labour in Sub-Saharan Africa. But it can offer much more than mere labour absorption – agriculture and the related industries can become a career pathway for rural youth and provide important employment and business options. Growing food demand as well as food system transformation, as a consequence of rising per capita incomes, urbanization and new export opportunities, are expected to result in a shift of production from cereals to high value fresh, processed and convenience foods (World Bank, 2013). This shift will represent important opportunities for young people employed in the food sector. Downstream industries are expected to play an increasingly important role in youth employment as job creation is very dynamic in the sector (Allen et al., 2016). While the agroprocessing sector provides a low number of jobs compared to other sectors, it is considered to offer relatively good quality employment and decent wages, at least in countries where the sector is already well developed (Kubik et al., forthcoming).

Despite evidence suggesting that in certain contexts, young Africans are losing interest in agriculture (Bezu and Holden, 2014; Kosec et al., 2017), data covering 10,000 individuals between 18 and 35 years old from rural areas in 21 countries in Sub-Saharan Africa[27] shows that agriculture still occupies a relatively important place in their employment aspirations. Overall, close to 25 percent of young Africans want to work in the food and agriculture sector (in this survey defined as crops and livestock), but the share is higher in some countries, close to 40 percent in Kenya, Liberia, Malawi and Tanzania (Figure 16). The fisheries sector is largely unattractive to youth, with the notable exception of Madagascar where it is as important as agriculture.[28] The highest share of respondents, more than a third, want to work in services, communication and transport; and a quarter in the public sector. These figures, combined with relatively low importance of manufacturing, go in line with the discussion on structural transformation without industrialization (Gollin, 2018).

The share of youth actually involved in agriculture and related industries is even higher, especially when looking at the time spent in agriculture compared to other forms of income-generating activities (Dolislager et al., 2019). Figure 17 presents various categories of employment in food and agriculture: own farm self-employment, farm wage employment, agri-food system wage employment and self-employment, and other sector wage and self-employment. The results are presented for several age categories (adults are also included for comparison) and several categories of rural areas (depending on their remoteness) and ur-

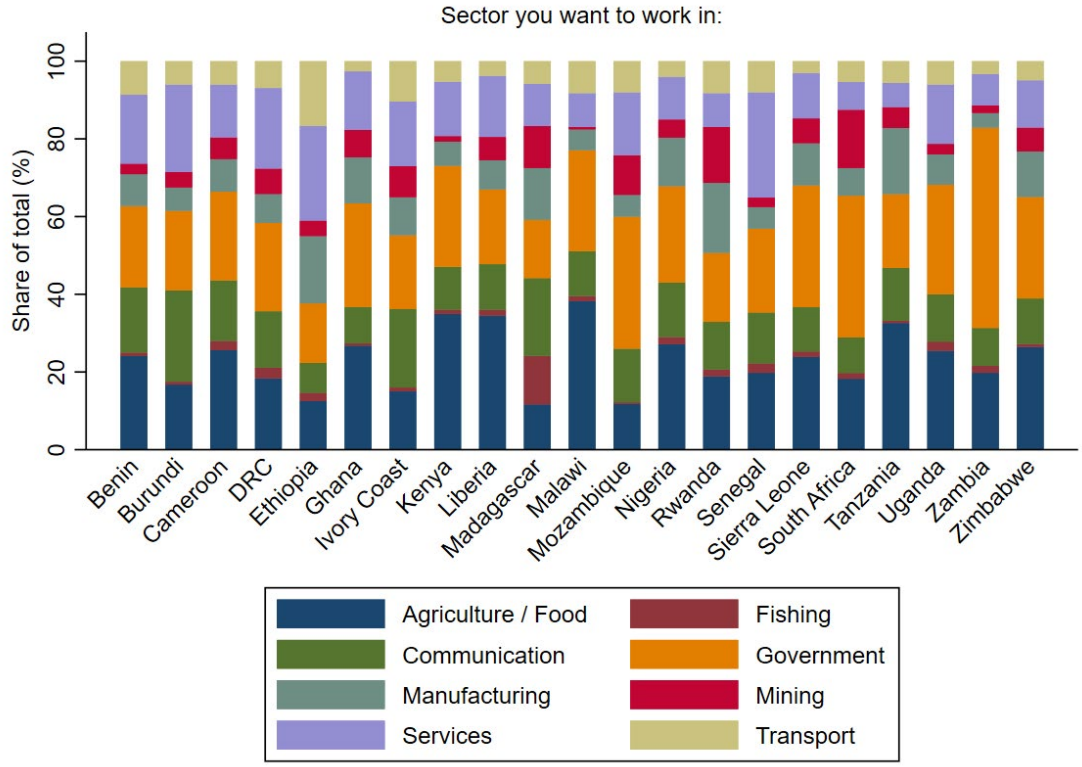
25 This definition follows ILO (2015). Note that the African Union (AU) defines youth as people aged 15-35 years; while many sub-Saharan countries apply their own definitions, ranging up to 40 years old.

26 Demographic dividend is defined as a situation wherein the number of people in the workforce is higher than the number of dependents. Some authors consider that the decline in fertility rates across Africa is too slow and might hamper the expected benefits from the demographic dividend (see Page, 2019).

27 Collected by GeoPoll for GIZ / BMZ, the data is referred to throughout this section. Respondents living in rural areas, as well as those moving between rural and urban areas are included. Note that the exclusion of those who move between village and town does not significantly alter the results presented in this section.

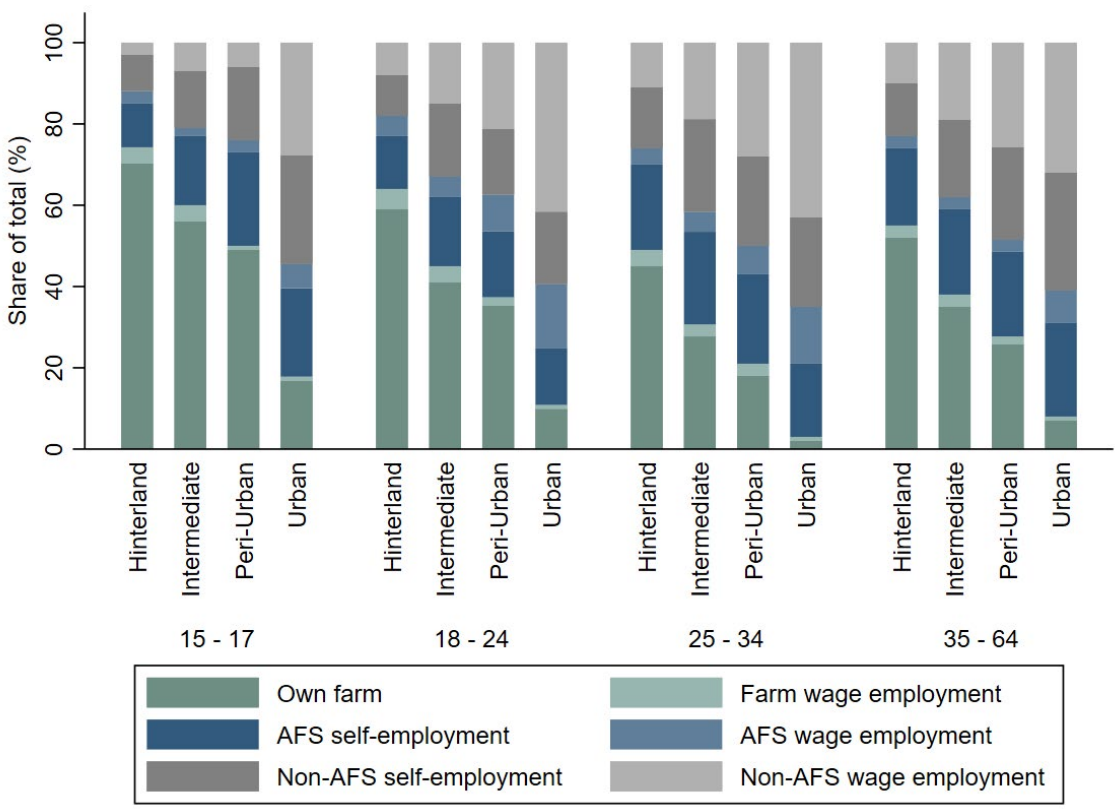
28 The survey included fishery as a response option, but not aquaculture. Therefore, we can expect that the low share of fishery sector in the sample was affected by geographical constraints of the locations. The relatively large share of fishery in case of Madagascar is a good case in point.

Figure 16: Rural youth employment aspirations in selected countries



Source: Authors' own elaboration based on GeoPoll dataset.

Figure 17: Time allocation by category of employment (share of Full Time Equivalents)



*AFS: agrifood system

Source: Authors' own elaboration based on figures from Dolislager et al. (2019)

ban areas. The participation of youth in farming their own land is observed to be relatively high, declining with youth age categories, and then increasing again for adults, i.e. exhibiting a J-curve shape. In line with expectations, participation in farming is highest in the most remote rural areas and declines for less remote areas and locations in proximity to towns. Self-employment in the agri-food sector turns out to be the second most important employment category in rural areas for all age categories, whereas for older age categories and in areas located closer to towns self- and wage employment in other sectors is most prevalent.

These figures show that a large share of the rural youth is involved in food production, either in primary agriculture or in downstream industries, such as processing, logistics or retail. This high degree of involvement in agriculture puts downward pressure on the age structure of the sectoral workforce. Contrary to popular perceptions, the average age of African farmers is not rising – it is either stagnating or even falling in some countries (Yeboah and Jayne, 2018). It is also much lower than previously claimed – not 60 years (FAO, 2014), but 34, once all the household members involved in family farming are considered rather than only the household heads (Arslan, 2019). In the case of aquaculture, the majority of workers are between 20 and 39 (Hishamunda et al., 2014). The question therefore, at least in the short run, is not so much how to attract youth to agriculture, but rather how to make the best out those who are already there. Indeed, youth is often considered as a likely driver of change in agriculture (AGRA, 2015). The Berlin Charter[29], elaborated under the German presidency of the G20, states that it is essential to "use the diversity, energy, creativity and innovative capacity of youth to seek local solutions to global challenges, foster inclusive rural transformation and ensure that no one is left behind".

Does the youth indeed have the potential to boost the African agriculture sector and its productivity? The evidence on the performance of young versus old workers in agriculture[30] is very scant.[31] To our knowledge, such evidence is entirely missing in the case of Africa. However, the available evidence from the US clearly points to the existence of a concave lifecycle pattern in agricultural production and productivity, with a peak in the age group of 35-44 (Lordkipanidze and Tauer, 2000; Tauer, 1995, 1984), even though the pattern have become much less pronounced in recent years, Tauer (2017) possibly due to the impacts of mechanization (see also section 4.1.2). Several possible explanations for this lifecycle pattern have been advanced. Younger farmers lack productive capital and experience (Tauer, 1995), but have advantages in terms of physical strength and health as well as cognitive abilities (Lallemand and Rycx, 2016). Katchova and Ahearn (2016) show that because they have longer time horizon, young farmers invest much more in farm expansion, with the operated land area growing by 6.3% on average over a decade for farmers below 35 compared to 0.3% for those between 35 and 64. This also goes hand in hand with higher adoption of new technologies and farming practices as well as higher use of inputs (Tauer, 2017). Even though the context varies significantly, these mechanisms can be expected to operate also in case of the African agriculture. In addition to the life-cycle effects, we observe that the current cohort of African youth offers clear advantages in terms of human capital: it is the most schooled cohort ever in Sub-Saharan Africa (Filmer and Fox, 2014), with higher technology and, in particular, digital literacy levels compared to the adult population (AGRA, 2015). Therefore, indeed, youth presents an important resource to advance the agriculture sector.

To date, however, the potential of the African youth has not been mobilized; quite the contrary, youth, and particularly rural youth, struggle to find productive and decent employment. Apart from various structural inefficiencies in agriculture discussed throughout this report, the youth in agriculture are exposed to a range of specific problems, which, in some contexts, can be perceived as barriers to entry as well. These need to be addressed in a systematic way if the African youth is to fully contribute to the development of the food and agriculture sector and the improvement of food production capacities across the continent. These constraints are twofold: first, skills and qualifications, and second, access to resources. Regarding the former, although the level of educational attainment has greatly improved in Africa, youth still lacks the technical and soft skills needed in modern

29 www.bmz.de/en/publications/topics/education/Materialie295_berlin_charta.pdf

30 We refer here to farmers only as the relevant literature is largely limited to crop and livestock producers but excludes fishery and forestry.

31 Note that there is a vast literature in labour economics on the effect of age on workers performance in manufacturing and services sector, mostly in developed countries.

agriculture (see section 5.1). Regarding the latter, the youth is mainly limited in its access to land, which is well documented in the literature (Bezu and Holden, 2014; Kosec et al., 2017), as well as access to finance, usually due to lack of collateral, forcing young people out of the formal financial system (Demirguc-Kunt et al., 2015).

Women in particular face higher constraints in agriculture, especially in terms of access to resources. Women represent less than 15 percent of agricultural land-holders in Sub-Saharan Africa, and less than 5 percent in Western Africa (FAO, 2011) (see section 6.4). Female-headed households are also found to make consistently less on-farm investments than male-headed households (Karamba and Winters, 2015). Women make up around 50 percent of the agricultural labour force in Sub-Saharan Africa – their labour burden often exceeding that of men – but are overrepresented in unpaid, seasonal and part-time work, with limited control over resources (SOFA Team and Doss, 2011). The off-farm food system also tends to employ more women than men, especially in the sector of 'food away from home' where up to 90 per cent of jobs are held by women (Allen et al., 2016). But again, women tend to be concentrated in labour-intensive sectors rather than capital intensive ones, thereby remaining trapped in low investment and low productivity rural non-farm enterprises (Haggblade et al., 2010).

Gender disparities are observed across all employment sectors in Sub-Saharan Africa. Women's earnings are lower than men's earnings; measured as a fraction of men's earnings, they range from 79 percent in Ghana to 23 percent in Burkina Faso (Arbache et al., 2010). Even though it is tempting to conclude that the wage gap is a sign of discrimination against women, to a great extent it only reflects gender inequalities in the underlying factors, such as fewer educational opportunities or limited access to assets, which in turn also limits access to credit as women do not have the necessary collateral. In addition, women and young girls alike have less income-earning opportunities because of the extent of their domestic chores, as well as social norms related to childbearing and marriage (Arbache et al., 2010; Njiraini et al., 2018). Social norms and limited agency affect young boys as well, albeit in a different way. These youth and gender-specific challenges are further exacerbated by the existing structural deficiencies of local economies, and especially segmented labour markets and low employment elasticities of growth that undermine the inclusiveness of economic development.

Investment and policy priorities

In light of the above and in line with the Berlin Charter, it is crucial that policymakers actively engage in policies targeting youth in agriculture and related industries. Taking into account the heterogeneity of contexts and constraints across African countries, it is important that the intervention and investment priorities are adapted to the local conditions (World Bank and IFAD, 2017).

In the short run, the objective should be to improve the productivity of those already employed in the sector. The key priorities should include:

- **Improving access to land** (including land rental systems), with legislation (including receipts and rights to use land) and mechanisms targeting young land-owners specifically.
- **Improving access to credit**, also by providing loan guarantees and insurance.
- **Improving access to technologies**, and in particular, digital technologies.
- **Improving skills**, mainly throughout TVET adapted to the requirements of modern agriculture.
- **Offering internship programs** where young aspiring farmers will have the opportunity to learn modern practical skills and new technologies.
- **Promoting rural non-farm activities**.

Policymakers must acknowledge that these actions will not bring the expected results if unaccompanied by systemic investments in agriculture in the long run. In this regard, policymakers should take actions to:

- **Boost agricultural productivity** by addressing challenges exposed throughout this report.
- **Enhance market linkages** between agriculture and the rest of the economy.

- **Adapt educational curricula** to the demands of agriculture and related industries, focusing not only on farming, but also on high-skill technical occupations.
- **Invest in rural infrastructure** in order to boost connectivity, both physical, i.e. road network and transport facilities, and virtual, i.e. fast Internet and mobile network coverage.
- **Invest in rural development** in order to make rural areas attractive for young people, by improving accessibility and quality of public amenities and services, including cultural services.
- **Engage rural youth in the policy process** so that their voices are heard.

5.3 Digitalization

Digital technologies hold the potential to boost supply-side capacities in African food and agriculture. Mobile phones are the most widely used digital technology across the continent. They can facilitate business operations, either as a communication tool or via dedicated services offered to farmers and others in the agricultural value chain. They can thereby enable access to information, input and output markets or financial services (Baumüller, 2018; Malabo Montpellier Panel, 2019a). Other as yet less widely used digital technologies include computers, tablets, 3D printers or various data collection devices such as sensors, GPS trackers or drones. Often, a combination of various technologies are used.

Supply-side improvements with the help of digital technologies can potentially occur along the entire value chain. To date, much of the focus has been on improving the productivity of smallholder farmers or livestock producers. A recent review of digital solutions in the agriculture sector (D4Ag), which identified 390 such solutions in operation across Sub-Saharan Africa (Tsan et al., 2019)[32], found that digital services were most commonly used to offer **advisory services** to smallholders (68 percent of registered users). The largest advisory service in SSA is in Ethiopia where the state-run 80-82 Farmer Hotline reaches four million farmers via interactive voice response and SMS.[33] Another example is WeFarm, which offers a social networking platform that enables East African farmers to seek advice from other farmers.[34]

Among the most promising use cases, digital technologies can improve access to **financial services,** and thereby enable investments and help mitigate risks. Mobile phones are already widely used to send or receive money through mobile payment systems, such as M-Pesa in Kenya. Digital technologies can also facilitate access to loans, for instance, by using data collected through the mobile phone for credit scoring or by assisting in the transfer and management of loans and related payments (see section 5.5). A third area includes insurance provision. For instance, the crop insurance scheme ACRE Africa[35] uses remotely collected weather data to trigger insurance payouts in the case of crop or livestock losses.

Another important area of application relates to improving **market linkages**, including input, labour and output markets. Such functions are increasingly being offered together with informational services, in particular to link sellers and buyers of produce through virtual trading platforms. Digital tools can also improve market linkages by better integrating supply chains to increase efficiency, reduce post-harvest losses (see section 4.1.4), improve traceability and facilitate participation in regional and global value chains. The German software company SAP, for instance, has developed a digital tool to trace raw material all the way back to the individual producer.[36] Another example is

32 Tsan et al. (2019) define D4Ag as the use of digital technologies, innovations, and data to transform business models and practices across the agricultural value chain and address bottlenecks in, among other things, productivity, postharvest handling, market access, finance, and supply chain management so as to achieve greater income for smallholder farmers, improve food and nutrition security, build climate resilience, and expand inclusion of youth and women.

33 www.ata.gov.et/programs/highlighted-deliverables/8028-farmer-hotline/

34 https://wefarm.co

35 https://acreafrica.com/

36 www.sap.com/germany/products/agriculture-supply-chain-mgmt.html

the Kenyan company iProcure, which prides itself on being the largest agricultural supply chain platform in rural Africa.[37]

So far, the level of uptake and impact of digital technologies are difficult to quantify. While the widespread adoption of mobile phones across the continent is well-documented[38], it is unclear to what extent they have been employed in the food and agriculture sector, and if they have brought the anticipated benefits.

Data collected on the use of dedicated D4Ag solutions suggests that many such services exist in Africa, but that their reach is limited and geographical spread uneven. Of the 33 million registered users of the 390 services identified in the review, 42 percent are thought to be engaged, i.e. know how to use the services, and just 15-30 percent are active users (Tsan et al., 2019). Most of the users (70 percent) are located in East Africa where over half of the providers are headquartered. Young people are the main users of the digital services; the majority of registered users (>70 percent) are below the age of 35. The reach of most services is small and just 15 D4Ag solutions exceed the one million-user mark.

Limited access to finance can partially explain these numbers. Many D4Ag solutions still rely on investments from donors while private sector investments are lagging. In 2018, investment in Africa-based D4Ag start-ups represented only 3-6 percent of all Africa tech start-up investment (Tsan et al., 2019). Although most of the available digital solutions seek to generate revenue from their services, only about a quarter of surveyed companies self-reported to be financially sustainable (Tsan et al., 2019). This is unsurprising given that many of the services are still new (i.e. less than three years old). It is estimated that the current revenue of all of the solutions only accounts for 6 percent of the addressable market, highlighting a significant potential for expansion.

Based on the evidence available to date, it is not possible to quantify the impact of information and communications technology (ICT) on the food and agriculture sector, e.g. on yields, productivity, incomes or food security. The few available studies are limited in their scope and rely on the perception of their users or self-reporting by providers rather than collected data. Investments in future research in this area are necessary to understand the scale and pathways of impact. Nevertheless, available evidence on the impact of D4Ag solutions hints at some positive impacts on agricultural productivity (Baumüller, 2018; Tsan et al., 2019):[39]

- Farmers report that improved **access to information** through D4Ag solutions has helped them to better deal with weather-related risks and improve management practices. Evidence suggests that access to price information via digital solutions can improve production planning, but has had limited impacts on the prices received for produce.
- In the area of **financial services**, most studies have focused on digital payment services, which have benefited farmers by enabling them to receive money more easily, either in the form of remittances or from their off-farm business activities. Studies on the role of digital technologies in accessing finance are not available.
- Empirical evidence suggests that D4Ag solutions that facilitate **marketing** of produce have had a limited impact on trading patterns because of other constraints in the rural context that undermine the functioning of markets.
- Evidence on the impact of digital solutions on **supply-side efficiency** is limited. An internal review by the Kenyan company Virtual City of its Agrimanagr service showed that the use of digital tools could speed up payments to farmers, cut purchasing times and reduce fraud.

A number of trends are likely to increase the reach and transformative power of digital technologies in African food and agriculture:

Different types of services are increasingly being bundled and offered via platforms. Indeed, more than half of D4Ag's 390 services provided more than one function. Such platforms allow for a better integration of different types of services, reduce operational costs and enable users to benefit from different functions without having to subscribe to a myriad of different digital solutions. Research into the impact of such platforms is still lacking.

Smaller start-ups have to date dominated the D4Ag sector in Africa however the move toward platforms is increasingly attracting larger players to the scene. The

37 https://iprocu.re/

38 www.itu.int/en/ITU-D/Statistics/Pages/default.aspx

39 This section provides a summary of key findings from empirical literature. Details and related references for the specific studies from which the findings were drawn are provided in Baumüller (2018).

Kenyan mobile network operator Safaricom, for instance, has launched Digifarm, which works together with other service providers to provide "one-stop access" to advisory, financial and marketing services for farmers.[40] The engagement of larger players is likely to increase the reach and quality of digital services, as they tend to have more resources, larger networks and are able to initially take financial losses or offer services free or at reduced prices. Care must be taken to ensure that they do not push out the local start-ups that have so far driven this sector in Africa and thereby contributed to income and employment generation.

The trend towards more integrated services is supported by the growing adoption of emerging digital technologies beyond the mobile phone (Baumüller and Kah, 2020):

- Among the most promising technologies are **devices to collect large amounts of data** on the ground or remotely through satellites, combined with artificial intelligence-enabled systems for data analysis to inform decision-making. In South Africa, for instance, the company Aerobotics uses satellite and drone images to detect pest and disease outbreaks on farms.[41] While the resulting solutions are complex, the interface for the end-user can be relatively simple, thus catering to the lower technological capacities and (digital) literacy of small-scale producers.
- **Blockchains**, or distributed ledger technologies, promise to revolutionize record keeping, product tracing and contracting (Tripoli and Schmidhuber, 2018). In the food and agriculture sector, areas of application include, for instance, smart contracts, management of registries, supply chain management and financial services. While not yet widely applied in the African sector, existing examples hint at the potential. AgriLedger, for instance, is using its blockchain-based traceability system with Kenyan wheat farmers to assist them with record-keeping on their own farm and to track the produce along the value chain.[42]
- Another area that holds promise is the use of **digital technologies to automate operations** in agricultural production and food processing. Drones and robots are being developed that can be used for seeding, weeding or the application of fertilizer or pesticides on farms; the Nigerian company BeatDrone, for instance, employs drones to spray on farms.[43] In the manufacturing sector, automation technologies (also referred to as Industry 4.0) can help to improve efficiencies and ensure better and more consistent quality.

With such trends, data collection and use will become increasingly important. There is a need to strike a balance between reaping the benefits of such data while also protecting the rights of those providing the data. While many African countries already have data protection laws in place or are in the process of developing them, implementation of these regulations will need to be improved. Moreover, a review of D4Ag solutions across Africa has shown that only a minority actually comply with national regulations by asking for consent or informing users of how data is collected and shared (Chichaibelu et al., forthcoming).

40 www.safaricom.co.ke/business/digifarm

41 www.aerobotics.com/

42 www.agriledger.io/

43 http://beatdrone.co

Investment and policy priorities

Increase investments in infrastructure for mobile connectivity across Africa, not only to expand the reach of networks, but also to improve network speed, reliability and affordability. The African Development Bank estimates that an addition US$ 4-7 billion needs to be invested in ICT infrastructure every year (AfDB, 2018). This will increasingly become important to enable the use of emerging technologies that rely on a fast and stable internet. Priorities for investments are terrestrial fibre optic cables as well as "last mile" infrastructure to connect end-users to existing networks. In terms of affordability, reducing the cost of data will be most important to increase the use of the internet and related services. Particular attention to reach currently under-served rural areas and population groups is necessary, for instance through universal access funds that use levies on telecom operators to finance infrastructure, on-site connectivity or digital literacy training.

Provide a conducive innovation environment for local D4Ag services providers. Expansion of innovation hubs and accelerators would offer a space for local developers to engage with mentors, collaborators and funders, and to help bring start-ups to scale. Across Africa, over 600 such hubs are already active and additional investments would support them. In addition, improving access to mid-level finance would enable entrepreneurs to move beyond the start-up phase. Finally, the business environment as a whole needs to be strengthened to incentivise investments and ensure survival of promising start-ups, including legal predictability, positive fiscal policies providing incentives, and low levels of corruption.

Strengthen human capacities to develop and use digital innovations in food and agriculture. Two areas of investment are important here. First, to strengthen the human capacities of digital innovation service providers through dedicated higher-education courses. Several such courses have already emerged, in particular in East Africa. Courses that convey sectoral expertise related to food and agriculture should be included as part of the training. Second, improve digital literacy of users to facilitate uptake of D4Ag solutions by integrating related training into school, vocational training and university curricula. Training activities should also target possible intermediaries between D4Ag services and farmers, such as extension agents, agro-dealers or mobile money agents.

Most importantly, digital technologies need to be embedded in **broader agricultural and rural development strategies** (as outlined in the remainder of this report) to improve the overall context in which the D4Ag solutions are provided and to enable users to take advantage of all their functions.

5.4 Research investments in partnership

Investment in agricultural research and development (R&D) is one of the most important drivers of agricultural productivity growth (Evenson and Gollin, 2003; Fuglie and Rada, 2013; McIntyre et al., 2009). Different studies have shown that the returns to agricultural R&D investments is huge (Alston and Pardey, 2017; Gardner et al., 2001; Mogues et al., 2015). For example, it is estimated that every US dollar spent on national agricultural R&D generates average returns in the order of US$ 3 (Fuglie and Rada, 2013; Lynam et al., 2016). Studies have also shown that the impact of expenditure on agricultural R&D is much higher when compared with expenditure on other modern agricultural inputs (Mogues et al., 2012). Moreover, sustained spending on agricultural research is critical given the time lag between investments and expected returns – about 10 years, according to a study by Alene (2010).

5.4.1 Research and development investments

African governments have recognised the critical role played by agricultural research and development. The CAADP has stressed the need to expand agricultural research and technology dissemination and adoption as one its "four pillars" strategies, and the African Union through NEPAD has set a target for government spending on agricultural R&D of at least one percent of agricultural GDP. The Science Agenda for Agriculture in Africa (S3A), adopted at the 2014 African Heads of State Summit, also stressed the need to develop a continent-wide implementation plan.

However, actual R&D investments by central and local governments in Africa are still too low to impact agricultural productivity (Alston and Pardey, 2014),[44] even though they remain the most important source of funding for public agricultural R&D. Generally, the Global Forum on Agricultural Research recommends that lower-income countries invest at least one to 1.5 percent of their agricultural GDP in agricultural research (Lele et al., 2010). A report by the International Food Policy Research Institute on agricultural research investments in Sub-Saharan Africa showed that the agricultural investment intensity has actually declined since 2014 (Beintema and Stads, 2017)[45]. In spite of the NEPAD's at least one percent public spending target on agricultural R&D, only six of 36 countries in-

44 A study by Benin et al. (2016) reveals that most Sub-Saharan African countries allocated less than five percent of their agricultural budget to research over the period from 2010 to 2015.

45 Agricultural investment intensity is defined as the expenditure in agricultural R&D expressed as a share of agricultural GDP.

cluded in the study invested more than one percent of their agricultural GDP in research and development in 2014 (Beintema and Stads, 2017; World Bank, 2016). There are also huge variations in spending among these countries. In general, Africa's average agricultural research intensity ratio dropped from 0.68 percent in 2000 to 0.46 percent in 2014 (Beintema and Stads, 2017).

Most of the available finances to agricultural R&D are devoured by staff salaries and operating and programme costs, with little leftover for capital improvements. According to a study by Beintema and Stads (2017), for the period 2009 to 2014, about 54 percent of public spending in the 36 countries studied was used to finance staff salaries while operations and programmes, and capital improvements received only 29 and 17 percent of public spending respectively. Many African countries have insufficiently trained and experienced staff with relevant post graduate qualifications (Lynam et al., 2016). Faculties of agriculture and agricultural research organizations are in short supply of master's degree and doctoral level agricultural scientists. Though student enrolment at African universities has grown rapidly in the past few decades, the number of students enrolled in postgraduate programmes in the faculties of agriculture is still quite small. When faced with budget constraints, and due to their large number of staff and programmes, National agricultural research systems (NARS) in Africa are often forced to cut non-wage operating expenses such as expenditures on laboratory supplies, equipment, spare parts, training, maintenance, fuel, and the like. Between 2000 and 2011 half of all Sub-Saharan countries experienced near-zero or negative growth in agricultural R&D spending (World Bank, 2016). As a result, the performance of the research systems has been unsatisfactory.

5.4.2 The case for collaboration and partnership

In a context of limited and declining public spending for agricultural research at the national level, inadequate resources are allocated over too many topics and programmes. In addition, there is a duplication of efforts as each country pursues the same, rather limited, research agenda. Collaboration and partnership with regional and sub-regional organizations will, therefore, play a prominent role in financing and enhancing the effectiveness of agricultural research systems in Africa. Research partnerships with national and international organizations is necessary for developing and promoting agricultural innovations to increase food production and reduce poverty. Recognizing this fact, the NEPAD has clearly stressed the need to establish partnerships, through collaborative research, between regional, continental and global research centres.

By pooling limited resources and talent, partnerships can facilitate the undertaking of joint research agendas among participating countries and thereby help to improve the effectiveness of agricultural research systems. Cooperation in the form of research alliances and partnerships could include the establishment of multi-sectoral platforms for mutual learning, peer review and mutual accountability (NASAC, 2018). Partnerships are also presumed to lead to the generation of technical, institutional and organizational innovations for quality improvement (Hall et al., 2004). A partnership approach in agricultural R&D would furthermore enable new technologies generated in one location to be evaluated and adapted to diverse production environments in other locations. This is important since modern technologies in agriculture are not always universally adaptable to environments other than those in which they are developed. Much, but not all, agricultural research is location-specific.

Research partnerships should include all the key stakeholders in the research value chain, including the national agricultural research system (NARS), local administrators, farmers, farmers' organisations, non-governmental organizations, the private sector, and Consultative Group on International Agricultural Research centres (CGIAR), etc. National agricultural research institutes (NARIs) could work with national, regional and international partners and collaborators based on mutually agreed frameworks. For example, the NARS provide local knowledge, farmers provide their indigenous knowledge, land and labour, the private sector provides production, marketing and information; NGOs participate in training and financing, the CGIAR centres help with capacity development, farmers' organisations rally farmers at the local, regional and national level; and local government administration provides policy support. The partnership and collaboration could involve joint research projects, technology demonstration and promotion, exchange of staff, student, and funding, etc.

Creating and strengthening partnership between African NARS and national and global research centres

would allow participating institutes to specialize in selected strategic research areas only. The huge diversity among countries makes generalisations about the actors involved in African agriculture difficult. In most cases, the NARS includes NARIs as well as several higher education institutions (Roseboom and Flaherty, 2016). African NARSs are often highly fragmented at the national level, and have only limited agricultural research capacity forcing them to focus mostly on adaptive research. Therefore, such partnerships would enable NARSs to benefit from economies of scale and would eliminate wasteful, duplicative research. Efforts should also be made to enhance the partnerships of researchers from NARS and sub-regional research organizations with the private sector and the civil society sector. NGOs have always been active partners in fighting poverty and strong advocates for the social, economic and political rights of the poor. Hence, NARIs should try to improve their collaboration with NGOs. The African research system is also dominated by a public sector research approach with little or no private sector participation. Wherever conditions permit, NARIs and continental and sub-regional agricultural research institutions should establish partnerships with the private sector.

5.4.3 Pre-existing research partnerships

Four sub-regional research organizations[46] exist to coordinate agricultural R&D efforts across Africa's regions. The Forum for Agricultural Research in Africa (FARA) was established in 2001 as an apex continental organization to promote and coordinate collaboration in agricultural research. Development of partnerships and strategic alliances is considered as one of FARA's core practice areas, as a part of its networking support functions (Adekunle et al., 2013). This function aims to identify effective partnership models that would better serve national and sub-regional research systems across the continent. Nevertheless, better coordination and clear separation of responsibility is required since the mandates of FARA and the sub-regional research organizations strongly overlap. In addition, both FARA and the SROs depend heavily on donor funding, which may be unsustainable.

At the global level the Consultative Group on International Agricultural Research (CGIAR) Consortium, comprising a group of 15 international agricultural research centres, is an important platform for agricultural research partnership. The CG centres try to address global development challenges by conducting joint research with NARSs, training scientists, and providing access to improved germplasm, among other activities. Over the years the CGIAR centres have been the main suppliers of agricultural innovation in Africa. The CGIAR centres are better funded than African NARSs. However, there has been weak coordination among the different CGIAR centres and programmes leading to duplication and sometimes competition (CGIAR, 2005). In more recent times, attempt has been made to improve the collaboration between the CGIAR centres, the sub-regional research organizations and the NARS through the setting of joint research priorities.

In addition to collaboration with CGIAR centres, the African agricultural research system as a whole has benefited from strong bilateral research cooperation with research institutions in industrialized countries. Research institutes and universities in industrialized countries have provided various kinds of scientific support to address specific agricultural research problems in African countries. For instance, the Platform for African-European Partnership on Agricultural Research for Development, hosted by FARA is an effort to strengthen agricultural research collaboration between Europe and Africa. Similarly, the Green Innovation Centres supported by the German government offer an important opportunity for bilateral research partnerships. South-South collaboration in agricultural research has also been growing, in particular with Brazil and China.

The potential for private sector involvement in agricultural R&D in Africa is enormous. Private agricultural research actors can be divided into three categories: research conducted by agricultural input industries, research conducted by companies involved in production, and research conducted by the agricultural processing industry (IFPRI, 2016). However, there is very little private agricultural research effort in Africa and it is limited to a few food crops only. African private agricultural research is constrained by limited markets, shortage of technical research staff, weak public sector research programmes and an unfavourable business environment (such as weak intellectual property rights) (IFPRI, 2016). Private firms could potentially finance research activities hosted by national agricultural research institutes and universities.

46 North Africa Research Organization (NARO), West and Central African Council for Agricultural Development (CORAF/WECARD), Center for Coordination of Agricultural Resources and Development for Southern Africa (CCARDESA) and the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA).

Investment and policy priorities

Invest in food and agricultural research and development (R&D) as an important tool for broad-based innovation. Agriculture in SSA requires significantly higher investment in R&D. Although agriculture and food security are currently clear priorities on the political agenda of many low-income countries, investments in R&D have not increased sufficiently. Stronger international food and agriculture science partnerships between science-rich countries and emerging economies can make important contributions. Besides, introduction of innovative funding modalities, and coordination and prioritization of relevant work among research agencies is needed in the face of scarce funding.

Amplify the benefits of agricultural R&D by improving the linkages in agricultural research between producers, private and non-profit sectors to ensure more effective use of agricultural R&D. The NARIs in Africa could enhance the adoption of their research outputs if they engage and interact with the private sector, farmers' organizations and civil society actors. These organizations are particularly important partners in problem identification and in validating and disseminating new technologies. These partners can also participate in lobbying African governments for increased support to agricultural R&D.

Improve linkages between agricultural research centres and extension providers. A crucial element to improve the performance of the agricultural research system is the effectiveness of the link between research and the extension system. Thus, improving the efficiency and addressing the capacity and funding challenges of agricultural extension services is necessary.

5.5 Rural and agricultural finance

After years of policy reforms, Africa countries still lag in providing efficient financial services to both agriculture and rural areas. New products, delivery channels, and partnerships, along with greater attention to savings and other financial services, present an array of hope to rural dwellers with regards to financial inclusion and all the benefits that come with it.

5.5.1 The current status of rural and agricultural finance in Africa

Improving access to financial services for agricultural producers and agribusinesses is vital to unlocking Africa's agricultural potential and financing the growth of the sector. Agricultural producers and agribusinesses are the biggest investors in agriculture, thus improving their access to financial services, such as credit, savings, payments and insurance products, is pivotal for enhancing investment in the sector and hence growth, and improve the viability of agricultural credit products (AU and GIZ, 2012).

The agricultural finance sector in Africa has a lot of potential for development, because producers' and agribusinesses' financial needs remain unmet. Of the total credit available to industry and other sectors, agriculture receives the least. This leaves actors in the agricultural value chain, particularly small-scale producers, reliant on whatever little savings they have or upon other informal sources of credit. Currently, credit to agriculture, forestry, and fishing consists of a small percentage of commercial lending in Africa, with the share of commercial lending to agriculture, forestry, and fishing ranging from three percent in Sierra Leone to 12 percent in Tanzania, while general access to financial services in the agricultural and rural sectors remains low (AfDB, 2016a). Overall, SMEs in Sub-Saharan Africa are estimated to suffer from a financing gap of US$ 331 billion (IFC, 2020), a large portion of which stems from the agricultural sector (CTA, 2016). Where there is access, transactional costs are high and some services are of unacceptable quality (Dalberg Global Development Advisors, 2016; Sarris, 2016).

Furthermore, most of the agricultural financing to small-scale producers is available only in the form of short-term export trade financing offered to producer organisations. This is problematic because just ten percent of smallholder farmers belong to such organ-

isations and hence only about five percent of their total financing demand is actually met. Since this type of financing mostly focuses on export trade financing, it overlooks the demand for financing staples, which comprises 90 percent of overall demand (Sarris, 2016).

A number of existing finance models for small-scale producers target agricultural needs, including credit inputs paid to producers directly by value chain actors, trade finance loans for producer groups and working capital loans paid directly from micro-finance institutions (MFIs) or from state banks (Dalberg Global Development Advisors, 2016). However, the significant disparity between supply and demand creates a gap which informal finance providers such as rotating savings and credit associations, local credit unions, financial NGOs, local private moneylenders, and friends and relatives attempt to fill (Sarris, 2016).

Agriculture faces high systemic risks that make it difficult for financial institutions to engage with the sector. Financial institutions are often unable to adequately assess risk in the sector and therefore reluctant to develop sustainable financial products for producers, agribusiness and other actors in the agricultural value chain. As a result, actors such as smallholder farmers and other small-scale producers lack access to adequate financial services which in turn limits their growth. Specific agricultural constraints make it particularly difficult to finance the sector, as land tenure systems prevent the use of land as collateral, rain-fed agriculture is associated with high risk, and prices fluctuate. While MFIs have attempted to service poor farmers, they are largely urban-based, leaving out more rural farmers, and generally provide only limited support that is confined to covering the need for working capital (Odhiambo, 2007). Rural providers tend to lack institutional capacity and perceive the risks of servicing the agricultural sector as too high (Beck and Maimbo, 2013).

5.5.2 Innovations and emerging trends

Some promising innovative approaches are being introduced in Africa. Agricultural leasing offers a cushion to young entrepreneurs and producers without much collateral. By borrowing, or leasing, an asset for a specific amount of time in exchange for periodic payments, lessees have greater access to equipment and land since they are not required to have a lengthy credit history or assets to serve as collateral. Rural lessees in lower-income countries, however, are expected to contribute additional collateral and a higher security deposit or down payment when leasing (IFC, 2012). Micro-leasing offers asset-backed loans to rural micro entrepreneurs so that they may purchase assets to generate income. This offers flexibility in repayment and a suitable grace period (Dalberg Global Development Advisors, 2016).

Warehouse receipt financing, a form of funding secured by commodities stored in a warehouse whose existence is proven by a receipt, could improve access to funds. This gives liquid collateral to banks, allowing producers to have easier access to credit (IFC, 2012). Crop receipt financing is a similar type of innovative funding; however, it secures funding prior to harvest as opposed to after. A crop receipt is a promissory note issued to a producer or farmer organization that stipulates delivery of a specified number of crops, livestock or the cash equivalent at a future date. Physical crop receipts work similarly to a prepaid forward delivery contract, whereas financial crop receipts function as collateralized loans (Hollinger and Gross, 2019).

The rise of digital financial services opens up the potential to overcome barriers and increase funding in the agricultural and rural sectors. Digital financial services can improve access to agricultural credit by reducing transactional costs. For example, E-warehousing, the digitalised use of warehouse receipts, can be used for loan collateral. By using mobile registration and payments, insurance providers can provide insurance with lower costs to smallholders. Digital finance also allows mobile money transfers, rendering payments to smallholders for agricultural purposes easier, particularly on behalf of governments and organizations. Savings products for small-scale producers are also being offered digitally (GPFI, 2015) (see section 5.3).

The concept of value chain finance has also emerged as a potential way to finance African agriculture. As a finance model it occurs within the value chain and is made possible through the use of value chain relationships and mechanisms (Miller and Jones, 2010; Triki and Faye, 2013). Two strategies can be used to implement value chain finance: the first provides financing against guaranteed purchase agreements with mall-scale producers, and the second provides lending to small-scale producers through the value chains of large multinational commodity buyers. Value chain finance can allow for greater affordability and improved accessibility to financial resources for producers and

rural people in Africa (Triki and Faye, 2013). However, it creates dependence on a single buyer, leaving producers vulnerable (IFC, 2012).

Agricultural insurance cannot be separated from credit as it serves to reduce the risks of agricultural production activities and improve the viability of agricultural credit products. In Sub-Saharan Africa, agricultural insurance had penetrated to just six percent of smallholders in 2015 (Dalberg Global Development Advisors, 2016). Access to insurance has begun to increase in recent years, particularly within private-public partnerships. Non-profit organizations pull the weight of their networks to reach small-scale producers, while private insurers provide and underwrite the insurance contracts. Another form of insurance, index-based insurance, attempts to overcome the challenges faced in traditional forms of crop insurance by covering events negatively correlated with regional agricultural production or income (GPFI, 2015).

5.5.3 Priority areas for action to improve access to rural and agricultural finance

A strategy of strong policy advocacy for expanding agricultural finance should be adopted and anchored within a strong and dedicated institution. Agricultural finance is a policy orphan (AU and GIZ, 2012), necessitating a country-level policy champion that can engage with various stakeholders and lead a specific high-level coordination body to promote policy initiatives. At the same time, political-based interference in agricultural finance markets should be eliminated while still ensuring a well-defined and appropriate role for the government mainly directed at fostering sustainable financial systems and funding agriculture when appropriate. Policymakers must also recognize that the adopted imposition of interest rate caps are detrimental to the sustainable delivery of agricultural finance services and should only be considered where abusive practices occur. Governments should rather focus on reducing risks and increasing confidence in the sector by providing information and incentives to enhance the performance of financial institutions (AU and GIZ, 2012).

Smart subsidies focus on minimizing distortions and maximizing benefits, while also being transparent, rules-bound, and limited and time-bound with clearly upfront defined exit strategies (AU and GIZ, 2012). The approach should centre on supporting public goods that support financial systems, but not on supporting target groups and therefore private goods. Some examples of smart subsidies include time-bound subsidies for financial intermediaries with an anticipated replication effect, subsidies for financial infrastructure, which generates higher returns, and subsidies for economic and social infrastructure to build the capacity of smallholders and other agricultural value chain participants (AU and GIZ, 2012).

A conducive legal and regulatory environment, which considers the specificity of agricultural finance and removes barriers to financing, is necessary. Existing banking regulations may unnecessarily impede agricultural lending to small-scale producers, as (i) producers may be unable to meet loan collateral requirements, (ii) provisioning requirements may be too strict and add to the cost of lending and branching regulations and (iii) reporting requirements may overburden rural finance institutions with unnecessary costs (AU and GIZ, 2012). Allowing the use of alternative forms of collateral such as moveable tangible personal assets, warehouse receipts, future harvest, and other collateral substitutes, may allow producers to meet collateral requirements and improve their access to credit.

State-owned agricultural development banks have traditionally performed poorly. By reforming these banks, through improving their governance and management, agricultural finance can be expanded. The most appropriate strategy for dealing with such banks is the subject of much debate. Some banks have successfully undergone reform, such as the Banque National de Développement Agricole in Mali (AU and GIZ, 2012).

The development of financial infrastructure and reform of land tenure are important. Financial infrastructure, in its infancy in Africa, can be supported by developing credit information bureaus, collateral registries and training institutes for financial institutions. The expansion of financial infrastructure into rural areas has the potential to return high benefits (AU and GIZ, 2012). Land tenure is another important policy consideration. Private ownership of land often does not exist and rights to land, particularly among women, vary from region to region (see section 6.3). To secure land rights and therefore promote financial and agricultural development, policies should promote long-term forms of land tenure for agricultural use (AU and GIZ, 2012). This should be considered on a case-by-case basis, depending on existing traditions.

Large information gaps exist between the African financial and agricultural sectors. This poses an issue to lending, as there is an insufficient understanding of client risk profiles (AU and GIZ, 2012). Farmers must also have access to market data, financial mechanisms and marketing channels to be able to sell goods effectively and pay back loans. Policymakers should take care to invest in better data, knowledge generation and management in order to bridge the information gap. The use of alternative credit data and digital credit scoring system might help financial institutions assess their client risk profiles, reduce transaction costs and allow instant loan approval and disbursement. In this regard, digital finance service providers are strongly positioned to take advantage of data and analytics to broaden their client base and offer a higher quality service to agricultural value chain actors.

Investment and policy priorities

- **Adopt and anchor long term policies to expand agricultural finance in dedicated institutions.** This can be achieved by building awareness of (i) the risks of political intervention on promoting inclusive agricultural finance, (ii) the positive impact of long-term, sound agricultural finance policy.
- **Adopt a smart subsidies approach that supports agricultural finance without causing market distortion.** This approach centres on supporting public goods that help financial systems, rather than on supporting target groups and therefore private goods.
- **Promote conducive legal and regulatory environments that consider the specificity of agricultural finance and remove barriers to financing.** Allow the use of alternative forms of collateral such as moveable tangible personal assets, warehouse receipts, future harvests.
- **Reform state-owned agricultural development banks.**
- **Support the development of financial infrastructure in Africa.**
- **Implement land tenure reforms to encourage the development of agriculture and increased productivity.**
- **Invest in better data, knowledge generation and management** to bridge the information gap between the financial and agricultural sectors.

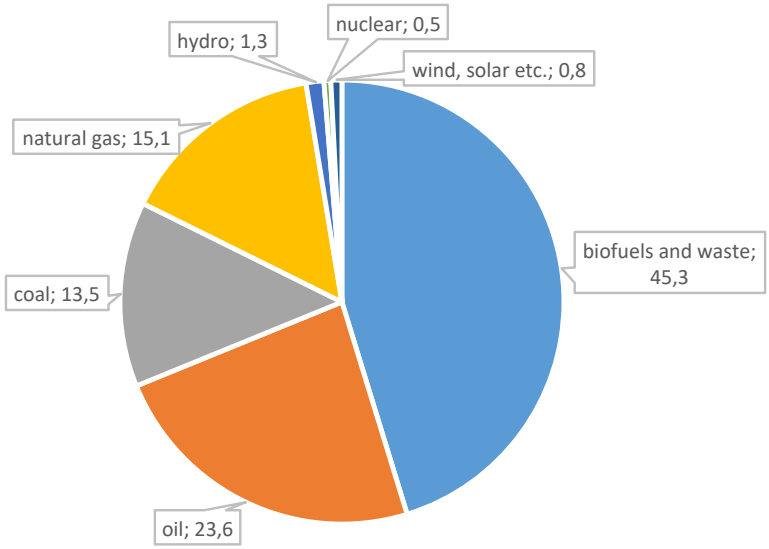
All the above policies, summarised below, must take the mainstreaming of women and minorities into consideration. Outreach services and financial products should be tailored to women, youth and vulnerable populations (GPFI, 2015). The role of digital technology as a potential game changer should not be overlooked: it holds huge potential to increase financial inclusion and innovations that can reach more small-scale producers (GPFI, 2015).

5.6 Energy

Expanding access to energy is a vital component of sustainable development, economic growth, poverty reduction, job creation and enhancing food security in Africa. Currently, about 45 percent of the continent's primary energy supply comes from traditional biomass, i.e. mainly fuelwood, with the remaining share covered by oil (23 percent), natural gas (15 percent) and coal (13 percent) (Figure 18). Renewable energy sources make up only 2 percent of the total primary energy supply. These aggregate numbers, however, are strongly influenced by energy supply mixes in Africa's major energy consuming countries, namely South Africa and the countries of North Africa. In many countries across Sub-Saharan Africa, however, the share of traditional biomass in total energy supply is between 70-90 percent (Mirzabaev et al., 2015).

Currently, about 600 million people, i.e. half of the population in Africa, do not have access to electricity. At the same time, electricity expansion is progressing at a rapid speed: annually, about 20 million people gaining access to electricity across the continent (Malabo Montpellier Panel, 2019b). Ethiopia, for example, was able to expand access to electricity from 12 percent of the population in 2000 to 45 percent in 2018,

Figure 18: Total primary energy supply shares by source in Africa in 2017



Source: Malabo Montpellier Panel (2019b) based on International Energy Agency data

Senegal from 37 to 67 percent, Ghana from 43 to 82 percent, Morocco from 69 to 100 percent, and South Africa from 71 to 91 percent during the same period (World Bank, 2020e). Ethiopia specifically targeted expanding access to renewables and energy-efficient technologies in the agricultural sector as part of its Climate Resilient Green Economy strategy. Ghana and Senegal liberalized their energy sectors to boost energy production and distribution by private companies. Morocco is providing fiscal incentives and subsidies to farmers for the installation of solar energy-driven water pumps. South Africa is investing in off-grid solar systems to provide access to electricity in poor, previously marginalized, rural communities (Malabo Montpellier Panel, 2019b).

Despite this progress in many African countries, it is projected that, taking population growth into account, 530 million people will still be lacking access to electricity by 2030. The lack of access to electricity is particularly high in rural areas: 80 percent of people without access to electricity live in rural areas (Malabo Montpellier Panel, 2019b). Strong reliance on traditional biomass and lack of access to clean energy sources and electricity cause substantial health costs through indoor air pollution and by constraining the expansion of industrial development in rural areas, ultimately limiting opportunities for job creation (Mirzabaev et al., 2015). Reliance on biomass also leads to land degradation across the continent, since trees in forests, woodlands and shrublands are felled for fuelwood and charcoal (Mirzabaev et al., 2019; Nkonya et al., 2016). Moreover, biomass production for energy purposes, including biofuels, often competes with food production for land and other inputs (Mirzabaev et al., 2015).

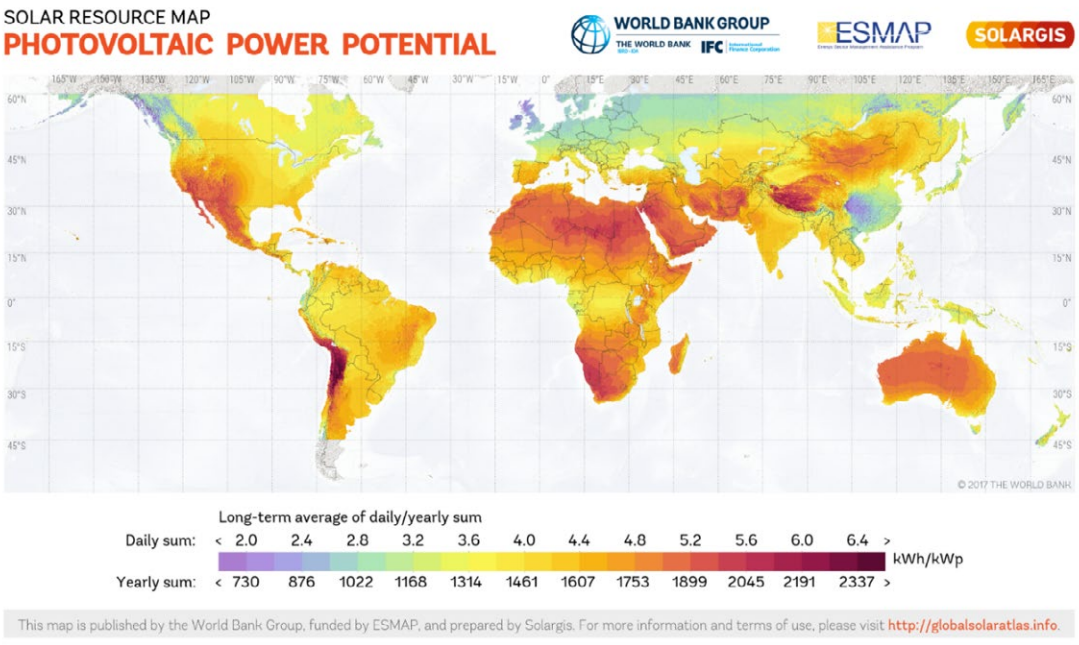
Providing access to electricity in rural areas is a major challenge facing the countries of SSA. Currently, only 23 percent of the rural population has access to electricity. Most of the electricity access is concentrated in capital cities and other urban areas, hence, the access rates to electricity in rural areas are significantly lower. Often the quality of electricity access in many of those areas with grid connection is highly unreliable. Many electricity utilities in the continent are not viable without heavy government subsidies despite growing electricity prices charged to consumers (Trimble et al., 2016). This is due to losses in transmission, distribution and bill collection, as well as overstaffing of public electricity utilities (Trimble et al., 2016). Electricity access across Africa is currently growing at a rate of 5.4 percent per year, but would need to be increased to 8.4 percent annually if the sustainable development goal of universal access to energy to be achieved by 2030 (World Bank, 2017a). Investments of about US$ 120 billion per year are needed until 2040 to achieve reliable electricity supply in Africa, but only about US$ 100 billion were invested in the energy sector in Africa in 2018 (IEA, 2019). For comparison, the amount of European commitments to African energy projects was about US$ 3.3 billion in 2016 (AEEP, 2017).

The Malabo Montpellier Panel (2019b) highlights a strong positive relationship between more energy consumption in agriculture and higher value added per agricultural worker, thus adding to incomes and creating new jobs. The key mechanisms through which expanded access to energy and electricity boosts food production and supply are several. Firstly, having access to energy would allow a shift from manual labour to mechanization in production, thereby raising agricultural labour productivity. Secondly, expanded availability of electricity can facilitate pumping groundwater for irrigation expansion. Thirdly, increasing access to energy and electricity in rural areas and among agricultural producers would mean expanding opportunities for post-harvest processing of agricultural produce, including cold storage, milling, grinding, etc. For the whole Africa, a 1 percent reduction in food losses implies annual gains of US$ 40 million (Obayelu, 2014). Fourthly, more access to energy will help develop food transportation and distribution networks through refrigeration and expansion of transportation opportunities. Lastly, availability of clean and affordable energy at the household level enables cooking without indoor air pollution, and facilitates the expanded use of household appliances, e.g. washing machines (Malabo Montpellier Panel, 2019b).

Africa has a substantial underutilized potential for renewable energy production, particularly through harvesting solar energy (Figure 19). In many locations across the continent, the use of renewable energy sources, as part of decentralized local grids, can be less costly than electricity-generation using fossil fuels. To illustrate, connecting a rural household to the centralized grid could cost US$ 2000 in Rwanda and US$ 1400-1800 in Kenya, mainly because of the expenses on poles and wires (Taneja, 2018). Renewable energy development also has substantial employment generation opportunities. In fact, many governments across Africa are identifying the renewable energy sector as the major action area for creating “green jobs”. It could generate year-round employment for young people engaged in the agricultural sector (Malabo Montpellier Panel, 2019b).

Investing into renewable energy resources in Africa will also have important climate change mitigation and sustainable land management implications (Mirzabaev et al., 2019). The climate change mitigation potential comes not only from reductions in greenhouse gas emissions because of lowered use of fossil fuels, but also through more carbon sequestration via reducing deforestation for obtaining charcoal and fuelwood. Moreover, modelling suggests that large-scale installations of solar and wind farms in the Sahara Desert could lead to a doubling of the precipitation in the Sahel region (Li et al., 2018), with positive impacts on vegetation growth and agricultural productivity across the Sahel.

Figure 19: Solar power potential across the world and in the Sahel region



Sources: https://globalsolaratlas.info. Author: Solargis. Attribution: © The World Bank / CC BY 4.0

Investment and policy priorities

Expand energy access targeting agricultural growth and rural development. Energy is an essential input for agricultural transformation. Energy needs to become an interagency issue with different ministries and public organizations planning and working closely together to expand access to energy in rural areas, with specific programmes expanding energy access for farm mechanization and irrigation, post-harvest processing, and transport and distribution.

Scale up investments in off-grid and mini-grid solutions, including renewable energies, such as solar, wind, and sustainable biomass-based energy. Instead of relying on the expansion of centralized grid connections, off-grid and mini-grid technologies are already rapidly changing Africa's energy outlooks. With the right policy and institutional changes, small-scale energy solutions could offer tailored services for the specific needs of farmers. Investments in start-ups that can innovate and expand electricity access are necessary.

Promote the liberalization of the energy sector and higher involvement of private energy producers. Incentives and an enabling regulatory environment are critically important for the dynamic development of private sector energy producers. Countries that encouraged the emergence of nimble and rapidly evolving private companies in their energy sectors were able to expand electricity access much more rapidly than those relying on sclerotic public utilities.

Develop cross-border policies for energy security. Cross-border cooperation in energy could help stabilize African energy systems, especially in the context of a growing share of renewables (Malabo Montpellier Panel, 2019b). Regional energy integration in SSA could save US$ 40 billion of energy infrastructure costs and reduce consumer electricity bills by US$ 10 billion per year by 2040 (Castellano et al., 2015).

5.7 Inclusive markets

Small farms are highly heterogeneous and diverse. Usually farmers with a landholding of two hectares and below are considered as smallholders, but criteria such as employment, total economic value and social roles are sometimes considered too (Gatzweiler and von Braun, 2016). Small farmers constitute the majority of poor and marginalized rural people in Africa. Their businesses, predominantly crop and livestock production, are highly localized both in terms of resource use and constraints, however they are increasingly affected by complex national and global economic changes (Gatzweiler and von Braun, 2016). Thus, though commercialization of smallholders' businesses heavily depends on local markets, there is a direct connection with national and global technological and institutional changes.

5.7.1 The benefits and challenges of agricultural commercialization

Agricultural commercialization is most widely defined as the participation of small-scale producers in cash crops production. Other definitions are based on the share of outputs sold to the market and the amount of external inputs used for the production of crops. A broader definition of agricultural commercialization includes participation in cash crops production as well as the production of market-oriented food crops and livestock products (von Braun, 1995). Agricultural commercialization has long been recognized as an important engine to rural economic transformation through backward and forward linkages among on-farm and off-farm activities (Pingali, 1997; Pingali and Rosegrant, 1995). Commercialization helps to increase the market participation of small-scale producers through increasing their access to input and output markets. This can be achieved through the development of agricultural input supply systems, farmer organizations, agribusiness development, and market infrastructure development and management.

Another form of commercialization is the commodification and improved production of food crops, often staples, also acknowledged as a strategy to enhance food security and increase the incomes of rural households. The productivity effect occurs in

two different ways. On the one hand, the commercialization of food commodities — as for example with teff and wheat in Ethiopia, with millet in Senegal, and with cassava and white maize in many African countries — directly contributes to improvements in the productivity of these food commodities and the overall supply of food. On the other hand, commercialization relaxes liquidity constraints thereby increasing the use of external inputs not only for cash crops but also for food crops. This creates synergies among cash and food commodities, and facilitates the adoption of new technologies for food crops as most technological innovations are characterized by increased use of purchased inputs and specialization.

The empirical evidence for the positive impact of commercialization on productivity in food crops is compelling. For instance, a 2016 study in rural Rwanda and the Democratic Republic of Congo (DRC) showed a 22 percent increase in banana and legume yields per hectare as a result of a one percent increase in commercialisation index (Ochieng et al., 2016). This result is consistent with previous findings in Ethiopia (Bekele et al., 2010) and confirms the importance of encouraging farmers to engage in commercial oriented farming. Regarding the on-farm income effect, many case studies in Africa demonstrate that household income increases as farm resources are reallocated from subsistence to commercial crops. In Kenya, growing vegetables for export increases the income of smallholders by 49 to 52 percent compared to non-commercialized farmers (Muriithi and Matz, 2015). The effect is robust only for poorer households. A similar income effect is observed in Tanzania (Herrmann et al., 2018).

Agricultural commercialization can also serve as a catalyst for a rise in rural off-farm incomes and the wider commercialization of the rural economy. For example, greater agricultural commercialization increases the agricultural supply of marketable surpluses and demand for inputs and services, which attracts the emergence of small businesses such as traders, processors, brokers, and logistic providers. A rise in off-farm businesses in turn increases demand for agricultural products and labour that increases farm gate prices, employment and productivity. The end result is an improvement in the total cash income of smallholders, small businesses and other households from employment in both on- and off-farm activities (von Braun, 1995).

Since the majority of poor people in Africa live in rural areas, an increase in the income of rural households is expected to have a higher effect on food security and poverty reduction than increases to the incomes of urban households. However, the actual impact of commercialization on rural households' food and nutrition security remains an important public concern due to two major empirical challenges. The first relates to the question whether increased income actually results in improved food and nutrition security. In areas where commercialization is dictated by a shift of production from subsistence crops to a few commercial crops, commercialization may not necessarily improve welfare outcomes (Carletto et al., 2017; Herrmann et al., 2018; Radchenko and Corral, 2018). If households specialize in a few commercial crops such as cereals, coffee or cocoa and have limited market access to nutritious foods such as animal products, vegetables and fruits, they tend to consume less diversified food; hence commercialization will not necessarily improve food and nutrition security. In contrast, if commercialization involves the production of diversified agricultural commodities, both for subsistence and markets, and/or is complemented by increased access to food markets, commercialization will lead to significant improvements both in the amount and the diversity of food being consumed (Kuma et al., 2019; Ogutu et al., 2014). For instance, a recent study indicates that production diversification is positively and significantly associated with dietary diversity, and that access to markets significantly improves dietary diversity (Ludwig, 2018).

The second empirical challenge relates to the inclusiveness of agricultural commercialization in Africa. Studies reveal that unlike the huge anticipation of pro-poor economic growth, the recent surge in economic and agricultural growth in Africa is less inclusive of land-poor, young, and female-headed households, as it has little effect on their incomes and productivity (Ngepah, 2017). This is partly due to the inherent characteristics of economic growth driven by – albeit with differences across countries – demand-side factors such as increased demand for primary products, and constrained by supply-side factors that include lack of access to (i) finance, (ii) effective institutions providing productivity enhancing inputs and technologies, and (iii) basic resources including land and energy. Unfortunately supply constraints are much more prev-

alent and detrimental to rural poor households, and hence these households are excluded from emerging economic growth. This is reflected in high levels of rural young unemployment, significant outmigration and widespread malnutrition in some parts of the continent. The promotion of inclusive and sustainable agri-food systems that can generate larger incomes, decent jobs, and contribute to healthier diets for the rural poor is required.

A diverse set of factors influence whether or not, or how far, a small-scale producers will commercialize, with farm size, production technology and market access among the most important. Guided by this, strategies that aim to commercialize rural farm businesses promote production technologies and the creation of market access for outputs, inputs and labour. The strategies commonly used to create or improve market access for rural households aim at relaxing supply-side and/or demand-side constraints. Supply-side constraints can be relaxed by enhancing the capacity of rural households to improve their productivity and participate in markets and business, e.g. by promoting collective action, contract farming, training, access to credit, construction and maintenance of small-scale feed roads, development and management of rural centres (Table 8). Demand-side constraints can be relaxed by improving the overall functioning of markets, e.g. expansion of roads, ICTs, warehouse receipts systems, commodity exchange markets. Experience shows that in many African countries, interventions that relax supply-side constraints are more effective than those that relax demand-side constraints (Aragie and Balié, 2020).

Table 8: Strategies and innovations that link farmers with markets and promote rural business in Africa

PURPOSE	STRATEGY	INNOVATIONS	LIMITATIONS
Linking producers to markets	Farmers' Marketing Organizations (FMOs)	Training to group leaders; Reduction in external / government interference; inclusive governance	Side-selling of members; lack of trust and commitment among members and leaders; less participatory governance
	Contract farming /out growers' schemes	Third party contract enforcement; incentive-based contracts	High costs of contract enforcement; limited coverage of staples
	Mobile phone-based access to market information services	Institutionalization of MIS systems; producer-friendly apps; the use of FMOs as MIS intermediaries	Producers' limited ability to use mobile phones; lack of reliable and accessible information sources; limited network coverage; producers unable to make spatial and temporal arbitrage
	Grading and standards	Introduction of weighing scale; training on quality measurement	Lack of commodity-based standards for quality and size; problems of enforcement
Promoting small business in rural areas and small towns	Entrepreneurial skill development	Need- and growth-based trainings	Misalignment with needs; repetitive
	Access to finance	Defining typology of rural households; grants to poorest households	Inefficient targeting leading to incentive problems; exclusion of credit to risk averse households
	Marketing support (access to marketplace and linking producers with consumers and firms)	Supporting small businesses to access lucrative markets; allowing businesses to compete among themselves	Low level of marketing support; protection from competition

Source: Based on Abate and Bernard, 2017; Bernard et al., 2019, 2014; Saenger et al., 2014; Tadesse and Kassie, 2017

5.7.2 Linking smallholders with markets through collective action

Promoting collective action in the form of membership-based Farmers Marketing Organizations (FMOs) is a widespread innovative intervention to enhance smallholders' market access through increasing bargaining power, reducing transaction costs and creating economies of scale in output and input markets. Both theoretically and empirically, there is little doubt about the positive impacts of FMOs in improving smallholder farmers' market participation, productivity, marketed surplus and incomes. Recent case studies conducted in Kenya, Rwanda and Ethiopia indicate that participation in FMOs has significantly increased input use, technical-efficiency, crop yields, marketed surplus, incomes, and asset-holdings of smallholder farmers. In Kenya, membership to an FMO increased total household incomes by 24 to 35 percent and decreased poverty incidence by three to four percent (Mutonyi, 2019). In Rwanda, cooperative members received 18 percent more income from coffee than non-members (Ortega et al., 2019). In Ethiopia, membership to an FMO increased farmers' income by about 13 percent (Wassie et al., 2019). FMOs have also significantly contributed to input use, technical efficiency, crop yields and marketed surplus as these organizations provide farm supplies and marketing services that address market failures. There is, therefore, compelling evidence that farmers' organizations can enhance food supply and food security in Africa.

However, many FMOs in Africa remain less inclusive of poorer households and uncompetitive. While entry barriers exclude land-poor households, the strategic and operational pitfalls of FMOs can make them uncompetitive (see Table 8 for some of the limitations). One of the largest challenges to African FMOs, indeed, is the negative correlation between their inclusiveness and competitiveness. Members of well-performing marketing cooperatives have larger landholdings, better farm resources, and better access to extension services compared to non-member farmers (Tefera and Bijman, 2019). Thus, innovative business models are needed to disentangle the negative correlation between inclusiveness and competitiveness in small-scale producer organizations.

The promotion of specialized FMOs having uniform members and limited activities seems to help achieve both inclusiveness and competitiveness. Some studies suggest that the uniformity of membership is more important than the average capacity of members for cooperative performance. For example, in female-dominated cooperatives in Senegal, the probability of an additional member being a woman rather than a man has a higher positive effect on the performance of the cooperative (Faye and Wouterse, 2020). This implies that FMOs owned by all poor or all female members perform, relative to their needs and investments, as well as FMOs owned by all better-off or all male members. Moreover, specialized FMOs that only provide limited services to committed members are more successful than FMOs providing a wide range of services to accommodate diverse needs (Tadesse et al., 2019). For instance, FMOs that only supply inputs to their members are more competitive than FMOs that provide market information to the whole village community irrespective of membership. While the former is a club good, the latter is a public good that should actually be supplied by a public service rather than by a FMO. Therefore, promoting farmers groups which serve specific and targeted needs, rather than FMOs which entertain diverse needs and members, ensures competitiveness as well as inclusiveness. Relaxing entry barriers would also help to accommodate potentially active members.

5.7.3 Linking smallholders with markets and processing

Contract farming, sometimes referred to as 'out grower' schemes, is the other most widely used institutional innovation to link smallholders with traders, retailers and large-scale agro-processers, the latter being the most dominant. Contract farming helps to encourage smallholders to participate in commercial crops and livestock production through secured market outlets, with support covering input supply (with or without credit) and extensions services. In Africa, these contracts cover a wide range of agricultural commodities including cash and food crops, fisheries and livestock products.

The dense literature on contract farming – both in Africa and elsewhere – generally shows its positive impact on the commercialization and incomes of smallholders. Nevertheless it is a rare practice in many African countries. A meta-analysis, which includes mixed evidence from 26 contract farming programmes in 13 African countries indicates that contract farming increases the overall pooled average farmers' income by about 38 percent (Ton et al., 2018). Moreover,

unlike the popular belief that contract farming is feasible only for cash crops, recent studies conducted in Senegal, Ghana and Benin confirm the positive and significant contribution of contract farming to increased commercialization, productivity and supply of food crops such as rice and cashew. For instance, in Benin, participation in rice production contract farming increased farmers' income by 17 percent and rice yield by 13 percent (Maertens and Vande Velde, 2017). Similarly, participation in rice markets and production contracts in Senegal have reduced the household food insecurity scale of participant farmers by 10 and 6 percentage points respectively (Soullier and Moustier, 2018). In Ghana, farmers' technical, allocative and economic efficiencies increased by 21 to 26 percent due to contract farming (Bidzakin et al., 2020). One positive aspect of contract farming in food crops is that it is more inclusive than contract farming in cash crops. For example, in cashew contract farming in Ghana, small-sized farms tended to benefit more than medium- and large-sized farms (Dubbert, 2019).

A further analysis of the evidence presented above suggests the need for a number of programme design reforms to expand the positive welfare impacts and inclusiveness of contract farming. One way to do so is to improve service packages. Rice production contracts in Senegal that complement the introduction of new crops and inputs increased the productivity of small-scale producers more than market contracts[47]. Discretionary payments based on the quality and quantity supplied by producers could help create incentives for increased investment to increase productivity and improve the quality of products. Building the capacity and commitment of the contracting firm to deliver production and marketing services to its out growers is a second programme redesign that could improve the welfare and sustainability impacts of contract farming. The involvement of third parties such as governments, NGOs and FMOs as facilitators and promoters in out grower schemes is also a viable option to harness the strengths of the firm and the farmers and to overcome their institutional weaknesses. Involving farmers' organizations as brokers helps to increase bargaining power and secure a higher price premium. Other interventions for farmers who engage in contract farming may include the promotion of subsistence food commodities, such as vegetables, chickens and cows, for home consumption. This helps to reduce the widespread malnutrition problem associated with specialized food production. Promoting inclusive private sector development, wherein the contracting farmers could become shareholders in the agro-processing firm, can be considered an innovative strategy to enhance both efficiency and equity.

5.7.4 Innovations for small businesses in rural areas

Pervasive entry barriers may prevent land-poor rural households from participating in farmers' organizations and contract farming schemes, irrespective of efforts to help them. An alternative option is to help them engage in micro and small business. The business venture possibilities for rural households are quite diverse and comprise both on-farm activities including poultry, beekeeping, aquaculture, forestry and production of vegetables, and off-farm activities including petty trade, handcrafts and rural services. Such activities do not require large investments and can be easily managed by low-skilled rural households. Since the demand for these products and services are increasing in small towns, they are becoming profitable and attractive. However, both public and private support is required to help poor households engage and become competitive in such activities. The most common public interventions include the provision of financial and skill development services in the form of vocational trainings, concessional loans and business start-up grants, and to a lesser extent, marketing support such as access to marketplace and linking up with large businesses and consumers (Table 8).

The impact of entrepreneurship training is generally positive, enhancing entrepreneurial orientation, innovativeness, risk taking and pro-activeness (Al-Awlaqi et al., 2018). However, for more effective outcomes, training must be aligned with small businesses' needs following their growth trajectories. This means that vocational, commercial and institutional training become more effective if they are provided at the start-up stage, growth stage and maturation stage of the business respectively (Tadesse and Badiane, forthcoming). Training sessions are more effective

47 Market contracts include output transactions and specifies only the quantity, quality and prices of the contract before or after harvest. Production contracts involve transactions of inputs and services besides outputs, and are usually made before planting. While market contracts only help to minimize risk, production contracts help farmers to gain access to production inputs and services too.

and impactful when the selected participants have a balanced set of qualifications and skills. The content of the training should match the ability and needs of the participants. For example, financial literacy training is effective in improving the business performance of women if it is given to women with tertiary education, rather than to women without this education (Brixiová et al., 2020). This implies that public investment in tertiary education is essential to boost the effectiveness of entrepreneurial skill development, which in turn increases the performance of small businesses.

Concessional credit and grants are traditionally given to rural poor households to start businesses. Recent evidence suggests that for the poor who are credit risk-averse, the internal rate of return (which measures the profitability of an investment over time) and the capital growth is higher for grant-based investments compared to investments that were provided in the form of credit, by 9 and 16 percentage points respectively (Tadesse and Zewdie, 2019). This is because grants have reduced repayment disincentives and the fear of risk is avoided. Similarly a long-term experiment to monitor start-up grant recipients in Uganda shows that recipients' incomes increased by 38 percent after four years of the business start-up. Evaluation of the same recipients after nine years demonstrated the lasting impacts of the grants on assets, skilled work, and child health (Blattman et al., 2018). This evidence suggests that grants are more appropriate than credit for small business start-ups. This finding is particularly important when considering that the lowest segment of rural households in Africa are credit-risk averse and have limited social networks. However, efficient identification and targeting is crucial to increase impact and avoid disincentives.

5.7.5 The role of expanding food-retailing in Africa

The expansion of the food-retailing sector, not only through local SMEs but also through national-level and large-scale international supermarket chains, is helping to improve rural-urban consumers' food security (Minten et al., 2017; Reardon et al., 2003). For instance, the rapid growth of large-scale supermarkets in cities plays a critical role in shaping agricultural value chains, by increasing the flows of agricultural goods and increasing the demand for quality and convenience to meet urban food needs. Secondary cities and towns also play an increasingly important role in shaping agricultural value chains, as they account for about 60 percent of Africa's urban population and provide nearby markets for local producers and their input requirements (AGRA, 2019b). However, direct sourcing by supermarkets from farmers is still limited to a few fresh products such as fruits, vegetables, eggs and dairy products (Nair et al., 2018). Directly linking supermarkets with farmers – to reduce marketing costs and pass incentives to producers – is an area where public interventions could help.

Food retailing represents about 20 percent of the total value of the agri-food value chain in sub-Saharan Africa, suggesting that its performance is vital for food security both in urban and rural areas (AGRA, 2019b). Since the majority of retailing shops sell at least some high-value products, consumer demand for these products is transmitted from retailers to wholesalers to sub-Saharan African farmers. This relay passes a strong signal to producers to engage in high-value produce that includes roots and tubers, pulses, fish, meat, milk, vegetables, fruit, edible oil seeds, and feed grains. Expansion of global retailers into Africa's big cities could also help to positively impact domestic markets and products through the setting of quality and safety standards and the experiences and technologies they bring with them. Certification is becoming necessary to show food value chains' compliance with standards set by regulators, though this is partly constrained by the costly institutional and regulatory infrastructure required to sustain such schemes (Henson et al., 2005; Jaffee et al., 2011).

The emerging supermarkets revolution in Africa is fostering the consumption of more diversified foods by urban consumers, which can contribute to an increase in nutrition and more balanced diets (see section 3). Supermarkets' procurement systems can induce the concentration of medium and large food processors, which is an essential element for the growth of the agro-processing industry. These procurement systems and customer demand encourages the fortification of staple foods and preservation of perishables such as fruits and vegetables (IFPRI, 2011). It can also reduce pressure on land and water, thereby enhancing the sustainable use of natural resources (Jia et al., 2018). Fortification and preservation may require the provision of aggregation facilities, which could facilitate access to markets as well as a rise in the establishment of processing plants. However, the impact of supermarkets on food security is not unambiguous. Research in Kenya has shown that shopping in urban

supermarkets increases the body mass index as customers shift increasingly to processed foods (Demmler et al., 2018), which could further exacerbate existing trends of growing obesity rates (Bixby et al., 2019).

Improvements in food safety directly improves nutrition and health by reducing the outbreak and spread of diseases. Quality grading, standardization and food labelling also indirectly improves the food security of poor people in agri-food systems, through creating incentives for them to improve the quality of their food produce, which should eventually translate into an increase in income. This should help to create a competitive market that theoretically at least, should reduce effective food prices through avoiding quality information asymmetries.

In spite of encouraging progress and transformation, the African agri-food value chain is yet to meet the increasing diversified food demands of the population and absorb the growing young labour force. Table 9 summarizes some of the key constraints that limit the midstream segments, including the agro-distribution segments comprising wholesaling, logistics as well as retailing, and presents suggestive intervention areas to mitigate the constraints.

The wholesaling and logistics segment is wrongly perceived to be the "missing middle" in African agri-food value chains, and is often referred to as "the missing link". However, a quiet revolution in the SME trader and logistics segments is underway in sub-Saharan Africa. For instance, the number of SMEs en-

Table 9: Key constraints affecting midstream actors and possible intervention areas

THE MIDSTREAM SEGMENT	CONSTRAINTS/LIMITATIONS	INTERVENTION AREAS
Agri-food distribution (wholesale, logistics and retail	The myths that traders are "exploiters" and logistics service providers are missing	Governments and donors need not and should not "reinvent the wheel"; emerging private actors can take on warehouses, transport, and aggregation facilities services
	Degraded and congested wholesale markets	Restructuring and investing in wholesale
	Lack of knowledge and training of traders and truckers	Training of traders at wholesale markets in handling products at loading and unloading stages
	Poor condition of roads; corruption in the governance of roads	Investing to improve the reach and quality of roads; strong control to reduce corruption
	High fuel costs, and difficult vehicle and machinery importation process	Polices to reduce fuel costs and ease the importation process
Agri-food processing	Limited number of large processors sourcing from small farmers	Aggregation opportunities to pool produce; promotion of direct linkages between agro-processors and contract farmers
	Limited access to energy; uncertainty; excessive regulation	Investment in energy; ease doing business
	Food safety concerns in first and second stage processed milk, meat, fish, vegetables, edible oil, and peanut butter, as well as second-staged processed food and prepared food in restaurants	Expanding and institutionalizing food safety regulations and implementation; investment in food safety capacity; enforcement capacity needs strengthening
	Less diversified and low-quality products	Promoting innovations; protecting property rights
	Low quality and high cost of intermediate inputs such as agricultural outputs	Upstream interventions to reduce production and marketing costs and improve output quality of farmers

Sources: Jaffee et al. (2011); AGRA (2019b); and author's compilation

gaged in millet trading and processing in Senegal has increased by about 400 percent within the past two decades (Tadesse and Badiane, forthcoming). SMEs are proliferating and making large investments, in the aggregate and individually, in vehicles and equipment. Third party logistics services in trucking and warehousing are also flourishing. Despite this fact, the "missing middle" perception has caused governments and donors to engage in the provision of intermediary services, crowding out the reviving private sector particularly at the grassroots level (AGRA, 2019b). This requires a swift political commitment not only to limit governments' direct involvement in these services, but also to support emerging private-sector wholesale traders, truckers and warehouse operators.

Regarding logistics, poor road conditions are detrimental to traders and truckers, delaying deliveries and increasing costs of transportation. Road maintenance is a huge problem that is yet to be given due attention in many African countries. Existence of knowledge gaps in product handling among traders and truckers, especially for perishable products, also exacerbates the real costs of the agri-food distribution system.

In processing, the linkage of agro-processors with small-scale producers remains a challenge. For instance, in Sub-Saharan Africa only five percent of the large agro-processors directly procure from smallholder farmers, through contract farming (AGRA, 2019b). This is partly due to the low quality and quantity of outputs smallholders can supply to these firms (Abebe et al., 2013; Goodhue, 2011). For instance, in a contract farming scheme, quality considerations and sufficiency of supply are among the main contract design problems often reported by major players in the agri-food chain. However, firms are often unwilling to work with smallholder farmers who they consider unviable and not credible for business intermediation (Minot, 2011). For instance, in some cases, farmers try to sell to other buyers to take advantage of good market prices. Since most contracts are not legally enforceable, even when they are legally binding on paper, firms that incur bad experiences often refuse to work directly with farmers in the future. To mitigate this problem, measures such as group lending, information sharing, good communication and proper monitoring are required.[48]

One final problem experienced by the African agri-food processing sector is the low quality and safety of processed products (Henson et al., 2005). For instance, supermarket suppliers in South Africa, who import from Zimbabwe's largest fresh producer, Hortico Fresh Produce Ltd (who in turn are supplied by small-scale contract farmers), face considerable challenges and costs due to South Africa's evolving food safety and quality standards. This has led to exclusion of farmers from export supply chains (Henson et al., 2005). Similarly, difficulties in making adjustments (or lack of conformity) to sanitary and safety regulations has driven many SMEs and Lake Victoria based fish factories out of business (AGRA, 2019b). This is particularly important in a context of emerging middle-class consumers who demand more diversified, quality and safe products.

48 See Coulter et al. (2000) for possible approaches to reduce such strategic defaults.

Investment and policy priorities

In order to capture emerging opportunities and deepen value chain functions, the role of governments, non-governmental organisations and donors has to be broadened and strengthened, not only to integrate small-scale producers into value chains but also to create jobs for the youth. Institutional investment that favours linkages between producers and secondary cities and towns is required for inclusive small-scale producer development. Moreover, beyond the promotion of firm-level innovation through targeted trainings, innovation grants and property rights value, institutional interventions are required to tackle system-wide constraints that affect actors throughout the entire value chain. Focussing on system-wide constraints would help to reduce the costs of doing business, motivate firms' innovativeness, enhance business performance, and ultimately lead to economy-wide competitiveness. The following are key priority policy and investments needed to address the constraints related to poor business environment and value chain governance. Some priorities are:

- Invest in physical transport infrastructure such as roads and railways to tap the potential of inclusive markets for smallholders, agri-food value chains and intra-African trade, with investment needs estimated at US$ 35-47 billion per year (AfDB, 2018).
- Develop and implement more inclusive and comprehensive **commercialization strategies for small-scale producers**, to generate larger incomes, decent jobs and healthier diets for rural poor households. Inclusiveness refers to land poor, youth and female headed rural households, and comprehensiveness refers to creating access to food markets, and diversification of subsistence production and rural employment opportunities including off-farm.
- Provide **business-start up grants to the poor and marginalised**, rather than regular food assistance. Business training is not as important as access to finance, which can be made accessible to rural households in two ways: concessional micro-credit and start-up grants. The latter is more effective than the former especially for those who are credit risk-averse.
- Increase public **investment in rural market infrastructure**, e.g. constructions of feeder roads, bridges, rural market centres. Smallholder producers and small enterprises providing rural services face huge transaction costs at the last mile of the marketing system. These 'last miles', which link producers to nearby markets, determine the extent of producers' supply to the market as well as their input use. The reduction of the costs that producers incur will substantially increase the market gains.
- Promote specialized **farmers' marketing organizations (FMOs**) that can attract members of similar capacity and needs. Heterogeneity of membership excludes those who are less capable and competent, thus the promotion of specialized FMOs with homogeneous member profiles (e.g. poor, female, youth), interests and capacities will help to achieve both inclusiveness and competitiveness.
- **Improve contract farming** to assure contract security for participants and a fair return to producers. Contract farming should be encouraged and expanded, but designed in a way that favours socially responsible firms with the capacity and willingness to provide production enhancing packages such as new technologies, inputs and extension services**.**
- **Enhance access to infrastructural services for agri-food processers.** Public investments are required to facilitate the aggregation of produce and improve access of emerging small and large food processing firms to hard and soft infrastructure, such as electricity, roads, ICTs, storage facilities.
- **Expand public investment in wholesale markets.** Poor organization and localized monopolized power characterizes wholesale markets, where most prices are determined. Thus, organized and modernized marketplaces supported by digital technologies are required to improve their efficiency, signal the right prices and facilitate the smooth exchange of products. Modern Commodity Exchange markets are expanding in a few African countries but their operation is limited to a few commodities and places (Minten et al., 2017). Public investments are required to build the infrastructures for a competitive, efficient and modern exchange system.
- **Improve quality grading and standardization.** Formulate and implement a system of quality grades and standards for food items, for the sustainable provision of diversified, quality and safe products for rural and urban consumers. Formulation of regulations and regulatory actions is required alongside the creation or strengthening of existing institutions and organizations.
- **Expand food safety regulations and enforcement**. At the policy level there is a need to streamline and implement food safety regulations and regulatory actions and their enforcement. Create or strengthen appropriate institutions capable of promoting and protecting innovations, and enhance linkages between processors and small-scale producers.

6 INVESTMENTS IN GOVERNANCE

Any efforts to improve the production, processing and distribution of food will need to take place within sound governance frameworks. This section discusses four priority areas of investment in this regard. The first section outlines different elements of a conducive policy environment for production and productivity growth and food security, focusing on strengthening regulatory frameworks, reducing corruption, ensuring accountability and representation of all population groups, and promoting peace and stability. The second section explores the role of farmers' organisations in providing productivity-enhancing services to their members and representing their interests in policy processes. The following section focuses on the protection of land and water rights to incentivise investments, increase transparency and resolve potential conflicts between private and communal rights. Last but not least, the final section addresses the question how to strengthen the rights and capacities of women, given that they remain seriously disadvantaged despite their important role in agricultural and food systems.

6.1 Agricultural and food security policies

The absence of "Rule of Law" or weak enforcement of it, can discourage small-scale producers from participating in economic activities such as crop production (Kaufmann et al. 2005).[49] For instance, in the early 1990s, violence and theft resulted in the "failure of Somalian farmers to plant their fields, and this in turn led to mass starvation" (Lio and Liu, 2008, p. 505). Furthermore, corruption can undermine the functions of government such as to protect property rights and enforce contracts, which greatly affects agricultural investments (Kaufmann et al. 2005). Governance affects agricultural productivity through various channels, some direct and others indirect:

- Taxes (encourages or discourages production) (Meon and Weill, 2005);
- Corruption (affects the efficiency of production) (Kaufmann et al., 2004);
- Policies or institutions (crucial to the functioning of market systems) (Kaufmann et al., 2004);
- Protection of property rights (to enforce contracts pertinent for production and investment);
- Support for agricultural innovation (providing supports and stimulus);
- Provision of rural public goods and services (essential for production and markets) (La Porta, 1999);
- Political stability (determines investment decisions) (Kaufmann et al., 2005); among others.

Using the World Bank's aggregate governance indicators for 118 countries, Lio and Liu (2008) found that a country with better governance infrastructure produces more agricultural outputs, suggesting that investments in governance infrastructure can improve agricultural productivity. For example, an increase in Governance Infrastructure Index of 1 percent, would increase the agricultural output (agricultural value-added per worker in constant US$ 2000) by about 0.38 percent, given the same amounts of agricultural production inputs.[50] Of the different dimensions of governance indicators, the rule of law and control of corruption have a stronger effect on agricultural production than other indicators (such as political stability, and voice and accountability), 0.34 percent and 0.27 percent, respectively. The African Governance Report also suggests that securing property rights and improving transparency and accountably are crucial for sustainable agricultural production and productivity growth (APRM and AGA, 2019). The Alliance for a Green Revolution in Africa (AGRA) also emphasizes improvement in governance infrastructure, welfare and anti-corruption policies to improve food and nutrition security and the agribusiness environment.

49 For Kaufmann, governance encompasses six dimensions: (1) voice and accountability; (2) political instability and violence; (3) government effectiveness; (4) regulatory quality; (5) rule of law, and (6) control of corruption.

50 Governance Infrastructure Index was computed as the mean value of all the six dimensions of World Bank's governance indictors proposed by Kaufmann et al. (2005), but rescaled to a value between 0 and 1.

Voice and accountability as well as peace and stability are other key aspects of good governance pertinent for agricultural development. They influence agrarian relations and shape agricultural support policies (such as agricultural taxation, subsidies, and provision of public infrastructures). On the other hand, instability can hinder agricultural production by lowering investments in agriculture, increasing production costs, and restricting access to finance and trade flows (Arias et al., 2017). It is also important to note that a permanent improvement in agricultural productivity can reduce conflicts by reducing competition over the control of scarce resources such as land (Iyigun et al., 2017).

The various governance indicators are highly interrelated: the effectiveness of one governance dimension affects the effectiveness of others. For instance, corruption reduces agricultural production by raising transaction costs and lowering agricultural profits. Similarly, corruption reduces a government's ability to effectively provide infrastructure such as rural roads and other related services, which in turn raises the costs of agricultural production.

A good governance structure creates a conducive and enabling environment for agricultural transformation by allowing the formulation of sound agricultural policies and strategies (AGRA, 2018). This requires building capacity for innovation policy analysis and priority setting. Good political leadership supports the capacity of governments to improve the business environment, including the creation of forums through which producers and consumers can frame and articulate their interests, and the channelling of investments that enhance institutional capabilities. In this process, international organizations and institutions (AGRA, FAO, World Bank and other UN agencies), civil society and the corporate sector play an important role in transferring skills on how evidence-based policy change for agricultural transformation can be supported (AGRA, 2019b; AUDA-NEPAD, 2013; OECD, 2013).

According to the World Bank's data on laws and regulations that impact the business environment for agriculture, countries with stronger regulations in place related to agricultural production inputs, tend to have on average higher rates of food security (World Bank, 2019). This is in line with the earlier discussion that functioning legal frameworks are key in enabling farmers to generate surplus production for commercialization (World Bank, 2020f). However, it is not always the case that the existence of strong legal authority would enhance efficiency. For instance, although Malawi has a good set of laws related to the registration of seed varieties and fertilizers, the transaction costs related to the process of registering new seed varieties and fertilizer are high compared to the other 62 countries covered in the World Bank Enabling the Business of Agriculture (EBA) 2017 report (World Bank, 2017b).[51] In terms of regions, SSA countries are still lagging behind others on all EBA indicators that positively impact the agribusiness environment (with an aggregate EBA score of about 40; on a scale of 0 to 100 where 0 means the worst performance and 100 represents the best performance). Looking at individual countries' average EBA score, many SSA countries are struggling to improve the agribusiness environment: Angola (27), Benin (33), Burkina Faso (35) and Burundi (36) are among the worst performers in 2018 (World Bank, 2019).

As to the role of incentives provided to promote agricultural production, it is important to mention two of the most common and widely promoted agricultural pricing policies: agricultural input subsidies and taxes (see Anderson et al. (2013) for a detail discussion on the political economy of public policies in the agriculture and food sector). Jayne and Rashid (2013) suggest that the benefits of input subsidies can be enhanced by changing the governance structures related to design and implementation modalities. While input subsidies in Africa can have positive impacts on food production, their mode of delivery is highly political and subject to corruption, and once implemented they are difficult to remove.

Agricultural taxation on inputs is relatively high in most African countries because of multiple taxations on various products and services (Malan et al., 2016). For instance, a recent survey carried out by AGRA among agribusiness leaders to determine their views on issues related to an enabling agribusiness environment suggest that a typical seed company is required to pay payroll taxes of 20 percent, VAT of 16 percent, and profit tax of 30 percent (AGRA, 2018). The survey finds that such taxes are impeding the growth of agribusiness firms and limiting productivity. As to the effect of taxes levied on cash crops (e.g. coffee and cocoa), studies suggest that decreasing taxes on these crops led to an increase in productivity although the

51 The EBA is one of the tools available for measuring performance in agribusiness (i.e. assess the regulatory environment in agriculture).

effect varies greatly across countries (Malan et al., 2016). On the other hand, with proper tax policies and effective administration, the revenues generated from these taxes can be reinvested in such a way that agricultural productivity and food security can be improved (see Khan (2005) and OECD (2013) for details). For instance, revenues raised by taxes can be used to finance public infrastructure related to agricultural development, including agricultural R&D activities, and help to redistribute income to resource-poor households.

The formulation and implementation of consistent, coherent, and favourable agricultural policies, laws, and regulations for enhancing production across countries has to date had limited success. The participatory development of policies oriented toward agricultural development is necessary, through consultative and frequent dialogue with key actors. Arranging learning visits and experience sharing within and between countries who have registered progress in governance structures would be helpful.

Promoting good governance for sustainable production and food security also requires understanding the role of other key actors, such as civil society and the corporate sector. For instance, civil society participation is integral to the implementation and success of policies and programmes aimed at sustainable agricultural production and conservation of natural resources such as forests and fisheries (Mikalsen et al., 2007). Civil society participation is often essential to facilitate knowledge flows and interactions within agricultural systems (OECD, 2013; Warshawsky, 2014), to advocate and lobby the promotion of sustainable agricultural production and conservation practices (Akinola, 2016; Scholte, 2012), to link farmers and agro-businesses (Warshawsky, 2016), and to promote innovative market-oriented approaches to environmental and social sustainability.

Governance, however, remains a key challenge in most African countries. In Ethiopia, for instance, the strong influence of the public administration and its regulations hinders the participation of civil society in smallholder innovation networks in the agricultural sector (Spielman et al., 2011). As to the role of the corporate sector in agricultural development and food security, evidence is mixed. Some suggest that investment by the corporate sector has positively impacted agricultural productivity and food security, employment creation, environmental outcomes such as pollution reduction (van Dijk and Vander Stichele, 2008), and the fostering of good governance (Jensen, 2006). Others argue that the corporate sector can exacerbate food insecurity and environmental pollution (de Schutter, 2009). For example, in some instances the corporate sector chooses to invest in a country where wages are low and labour and environmental legislations are weak, allowing for large corporate land acquisitions which exacerbate tenure insecurity for small farmers (da Vià, 2011; Deininger et al., 2011).

Investment and policy priorities

Implement reforms in the rule of law and strong enforcement to promote good governance for improved agricultural productivity and food security. Specific interventions include:

- Protection of property rights for key resources (such as land, water, seed and machinery) and the promotion of their commercial use. In this regard, appropriate policies are required to prevent monopoly of the property rights.
- Regulation of production technologies (pesticides, veterinary drugs, seed certification, fertilizer quality control, mechanization) and enforcement of contracts.
- Design of appropriate incentive mechanisms for both domestic and international investors and improvement of current regulations governing these incentives (e.g. subsidies, taxes or price-related policies).
- Establishment of agencies to implement agricultural development programmes and projects, as well as manage legal issues.
- Promotion of civil society organizations and capacity building activities to increase the capacity of smallholders.

Create sound coordination structures to ensure efficiency of operations and resource use.

Control of corruption and accountability to improve the effective provision of infrastructure and service delivery pertinent for agricultural development. Key interventions include investments in ICT and energy, and the development of electronic systems and online platforms to ensure transparency and accountability, and compliance with regulatory requirements, to improve service delivery related to agriculture.

Provide a voice and opportunities to women, youth and marginalized groups such as pastoralists, and integrate them into agricultural development programmes. Improving and enhancing inclusiveness of such groups requires focused interventions, such as training women farmers and increasing their participation in decision-making processes at various levels, and mainstreaming gender issues in policies and programmes.

Foster peace and stability (a high priority for the Sahel region) by strengthening democratic processes, supporting private investment, and assisting local actors engaged in the redistribution of resources, as well as enhancing cooperation among neighbouring countries.

Create a regulatory environment that optimises the role of civil society and the corporate sector to allow them to drive agricultural development. This requires the easing of government controls, leadership support at the top level, establishment of inter-sectoral coordination and accountability mechanisms, and investment in a skilled work force.

6.2 Farmers' organisations

6.2.1 The role of farmers' organisations in Africa

Farmers' organisations (FOs) can play an important role in the agricultural transformation in Africa, especially by promoting collective action among farmers and by giving them a political voice. The basic mission of FOs is to represent farmers, in order to ensure their participation in the formulation and implementation of policies and agricultural development actions. FOs can be defined as formal or informal (registered or unregistered) membership-based collective action groups serving members who receive part or all of their livelihood from agriculture (crops, livestock, fisheries and/or other rural activities) (Mastercard Foundation, 2020). More often than not, FOs refers to farmers' associations (unions) at the local, regional or national levels. They aim to improve their members' livelihoods by facilitating access to information, markets, inputs, and advocacy. There are various types of FOs such as general farmers' organizations, commodity-oriented organizations (such as farmer marketing organizations – FMOs), organizations that focus on specific subgroups of farmers (youth, women), umbrella organizations of cooperatives, and regional organizations (NEPAD, 2014).

Conceptually, there are several mechanisms through which FOs can potentially foster agricultural development, and help improve food security and alleviate poverty. FOs are essential institutions for the empowerment and advancement of farmers and the rural poor (Penunia, 2011). By organizing themselves, farmers can access information needed to improve production, add value, market their commodities and develop effective linkages with input agencies such as financial service providers or output markets. FOs can help farmers gain skills, access inputs, form enterprises, and process and market their products more effectively to generate higher incomes (Sinyolo and Mudhara, 2018). Importantly, FOs can achieve economies of scale, thereby lowering costs and facilitating the processing and marketing of commodities for individual farmers. Marketing-oriented FOs can assist their members to purchase inputs, equipment, meet quality standards and manage the drying, storage, grading, cleaning, processing, packing, branding, collection and transportation of produce (Tolno et al., 2015).

Politically, FOs strengthen the bargaining power of farmers, by increasing the likelihood that their needs and opinions will be heard by policy makers and the public (Penunia, 2011). On the one hand, FOs can communicate farmers' views on their predicament and that of the agricultural sector. On the other hand, when well-organised, they can participate in the formulation of agricultural policies and the strategies to be considered for rural development. FOs are also an important means by which smallholder farmers could hold governmental and non-govern-

mental organizations accountable for their role in rural development. Properly organized FOs can be effective rural institutions that ensure the voices of farmers are heard and their demands met. More generally, strong and accountable rural institutions also promote social cohesion and stability, and decrease the adverse consequences of political and economic disenfranchisement. When FOs join forces at higher levels, they can influence policy dialogue and decisions that affect their ability to succeed.

6.2.2 The state of farmers' organisations in Africa

Farmers' organisations in Africa are said to be poorly and weakly organised (FAO, 2017b; Penunia, 2011). For example, the total number of farmers enrolled in various FOs that constitute the umbrella organizations in Kenya, Burkina Faso, Tanzania, Uganda, Senegal, and Zambia hardly represent ten percent of the farmers in these countries (Kampmann and Kirui, forthcoming; Wortmann-Kolundžija, 2019). The membership of Kenya National Farmers Federation is about two million farmers while the Agricultural Council of Tanzania has about 2.7 million members. The Farmers Union of Malawi and the National Smallholder Farmers Association of Malawi have about 1.1 million and 100,000 members respectively (Kampmann and Kirui, forthcoming; Wortmann-Kolundžija, 2019). Moreover, FOs in most countries in Africa have not effectively engaged in the design of agricultural policies – unlike elsewhere in Europe, North America and Asia where FOs are widely respected and recognized partners in the policy making process (Davidova and Thomson, 2014; FAO, 2017c; Vorley et al., 2012; Wolfenson, 2013) .

Enrolment in a farmers' group, however, does not automatically increase productivity, income or the prices received for produce. As Fischer and Qaim (2012a) show, the objectives of FOs and the activities they engage in need to be carefully considered. Significant increases in productivity and income are only possible when relevant services are offered (such as collective marketing, actions to improve quality and efficiency along the supply chain, efficient information flows) (Fischer and Qaim, 2012b, 2012a). FOs must consider which activities will best improve the well-being of their members and which incentives will be the most appealing (Verhofstadt and Maertens, 2014; 2015). Previous studies have shown that different structural components (such as the type of organization, field of action, availability of resources) influence the impact FOs have on their members (Francesconi and Wouterse, 2015; McInerney, 2014; Vanni, 2014). For example, production cooperatives seem to be less efficient in increasing the gains for their members as compared to land and marketing cooperatives, while maize cooperatives seem to perform more efficiently and with higher returns than horticulture cooperatives (Verhofstadt and Maertens, 2015, 2014). Linking FOs to the market might only be meaningful if individual members have access to natural and productive assets, but the groups' participation within such markets also relies upon the social capital of the members (Barham and Chitemi, 2009). Further, market-oriented trainings and interventions fail if farmers' groups' members do not have access to resources (Barham and Chitemi, 2009).

Nevertheless, empirical evidence from Africa shows that membership in farmers' organisations can improve agricultural productivity. In Nigeria, belonging to a producer organization increased the probability and intensity of adopting improved dual purpose cowpea varieties by 14 percent (Kristjanson et al., 2005; Shiferaw et al., 2011), while cooperative membership increased the adoption of improved cassava varieties by about 22 percent (Wossen et al., 2017). In Zimbabwe membership in FOs increased by twofold the probability of adopting fodder bank technology for improving livestock production (Jera and Ajayi, 2008). A national survey in Mozambique found that membership in FOs enhanced the welfare of smallholders – it increased the marketed surplus (by 25 percent), the value of agricultural production (by 18 percent) and the total income (by 15 percent) (Bachke, 2019). In Ethiopia the yield and quality of malt barley improved after farmer cooperatives organized farm management trainings and facilitated technical trainings regarding productivity and quality improvement (Windsperger et al., 2019). The quality improvement led to an increase in the price premiums received by cooperative members of up to 20 percent (Windsperger et al., 2019).

Across the world, similar such gains to FO membership are apparent. Cooperatives in China increased productivity by an average of about 5.4 percent, increased net returns by 6.1 percent and improved income by 4.7 percent (Ma and Abdulai, 2016). These effects tended to be larger for small-scale farmers than for medium and large-scale farmers. In Nepal, commodity-specific (tomato) farmers' organization

increased productivity by about 27 percent (Mishra et al., 2018). Other similar studies find an increase in the yield of tomatoes of about 64 percent in India (Eaton and Shepherd, 2001) and a productivity increase of about 100 percent for Ghanaian maize farmers (Ragasa et al., 2018b). In Ethiopia, farmers who enrolled in collective action groups (for about five years) reported an average of ten percent increase in crop and livestock productivity. These farmers received extension messages in the group and their participation in the association enhanced their adoption and use of agricultural technologies.

6.2.3 Governance challenges of farmers' organizations

Though FOs are undeniably an important component in the development and agricultural transformation of Africa, the capacity of the existing organizations remains limited (Kampmann and Kirui, forthcoming; Zimmermann et al., 2009). FOs lack a transparent register of the members they represent, and are thus unable to broker the interest of their members. Information about the actual number of members is hard to come by and verify, which poses accountability challenges to FOs. Indeed, not enough efforts and resources have been deployed to build the FOs and mobilize farmers from the bottom-up. Many FOs do not have a clear strategy nor the capacity to engage and influence policies in the agricultural sector. Their weak capacity prevents them from preparing or participating in policy processes (e.g. they are unable to follow debates in policy formulation and implementation) (FAO, 2017b; Zimmermann et al., 2009). Though the umbrella FOs in some countries (e.g. Senegal, Uganda and Zambia) can be considered well-structured and are occasionally engaged by government ministries and parliaments on important agricultural issues, for the large part FOs remain weak and lack appropriate leadership.

Multiple efforts are needed to address these challenges. For instance, existing FOs require energizing, through (i) building the capacity of existing leaders, (ii) increasing the membership base and their financial contribution to support the operations of the organizations, and (iii) by creating opportunities for the FOs to engage policy makers on a regular basis. In order to increase members' participation in collective activities, existing organizations have to establish a reliable, cooperative working atmosphere of mutual commitment, trust, accountability, and a sense of community. Moreover, members have to see a clear benefit of enlisting in a group. Leaders must be prudent and transparent on how finances are used, clearly set their agenda, not shy away from the scrutiny of members, and submit to performance-based leadership terms. Grants to FOs should focus on strengthening FOs through institutional development rather than being used to support micro-projects. Governments should also give FOs the right to sit in on all decision-making bodies examining agri-food issues.

Investment and policy priorities

- **Investments to enhance FOs capacity for advocacy and lobbying.** Government officials need training on issues related to policy processes and multi-stakeholder engagement. Cross-country learning and exchange (e.g. on agricultural policies, advocacy, technical and practical agricultural training, organizational strengthening), including with established European (or other global) FOs would benefit Africa's FOs.
- **Investments to support FOs to provide economic services to their members**. There are three categories of services that FOs in Africa typically provide to their members:
  - Services to support production (access to inputs, productive equipment, advisory services),
  - Services to add value to products (processing and certification, post-harvest management, storage facilities, processing facilities for fresh commodities),
  - Services to support marketing (collecting the supply, prospecting potential buyers, negotiating contracts with buyers, providing information on market prices).
- **Implementation of a set of rules and code of conducts, to be enforced with sanctions and rewards.** FOs must also encourage members' commitment (and financial contribution through fees) to ensure financial sustainability.

6.3 Land and water rights

Coordinating land and water governance matters for food security because both fresh water and arable land upon which food production depends are becoming increasingly scarce. Failure to coordinate both these resources may jeopardize food security (Niasse and Cherlet, 2014). Despite interaction and interdependence, the governance of land and water resources remains mostly disconnected and the institutions dealing with them are often quite separate and fragmented. Despite an increasing recognition and acceptance (Niasse and Cherlet, 2014), progress in enhancing agricultural productivity through coordinating land and water governance has been so slow in Africa (AGRA, 2014).

The land and water policies, strategies and guidelines which many African countries have adopted states the important role of land tenure security and water rights for agricultural investment, growth and their perceived effects on productivity. For instance, the report of the Commission for Africa (2005), the 2005 State of Food Insecurity Report (FAO, 2005), the NEPAD's CAADP (2003), the SGDs (2015) and the Poverty Reduction Strategy Papers of many African countries name land tenure as an important issue. In its assessment of constraints facing African agriculture, the NEPAD lists poorly defined property rights as one of the key constraints facing investors (AUDA-NEPAD, 2013). Deininger et al. (2014) identified ineffectiveness of institutions to record rights and resolve disputes, weak protection of rights in practice, and large gaps in women's access to land among the key constraints of land governance in ten African countries. To bridge these gaps, various reforms and initiatives have been carried out at different times to enhance the access of women and younger farmers to land and water at national, regional and international levels. These reforms have been initiated by governments, regional economic communities, the African Union, the European, the United Nations and development agencies (see for instance, Adams and Palmer (2007); van Koppen (2003); WPP (2010)). Securing land rights generally enhances access to water, hence water rights, as access to land mediates access to water in many settings (FAO, 2011; Niasse and Cherlet, 2014; World Bank, 2012).

Land tenure systems, which in many instances discriminate against small-scale producers and women, continue to influence water policies in many African countries (Olagunju et al., 2019). Based on the sociocultural setting and economic conditions, there are different types of land tenure systems (for instance, owner-operated with full property rights, owner-operated with restricted rights, fixed-rent, and sharecropping contract). These differing tenure systems affect farmers in a variety of ways. For instance in Ghana, being a "fixed-rent tenant" tends to increase the likelihood of investing in fertilizer by 16 percent, whereas being an "owner-cultivator" increases the probability of investing in fertilizer by 11 percent. The probability of investing in soil-improving and conservation measures (such as trees and mulch) also differs by tenure arrangements (Abdulai et al., 2011). Means of land access, levels of equality of land holdings and individualization of rights including their means of control and the ability to uphold those rights also differs (Deininger et al., 2017).

Although the notion that secured rights matters for investment in productivity-enhancing measures is widely promoted (Abdulai et al., 2011), there is inconclusive evidence of the impact of land tenure rights on agricultural productivity. The impacts depend on local context and the macro and sectoral conditions within which tenure systems operate (see Place (2009) for a synthesis on land tenure). A recent synthesis by Singirankabo and Ertsen (2020) also confirms the heterogeneous impact of land tenure on productivity. For instance, in Kenya, the relationship between crop yield and land rights is insignificant. In Ethiopia, land certification fails to improve tenure security, land dealings and productivity; and gendered realization of land registration and security has led to asymmetric distribution of costs and benefits; which is often ignored in this kind of analysis. In this regard, the existence of various types of tenure system complicates an understanding of tenure effects on agricultural productivity (which also depends on tenure's ability to stimulate investment in agriculture). If the context is not conducive, formalizing land tenure may exacerbate inequality in land ownership and bring new challenges. In such situations the marginalized such as women, children and pastoralists may suffer (Singirankabo and Ertsen, 2020).

Nilsson (2019) further argues that purchase restrictions hardly exist in Africa, which has led international companies and governments to embark on land purchases exposing smallholder farmers to arbitrary land acquisitions; the phenomenon some-

times referred to as land grabbing (Niasse and Cherlet, 2014). This has become a source of conflict in many African countries. Although a majority of researchers argue that land tenure reform has a positive impact on improving agricultural productivity in Africa (Li and Zhang, 2017), such as in Ghana (Abdulai et al., 2011), Benin (Kariuki, 2011) and Burkina Faso (Ali et al., 2019), most reviews suggest the need for more evidence to guide land tenure security interventions.

Communal land tenure is yet another tenure type. Empirical findings suggest that communal land tenure is less effective in enhancing investments that improve the long-term productivity of local resources (e.g. trees, irrigation, forests) and household food security. For instance, using a macro simulation exercise adjusted to represent Ethiopia's context, (Gottlieb and Grobovšek, 2019) found that removing communal tenure increases GDP by about 9 percent but lowers agricultural employment by about 18 percentage points. Specifically, removing communal land tenure increases agricultural productivity but non-agricultural productivity decreases. Membership to a local community assures the use rights to land under customary tenure arrangements, a common arrangement in the use of communal resources in pastoralist areas. Such use rights retain sufficient flexibility to recognize multiple use rights over some resources, for example shared tree rights or pastoralists' grazing rights on cropped land after harvest (Migot-Adholla et al., 1991). However, the same tenure system may discourage investments in conservation practices, e.g. farmers may be reluctant to invest in disputed land. As a result, conflict over such resources stems from the differing interests and priorities of individual rights holders (e.g. farmers) and communal rights holders (e.g. herders). From our review it seems that individual rights are more important for food security than communal rights however the latter could be more important in terms of environmental conservation (e.g. carbon sequestration) (Alaanuloluwa Ikhuoso et al., 2020).

One driver of land and water use conflicts is the **lack of well-defined land and water rights and their weak enforcement**. Uncertainty over land and water rights and associated resources have ignited competition over scarce supplies at various levels, sometimes resulting in conflicts: for example, between local tribes, between states over transboundary resources, or farmer-herder conflicts over the use of common-pool resources (Cabot, 2017; Sakketa, 2018). The institutions required to manage such disputes over land and water allocations are absent in most countries, and if available, are not easily accessible at different levels and do not have clearly defined mandates. In addition, many countries recognize a range of land rights held by individuals and groups but their enforcement still remains a challenge (Deininger et al., 2014; Hegre and Nygård, 2015).

Another driver of conflict, closely related to the above, is **loss of rights and absence of compensation**. When land and water users' lose their rights as a result of land use change or displacement, failure to properly compensate either in cash or kind often leads to conflict (FAO, 2019c). Expropriation of land and water resources with insufficient compensation is common, for instance in Nigeria and Ethiopia. Where such expropriation occurs, the resources are unlikely to be developed for decades which impacts food production and food security (Deininger et al., 2017, 2014). Many countries are yet to have developed publicly available, detailed information on land ownership and water allocation and if it exists, it is partial, unreliable and outdated, and not shared among relevant public agencies, sometimes leading to fraud (Deininger et al., 2014). In addition, ineffective institutions have often led to the inappropriate use of state's powers of expropriation, due to ambiguities in the legal framework, and the inobservance of the law and land administration procedures. Conflicts induced by loss of rights can be better managed by transparency (e.g. public provision of land information), accountability and fairness of expropriation (Olagunju et al., 2019).

A third driver relates to population growth and rapid urbanization (Malthusianism). Increasing pressure over land and water resources has resulted in loss of arable lands, increased displacement; and absence of governance capacities to address these issues intensifies conflict (Olagunju et al., 2019).

Last but certainly not least, **climate change** increases the pressure on land and water resources is exacerbated, further increasing tension and competition over limited and scarce land and water resources (Alaanuloluwa Ikhuoso et al., 2020).

In dealing (both prevention and resolution) with land and water use conflicts, both formal and informal aspects of governance have been widely used. The formal approaches entail both legal rights recognition and practices in land and water conflict resolution when disputes arise. As for the informal approaches,

traditional or tribal legal systems to restrict access and control over land and water resources are the most common method used – mostly at the local level – in many African countries (Hegre and Nygård, 2015). Most African countries using indigenous institutions, such as kinship and chiefs, are better able to enforce rights than those that rely solely on formal institutions established to ensure formal rules (Schnegg and Bollig, 2016). However, this is usually missing in national, regional and international land and water governance frameworks In most countries, water users are expected to balance divergent priorities such as legislation, cultural norms and ecological circumstances to inform effective water use and management (Sakketa, 2018).

Investment and policy priorities

Secure and enforce land and water rights. Appropriate policies with localized context are important to create the conducive environment required to make land accessible to, and end discrimination against, small-scale producers, especially women, youth and pastoralists. The documentation of land rights and information exchange between government agencies need to be improved. Both hard and soft infrastructure capable of managing land and water governance issues is required. Investment in the use of advanced digital technologies is required to develop land registries, and identify and document available land and water resources. Rwanda is a good example of the use of advanced digital technologies.[1]

Strengthen land and water use conflict resolution. Well-functioning institutions with the mandate to resolve disputes over land and water use conflicts are required. The lack of codified land rights and a legal title, for instance, has exposed smallholder farmers and pastoralists to displacement by the rich and states. Innovative, cost-effective and efficient investments in dispute resolution, including the establishment of an independent judiciary system to deal with conflict prevention, the management of trade-offs, and conflict management strategies, is required (high priority).

Establish a legal framework at various levels to coordinate the management of land and water. Proper coordination and cooperation is necessary to reconcile competing interests between sectors, agencies and countries (e.g. tension between Ethiopia, Egypt and Sudan), with strong political will. This requires institutional cooperation between land, water and related sectors to foster synergies. An agency is required to strengthen governance mechanisms between different sectors. Relevant data for meaningful planning and monitoring practices needs generation and management. Dialogue is required between small-scale producers, researchers, policy makers and development agents. Investments in the use of satellites for land-water use planning and management may be necessary to ensure coordination and cooperation.

1 See https://mediciland.com/

6.4 Gender Equality

The labour of women, both paid and unpaid, is integral to food systems in Africa. However by-and-large, women have more limited access to and control over productive resources for agriculture and less information and decision-making power than their male counterparts. This translates to a significant gender gap in agricultural productivity and income in the aggregate. Empowering women in agriculture is therefore both necessary for reaching the intrinsic goal of gender equality and instrumental to the goal of food security and increasing the productivity and supply of safe and nutritious food. The importance of addressing the disadvantages that limit the potential of women working in agriculture is recognized in the policy objectives and agenda-setting of leading continental and global development institutions and declarations.

The agricultural sector is estimated to employ 60 percent of women in Sub-Saharan Africa, making it the largest employment sector for women (UNDESA, 2015). Where access to alternative employment opportunities for women are limited, women are especially dependent on agricultural work and income

(Agarwal & Herring, 2014). Reciprocally, food systems in Africa are dependent on the labour of women, both paid and unpaid, all along the value chain. Women especially work in food production, managing their own or designated plots of land, providing labour on male-run plots and as livestock keepers. Their labour is also essential to the post-harvest stage of agricultural value chains, namely food processing and preparation (Care Canada, 2016; Njiraini et al., 2018; SIDA, 2015). The importance of women's labour to food security is well-documented, especially as it relates to their common role as managers of food within the household and family, growing what is to be consumed by the household and in the process ensuring dietary diversity, and finally preparing the food for home consumption (Agarwal, 2015; Doss and Morris, 2001).

6.4.1 The agricultural gender gap

The patterns of inequality in agricultural income and productivity between men and women has been studied across communities, regions and countries in Africa. At the root of these differences are discrepancies in access to and control over productive resources, as well as in information and decision-making power differentials, perpetuated by gender norms. Gender norms are the informal rules that govern individual interactions, collective behaviours and expectations about others' behaviours (Markel et al., 2016). These norms shape behaviours, institutions and systems that constrain women's set of options and therefore their income and productivity (Njiraini et al., 2018). The concept of gender gap covers a complex array of individual experiences, which are affected by geographical, cultural, as well as socio-economic factors. Gender roles and relations are highly contextual and manifest in different ways and to varying degrees between cultures, social groups and over time. They also change in response to socio-economic and environmental stresses, technological developments, and changes in employment patterns (Huyer, 2016).

Gender norms are associated with systematic disadvantages for women working in agriculture that can be observed through the aggregate differences in productivity and earnings from agriculture between men and women. This inequality commonly manifests in unequal access to and control over land, gender roles and division of labour within the household, access to extension services and agricultural information, and the financial exclusion of women (Njiraini et al., 2018).

In much of Africa, women have lesser access to land than men and lack formalized land titles. For instance, in Nigeria, women hold four percent of household agricultural land, while men hold 87 percent (Doss et al., 2018). In other countries such as Niger, Ethiopia and Tanzania, men own three to seven times more agricultural land than women. Though women's rights to land are enshrined in the constitutions of many African countries, inheritance laws often do not explicitly safeguard women's rights. Besides, women and their communities are not always aware of their rights, and customary systems can run counter to state laws, meaning that legal rights are not always respected.

Though many women live in households with male members who do have access to and control over some of these resources, assets and decision-making cannot assumed to be pooled (Meinzen-Dick, et autres, 2011). These inequalities tend to (i) limit women's investments in their own agricultural production, (ii) affect their ability to adopt productivity-enhancing technologies and innovations, (iii) limit their ability to adapt to environmental and economic shocks, and (iv) shape their incentives towards lower-productivity agriculture (Meinzen-Dick et al., 2011; Njiraini et al., 2018).

Estimating the impact of the gender productivity gap on food supply and food security is challenging. The FAO's 2011 estimates are commonly referenced, namely that eliminating the gender productivity gap would raise the yield of women-run plots by between 2 and 30 percent, and raise the total agricultural output in lower-income countries by 2.5 to 4 percent (FAO, 2011). UN Women research in five Sub-Saharan African countries estimates that increasing women's access to inputs and equipment could raise crop production by up to 19 percent (UN Women, 2018). The findings of other researchers, however, suggest that the return to closing the gender productivity gap may be significantly lower. For instance, Palacios-Lopez et al. (2017) estimate that a full elimination of the gender gap in land productivity in Africa would increase aggregate crop output by no more than 6.25 percent.

Nonetheless, a sole focus on productivity gaps in crop production is likely to overlook other ways in which empowering women may contribute to increased food security (including through livestock production) that are harder to quantify, especially since women's agricultural labour is likely underre-

ported (Doss et al., 2018). For instance, in societies where roles and tasks associated with agricultural production are strictly governed by gender norms, women may hold valuable knowledge and expertise related to certain crop types, biodiversity-enhancing production practices or livestock production systems (Assan, 2014; Doss et al., 2018; Garcia, 2013). Reducing the constraints faced by women in their roles in the post-harvest, processing and food preparation stages of agricultural value chains could have positive implications for food safety and security through, for example, reductions in food loss. Supporting women's empowerment through initiatives aimed at increasing their control and access over productive resources, and increasing their access to information and decision-making power, may for example, unlock untapped productive potential and innovations or benefits for household nutrition (Doss et al., 2018). These would all advance the goals of ensuring a sustainable and secure food supply beyond simply increasing food production.

Importantly, a focus on innovations and policies that go beyond women's direct engagement in agricultural value chains is needed. Women still carry the main responsibility for taking care of children and other household members, especially the elderly, which remains a major constraint on their labour and also their mobility. This time is rarely taken into account when measuring agricultural labour productivity (Doss, 2018). Any innovations that reduce the level of drudgery associated with their many manual household chores and tasks (findings and chopping wood, making fires, carrying water, laundry, milling, grindings, food preparation etc.) could release time for them to engage in food and agriculture-related remunerative work and, along with their husbands, to care for their own and their family members' wellbeing.

6.4.2 Gender equality and food security

In the past decade, leading international organizations, including the United Nations and many countries' national development agencies, have embraced the idea that maximizing the productive potential of women is an effective avenue for achieving the goals of food security and poverty alleviation worldwide. In 2011, the FAO stated that bridging the gender gap is necessary in order to increase agricultural productivity, achieve food security and reduce hunger (FAO, 2011). Subsequently, the 2012 World Development Report reinforced this message, identifying the significant effect that empowering women can have on the efficiency and welfare outcomes of projects and policy interventions (Alkire et al., 2013; World Bank, 2012). This notion was also the impetus behind the "Joint Programme on Accelerating Progress towards the Economic Empowerment of Rural Women", launched in 2012 as a five-year partnership between UN Women, the FAO, the World Food Programme and the International Fund for Agricultural Development. It is further reflected in the SDGs, notably SDG 2, Ending World Hunger, which explicitly mentions addressing the constraints for women small-scale food producers and the nutritional needs of women and adolescent girls in its targets. The African Union Development Agency's strategic priority "Build Healthy National and Regional Food Systems and Culture and Empower Rural Communities" references the importance of women to African food systems and the need to address resource inequalities.

Investment and policy priorities

Invest in the development of agricultural and household innovations and technologies that specifically benefit women. Current innovations often do not take into account women's needs and can therefore deepen inequalities in the agriculture sector by making women more dependent on help from men, e.g. tools that are too heavy or technologies that require the operator to wear pants. Innovations that could benefit women include technologies that reduce the amount of labour necessary to complete tasks traditionally assigned to women. This can help free up women's time and enable them to make better use of their limited resources.

Make extension services more accessible to female producers. Extension services can target women by providing training in women's gathering places; ensuring the training considers women's busy schedules, offering couples training; adapting services to potentially lower levels of education; and delivering training through female extension officers. The first step is increasing extension officers' awareness of gender issues and how to address them, which will require buy-in and support from extension agencies.

Secure women's land rights. Some strategies include:

- **Reform inheritance laws** where these do not specifically address the rights of women to inherit lands and resources.
- **Ensure women and communities are aware of their legal rights** through training and support, e.g. by facilitating partnerships between local NGOs, paralegal networks and legal empowerment agencies.
- **Formalize existing progressive social norms within communities** (rather than creating new norms) and secure buy-in from all levels of customary and state authority to ensure these legal or institutional innovations are sustained.
- **Support research initiatives on land governance and tenure systems** and the sharing of expertise and best practices.

Implement affirmative policy measures to increase resource access (e.g. policies that encourage parents to send their daughter to school) and asset holdings (e.g. fair asset dissolution during divorce) of women.

Support the expansion of labor intensive agro-industrial jobs for women such as in the leather, textile and garment sector, and in food and beverage industries.

Mainstream gender-related considerations in the design of policies, interventions and investments aimed at growing the supply of safe and nutritious food in Sub-Saharan Africa. This means integrating gender concerns by making them a systematic part of development investments, policy and practice. Gender transformative approaches are leading approaches in the realm of gender mainstreaming. Such approaches not only address the symptoms of gender inequality, i.e. the reduction of gaps, but also their root causes, which often involves challenging existing gender paradigms and power structures (Danielsen et al., 2018). This involves recognizing that interventions must consider how gender will affect impact from the design of the intervention to staffing to capacity development of beneficiaries and local organizations (IFAD, 2018). The goal of Gender transformative approaches is to ensure that both men and women have control over important assets that can be used for improving their livelihoods, well-being and bargaining power within their households and communities (Meinzen-Dick et al., 2011).

7 DEVELOPMENT ASSISTANCE, INVESTMENT AND INTERNATIONAL COOPERATION

African countries will not be able, in isolation, to broaden and sustain the pace of agricultural sector growth fast enough to meet the rapidly growing needs facing national food systems. Cooperation at various levels, both within the continent and with international partners, and involving different actors will be needed. Four areas of cooperation are discussed here. The first section reviews current volumes and targeting of **overseas development** assistance in African food and agriculture. The second section examines how domestic and foreign **private sector investments** could be mobilized to improve access to capital in the African food and agriculture sector. The third section discusses opportunities and constraints for African producers to benefit from **international trade**. The final section presents various African and international **policy initiatives and processes** that offer opportunities to advance the priorities outlined in this report.

7.1 Development Assistance for agriculture

After decades of declining attention to agriculture in development cooperation, there is a broad recognition of the need to significantly increase investment in agriculture to achieve the sustainable development goals of poverty reduction, and food and nutrition security. This awareness has come at a time when there is a renewed commitment to significantly scale-up development investments in Africa. In 2018, Africa received 52 percent of the development flows to agriculture (United Nations, 2020). Over the last two decades, aid to Africa has almost doubled (98 percent) from around $ 16 billion in 1998 to US$ 32 billion in 2018.[52] In Africa, the sectoral allocation of overseas development assistance (ODA) from members of the Development Assistance Committee (DAC)[53] has shifted over the years with more resources being allocated to the social sector. The agriculture, forestry and fishing sector received about nine percent of the total ODA to Africa.

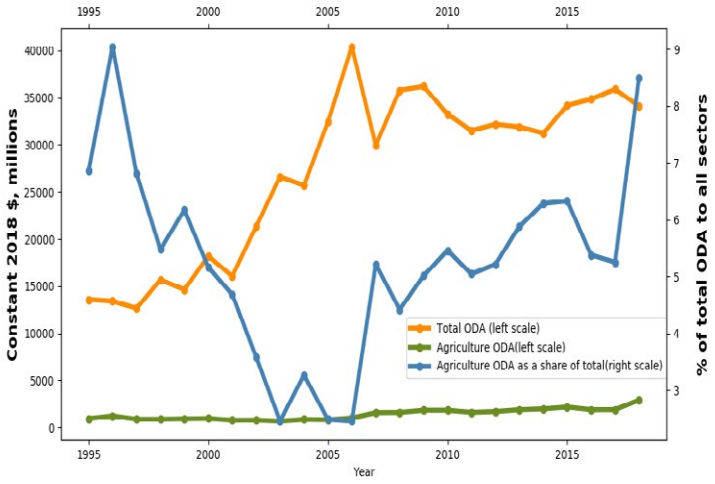
ODA commitments to agriculture fluctuated over the years and grew in recent years with renewed commitments to the sector after the global food crisis in 2008 (Figure 20). Only after 2006 did agriculture ODA again start to constitute a growing share of total ODA.

Agriculture ODA funding is supported almost equally by bilateral and multilateral institutions, but with a rapid increase in support from multilaterals in recent years. During 2000-2018 US$ 67 billion was allocated to agriculture ODA in Africa (all official donors), of which US$ 33 billion was issued by DAC

52 Unless otherwise specified, all ODA flows presented in this section are measured in US$ constant prices, using 2018 as the base year.

53 A list of the 30 DAC members can be found here: www.oecd.org/dac/development-assistance-committee.

Figure 20: Trend and ODA commitments by DAC member countries to agriculture in Africa, 1995-2018



Source: Author's own elaboration based on OECD (2020), ODA by sector indicator. Doi: 10.1787/a5a1f674-en (Cited on 12 Aug 2020)

member states and US$ 32 billion by multilaterals (the remaining was issued by non-DAC countries).

The sub-sectoral allocation of agriculture ODA from DAC members seems to have remained relatively constant over time, with agricultural development and agricultural policy and administrative management receiving the most funding; more than for activities such as agricultural research, food crop production, and livestock (Figure 20).

In recent years, short-term support to Africa for emergency food assistance and development food assistance has grown more rapidly than long-term support for agricultural production. While a substantial US$ 2.8 billion was directed at emergency food assistance in 2017, development food assistance reached US$ 1.2 billion in 2018. This highlights the risk of an increasing imbalance between short-term interventions and long-term development investment for the agriculture sector.

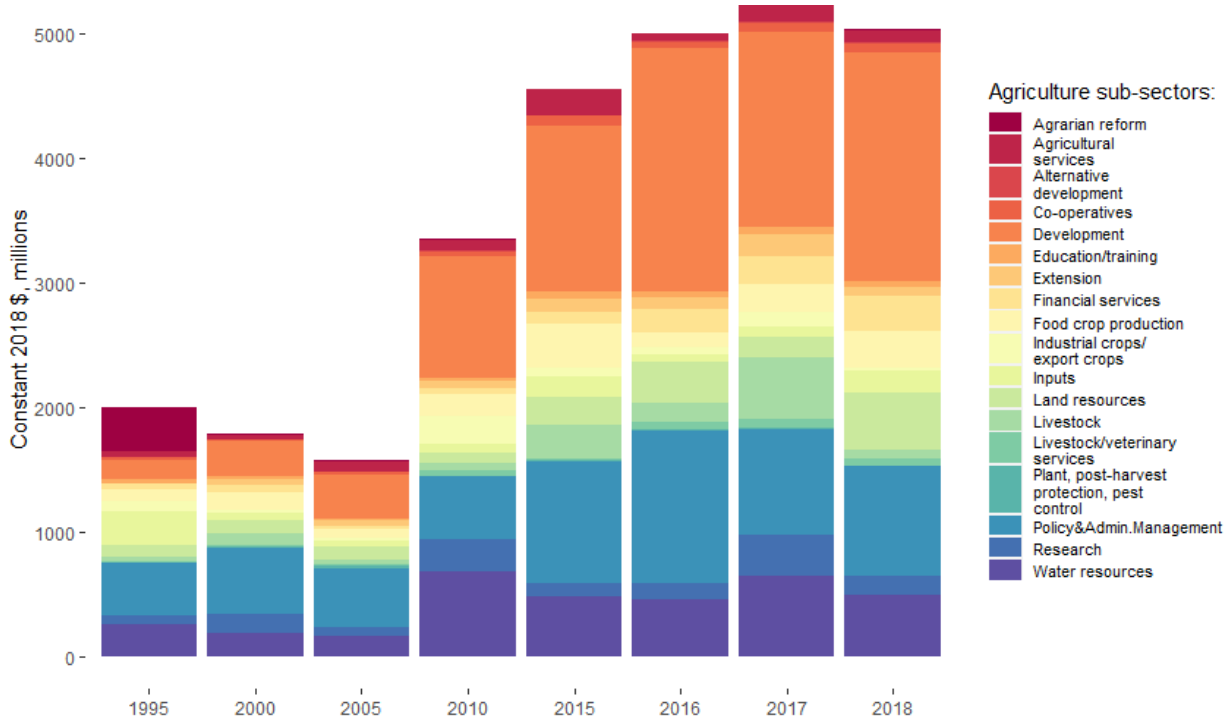
Over the last decade, South-South cooperation has emerged as an important element of the global cooperation where several emerging economies that are not members of the OECD have become active partners in development cooperation with Africa.

Some of these countries[54] report their ODA flows to the OECD. In 2018, Saudi Arabia, the United Arab Emirates, Kuwait and Turkey were the main non-DAC donors to Africa, accounting for almost all non-DAC commitments.[55] Overall, non-DAC donors provided on average ODA of about US$ 2.5 billion to Africa annually between 2015 and 2018. Agriculture ODA from non-DAC countries has been very volatile with sharp peaks and troughs (Figure 22). Overall, non-DAC countries reporting to the OECD provided US$ 1.6 billion ODA to the agriculture sector in Africa during that period. Other prominent donors to Africa, in particular China and Brazil, do not report their development assistance to the OECD. In the period between 2000 and 2011, China's development aid to Africa amounted to about US$ 73 billion (of which US$ 15 billion is comparable with that reported following the OECD definition), and US$ 3.5 billion was allocated to Agriculture, Forestry and Fishing (Strange et al., 2017).

54 Data on total ODA by OECD included the following non-DAC member states: Azerbaijan, Croatia, Estonia, Kazakhstan, Kuwait, Latvia, Lithuania, Romania, Turkey, Saudi Arabia, Timor-Leste, and the United Arab Emirates.

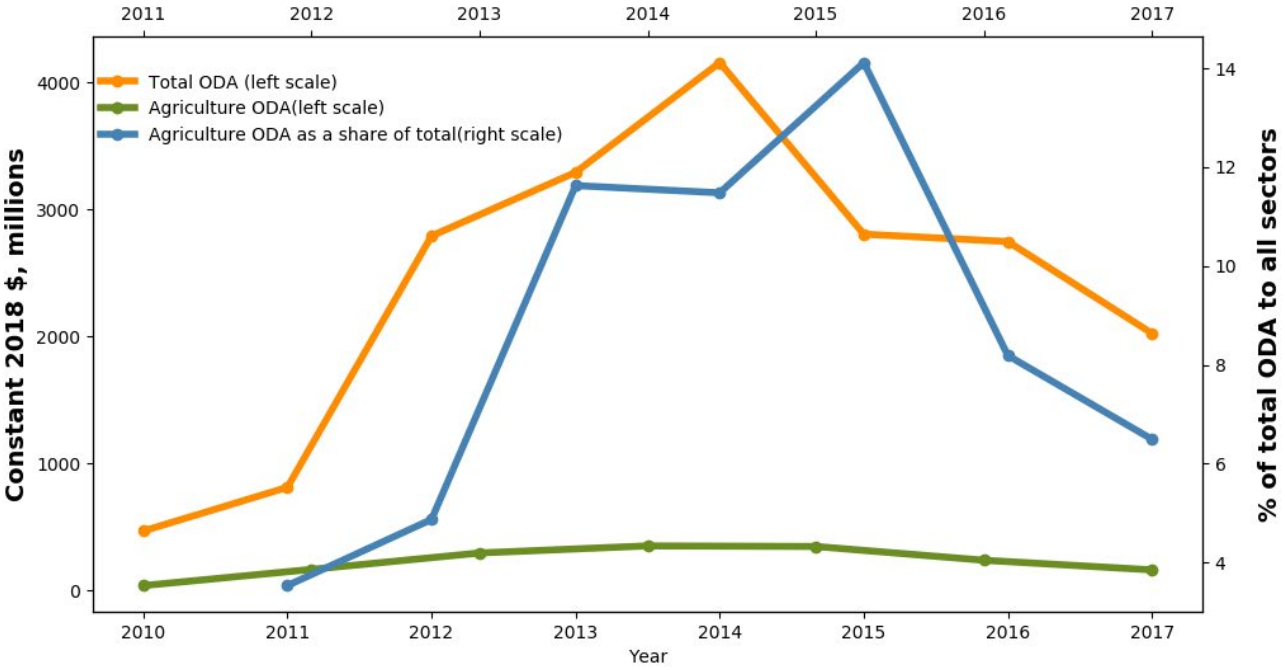
55 The private sector accounts for a significant share of ODA from non-DAC members to Africa, accounting for about 24.4 percent in 2018.

Figure 21: Sub-sectoral allocation agriculture ODA by DAC member countries in Africa, 1995-2018



Source: Authors own elaboration based on OECD (2020), ODA by sector indicator. Doi: 10.1787/a5a1f674-en (Cited on 12 Aug 2020)

Figure 22: Trend and ODA commitments to agriculture in Africa by non-DAC countries reporting to the OECD, 2009-2018



Source: Author's own elaboration based on OECD (2020), ODA by sector indicator. Doi: 10.1787/a5a1f674-en (Cited on 12 Aug 2020)

Investment and policy priorities

The priorities in development assistance for food systems' and agricultural development are to be in sync with those specified in remaining chapters of this study, and should not be out of line with strategic agendas of Africa. The following priorities are highlighted here again:

- **Maintain the renewed commitment and interest in African agriculture by increasing and sustaining the amount of aid to food system and agriculture.** A special focus on the sectors that directly enhance agricultural productivity and small-scale producers' income and livelihoods is required, by strengthening production systems and markets and trade.
- **Increase aid flows to the main systemic drivers of development in rural areas connected to food systems and farming**, such as education, research, technologies, and institutional innovations, to increase agricultural production and growth.
- **Invest in infrastructure.** Agriculture-focused interventions alone will not be enough to achieve the goal of sustainable food security. Infrastructure that connect producers with consumers – reducing the costs of transportation of food, locally and nationally – are also important for food security.

7.2 Domestic and foreign private sector investment in the food and agriculture sector

The case for investing in food and agriculture in Africa is very strong. Investment is essential for boosting agricultural productivity and output (see, for example, Bardhan (2008) and Basu and Weil (1998)). Even though capital accumulation alone cannot sustain long-run growth if not accompanied by technological progress, it nevertheless remains central in the growth process. This is particularly relevant for economies with low capital stock, as is the case of Sub-Saharan Africa.

This section focuses on more aggregate capital investment in agriculture, and related upstream and downstream industries. It covers private sector investment by both domestic, mainly farmers, and foreign investors, but we acknowledge the complementarities existing between private and public investment, and ODA discussed above.

Empirical evidence on agricultural growth largely supports the idea that capital accumulation plays a central role in boosting output and productivity, especially for countries lagging behind. Gong (2020) points out that worldwide elasticity of agricultural output with respect to various forms of physical capital has been increasing over the last five decades, and that in agriculture, labour is being slowly replaced by capital. For low and lower-middle income countries, input accumulation still contributes more than productivity gains to the agricultural output growth. Benin and Nin-Pratt (2016) show that rapid technological change in agriculture over the last decades was possible in countries with high capital endowments, but it was slow or even stagnant in undercapitalized economies, mostly in Sub-Saharan Africa. These observations make it clear that agriculture in Sub-Saharan Africa is undercapitalized and therefore requires more investments to stimulate productivity growth. But the case for investment is even more pressing because growing food demand on the one hand, and a growing rural workforce on the other, will put additional pressure on the already scarce capital resources.

Private sector investment in agriculture involves a range of actors, both domestic and foreign. Domestic investors include farmers and local companies in upstream and downstream industries. In low- and middle-income countries, farmers are by far the biggest investors in agriculture. On-farm investment in agricultural capital stock is more than three times higher than investment from all other sources, private and public, combined (FAO, 2012). Figure 23 shows that this is also the case in Sub-Saharan Africa, with the gap between private investment and public investment[56] in agriculture widening especially in recent years.

The role of foreign investment in agriculture in Sub-Saharan Africa is still marginal compared to domestic investment, albeit growing over time. Note that the numbers in Figure 23 are rough estimates and therefore should be treated with caution.[57] Nevertheless, they clearly point to the fact that policymakers in Sub-Saharan Africa need to consider all of the actors on the spectrum of agricultural investors, including both small-scale domestic producers as well as large-scale foreign companies.

Precise estimates of capital investment in the African agriculture are difficult to obtain, not only because of the usual data availability issues, but also because the definition of agricultural investment poses challenges. In a broad sense, investment is understood as allocation of resources resulting in accumulation of capital which yields a stream of returns over time. In case of farm agriculture, FAO (2012) makes a distinction between investment and spending on inputs, and includes land development, livestock, machinery and equipment, plantation crops, and structures for livestock in its measure of agricultural capital stock. An equivalent measure of investment in fisheries and forestry is assumed in this section, i.e. covering capital investment but excluding inputs. For investment in upstream and downstream food and agriculture industries, the usual definition applies.

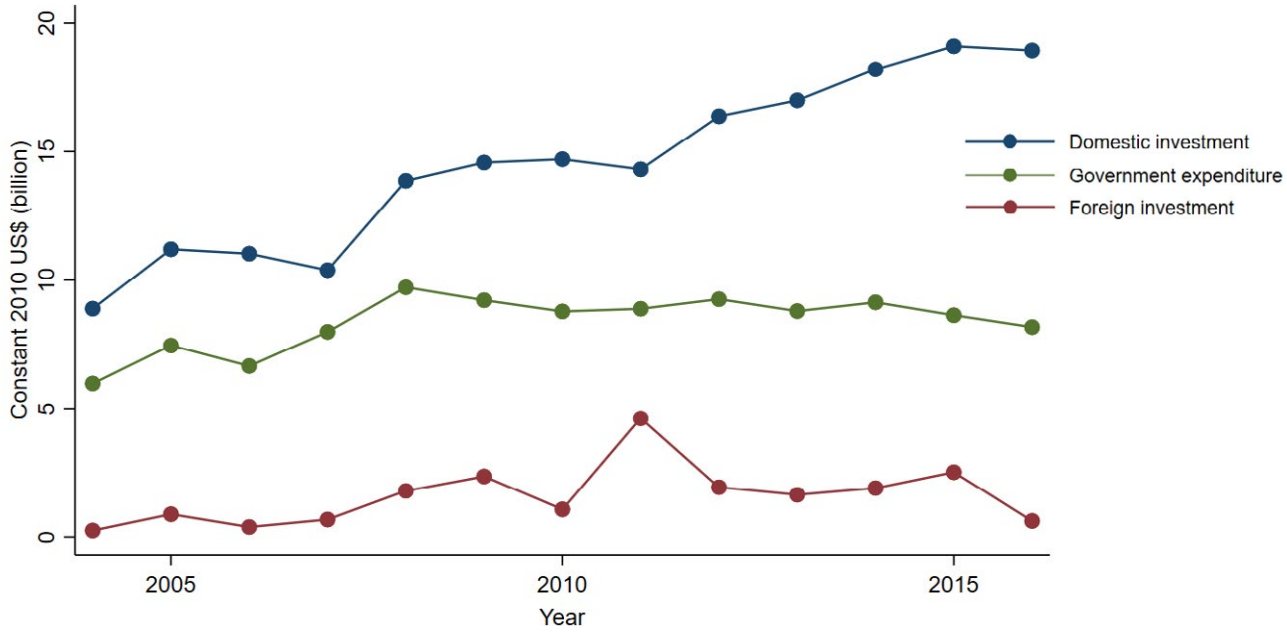
7.2.1 Under-capitalized African agriculture

Compared to other regions of the world, Africa is still lagging behind in terms of capital investment in agriculture, as measured by agricultural Gross Fixed Capital Formation (GFCF). This measure is referred to here as domestic investment since the share of foreign investment in crop production, livestock, fishery and

56 Note that we present here figures for government expenditure, i.e. capital investment and recurrent spending. Data on capital investment in agriculture by public sector is unavailable.

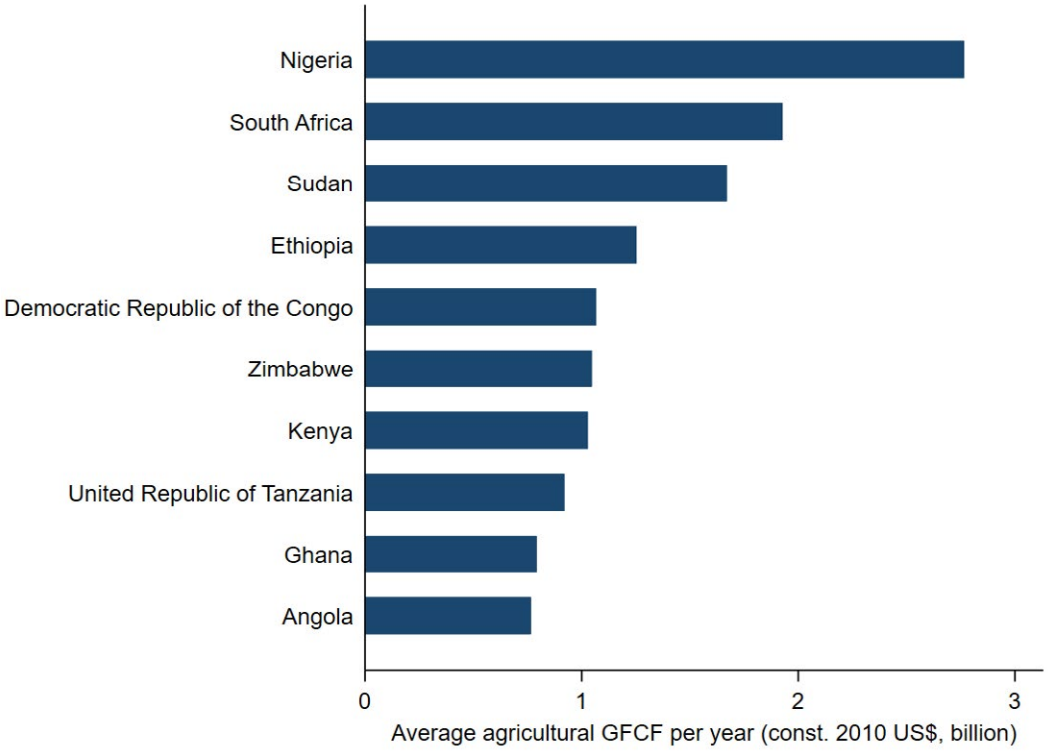
57 Also, the sectoral coverage differs between the three types of investments. Note that data for domestic investment in downstream industries is not available.

Figure 23: Estimated levels of investment in agriculture, fishery and forestry by private and public sector in Sub-Saharan Africa



Source: Authors' own elaboration based on data from ESS-FAO, fDi Markets, IMF COFOG, WEO, FAOSTAT and IFPRI SPEED. Domestic investment includes all investment by domestic private sector in agriculture, fishery and forestry. Foreign investment includes all greenfield investment by foreign private sector in agriculture, fishery and forestry but also downstream food industry; investment in the form of mergers and acquisitions is excluded. Government expenditure includes capital investment, but also recurrent spending related to agriculture, fishery and forestry; and is measured at general government level.

Figure 24: Top ten countries in Saharan Africa in with the highest agricultural GFCF in 1995–2016



Source: Authors' own elaboration based on data from ESS-FAO.

forestry[58] is marginal (close to 2 percent). In 2016, US$ 19 billion[59] were invested in Sub-Saharan Africa, compared to more than US$ 100 billion in East Asia and Pacific, including more than US$ 50 billion in China alone. The investment gaps are large within Sub-Saharan Africa itself. Figure 24 presents the top ten countries with the highest GFCF over the period 1995-2016. Among them, Nigeria, with close to US$ 3 billion investment per year on average, is leading the ranking, followed by South Africa, Sudan and Ethiopia. Countries with investment as low as US$ 1 million to US$ 10 million per year can be found on the other end of the spectrum.

Low levels of capital investments translate into a very low capital-labour ratio that can be observed in agriculture in Sub-Saharan Africa. Along with South Asia, Sub-Saharan Africa exhibits the lowest level of agricultural capital stock per worker, less than US$ 3,000 as of 2016 (Table 10) which points to the very labour-intensive character of agriculture in the region. Looking at changes over the last two decades, we note that a twice higher growth rate in total agricultural capital stock was compromised by a still significant growth of population engaged in agriculture. This phenomenon is particularly visible in case of Western Africa where capital intensity remains very low, despite an acceleration of capital stock accumulation over the last decade (Figure 25, Figure 26).

Capital investment levels in agriculture in Sub-Saharan Africa, even though they have almost tripled in comparison to the late 1990s, are still much below what is required to bring African agriculture to its full potential. Schmidhuber et al. (2009) estimated the investment requirements[60] for Sub-Saharan Africa to be US$ 940 billion[61] over the period 2005-2050, including US$ 496 billion for primary agriculture and US$ 444 billion for downstream industries. These estimates might already be outdated and also represent the lower bound of investment needs as they only reflect the FAO long-term estimates of food production rather than the objectives of moving the agricultural production frontier further. Nevertheless, they clearly indicate an important investment gap to still be filled. More recent estimates of financing requirements towards achieving food security by FAO et al. (2015) suggest that around US$ 43 billion annually need to be invested in the food and agriculture sector in

58 In case of FDI in forestry sector, we only refer to food production within the forestry system, but we exclude timber production.

59 All monetary values in this section are presented in constant 2010 US$.

60 These estimates reflect capital requirements necessary to produce the total amounts of crops and livestock products projected on FAO's long-term outlook to 2050.

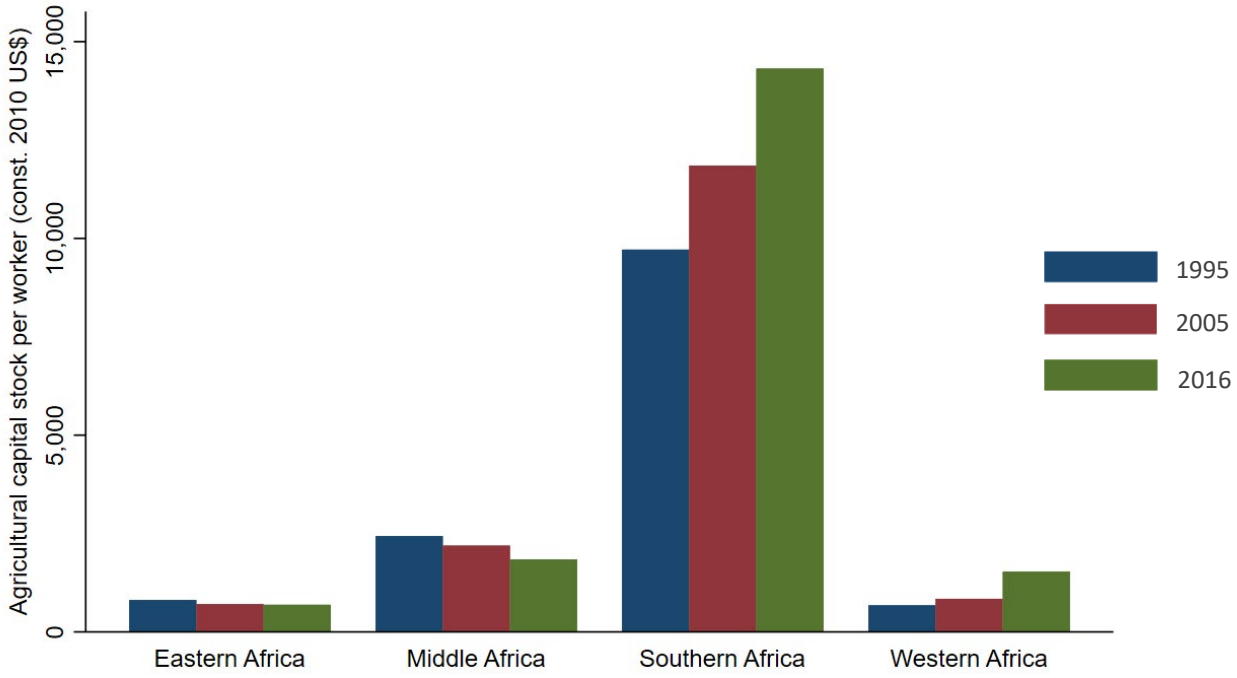
61 In constant 2009 US$.

Table 10: Agricultural capital stock per worker

	AVERAGE AGRICULTURAL CAPITAL STOCK PER WORKER (2016)	AVERAGE ANNUAL CHANGE (1995-2016)		
		Agricultural capital stock	Number of agricultural workers	Agricultural capital stock per worker
	(Constant 2010 US$)	(Percentage)		
High-income countries	**156595**	**1.4**	**-1.6**	**2.8**
Low and middle income countries	**5921**	**2.9**	**0.5**	**2.5**
Upper-middle income countries	10046	2.3	-0.3	2.6
Lower-middle income countries	3752	3.6	0.7	3.1
Low income countries	1492	2.7	1.7	1.2
Sub-Saharan Africa	**2870**	**3.4**	**1.7**	**1.7**

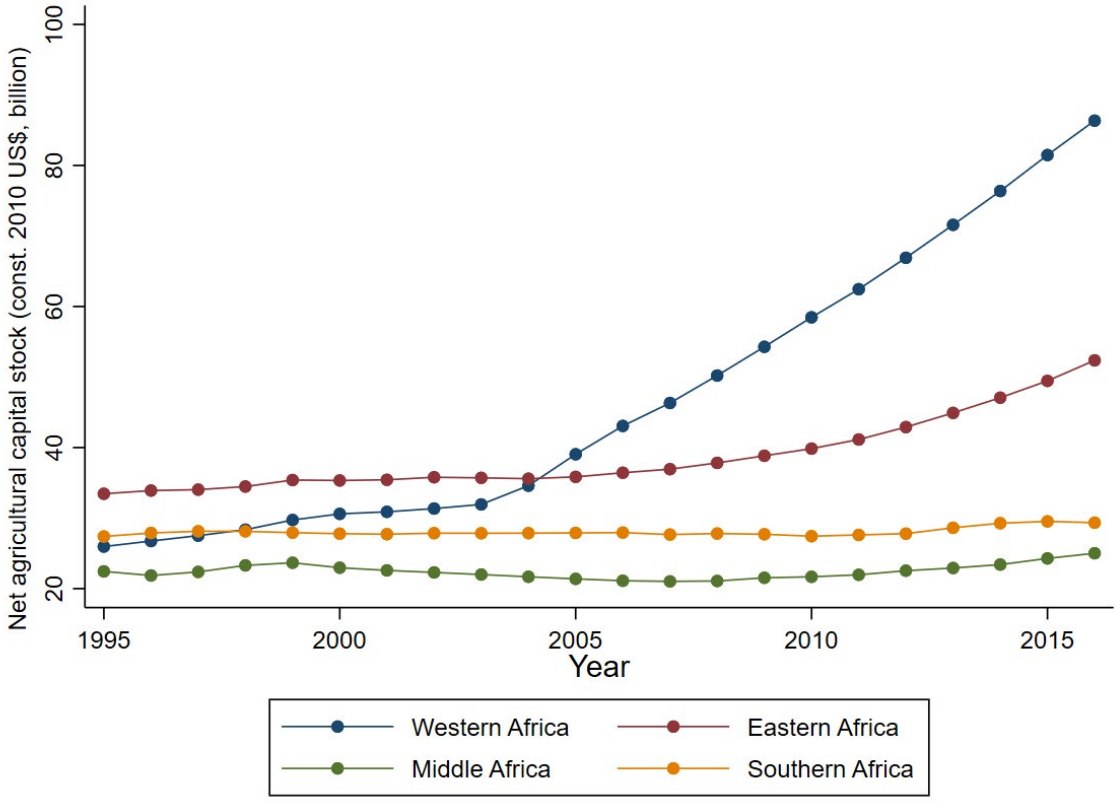
Annual changes computed at the country level and averaged over respective income groups and regions.Argentina and Belarus excluded from the analysis because of implausibly high figures compared to earlier FAO data.
Source: Authors' own elaboration based on data from ESS-FAO, UNDESA, ILOSTAT, and WDI.

Figure 25: Agricultural capital stock per worker in Sub-Saharan Africa



Source: Authors' own elaboration based on data from FAO, UNDESA, ILOSTAT, and WDI.

Figure 26: Net agricultural capital stock in Sub-Saharan Africa



Source: Authors' own elaboration based on data from FAO.

Sub-Saharan Africa in order to achieve food security by 2030.[62] They highlight an investment gap of US$ 17 billion annually current investment trends continue.[63]

The heavy underinvestment in African agriculture can be explained by the particular challenges that African small-scale producers face. Two of the most serious constraints preventing them from investment are lack of access to savings and credit, and to insurance against risk (Barrientos, 2012) (see section 5.5). Social protection transfers can be useful in addressing these constraints. They are found to enhance asset creation and better investment decisions, and to prevent households from asset depletion as a response to shocks by providing a level of protection against risk (Covarrubias et al., 2012; Hoddinott, 2008). Financial sector development as well as affordable insurance schemes will have the potential to further boost investment by farmers in a sustained way.

The broader system of incentives is not favourable to small-scale producers' investment either. Producers are disadvantaged in access to land, insecure property rights and access to markets, including inputs. Women producers in particular suffer from unequal access to resources which dwarfs their investment in agricultural assets even more than in the case of men (Karamba and Winters, 2015) (see section 6.4). In addition, agricultural policies, e.g. relative to taxation, subsidies or levels of protection, further discourage investments by creating market distortions (Anderson and Valenzuela, 2008). African governments have thus an important role to play in fostering private investment by creating an enabling environment, removing distortions, improving regulation and taxation and ensuring property rights, among others.

7.2.2 Foreign direct investment

In a context where domestic investment is not sufficient, it is expected that foreign direct investment (FDI) has the potential to fill this gap. So far, Africa only receives about 10.5 percent of the global food and agriculture FDI (Fiedler and Lafrate, 2017). In addition, FDI is very low compared to domestic investment (Figure 23). Looking at agriculture, fishery and forestry alone, the role of FDI is still marginal in monetary terms, even though the impacts of large-scale investments on local producers, for example throughout contract farming, can be substantial (Husmann and Kubik, 2019).

The contribution of FDI is most prominent in the upstream and downstream industries, which together receive 90 percent of food and agriculture FDI. In total, US$ 49 billion[64] were invested in the African food and agriculture sector over the period 2003-2017. Almost half of this amount was invested in the fertilizer sector. The second half was invested in downstream industries. While it is not possible to compare foreign and domestic investment in downstream industries because the cross-country data is missing for the latter, it can nevertheless be expected that these FDI flows have greatly contributed to the development of the agro-processing sector and to more value addition on the continent.

Potential benefits of FDI go beyond filling the financing gap. FDI is also expected to create employment, bring new technologies that increase productivity of domestic firms through spillover effects (Zhan et al., 2018), and increase the level of integration of the domestic food sector into global value chains (Amendolagine et al., 2019). These changes include a growing orientation towards export markets, especially the food markets of industrialized countries, and a consolidation of processing and retail which induced the so-called 'supermarket revolution' and the spread of fast-food chains in many lower-income countries (Reardon et al., 2009) (see section 5.7). A related organizational and institutional change is the rise of vertical coordination via contracts and market linkage arrangements, as well as private grades and standards (Dolan and Humphrey, 2004; Reardon et al., 2009; Swinnen and Maertens, 2007).

While food and agriculture FDI in Africa has started from a very low base, it has accelerated after the boom in agricultural commodities, indicating that foreign investors sought to capitalize on high food prices and high expected returns. However, an important heterogeneity can be observed across African countries (Figure 27), with the highest amount of capital invested in Nigeria (US$ 3.98 billion), followed by

62 The study does not distinguish between private and public investment and includes a range of investments that might also to some extent be funded from public sources.

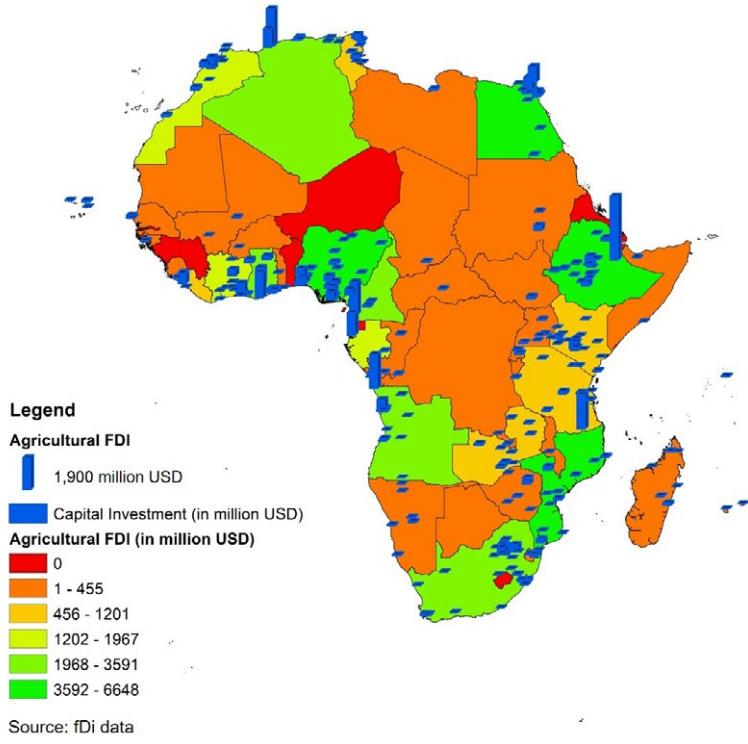
63 Note that these figures refer only to investment in agriculture. However, the total investment requirements towards food security are estimated to be much larger.

64 FDI values are presented in current US$. Taking into account short period of the analysis and low US$ inflation rate over that period, the use of deflator only has a marginal effect on the FDI values.

Egypt (US$ 2.91 billion), Cameroon (US$ 2.47 billion), and South Africa (US$ 2.46 billion). Husmann and Kubik (2019) show that foreign companies are primarily driven by the potential that a domestic emerging consumer class represents, and therefore choose to invest in big, more populous countries. Foreign investors are also attracted by countries' natural endowments and agricultural potential. While these factors are in line with economic rationale of investors, they might also explain why some African countries are left out.

In this context, several multi-stakeholder initiatives, such as New Alliance for Food Security and Nutrition and Grow Africa, have recently been launched in order to create a conducive environment for private sector investments. Even though the evidence is scarce, they seem to have fostered capital investment in African agriculture. While they may not have been effective in executing formal commitments by foreign investors, they may have been successful in creating a conducive environment for investment, with potential spillover effects on FDI realized outside the initiatives' framework (Husmann and Kubik, 2019). Along the same lines, local governments also need to support private investment by creating enabling environment, for example by investing in infrastructure, but also by improving governance which is a significant determinant of FDI in Africa (Husmann and Kubik, 2019) (see section 6.1). In addition, governments can crowd in private sector investment by channelling public expenditure towards agriculture, and research and development in particular.

Figure 27: Location of investment projects (excluding fertilizer) and investments per country (2003-2017)



Source: Husmann and Kubik (2019) based on data from fDi data (www.fdimarkets.com).

Investment and policy priorities

Capital investment is an essential component in agricultural production and a critical factor in agricultural productivity growth. However, agriculture in Sub-Saharan Africa is severely undercapitalized. Policymakers should devise policies that will target two important but very distinct actors: local small-scale producers on the one hand, and large-scale foreign investors on the other. With respect to **local small-scale producers**, the policy priorities should include in the short term:

- Facilitate access to finance and decrease cost of credit.
- Introduce affordable insurance schemes for agriculture, fishery and forestry.
- Ensure property rights.

With respect to **FDI**, the proposed measures are of a more long-term nature, but will also have the potential to improve domestic investment:

- Introduce conducive regulation and taxation regimes, but which does not undermine local interests.
- Improve ease of doing business.
- Facilitate international trade.
- Accelerate investment in infrastructure, and improve governance.

7.3 Regional and international trade

Africa's food imports amount to about US$ 46 billion per annum (in net terms). The three cereals (wheat, maize, rice) account for about US$ 25 billion per year, meat and dairy for about US$ 8 billion, the sugar sector US$ 4 billion and in the vegetable oil sector US$ 9 billion. Significant net exports are in coffee, cocoa, cotton, tea, pulses, and citrus fruits, tomatoes, South African wines, cut flowers, sesame seeds, and cashew nuts (Bouët and Odjo 2019).

The effect of trade on the different dimensions of food security is complex and requires a discussion of the different factors affecting food security, their interactions and the consideration of short- and long-term effects. For instance, in the short run, imports increase domestic supply and reduce food prices at the expense of the incomes of local farmers. In the long run, producers adjust to the increased supply and shift their production towards more profitable sectors (FAO, 2016b). Countries with limited markets access, due to geographical constraints, and larger populations require agricultural development for economic growth. Thus, a temporal protection of local industries can be desirable.

Importantly, trade and supply capability are not contrasting elements. Instead, international, particularly intra-African, trade has the potential to underpin the continent's efforts to feed itself. Africa's food security will depend on (1) the possibility of increasing Africa-wide production and intra-African trade on food items which are critical for the food (supply) chain and (2) the possibility of increasing access to food for poor (food insecure) people by enabling them to purchase food that their country cannot sufficiently produce domestically or by the country in question purchasing food from the rest of the world.

7.3.1 The gains from trade for Africa

The economic benefits of (regional) integration (e.g. creation of regional trade blocks) are not exclusive to the agriculture sector and mainly build on the re-allocation of production factors (e.g. labour, agricultural inputs) from inefficient to efficient producers, thus leading to product specialization (Baldwin and Venables, 1995). The exposure to regional or international competition for firms leads to an adjustment toward their optimal size and pushes inefficient firms out of the market. In addition, as an indirect effect, regional integration is linked to the investment in improved technologies, cross-border value chains, agricultural R&D, and related industries (UNCTAD, 2009).

In line with this, agricultural protectionism harms food security by reducing incentives and market opportunities for producers (Clapp, 2016). Therefore, it has been expected that Africa would benefit over-proportionately from trade liberalisation as proposed by the World Trade Organization Doha Round launched in 2001 (Anderson and Martin, 2005), and agricultural market integration could reduce the number of undernourished people globally by more than 100 million (Hertel and Baldos, 2018). However, to utilise this potential, trade reforms towards market liberalisation in lower-income countries are as important as the reduction of agricultural subsidies in high-income countries. The gains from trade liberalisation are partly driven by increases in agricultural productivity related to the utilisation of economies of scale in production. This is of importance for lower-income countries whose limited market size discourages the full use of the production potential. At the same time, trade liberalisation offers the potential to boost agricultural export earnings when free access to larger and more profitable markets in North America, Asia and Europe is granted. Those export earnings reduce foreign exchange deficits, create fiscal space for public investment, and generate income to purchase food at the international market. Some countries may lose in the short-run, until they restructure their economy after production has moved to a more competitive trade partner.

7.3.2 Africa's current trade position and international competitiveness

It has long been debated how Africa has become a food importer despite its vast agricultural potential related to its favourable climatic conditions, low land prices, and a large agricultural labour force as well as a balanced trade status around 1980 (Rakotoarisoa et al., 2012). The AfDB (2016b) calculates that the African food bill, representing the value of African food imports from outside of Africa, amounts to about US$ 35 billion and forecasts that it will reach US$ 110 billion by 2025. The share of intra-African in total African food import (by value) is about 15 percent and even lower for meat, wheat, and dairy products according to UNCTAD (2020) statistics. Yet, it is important to note that African agri-food trade is characterized by two

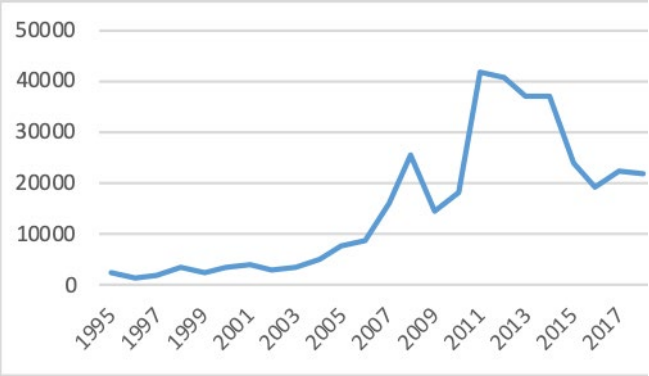
contrasting facts. On the one hand, the continent's agricultural exports mainly depend on a few raw commodities such as cocoa, coffee, cotton, and tea which make up the vast share of the continent's exports (Bouët et al., 2019). On the other hand, the continent remains a net importer of food products, particularly meat, dairy, rice, and processed foods (Kornher and von Braun, 2020). While self-sufficiency in all food commodities is not desirable due to environmental issues and resource availability (Clapp, 2016), Africa's large structural deficit in staple food production is concerning.

According to FAO (2020a) statistics, the level of food import dependency varies greatly across African countries and the type of food product within the same country. On average, import dependency is highest among cereal products with more than 40 percent and among animal-based products, such as dairy and meat, with around 20 percent. Generally, countries in West, Central, and North Africa are more import-dependent, particularly regarding cereals and dairy products (Matthews and Soldi, 2019). In an attempt to model the effects of global trade liberalisation under climate change, Cui et al. (2018) show that global food production could decline as a result of decreasing food prices, while exports and imports rise. Therefore, global trade liberalisation under the current conditions would foster Africa's current trade position and it is not expected to create incentives to expand the aggregate production of cereal crops and livestock in Africa.

However, despite low average agricultural productivity across the continent, the agricultural sector in many African countries has large export potential. This derives not from a country's potential per se but from that of individual exporting firms such that high average competitiveness is not a necessary condition for exports (Melitz, 2003). In line with this consideration, Dedehouanou et al. (2019) note that African global competitiveness has increased in recent years and is particularly concentrated in sesame seeds as well as legumes and pulses. Globalization has revealed another opportunity to benefit from international trade, namely by participating in cross-country value chains referred to as global or regional value chains. Data shows that the level of global value chain participation in Africa, relative terms, not different from other regions. In the agricultural and food sector, global value chain participation is generally, across all regions, lower than in other sectors and dominated by upstream value chain outputs, which are used by other countries to contribute to value addition. Unlike in the whole agricultural sector, in the food sector value chain activities are closer to the final consumer but constitute only around four percent of global value chain activities in sub-Saharan Africa and North Africa (Balié et al., 2019). Global value chain participation creates production incentives in two ways. First, participation in global value chains has economic benefits for accessing larger markets. This has helped to enhance productivity, sophistication and diversification of exports, irrespectively of whether a country uses imported inputs to produce goods for export or whether it provides inputs to foreign partners for their own export production (Kowalski et al., 2015). Simultaneously, upstream global value chain participation promotes agricultural productivity and provides incentives for land expansion. Higher rural incomes also contribute to poverty reduction and thus, food security in the long run, as studies from the horticulture sector across Africa show (Asfaw et al., 2009; Minten et al., 2009; Van den Broeck et al., 2017).

International trade contributes to food security also by generating export earnings and incomes for poor people. There is ample evidence that producing cash crops for export is associated with increased food security due to a relatively large share of smallholder participation in the production of those crops (Kuma et al., 2019; Wiggins et al., 2015). Particularly certified producers, e.g. for the fair-trade standard, benefit through higher wages and fair working conditions (Meemken et al., 2019). At the macro level, the terms of trade of agricultural products, that is the unit value of exports over the unit value of imports, is an indicator of how many imports a country or region can afford using its own export capacity. The costs for food importation amount to the terms of trade times the quantities exported and imported. After the net-costs of Africa's agricultural imports peaked around 2011-2013, the trade monetary deficit significantly reduced (Figure 28). If this trend continues, agricultural exports will contribute to the continent's capacity to feed itself by providing additional income to purchase food products at the international market.

Figure 28: Net cost of Africa's agricultural imports (imports-exports) (in million current US$)



Source: Authors elaboration based on UNCTAD (2020)

7.3.3 Intra-African trade and food security, including AfCTA

Regional integration

Africa is characterised by several, sometimes overlapping, Regional Trade Agreements (RTAs), which are referred to as regional economic communities (RECs). The largest economic zone having passed a RTA is the Economic Community of West African States (ECOWAS). ECOWAS is a free-trade area that overlaps with the West African Economic and Monetary Union (WAEMU)[65], which additionally applies a common external tariff. Eleven countries in Central Africa form the free-trade area of the Economic Community of Central African States (ECCAS), 6 of whom are also members of the Central African Economic and Monetary Community (CEMAC) with its common external tariff. Dominant RTAs in Eastern and Southern Africa are the East African Community (EAC) and the Southern Africa Development Community (SADC). The northern African states form the Arab Maghreb Union (AMU). The largest free-trade area is the Common Market for Eastern and Southern Africa (COMESA) comprising 20 members from the ECCAS, the SADC, and CEMAC. The level of economic integration varies significantly across different free-trade zones. According to the African Agriculture Trade Monitor (Bouët and Odjo, 2019), intra-African trade in agriculture remains low, ranging between less than 5 percent in the ECCAS and AMU and close to 30 percent in the SADC. However, official statistics may largely underestimate actual cross-border trade flows in Africa.

Regional integration impacts African food security in two ways. First, trade usually increases the accessibility of food by reducing prices. Second, trade has an effect on total food supply. A positive impact of the trade agreement on food supply requires that more trade was created than was diverted. In other words, additional trade flows between countries within the trade agreement have to outweigh the reduction in trade flows with countries outside the agreement. Mujahid and Kalkuhl (2016) show that, since 1990, regional trade agreements have increased food supply and food trade quite significantly which will presumably improve access to external markets for farm households and enhance their incomes. Among the RECs, the strongest impact was found for the SADC and COMESA, for which food trade doubled through regional integration, while food trade has not increased through the implementation of ECOWAS. However, taking into account not only tariffs but also non-tariff barriers reveals that regional trade integration has shown to be beneficial to the food supply in ECOWAS, thus underlining the importance of trade facilitation to increase production incentives (Seck et al., 2010). A study by Tadesse and Badiane (2018) predicts that if exporting and importing countries are in the same REC, a country's export value will increase by 3 to 5 percent. In conclusion, regional integration has raised agricultural production and created export earnings in Africa, albeit to a varying extent across the RECs.

The consideration of competitiveness and comparative advantages in different food commodities across the members of the RECs, allows a more nuanced assessment of the production incentives of regional trade integration. For instance, the commodity breakdown of the analysis by Cui et al. (2018) shows that trade liberalization would increase maize exports in both Eastern and Southern Africa despite a reduction in the net trade balance in maize in the two regions (Kornher, 2018). In line with this, Sukati (2016) ascertains a structural advantage in maize production for Malawi, Zambia, and Uganda. Maize is among the most traded commodities in COMESA and the SADC, and maize trade accounts for about 5 percent of the total agricultural trade in both RECs (Goundan and Fall, 2017). In West Africa, Mali is considered as internationally competitive in rice production due to the irrigation system installed along the Niger river, which enables the country to export to food-deficient neighbouring countries (European Commission, 2017).

65 Eight out of 15 ECOWAS member states form the WAEMU.

Intra-ECOWAS rice trade currently makes up 4 percent of regional trade in ECOWAS but has been among the fastest-growing sectors since 2006. Intra-African food trade has further diversified over the last decade with frozen fish being the most important traded commodity accounting for more than 7 percent of all trade value (Goundan and Fall, 2017). The growing demand for dairy products and meat, particularly in urban settings in Africa, will boost regional trade in milk and livestock. Uganda has become the largest exporter of dairy products in Africa and could serve its neighbouring countries. However, the expansion of production requires investments in improved technologies and the formalisation of the milk trade (Makoni et al., 2014).

The incentives to increase African production in these commodities and products, however, depends not only on the elimination of tariffs but also requires the abolishment of non-tariff barriers which lead to border price differentials of more than 15 percent in ECOWAS (Allen, 2017). Bonuedi et al. (2020) analyse the effects of non-tariff barriers on food security in Africa and find that lower transaction costs are associated with a reduced prevalence of undernourishment, an increase in dietary energy supply adequacy, and a lower food deficit in Africa.

There is ample evidence of the benefits of regional integration for economic growth, trade, and employment (Balistreri et al., 2018; Makochekanwa, 2014). As a result of better export opportunities, the income of trade partners will rise and contribute to their higher purchasing power. The integration of food markets, which stabilises prices to the benefit of both consumers and producers, will also benefit regional price stability in all regional trade blocs, most of all in West Africa. In addition, reduced transport and transaction costs could significantly boost regional trade (Badiane and Odjo, 2016).

Regional trade is not only critical to food security by improving food availability and accessibility, but also has great potential to smoothen domestic supply shocks, which are common and will, in rainfed agricultural systems, become more frequent with climate change. In integrated markets, spatial arbitrage guarantees the movement of available food between different countries given its relative scarcity. Therefore, food supply and commodity prices are automatically stabilised in case of production failures, e.g. caused by extreme weather events, through the means of efficient markets. The larger and more geographically diverse the common market is, the more stable is aggregated food production. Kornher and Kalkuhl (2019) examine the potential benefits of trade integration on the stability of food supply in West Africa. The results show that regional food supply has varied only by around 3 percent and, therefore, much less than the country-level food supply. Similarly, trade integration offers great potential to stabilise maize supply in Eastern and Southern Africa (Kornher, 2018).

African Continental Free Trade Area (AfCFTA)

In March 2018, during an Extraordinary Session of the African Union, representatives of 44 (out of 55) member countries of the African Union signed the consolidated text of the AfCFTA agreement. By July 2019, Nigeria, Africa's largest economy, also signed the agreement making it 54 countries that signed the declaration, with Eritrea being the only remaining African country outside of AfCFTA. Once in operation, the AfCFTA offers a US$ 3 trillion market (in terms of aggregate GDP) and could cover all 55 countries which would make it the largest free-trade area globally in terms of the number of countries.

The AfCFTA has the potential to support the realisation of the continent's economic promise and to enhance the structural transformation of African economies. Since the discussion about a pan-African trade zone has started, several studies have analysed its overall economic impact but not specifically its significance for obtaining food security. A review of the existing studies, however, gives a clear picture: a) intra-Africa trade would be boosted, b) overall GDP and employment would increase, c) real wages would increase and poverty decline, d) tariff revenues would collapse, and e) impacts would be heterogeneous with some countries experiencing losses.

The assessment of the potential economic gains of a pan-African trade zone is usually modelled through economy-wide trade models. Estimating the effects on different agriculture sectors and food security at the country level is, however, challenging due to the aggregation of commodities and various sectoral interlinkages. It was predicted that intra-African agricultural trade could be boosted by 20 to 35 percent, with the starkest increase being observed for meat and dairy products, sugar, beverages and tobacco, vegetables/fruit/nuts, and rice (UNECA and AU, 2020). For the agricultural sector as a whole, the World Bank (2020f) forecasts an increase in intra-African imports by 72

percent in 2035 compared to the current situation. Saygili et al. (2017) report sector-specific employment effects and show that employment in dairy, grains, and other agricultural sub-sectors significantly contributes to the overall employment gains. Abrego et al. (2019) show that agriculture is the second most important sector, after manufacturing, contributing 16 percent of the overall welfare gains of the AfCFTA. However, as indicated above, trade liberalisation would create losers and winners, and for some countries the tariff revenue loss would not be compensated by the gains in terms of trade creation and employment. Generally, consumers benefit from lower commodity prices while producers in countries with lower competitiveness lose. Therefore, in the short run, the AfCFTA is likely to foster existing comparative advantages in agricultural production while being problematic for vulnerable countries with high malnutrition rates and low agricultural potential.

7.3.4 Africa's international trade

As previously discussed, a pan-African free-trade zone could create strong production incentives. However, the current regulatory framework of the AfCFTA regarding trade with the rest of the world remains vague. The AfCFTA proposal talks about a free-trade area but not about a common external tariff. Furthermore, only 90 percent of the total trade shall be liberalised. Without a common external tariff, tariff differentiation could lead to tax competition between governments and open the door for cross-border smuggling between neighbouring countries applying different tax rates (Kornher and von Braun, 2020). Odijie (2019) argues that a regional trade policy without regional coordination of industrial policies could increase protectionism instead of promoting trade integration. An exclusion list, similar to the list of development goods in ECOWAS, allows countries to protect local producers of goods which could otherwise be imported from the region. In such a case, the market size argument for small countries disappears. As a consequence of external trade agreements, countries could eventually support and protect producers of the same goods as their trading partners, as the examples of cement and poultry from West Africa show. Therefore, the sameness of the industrial policy creates losses for consumers, and production capacities cannot be built up without the prospect of export (Odijie, 2019).

Africa's position in international trade is not only linked to a pan-African free-trade zone, but also to Africa's level of integration in the international trade system. Irrespective of the implementation of the pan-African free-trade zone, the landscape of existing and potential trade agreements remains confusing. Under the Cotonou Agreement, which governs Africa's trade relationship with the European Union, the EU's grant of non-reciprocal trade preferences was terminated. Economic Partnership Agreements (EPAs) allow African countries to restrict market access by making use of tariffs for sensitive agricultural products but ask for a gradual reduction of tariffs and an entirely free market access by 2035. The adoption of the EPAs has stagnated in recent years, partly owed to diverging interests of regional trade partners in the respective economic and trade zones in Africa and of the least-developed countries within RECs, which are granted free access to international markets under the Everything but Arms agreement (Schmieg, 2018). Since the Cotonou Agreement, agricultural trade between the EU and Africa as well as African exports to the EU have increased; however, the trade pattern, which has manifested, is that Africa exports raw commodities and imports food products (Kornher and von Braun, 2020).

The African Growth and Opportunity Act (AGOA) is the equivalent contractual base to govern the US-African trade. It includes a list of African countries that are granted free access to the US market. In reality, it mainly offers preferential market access for oil and gas exports from Africa (predominantly for Angola and Nigeria) and has not affected agricultural trade from Africa to the US since its implementation (Zenebe et al., 2014). Consequently, it did not create production incentives in Africa.

Several African countries also concluded special trade agreements with single states, most notably with China. Given the uncertainty and ambiguity in the regulatory framework of the AfCFTA, it will be important for the African continent to stipulate its external trade relations in new trade agreements with major trading partners, such as the EU, the US, and China. A pan-African free-trade area, that pools all African forces, has the potential to increase Africa's weight in international trade negotiations.

The international trade system has become fairer due to the World Trade Organization negotiations

and the reductions in agricultural subsidies in high-income countries. However, it still discriminates against African producers (Kornher and von Braun, 2020). Historically, agricultural policies in Africa have discriminated against local producers, which has in recent years been attenuated by policies in line with the CAADP objectives (Anderson et al., 2013; Anderson and Masters, 2009; Angelucci et al., 2014). Nevertheless, agricultural producers in developed countries are still supported by agricultural incentives (Anderson and Nelgen, 2012), despite the consideration of non-price subsidies, such as decoupled payments, in the agricultural incentives data (Kornher and von Braun, 2020). In addition, free-market access to the EU and the US market is conditional on quality, health, environmental and social standards of agricultural and food products from Africa. Yet, African producers often lack the technical capacity to meet these standards. For processed foods, the rules of origin regulation at destination make it difficult for African producers to export higher-value products since the proof of origin may be difficult to provide. To ensure that production incentives in Africa are created, future trade agreements should therefore provide for the concession of long and result-oriented transition periods, thus allowing African countries to protect key agricultural sectors. Furthermore, the simplification of origin rules and the continuation of "Aid for Trade" programs could improve the standards of African products to allow African countries to build up sufficient capacity to generate export earnings in higher-value agriculture products (Kornher and von Braun, 2020).

Investment and policy priorities

Regional trade integration in Africa is one of the most important strategies to enable Africa to feed itself. However, the following key policy and investment priorities have to be addressed to fully optimize the benefits of regional trade.

- **Facilitate the institutionalization and sustainability of non-tariff reporting.** The main obstacle to improving Africa's agricultural trade integration is that free trade exists only de jure, but de facto non-tariff barriers remain. Examples are administrative barriers such as time and costs spent on customs handling and declaration as well as ad hoc trade restrictions. These barriers continue to exist and create disincentives to invest in regional trading (Odijie, 2019). The AfCFTA is linked to the promise that market access in Africa will be enhanced and restrictive trade policies eliminated. In an attempt to improve the current situation, the African Union has launched a website to document non-tariff barriers in Africa.[1] On the website, businesses can report non-tariff barriers and monitor the process until their resolution. This is an important initiative that deserves due attention from governments and donors to ensure its institutionalization and sustainable operation.
- **Effectively implement the AfCFTA to address the regulatory barriers to trade within Africa and from Africa to other regions in the world.** Most notable are technical barriers to trade, which include social standards, such as minimum wages and the exclusion of child labour, as well as sanitary and phytosanitary standards (Kornher and von Braun, 2020). Such standards serve a legitimate and critical function in the destination market to protect public health as well as animal and plant life and health. Both, meeting the standards and providing the necessary proofs, increase the transaction costs of trade irrespective of the level of competitiveness of the producers. Currently, food safety issues in Arica are not well developed as they are characterized by weak institutional legitimation, inadequate laboratory capacity, and complicated outdated processes. The harmonisation of sanitary and phytosanitary standards and administrative procedures, possibly through the establishment of the African Food Safety Agency (AFSA), is a significant step towards improving institutional capacities, reducing transaction costs, and facilitating access to foreign markets (FAO, 2020d). In addition, public investment in quality testing equipment, such as moisture

1 https://tradebarriers.africa/

meter and laboratories, would be capable of reducing transaction costs and encouraging value chain participation. The implementation of the AfCFTA is associated with substantial costs to facilitate the negotiation process and harmonize standards and trade rules across the continent. The African Union should be supported financially and through capacity building to support this process.

- **Create a regulatory framework though the AfCFTA to overcome overlapping investment strategies, reduce redundant public investment, and complement the CAADP objectives** in facilitating national and regional agricultural investments necessary to increase agricultural productivity and improve food security in Africa. The framework could contribute to coordinating public investment in R&D, training and extension but also in programmes facilitating access to and the adoption of high-quality inputs (seeds, fertilizers, machinery) and technologies (FAO, 2020d).
- **Develop regional value chains with regional production hubs**, which benefit from spill-over effects due to agglomeration of knowledge and technology transfer, will help to improve income and food security in Africa.
- **Support least-developed countries** to increase their participation in international trade, by building trade and productive capacities so that the preferential market access provided to least-developed countries may improve their export capabilities and help diversify their economies. This entails continued systems of support such as Aid for Trade (United Nations, 2020). Between 2006 and 2017, donors have disbursed US$ 410 billion, of which Africa received US$ 146 billion. Empirical evidence has showed that this support has assisted low-income countries in expanding and diversifying their trade and helped create jobs both for men and women (OECD and WTO, 2019).

7.4 Policy processes and initiatives in Africa and at the international level

African governments, the development partner community, sub-regional and continental organizations have all formulated various initiatives and policies to improve the productivity of the agricultural sector and reduce food insecurity on the continent. The African Union Commission, the RECs as well as sub-regional organisations have embarked on various ambitious productivity enhancing programmes. Some of the ongoing initiatives are discussed in this section.

7.4.1 Ongoing initiatives in Africa

The African Union Commission has underscored at various points in time the need for African governments to increase their investment in their agricultural sector. The African Union Agenda 2063 and the CAADP are the two flagship initiatives formulated to improve the functioning of the agricultural sector and enhance overall progress. In addition, various progress monitoring mechanisms have been put in place. For instance, the African Peer Review Mechanism is a self-monitoring voluntary mechanism that was agreed and adopted by the African Union member states in 2002. The main objective of this mechanism is to improve governance dynamics at the local and continental level. The Agenda 2063 dashboard, the CAADP dashboard and the SDG dashboard are additional mechanisms to monitor progress in their respective areas. The different continental organizations established to coordinate various activities of the African Union also have their own strategies and programmes.

African Union Agenda 2063

The African Union Agenda 2063 is a strategic framework for the socio-economic transformation of the continent adopted in 2013 by the African Union Commission. It builds on and seeks to accelerate the implementation of past and existing continental initiatives for growth and sustainable development. Some of the main characteristics and intentions of the Agenda 2063 include the creation and maintenance of an effect-equitable and people-centred growth and development, the eradication of poverty, and the enabling of internal coherence and coordination to continental, regional and national frameworks and plans adopted by the African Union Commission, the RECs and

member states. Agenda 2063 has seven aspirations one of which focuses on modernizing agriculture for increased production, productivity and value addition using science, technology, innovation and indigenous knowledge so that it contributes to national prosperity and Africa's collective food security. More specifically, the vision aims at consolidating the modernization of African agriculture and the agribusiness sector through scaled up value addition and productivity (AU, 2015a). By 2063 it aims to:

- Completely eliminate hunger and food insecurity;
- Reduce the imports of food and raise intra-African trade in agriculture and food to 50 percent of total formal food and agricultural trade;
- Expand the introduction of modern agricultural systems, technology, practices and training, including the banishment of the hand-hoe;
- Develop and implement affirmative policies and advocacy to ensure women's increased access to land and inputs, and ensure that at least 30 percent of agricultural financing is accessed by women; and
- Economically empower women and youth by enhancing access to financial resources for investment.

The Comprehensive African Agricultural Development Programme (CAADP)

Recognizing the importance of the sector to the economies of its member states, the African Union, together with the NEPAD, created CAADP in 2003 in Maputo. CAADP is an Africa-wide blueprint for accelerated agricultural growth that seeks to promote policies and partnerships, raise investments in Africa's agricultural sector, and achieve better development outcomes. The principal objective of CAADP is to help African countries alleviate poverty and achieve food security by attaining an average annual agricultural growth rate of six percent through allocating at least ten percent of their total annual budgets to the sector, and one percent of agricultural GDP to agricultural research (AUDA-NEPAD, 2003). Although continental in scope, it is integral to national efforts to promote agricultural growth and economic development.

CAADP pursues the following principles and targets:

1. Agriculture-led growth as a main strategy to achieve the Millennium Development Goal of poverty reduction (MDG 1),
2. Pursuit of a six percent average annual agricultural growth rate at the national level,
3. Allocation of 10 percent of national budgets to the agricultural sector,
4. Exploitation of regional complementarities and cooperation to boost growth,
5. Policy efficiency, dialogue, review, and accountability, shared by all the NEPAD programmes,
6. Building partnerships and alliances to include farmers, agribusiness, and civil society communities,
7. Implementation principles, including programme implementation by countries, coordination by regional economic bodies, and facilitation by the NEPAD Secretariat.

CAADP defines four major intervention areas, or pillars, to accelerate agricultural growth, reduce poverty, and achieve food and nutrition security in alignment with the above principles and targets:

- Pillar I. Extend the area under sustainable land management and reliable water control systems.
- Pillar II. Improve rural infrastructure and trade-related capacities for market access.
- Pillar III. Increase food supply, reducing hunger, and improve responses to food emergency crises.
- Pillar IV. Improve agriculture research and technology dissemination and adoption.

In their Declaration in Malabo in 2014, African leaders noted the progress already made using the CAADP Results Framework. The CAADP principles and goals were reaffirmed in the Declaration and a set of goals and targets that will be pursued over the next decade in the "Accelerated Agricultural Growth and Transformation Goals 2025" were set. The Malabo Declaration further stressed the need to boost intra-African trade and enhance the resilience of livelihoods and production systems to climate risks and external shocks, and it expanded on mutual accountability requirements (AU, 2014).Assessment reports on the targets of Agenda 2063 and CAADP show mixed performances for African countries on agricultural indicators. The actual achievement of the ten percent target has been patchy. Some African countries have achieved the target some of the time, but very few countries have managed to consistently reach this level of funding (Benin and Yu, 2013; Husman et al., 2015). According to a study by Getahun et al. (2018), even the best performing countries have not consistently achieved these targets between 2005 and 2014 – the years for which data were available.

The African Development Bank's Feed Africa Strategy

Since agriculture is the mainstay of many African countries' economies, agricultural development is an area of focus of the African Development Bank (AfDB) group. Accordingly, the AfDB provides financial and technical support to African countries for agricultural sector development. To improve Africa's agricultural sector and achieve self-sufficiency as well as develop an improved value chain for export commodities, in 2016 the AfDB launched the "Feed Africa: Strategy for Agricultural Transformation in Africa, 2016-2025". The main aim of the strategy is to help end extreme poverty, eliminate malnutrition, end dependency on feed imports and move Africa to the top of the value chain in areas of its comparative advantage. It focuses on increasing agricultural production and productivity, boosting investments in enabling infrastructure and creating an enabling agribusiness environment while ensuring inclusivity, resilience and sustainability. The "Feed Africa" strategy intends to contribute and build on the Maputo Declaration and Malabo Commitments through the CAADP by providing support to the goals of the CAADP.

The Great Green Wall of the Sahara and Sahel Initiative (GGWSSI)

Desertification is a major problem particularly in the Sahel where some of the world's poorest communities reside. Desertification and land degradation have a strong negative impact on the food security and livelihoods of local communities in the region. Millions of people from Senegal to Djibouti are dealing with persistent droughts, famines, and rapidly depleting natural resources on an ongoing basis. Thus it was necessary to initiate a project that could save the Sahel region from ecological collapse. The Great Green Wall initiative, launched by the African Union in 2007, was conceived to help reverse desertification, improve food security and reduce poverty. The initiative is about sustainable and climate smart development and is a symbol of hope for millions of people in the region. By 2030, the initiative aims to restore 100 million hectares of currently degraded land, sequester 250 million tonnes of carbon and create 10 million green jobs (UNCCD, 2020). Millions of trees have already been planted across the southern edge of the Sahara desert.[66] Communities across the Sahel region are employed to build and maintain the wall, and as such, the project is intended to have long-lasting benefits for both people and planet. Once complete, the wall will be an 8000 km natural wall stretching across the entire continent. The initiative is now being implemented in more than 20 countries across Africa and more than US$ 8 billion has been mobilized and pledged in its support (UNCCD, 2020).

Agricultural programmes within the Regional Economic Communities (RECs)

As elaborated in section 7.3.3, several RECs have been created across Africa to serve their respective member States. So far, eight regional communities have been established and recognized as the building blocks of the African Union, namely: Arab Maghreb Union (AMU), the Community of Sahel-Saharan States (CEN-SAD), Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Economic Community of Central African States (ECCAS), Economic Community of West African States (ECOWAS), Intergovernmental Authority on Development (IGAD), and Southern African Development Community (SADC). Agricultural development and food security are among the priorities of these regional community interventions.

7.4.2 Some significant international processes

Marshall Plan with Africa

In 2017, Germany along with the European Union have chosen to focus on African relations and development. To this end, the Marshall Plan with Africa was introduced to "find a path to peace and development" (BMZ, 2017, p. 4) in the context of developing a new European strategy for Africa. The Marshall Plan focuses on fair trade, increased private investment, bottom-up economic development, increased entrepreneurial spirit and higher levels of employment (BMZ, 2017, p. 4). The Plan consists of 10 starting points based on these priorities, the 10th of which, entitled "We will leave no one behind," focuses on ensuring basic needs, including promoting rural and agricultural development (BMZ, 2017, p. 6). The Marshall Plan provides a roadmap to improving agricultural development from all sides, ranging from launching targeted programmes to improve food security in Africa to intensifying public research on the German

66 Although trees are the primary focus, other methods are being used to help restore the land based on the specific bio-geographical needs.

side to providing Africa better access to EU markets on the international end (BMZ, 2017, p. 26). Additionally, by increasing innovations, access to financial services, infrastructure and land rights, African agriculture can become competitive and improve the livelihoods and food security of millions of people.

Compact with Africa

The Compact with Africa (CwA), which was initiated under the German G20 presidency in 2017, aims to increase private investment in Africa by making investment more attractive. To this end, twelve African countries (Benin, Burkina Faso, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Guinea, Morocco, Rwanda, Senegal, Togo and Tunisia) have joined the Compact. These countries work with international organizations and G20 bilateral partners to come up with a country-specific reform agenda, support policy measures and promote investment opportunities to investors. The CwA is considered the central pillar of the G20 Partnership with Africa and is designed to complement other relevant initiatives in Africa. It is established within the G20 finance track and falls under the work of the Africa Advisory Group, a regular G20 working group (GwA, n.d.). Implementation is carried out in three steps. African countries must choose to participate in the initiative. By signaling this interest, the country in question meets with international organizations as a first step to discuss objectives and national priorities and contributions. The second step is working with international organizations to specify Compact priority areas for reforms and measures designed to encourage private investment. In the final step, the country works with international organizations and interested G20 members to create concrete reform measures for implementation (GwA, n.d.). As the CwA includes promoting private investment for infrastructure and technology, its implementation is therefore important for ensuring the modernisation of African agriculture. By improving infrastructure and good governance, investments would increase and therefore improve agricultural development (Kappel and Reisen, 2019). The modernisation of agriculture would, in turn, reduce poverty and ensure food security.

Special Initiative: ONE World-No Hunger of German Government

The large and comprehensive ONE World-No Hunger initiative launched by the German government in 2014 seeks to determine the structural causes of hunger and food insecurity and promote rural development with the end goal of ending hunger and malnutrition globally. At the same time, sustainable agriculture is ensured. The BMZ invests approximately 1.5 billion Euros per year in projects under this initiative. Investment in innovation is a central component (Green Innovation Centers). The initiative improves food security, increased knowledge in nutrition, green innovation and soil protection, and contributed to the protection and rehabilitation of land (BMZ, 2018).

Africa-EU Partnership

The Africa-EU Partnership is the formal political channel through which Africa and the European Union work together. The Partnership was established in 2000 and followed up by the Joint Africa-EU Strategy in 2007. The current four priority areas are: investing in people; strengthening resilience, peace, security and governance; mobilising investments for African structural sustainable transformation; and migration and mobility (AEP, 2019). The third priority area, in particular, includes projects that aim to improve African infrastructure, the livestock sector and establishment of a free-trade zone, among others. Such investments would support the development of the agricultural value chain and therefore lead to improved food security.

In 2018, the European Commission set up the **Task Force rural Africa** to advise the European Commission and African Union on how best to contribute to sustainable development and job creation in Africa's agri-food sector and rural economy. In its first report, the Task Force highlighted four four strategic areas of actions for a rural transformation in Africa: (1) a territorial approach for job creation and income growth; (2) sustainable land and natural resource management and climate action; (3) supporting the sustainable transformation of African agriculture; and (4) development of the African food industry and food markets (TFRA, 2019). In a recent update, the Task Force highlighted urgent actions needed to deal with the impact of the COVID-19 pandemic, including supporting the most vulnerable African populations impacted by COVID-19, strengthening the resilience of local food systems, and committing to an Africa Europe Climate Alliance to raise the political priority of climate action (TFRA, 2020).

UN Food Systems Summit

The UN Food Systems Summit, to be convened in 2021, aims to "help stakeholders and leaders of transformation initiatives better understand and manage the complex choices that affect the future of food systems and accelerate progress toward the SDGs" (FAO, 2020e). To this end, five goals have been identified that are in line with the Sustainable Development Goals:

1. Ensuring access to safe and nutritious food for all (enabling all people to be well nourished and healthy; progressive realization of the right to food).
2. Shifting to sustainable consumption patterns (promoting and creating demand for healthy and sustainable diets, reducing waste).
3. Boosting nature-positive production at sufficient scales (acting on climate change, reducing emissions and increasing carbon capture, regenerating and protecting critical ecosystems and reducing food loss and energy usage, without undermining health or nutritious diets).
4. Advancing equitable livelihoods and value distribution (raising incomes, distributing risk, expanding inclusion, promoting full and productive employment and decent work for all).
5. Building resilience to vulnerabilities, shocks and stresses (ensuring the continued functionality of healthy and sustainable food systems) (FAO, 2020e).

Each goal has a designated Action Track, towards which regional, national and multinational initiatives will work as preparation for the Summit. The Summit seeks solutions that drive forward the 2030 Agenda to implement the Sustainable Development Goals and also aims to create public dialogue around food systems and how they can function better. The Summit will consist of an Advisory Committee chaired by the UN Deputy Secretary-General, a Scientific Group, a Champions Network to mobilize stakeholders, and a UN Task Force. Initial meetings have already taken place in preparation for the

7.4.3 Towards effective development partnerships in agriculture

The above mentioned initiatives only materialize in terms of food security and agricultural development if partnerships work. Harmonization and even some consolidation among the initiatives on the side of Development partners is also considered. In any case, effective partnerships that produce impactful results will have to incorporate three main principles:[67]

- Sufficient alignment with country policies and priorities
- Adequate coordination of development assistance programs on the ground
- Collective adherence to shared mutual accountability processes

The traditional approach of isolated efforts that may or may not be aligned with country priorities, well-coordinated among development partners or inclusive of private sector and civil society has shown its limit. Although there seems to be consensus about what needs to be done, real change toward forging more impactful development partnerships has been extremely difficult to implement. One of the rare initiatives that have made earnest efforts in this area is the New Alliance for Food Security and Nutrition (NAFSN). Launched in 2012, in the aftermath of the global food crisis, as a joint initiative between African governments, the private sector, and development partners, the initiative sought to improve the policy environment, facilitate responsible private investment in the agricultural sector and improve households' poverty status within a selected group of African countries.

Under NAFSN, African governments, G7 development partners, African and global private sector companies, and civil society and farmer organizations pledged to implement a set of concrete actions and commitments, including policy reforms, multi-year funding commitments, and responsible investments, aimed at establishing an enabling environment for investment and accelerating agriculture-sector growth. NAFSN could be seen as a response by the global community then to efforts by African countries to restore growth to national economies through improved economic governance and renewed development cooperation under the NEPAD, with primary focus on the CAADP. NAFSN espoused the NEPAD and CAADP values and principles of alignment, inclusivity and mutual accountability, even if their implementation was at time wanting. In all participating countries, the initiative helped bring together major players in the food system, especially governments, development partner agencies, farmers associations, and the private

67 Based on Badiane et al. (2018).

sector around Country Cooperation Frameworks with a shared set of mutual commitments: policy commitments by countries, financial and technical commitments by development partners and investment commitments by private sector companies.

The different parties managed to make progress with respect to the implementation of commitments that are set out in the various Country Cooperation Frameworks, although many commitments were not fully realized. Governments made good progress in implementing many of the large number of policy commitments. The financial commitments were met at different degrees according to donors and countries. Finally, commitments made by individual development partners under the initiative did align with country priorities as spelled out in the respective National Agricultural Investment Plans. The review and dialogue processes were among the weakest aspects of NAFSN, as established modalities for accountability and reporting did not allow for full participation of the private sector or broad and sustained engagement among all stakeholders and beneficiary communities. The least progress was observed with respect to achieving the investment targets stated in private sector letters of intent, although evidence on the ground showed cases of significant new investments. The set of key lessons summarized below can be drawn from the NAFSN experience. They relate to reform ambitions, implementation capacity, additionality and scale, integration and synergy, private sector engagement, and mutual accountability.

1. ***Alignment and Coordination:*** Improved alignment with country strategies and priorities has been one of the stronger features of the NAFSN. The benefit of alignment is enhanced when it extends beyond the mere mapping of activities into joint planning and coordinated implementation.
2. ***Policy reform ambitions and implementation capacity:*** The urgent need to remove the many policy and regulatory bottlenecks hampering progress has to be balanced with the implementation capacity of countries. Too many reforms too fast are likely to lead to failure of action. Gradualism and better sequencing, accompanied with targeted capacity building, is likley to produce more and sustained progress.
3. ***Additionality and scale:*** Going to scale and achieving ambitious transformation goals call for new and additional resources beyond existing portfolios. The issue here is not just financial resources but also support for enhanced implementation capacity, without which additional commitments are not certain to lead to commensurate increases in achievements or outcomes.
4. ***Translating national level commitment into local action:*** NAFSN focused on national level commitments for practical reason, and for that reason lacked well thought out modalities to translate higher level commitments into local action. This is primarily an issue of execution capacity and the quality of sector governance. Therefore, greater attention to and investment in these areas ought to be a priority.
5. ***Deepening the private sector engagement:*** Full integration of and engagement by the private sector will require modalities which can adequately address the usual commercial concerns of private businesses such as to ensure their adequate participation in dialogue and accountability processes. In particular, it will be important to find tools and procedures that can satisfy both the requirement for effective accountability and address the sensitivities of commercial businesses.
6. ***Embedded monitoring & evaluation and learning:*** The New Alliance suffered from difficulties to measure and attribute impact. This can be remedied through the embedding of rigorous evaluation modalities in the design and implementation of main partnership activities. This is not only critical for adequate guidance of implementation and tracking of implementation progress and outcomes, it also facilitates the identification of success factors and provides useful guidance for replication and scaling out of successful interventions to more countries and donor organizations.

8 REFERENCES

Aanyu, Margaret, Denis, O., Cassius, A., Gertrude, A., 2020. Potential for enhancing and sustaining commercial aquaculture in Uganda: Producer organizations, contract farming schemes and public-private partnerships. Int. J. Fish. Aquat. Stud. 8, 258–264.

Abate, G.T., Abay, K.A., Spielman, D., 2020. Fertilizer Policies and Implications in Africa, in: Diao, X., Resnick, D., Tadesse, G. (Eds.), Sustaining Africa's Agrifood System Transformation: The Role of Public Policies. ReSAKSS Annual Trends and Outlook Reports 2020. International Food Policy Research Institute, Washington D.C.

Abate, G.T., Bernard, T., 2017. Farmers' quality assessment of their crops and its impact on commercialization behavior: A field experiment in Ethiopia. International Food Policy Research Institute, Washington D.C.

Abdulai, A., Owusu, V., Goetz, R., 2011. Land tenure differences and investment in land improvement measures: Theoretical and empirical analyses. Journal of Development Economics 96, 66–78.

Abebe, G.K., Bijman, J., Kemp, R., Omta, O., Tsegaye, A., 2013. Contract farming configuration: Smallholders' preferences for contract design attributes. Food Policy 40, 14–24.

Abrego, L., Amado, M.A., Gursoy, T., Nicholls, G.P., Perez-Saiz, H., 2019. The African Continental Free Trade Agreement: Welfare Gains Estimates from a General Equilibrium Model (Working Paper No. 19/124). International Monetary Fund, Washington D.C.

Access to Seeds Foundation, 2018. The Rise of the Seedproducing Cooperative in Western and Central Africa. Access to Seeds Foundation, Amsterdam.

ACET, 2014. Bushmeat and the Future of Protein in West Africa (No. 9), West Africa Trends. The African Center for Economic Transformation, Accra.

Acosta, D., Hendrickx, S., McKune, S., 2019. The livestock vaccine supply chain: Why it matters and how it can help eradicate peste des petits Ruminants, based on findings in Karamoja, Uganda. Vaccine 37, 6285–6290.

Adams, A.V., Coulombe, H., Wodon, Q., Razmara, S., Bank, W., 2009. Education, Skills, and Labor Market Outcomes in Ghana 35.

Adams, M., Palmer, R., 2007. Independent Review of Land Issues, Volume III, 2006-2007, Eastern and Southern Africa. Mokoro Ltd, Oxford.

Adekunle, A.A., Ajuruchukwu, O., Tunde, A., Mugabo, J., Oluwole, F.A., 2013. Lessons and impact of partnerships: Experiences from FARA's initiatives in Africa. Forum for Agricultural Research in Africa, Accra.

Adeleke, B., Robertson-Andersson, D., Moodley, G., Taylor, S., 2020. Aquaculture in Africa: A Comparative Review of Egypt, Nigeria, and Uganda Vis-À-Vis South Africa. Reviews in Fisheries Science & Aquaculture.

Adenle, A.A., Wedig, K., Azadi, H., 2019. Sustainable agriculture and food security in Africa: The role of innovative technologies and international organizations. Technology in Society 58, 101143.

Adu-Baffour, F., Daum, T., Birner, R., 2019. Can small farms benefit from big companies' initiatives to promote mechanization in Africa? A case study from Zambia. Food Policy 84, 133–145.

AEEP, 2017. Ten Years of the Africa-EU Energy Partnership: Status Report 2017-18 and future perspectives. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Eschborn.

AEP, 2019. The Partnership and Joint Africa-EU Strategy [WWW Document]. The Africa-EU Partnership. URL https://africa-eu-partnership.org/en/partnership-and-joint-africa-eu-strategy

AfDB, 2018. African Economic Outlook 2018. African Development Bank, Abidjan.

AfDB, 2016a. Design Workshop on Establishing an African Agriculture Risk Sharing and Financing Mechanism: Concept Note. Presented at the Design Workshop on Establishing an African Agriculture Risk Sharing and Financing Mechanism, African Development Bank, Nairobi, Kenya.

AfDB, 2016b. Feed Africa - Strategy for agricultural transformation in Africa 2016-2025. African Development Bank, Abidjan.

Affognon, H., Mutungi, C., Sanginga, P., Borgemeister, C., 2015. Unpacking Postharvest Losses in Sub-Saharan Africa: A Meta-Analysis. World Development 66, 49–68.

Africa Growth Initiative, 2019. Foresight Africa: Top priorities for the continent in 2019. Bookings Institution, Washington D.C.

Afshin, A., Sur, P.J., Fay, K.A., Cornaby, L., Ferrara, G., et al., 2019. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet 393, 1958–1972.

Agarwal, B., 2015. Food Security, Productivity, and Gender Inequality, in: Herring, R.J. (Ed.), The Oxford Handbook of Food, Politics and Society. Oxford University Press, Oxford.

Agboola, J.O., Yossa, R., Verreth, J., 2019. Assessment of existing and potential feed resources for improving aquaculture production in selected Asian and African countries. WorldFish, Penang.

Agea, J.G., Kirangwa, D., Waiswa, D., Okia, C.A., 2010. Household firewood consumption and its dynamics in Kalisizo sub-county, central Uganda. Ethnobotanical Leaflets 14, 841–855.

Agnew, D.J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J.R., Pitcher, T.J., 2009. Estimating the Worldwide Extent of Illegal Fishing. PLOS ONE 4, e4570.
AGRA, 2020. Africa Agriculture Status Report 2020: Feeding Africa's Cities: Opportunities, Challenges, and Policies for Linking African Farmers with Growing Urban Food Markets. Alliance for a Green Revolution in Africa, Nairobi.
AGRA, 2019a. Feeding Africa's Soils: Fertilizers to Support Africa's Agricultural Transformation. AGRA, Nairobi, Kenya.
AGRA, 2019b. Africa Agriculture Status Report 2019: The Hidden Middle: A Quiet Revolution in the Private Sector Driving Agricultural Transformation. Alliance for a Green Revolution in Africa, Nairobi.
AGRA, 2018. Africa Agriculture Status Report 2018: Catalyzing Government Capacity to Drive Agricultural Transformation. Alliance for a Green Revolution in Africa, Nairobi.
AGRA, 2015. Africa Agriculture Status Report 2015: Youth in Agriculture in Sub-Saharan Africa. Alliance for a Green Revolution in Africa, Nairobi.
AGRA, 2014. Africa Agriculture Status Report 2014: Climate change and smallholder agriculture in Sub-Saharan Africa. Alliance for a Green Revolution in Africa, Nairobi.
Agribusiness for Africa's prosperity, 2011. . United Nations Industrial Development Organization, Vienna.
Agriculture for Impact, n.d. Artificial Insemination. Agriculture for Impact. URL https://ag4impact.org/sid/genetic-intensification/livestock-breeding/artificial-insemination/ (accessed 8.20.20).
Agyei-Holmes, A., 2016. Technology transfer and agricultural mechanization in Tanzania: institutional adjustments to accommodate emerging economy innovations. Innovation and Development 6, 195–211.
Aikins, S.H.M., Haruna, K., 2012. Tractor Owners And Operators Perception About Tractor Breakdown Causes At Tamale, Ghana. International Journal of Engineering Research & Technology 1, 1–9.
Akinola, A., 2016. Human Rights, Civil Society and the Contradictions of Land Reform in South Africa. Politeia 35, 52–70.
Akiyama, T., Baffes, J., Larson, D.F., Varangis, P., 2003. Commodity Market Reform in Africa: Some Recent Experience. Economic Systems 27, 83–115.
Alaanuloluwa Ikhuoso, O., Adegbeye, M.J., Elghandour, M.M.Y., Mellado, M., Al-Dobaib, S.N., Salem, A.Z.M., 2020. Climate change and agriculture: The competition for limited resources amidst crop farmers-livestock herding conflict in Nigeria - A review. Journal of Cleaner Production 272, 123104.
Al-Awlaqi, M.A., Aamer, A.M., Habtoor, N., 2018. The effect of entrepreneurship training on entrepreneurial orientation: Evidence from a regression discontinuity design on micro-sized businesses. The International Journal of Management Education 100267.
Aleman, J.C., Jarzyna, M.A., Staver, A.C., 2018. Forest extent and deforestation in tropical Africa since 1900. Nature Ecology & Evolution 2, 26–33.
Alene, A.D., 2010. Productivity growth and the effects of R&D in African agriculture. Agricultural Economics 41, 223–238.
Al-Hussinee, L., Subramaniam, K., Surachetpong, W., Popov, V., Hartman, K., et al., 2019. Tilapia Lake Virus (TiLV): a Globally Emerging Threat to Tilapia Aquaculture. The Institute of Food and Agricultural Sciences, University of Florida, Gainesville.
Ali, D.A., Deininger, K., Mahofa, G., Nyakulama, R., 2019. Sustaining land registration benefits by addressing the challenges of reversion to informality in Rwanda. Land Use Policy 104317.
Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G., Vaz, A., 2013. The Women's Empowerment in Agriculture Index. World Development 52, 71–91.
Allen, A., Howard, J., Kondo, M., Jamison, A., Jayne, T.S., Snyder, J., Tschirley, D., Yeboah, F.K., 2016. Agrifood Youth Employment and Engagement Study'. Michigan State University, East Lansing.
Allen, T., 2017. The cost of high food prices in West Africa (No. 8), West African Papers. OECD Publishing, Paris.
Alston, J.M., Pardey, P.G., 2017. Developing-Country Perspectives on Agricultural R&D: New Pressures for Self-Reliance? Agricultural R&D in the developing world: too little, too late? 18.
Alston, J.M., Pardey, P.G., 2014. Agriculture in the global economy. Journal of Economic Perspectives 28, 121–46.
Altchenko, Y., Villholth, K.G., 2015. Mapping irrigation potential from renewable groundwater in Africa – a quantitative hydrological approach. Hydrology and Earth System Sciences 19, 1055–1067.
Amendolagine, V., Presbitero, A.F., Rabellotti, R., Sanfilippo, M., 2019. Local sourcing in developing countries: The role of foreign direct investments and global value chains. World Development 113, 73–88.
Anderson, K., Martin, W., 2005. Agricultural Trade Reform and the Doha Development Agenda. The World Economy 28, 1301–1327.
Anderson, K., Masters, W., 2009. Distortions to Agricultural Incentives in Africa. The World Bank, Washington D.C.
Anderson, K., Nelgen, S., 2012. Trade barrier volatility and agricultural price stabilization. World Development 40, 36–48.
Anderson, K., Nelgen, S., Valenzuela, E., 2013. Estimates of Distortions to Agricultural Incentives 1955-2011 [WWW Document]. World Bank Microdata Library. URL https://microdata.worldbank.org/index.php/catalog/388/
Anderson, K., Valenzuela, E., 2008. Estimates of Global Distortions to Agricultural Incentives, 1955 to 2007 [WWW Document]. URL www.worldbank.org/agdistortions (accessed 8.22.20).
Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N.J., Bauch, S., Börner, J., Smith-Hall, C., Wunder, S., 2014. Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. World Development 64, S12–S28.
Angelucci, F., Balié, J., Gourichon, H., Mas Aparisi, A., Witwer, M. (Eds.), 2014. Monitoring and analysing food and agri-

cutural policies in Africa: synthesis report 2013. Food and Agriculture Organization of the United Nations, Rome.
Apolloni, A., Nicolas, G., Coste, C., EL Mamy, A.B., Yahya, B., EL Arbi, A.S., Gueya, M.B., Baba, D., Gilbert, M., Lancelot, R., 2018. Towards the description of livestock mobility in Sahelian Africa: Some results from a survey in Mauritania. PLoS ONE 13, e0191565.
Appiah, M., Blay, D., Damnyag, L., Dwomoh, F.K., Pappinen, A., Luukkanen, O., 2009. Dependence on forest resources and tropical deforestation in Ghana. Environ Dev Sustain 11, 471–487.
APRM, AGA, 2019. The Africa Governance Report: Promoting African Union Shared Values. The African Peer Review Mechanism in Collaboration with the African Governance Architecture, Addis Ababa.
Aragie, E., Balié, J., 2020. Public spending on agricultural productivity and rural commercialization: A comparison of impacts using an economy-wide approach. Development Policy Review.
Arbache, J.S., Kolev, A., Filipiak, E., 2010. Gender disparities in Africa's labor market. The World Bank, Washington D.C.
ARC, 2014. Kaonafatso ya Dikgomo (KyD) [WWW Document]. Agricultural Research Council. URL https://www.arc.agric.za/arc-api/Pages/KyD.aspx (accessed 6.8.20).
ARC-Animal Production Institute, n.d. Kaonafatso ya Dikgomo Training Scheme. Agricultural Research Council, Pretoria.
Arias, M.A., Ibáñez, A.M., Zambrano, A., 2017. Agricultural Production Amid Conflict: Separating the Effects of Conflict into Shocks and Uncertainty (HiCN Working Paper No. 254). Institute of Development Studies, Brighton.
Arslan, A., 2019. How old is the average farmer in today's developing world? IFAD Blogs. URL https://www.ifad.org/en/web/latest/blog/asset/41207683 (accessed 8.22.20).
Asfaw, S., Mithöfer, D., Waibel, H., 2009. EU Food Safety Standards, Pesticide Use and Farm-level Productivity: The Case of High-value Crops in Kenya. Journal of Agricultural Economics 60, 645–667.
Assa, B.S.K., 2018. Foreign direct investment, bad governance and forest resources degradation: evidence in Sub-Saharan Africa. Econ Polit 35, 107–125.
Assan, N., 2014. Gender disparities in livestock production and their implication for livestock productivity in Africa. Scientific Journal of Animal Science 3, 126–128.
Atherstone, C., Galiwango, R.G., Grace, D., Alonso, S., Dhand, N.K., Ward, M.P., Mor, S.M., 2019. Analysis of pig trading networks and practices in Uganda. Trop Anim Health Prod 51, 137–147.
Atyi, R.E., 2018. Assessing progress in forest law enforcement and governance in Africa. African Development Bank Group, Abidjan.
AU, 2018. Strategy for Rational Management of African Fisheries. African Union, Addis Ababa.
AU, 2015a. The Livestock Development Strategy for Africa (LiDeSA) 2015 - 2035: The Roadmap to a Successful Livestock Sector. Executive Summary. Department of Rural Economy and Agriculture, African Union, Addis Ababa.
AU, 2015b. Agenda 2063: The Africa we want. African Union, Addis Ababa.
AU, 2014. Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods.African Union, Addis Ababa.
AU, 2013. Impact of livestock diseases in Africa [WWW Document]. African Union Interafrican Bureau for Animal Resources. URL https://www.au-ibar.org/vacnada-livestock-diseases (accessed 8.20.20).
AU, GIZ, 2012. Policy Brief on Agricultural Finance in Africa. African Development Bank, Tunis.
AUDA-NEPAD, 2013. Agriculture in Africa: Transformation and Outlook. African Union Development Agency - New Partnership for Africa Development, Midrand.
AUDA-NEPAD, 2003. Introducing the Comprehensive Africa Agriculture Development Programme. African Union Development Agency - New Partnership for Africa Development, Midrand.
AU-IBAR, 2019. Africa Blue Economy Strategy. African Union, Addis Ababa.
Babu, S.C., Manvatkar, R., Kolavalli, S., 2016. Strengthening Capacity for Agribusiness Development and Management in Sub-Saharan Africa. Africa Journal of Management 2, 1–30.
Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Deckers, J., Mathijs, E., 2008. Household livelihood strategies and forest dependence in the highlands of Tigray, Northern Ethiopia. Agricultural Systems 98, 147–155.
Bachke, M.E., 2019. Do farmers' organizations enhance the welfare of smallholders? Findings from the Mozambican national agricultural survey. Food Policy 89, 101792.
Badiane, O., Collins, J., 2020. Strengthening National Institutions for Tangible and Sustainable Impacts at Scale, in: Islamic Development Bank Group (Ed.), Inclusive Growth: Making Value Chains Work for Smallholder Farmers. Islamic Development Bank Group, Jeddah, pp. 98–113.
Badiane, O., Collins, J., Diao, X., Ulimwengu, J., 2014. Economic recovery in Africa and its determinants, in: Beyond a Middle Income Africa: Transforming African Economies for Sustained Growth with Rising Employment and Incomes. ReSAKSS Annual Trends and Outlook Report 2014. International Food Policy Research Institute, Washington D.C.
Badiane, O., Collins, J., Dimaranan, B., Ulimwengu, J., 2018. An assessment of the New Alliance for Food Security and Nutrition - Synthesis Report. Mimeo.
Badiane, O., Odjo, S., 2016. Regional Trade and Volatility in Staple Food Markets in Africa, in: Kalkuhl, M., von Braun, J., Torero, M. (Eds.), Food Price Volatility and Its Implications for Food Security and Policy. Springer International Publishing, Cham, pp. 385–412.
Bahadur KC, K., Haque, I., Legwegoh, A.F., Fraser, E.D.G., 2016. Strategies to Reduce Food Loss in the Global South. sustainability 8.
Balana, B.B., Bizimana, J.-C., Richardson, J.W., Lefore, N., Adimassu, Z., Herbst, B.K., 2020. Economic and food security

effects of small-scale irrigation technologies in northern Ghana. Water Resources and Economics 29, 100141.
Baldwin, R., Venables, A., 1995. Regional economic integration, in: Grossman, G., Rogoff, K. (Eds.), Handbook of International Economics. Elsevier, Amsterdam, pp. 1597–1644.
Balié, J., Del Prete, D., Magrini, E., Montalbano, P., Nenci, S., 2019. Does Trade Policy Impact Food and Agriculture Global Value Chain Participation of Sub-Saharan African Countries? Am J Agric Econ 101, 773–789.
Balistreri, E.J., Maliszewska, M., Osorio-Rodarte, I., Tarr, D.G., Yonezawa, H., 2018. Poverty, Welfare and Income Distribution Implications of Reducing Trade Costs Through Deep Integration in Eastern and Southern Africa. J Afr Econ 27, 172–200.
Bardhan, P., 2008. International Trade, Growth, and Development. John Wiley & Sons, Hoboken.
Barham, J., Chitemi, C., 2009. Collective action initiatives to improve marketing performance: Lessons from farmer groups in Tanzania. Food Policy, Collective Action for Smallholder Market Access 34, 53–59.
Barrientos, A., 2012. Social Transfers and Growth: What Do We Know? What Do We Need to Find Out? World Development 40, 11–20.
Bartlett, A.G., 2020. Exploring transformational outcomes from donor investments in agroforestry research for development. Agroforest Syst 12.
Bartlett, A.G., 2019. Fostering a systems-based agroforestry research for development. Agricultural Science 30/31, 20.
Basu, S., Weil, D.N., 1998. Appropriate Technology and Growth. Q J Econ 113, 1025–1054.
Baudron, F., Sims, B., Justice, S., Kahan, D.G., Rose, R., et al., 2015. Re-examining appropriate mechanization in Eastern and Southern Africa: two-wheel tractors, conservation agriculture, and private sector involvement. Food
Baumüller, H., 2018. The Little We Know: An Exploratory Literature Review on the Utility of Mobile Phone-Enabled Services for Smallholder Farmers. Journal of International Development 30, 134–154.
Baumüller, H., Kah, M.M.O., 2020. Going digital: Harnessing the power of emerging technologies for the transformation of Southern African agriculture, in: Sikora, R.A., Terry, E.R., Vlek, P.L.G., Chitja, J. (Eds.), Transforming Agriculture in Southern Africa: Constraints, Technologies, Policies and Processes. Routledge, Oxon, pp. 179–187.
Beck, T., Maimbo, S.M., 2013. Financing Agriculture: Selected Approaches for the Engagement of Commercial Finance, in: Financial Sector Development in Africa: Opportunities and Challenges, Directions in Development: Finance. The World Bank, Washington D.C., pp. 83–108.
Beegle, K., De Weerdt, J., Dercon, S., 2010. Migration and Economic Mobility in Tanzania: Evidence from a Tracking Survey. The Review of Economics and Statistics 93, 1010–1033.
Beintema, N., Stads, G.-J., 2017. A Comprehensive Overview of Investments and Human Resource Capacity in African Agricultural Research (ASTI Synthesis Report). International Food Policy Research Institute, Washington D.C.
Bekele, A., Belay, K., Legesse, B., Lemma, T., 2010. Effects of Crop Commercial Orientation on Productivity of Smallholder Farmers in Drought-prone Areas of the Central Rift Valley of Ethiopia. Journal of Rural Development/Nongchon-Gyeongje 33, 1–24.
Bekele, R., forthcoming. Essays on Irrigation Systems of Ethiopia: Institutional and Technological Performance Analysis (Doctoral thesis at the Faculty of Agriculture, University of Bonn). University of Bonn, Bonn.
Benfetta, H., Ouadja, A., 2020. Groundwater overuse in arid areas: case study of syncline Bouguirat-Mostaganem, Algeria. Arab J Geosci 13, 786.
Benin, S., McBride, L., Mogues, T., 2016. Why do African countries underinvest in agricultural RD? International Food Policy Research Institute, Washington D.C.
Benin, S., Nin-Pratt, A., 2016. Intertemporal trends in agricultural productivity, in: Agricultural Productivity in Africa: Trends, Patterns, and Determinants. International Food Policy Research Institute, Washington D.C., pp. 25–104.
Benin, S., Yu, B., 2013. Complying with the Maputo Declaration Target, 0 ed. International Food Policy Research Institute, Washington D.C.
Berhane, G., Dereje, M., Minten, B., Tamru, S., 2017. The rapid – but from a low base – uptake of agricultural mechanization in Ethiopia: Patterns, implications and challenges: (No. 105), ESSP working papers, ESSP working papers. International Food Policy Research Institute, Washington D.C.
Bernal, B., Murray, L.T., Pearson, T.R.H., 2018. Global carbon dioxide removal rates from forest landscape restoration activities. Carbon Balance Manage 13, 22.
Bernard, T., Hidrobo, M., Le Port, A., Rawat, R., 2019. Nutrition-Based Incentives in Dairy Contract Farming in Northern Senegal. Am J Agric Econ 101, 404–435.
Bernard, T., Sene, L., Wouterse, F., Viceisza, A., 2014. Leaders Needed: Experimental Evidence from Rural Producer Organizations in Senegal. International Food Policy Research Institute, Washington D.C.
Bèye, A., Komarek, A.M., forthcoming. Quantification and benefits of reducing post-harvest losses: Evidence for vegetables in Senegal (Draft), ZEF Discussion Papers on Development Policy. Center for Development Research, University of Bonn, Bonn.
Bezu, S., Holden, S., 2014. Are Rural Youth in Ethiopia Abandoning Agriculture? World Development 64, 259–272.
Bidzakin, J.K., Fialor, S.C., Awunyo-Vitor, D., Yahaya, I., 2020. Contract farming and rice production efficiency in Ghana. Journal of Agribusiness in Developing and Emerging Economies 10, 269–284.
Binswanger, H., 1986. Agricultural Mechanization: A Comparative Historical Perspective. The World Bank Research Observer 1, 27–56.
Bioversity, 2017. Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index. Bioversity International, Rome.
Bixby, H., Bentham, J., Zhou, B., Di Cesare, M., Paciorek, C.J., et al., NCD Risk Factor Collaboration (NCD-RisC), 2019. Ris-

ing rural body-mass index is the main driver of the global obesity epidemic in adults. Nature 569, 260–264.
Bjørndal, T., Lappo, A., Dey, M., Lem, A., Child, A., 2016. Economic analysis of food supply and demand in Sub-Saharan Africa up to 2022 - Special focus on fish and fishrey products. Food and Agriculture Organization of the United Nations, Rome.
Blattman, C., Fiala, N., Martinez, S., 2018. The Long Term Impacts of Grants on Poverty: 9-year Evidence From Uganda's Youth Opportunities Program, Working Paper Series. National Bureau of Economic Research, Cambridge.
Block, S., 2016. The Decline and Rise of Agricultural Productivity in Sub-Saharan Africa since 1961, in: Edwards, S., Johnson, S., Weil, D.N. (Eds.), African Successes, Volume IV: Sustainable Growth. University of Chicago Press, Chicago, pp. 13–67.
BMZ, 2018. Special Initiative: ONE World - No Hunger.
BMZ, 2017. Africa and Europe - A new partnership for development, peace and a better future: Cornerstones of a Marshall Plan with Africa. German Federal Ministry for Economic Cooperation and Development, Bonn und Berlin.
Bodiguel, C., Toppe, J., Wallemacq, F., 2016. Fish for life: nutrition and development in Eastern Africa and Western Indian Ocean. Indian Ocean Commission, Mauritius.
Bonuedi, I., Kamasa, K., Opoku, E.E.O., 2020. Enabling trade across borders and food security in Africa. Food Sec.
Bornemann, S., 2006. Spillovers in Vocational Training. An Analysis of Incentive Schemes and Reimbursement Clauses (Doctoral dissertation). Ludwig Maximilian University, Munich.
Börner, J., Schulz, D., Wunder, S., Pfaff, A., 2020. The Effectiveness of Forest Conservation Policies and Programs. Annu. Rev. Resour. Econ. 12, annurev-resource-110119-025703.
Bouët, A., Cosnard, L., Fall, S.F., 2019. Africa in Global Agricultural Trade, in: Bouët, A., Odjo, S.P. (Eds.), Africa Agriculture Trade Monitor 2019. International Food Policy Research Institute, Washington D.C., pp. 17–41.
Bouët, A., Odjo, S.P., 2019. Africa Agriculture Trade Monitor 2019. International Food Policy Research Institute, Washington D.C.
Bouët, A., Odjo, S.P., Zaki, C., 2020. Africa Agriculture Trade Monitor 2020. International Food Policy Research Institute, Washington D.C.
Breuer, T., Brenneis, K., Fortenbacher, D., 2015. Mechanisation – A Catalyst For Rural Development In Sub-Saharan Africa. Rural 21 21, 16–19.
Briggs, J., Moyo, B., 2012. The Resilience of Indigenous Knowledge in Small-scale African Agriculture: Key Drivers. Scottish Geographical Journal 128, 64–80.
Brixiová, Z., Kangoye, T., Said, M., 2020. Training, human capital, and gender gaps in entrepreneurial performance. Economic Modelling 85, 367–380.
Brummett, R.E., Lazard, J., Moehl, J., 2008. African aquaculture: Realizing the potential. Food Policy 33, 371–385.
Brummett, R.E., Noble, R., 1995. Aquaculture for African smallholders. WorldFish, Penang.
Bryan, E., Ringler, C., Okoba, B., Koo, J., Herrero, M., Silvestri, S., 2013. Can agriculture support climate change adaptation, greenhouse gas mitigation and rural livelihoods? insights from Kenya. Climatic Change 118, 151–165.
Buadi, D.K., Anaman, K.A., Kwarteng, J.A., 2013. Farmers' perceptions of the quality of extension services provided by non-governmental organisations in two municipalities in the Central Region of Ghana. Agricultural Systems 120, 20–26.
Burney, J.A., Naylor, R.L., 2012. Smallholder Irrigation as a Poverty Alleviation Tool in Sub-Saharan Africa. World Development 40, 110–123.
Busch, J., Ferretti-Gallon, K., 2017. What Drives Deforestation and What Stops It? A Meta-Analysis. Review of Environmental Economics and Policy 11, 3–23.
Cabot, C., 2017. Climate Change and Farmer–Herder Conflicts in West Africa, in: Climate Change, Security Risks and Conflict Reduction in Africa. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 11–44.
Cadiou, X., 2018. Africa: Growth and challenges in the animal feed sector [WWW Document]. AllAboutFeed. URL https://www.allaboutfeed.net/Feed-Additives/Articles/2018/4/Africa-Growth-and-challenges-for-animal-feed-275953E/ (accessed 8.20.20).
Cai, J., Quagrainie, K.K., Hishamunda, N. (Eds.), 2017. Social and economic performance of Tilapia farming in Africa, FAO fisheries and aquaculture circular. Food and Agriculture Organization of the United Nations, Rome.
Cai, W., 2011. Agricultural productivity, skill investment, farm size distribution, income differences.
Care Canada, 2016. Promoting inclusive agricultural growth, food security and resilience to climate change. Submission to the Government of Canada's Environment and Climate Change Policy Review.
Carletto, C., Corral, P., Guelfi, A., 2017. Agricultural commercialization and nutrition revisited: Empirical evidence from three African countries. Food Policy, Agriculture in Africa – Telling Myths from Facts 67, 106–118.
Carson, K.I., 2018. Agricultural training and the labour productivity challenge. International Journal of Agricultural Management 06.
Cassandro, M., 2020. Animal breeding and climate change, mitigation and adaptation. J Anim Breed Genet 137, 121–122.
Castellano, A., Kendall, A., Nikomarov, M., Swemmer, T., 2015. Brighter Africa: The growth potential of the sub-Saharan electricity sector, Electric Power and Natural Gas. McKinsey & Company, London.
CCAFS, n.d. Soil Management [WWW Document]. Climate Smart Agriculture 101. URL (accessed 9.9.20).
CGIAR, 2005. Report of the CGIAR Sub-Saharan Africa Task Forces: The Tervuren Consensus. Washington, DC: CGIAR Secretariat. CGIAR, Washington D.C.
Chamberlin, J., 2018. Africa's Unfolding Economic Transformation. The Journal of Development Studies 54, 777–787.

Chamberlin, J., Jayne, T.S., Headey, D., 2014. Scarcity amidst abundance? Reassessing the potential for cropland expansion in Africa. Food Policy, Boserup and Beyond: Mounting Land Pressures and Development Strategies in Africa 48, 51–65.

Chan, C.Y., Tran, N., Pethiyagoda, S., Crissman, C.C., Sulser, T.B., Phillips, M.J., 2019. Prospects and challenges of fish for food security in Africa. Global Food Security 20, 17–25.

Chemura, A., Schauberger, B., Gornott, C., 2020. Impacts of climate change on agro-climatic suitability of major food crops in Ghana. PLOS ONE 15, e0229881.

Chichaibelu, B., Matschuk, M.A., Baumüller, H., forthcoming. Data Protection in Africa: A Review of National Legislation and Data Privacy Provisions in Digital Agricultural Services, ZEF Working Paper. Center for Development Research, University of Bonn, Bonn.

Chinien, C., 2003. The Use of ICTs in Technical and Vocational Education and Training: An analytical survey. UNESCO Institute for Information Technologies in Education, Moscow.

Chirwa, P.W., Adeyemi, O., 2019. Deforestation in Africa: Implications on Food and Nutritional Security, in: Dietrich, M., Borrello, M., Harman, O. (Eds.), Handbook of the Historiography of Biology, Historiographies of Science. Springer International Publishing, Cham, pp. 1–15.

Chong, T., 2014. Vocational education in Singapore: meritocracy and hidden narratives. Discourse: Studies in the Cultural Politics of Education 35, 637–648.

Christiaensen, L., Martin, W., 2018. Agriculture, structural transformation and poverty reduction: Eight new insights. World Development 109, 413–416.

Christinck, A., Rattunde, F., Mulinge, W., Weltzien, E., 2018. Identifying Options for the Development of Sustainable Seed Systems - Insights from Kenya and Mali (No. 165), ZEF Working Papers. Center for Development Research, University of Bonn, Bonn.

Clapp, J., 2016. Food security and international trade Unpacking disputed narratives—Background Paper for The State of Agricultural Commodity Markets (SOCO) 2015-16. Food and Agriculture Organization of the United Nations, Rome.

Cockx, L., Colen, L., De Weerdt, J., 2018. From corn to popcorn? Urbanization and dietary change: Evidence from rural-urban migrants in Tanzania. World Development 110, 140–159.

Coe, R., Sinclair, F., Barrios, E., 2014. Scaling up agroforestry requires research 'in' rather than 'for' development. Current Opinion in Environmental Sustainability, Sustainability challenges 6, 73–77.

Commission for Africa, 2005. Our common interest: Report of the Commission for Africa. Commission for Africa.

Connolly, C., 2006. Constraints to sustainable forest management of Africa's humid forests: the ATIBT experience. int. forest. rev. 8, 78–82.

Conway, G., Badiane, O., Glatzel, K., 2019. Food for all in Africa: sustainable intensification for African farmers. Comstock Publishing Associates, an imprint of Cornell University Press, Ithaca.

Corbeels, M., Naudin, K., Whitbread, A.M., Kühne, R., Letourmy, P., 2020. Limits of conservation agriculture to overcome low crop yields in sub-Saharan Africa. Nature Food 1, 447–454.

Cossar, F., 2016. Boserupian pressure and agricultural mechanization in modern Ghana: (No. 1528), IFPRI discussion papers, IFPRI discussion papers. International Food Policy Research Institute, Washington D.C.

Coulter, J., Sondhi, J., Boxall, R., 2000. The economics of grain warehousing in Sub-Saharan Africa. African Review of Money Finance and Banking 97–116.

Covarrubias, K., Davis, B., Winters, P., 2012. From protection to production: productive impacts of the Malawi Social Cash Transfer scheme. Journal of Development Effectiveness 4, 50–77.

CTA, 2016. Opportunities for value chain finance in Africa's intra-regional food trade. CTA, Wageningen.

Cui, H.D., Kuiper, M., von Meijl, H., Tabeau, A., 2018. Climate change and global market integrationImplications for global economic activities, agricultural commodities, and food security—Background Paper for The State of Agricultural Commodity Markets (SOCO) 2018. Food and Agriculture Organization of the United Nations, Rome.

Curtis, P.G., Slay, C.M., Harris, N.L., Tyukavina, A., Hansen, M.C., 2018. Classifying drivers of global forest loss. Science 361, 1108–1111.

da Vià, E., 2011. The politics of "win-win" narratives: Land grab as development opportunity? Presented at the International Conference on Global Land Grabbing, Institute of Development Studies, University of Sussex, Brighton, UK.

Dalberg Global Development Advisors, 2016. Inflection Point: Unlocking growth in the era of farmer finance [WWW Document]. mastercard foundation Rural & Agricultural Finance Learning Lab. URL https://www.raflearning.org/post/inflection-point-unlocking-growth-the-era-farmer-finance

Danielsen, K., Wong, F., McLachlin, D., Sarapura, S., 2018. Typologies of Change Gender Integration in Agriculture Food Security Research.pdf. Royal Tropical Institute, Amsterdam.

Danso-Abbeam, G., Ehiakpor, D.S., Aidoo, R., 2018. Agricultural extension and its effects on farm productivity and income: insight from Northern Ghana. Agric & Food Secur 7, 74.

Daum, T., 2015. Sustainable mechanisation–a hard row to hoe. Rural 21 20–22.

Daum, T., Adegbola, Y., Kamau, G., Kergna, A.O., Daudu, C., Zossou, R.C., Crinot, G.F., Houssou, P., Mose, L., Ndirpaya, Y., Wahab, A.A., Kirui, O., Fatunbi, O., 2020a. Impacts of agricultural mechanization: Evidence from four African countries, Hohenheim Working Papers on Social and Institutional Change in Agricultural Development. University of Hohenheim, Hohenheim.

Daum, T., Birner, R., 2020. Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. Global Food Security 26, 100393.
Daum, T., Birner, R., 2017. The neglected governance challenges of agricultural mechanisation in Africa – insights from Ghana. Food Sec. 9, 959–979.
Daum, T., Huffman, W., Birner, R., 2018. How to create conducive institutions to enable agricultural mechanization: A comparative historical study from the United States and Germany. Iowa State University, Ames.
Daum, T., Villalba, R., Anidi, O., Mayienga, S.M., Gupta, S., Birner, R., 2020b. Uber for Tractors? Opportunities and Challenges of Digital Tools for Tractor Hire in India and Nigeria. University of Hohenheim, Hohenheim.
Davidova, S.M., Thomson, K., 2014. Family farming in Europe: challenges and prospects. European Union, Brussels.
de Schutter, O., 2009. Large-scale land acquisitions and leases: a set of core principles and measures to address the human rights challenge (UN Special Rapporteur on the Right to Food, reporting the UN General Assembly (Third Committee) and the Human Rights Council of the United Nations). United Nations, New York.
de Silva, S.S., Anderson, T.A., 1995. Fish Nutrition in Aquaculture, Aquaculture Series. Springer Netherlands, Dordrecht.
Dedehouanou, F., Dimaranan, B., Laborde, D., 2019. Competitiveness of African Agricultural Value Chains, in: Bouët, A., Odjo, S.P. (Eds.), Africa Agriculture Trade Monitor 2019. International Food Policy Research Institute, Washington D.C., pp. 73–106.
Deininger, K., Byerlee, D., Johnathan, L., Andrew, N., Harris, S., Stickler, M., 2011. Rising Global Interest in Farmland: Can it Yield Sustainable and Equitable Benefits? The World Bank, Washington D.C.
Deininger, K., Hilhorst, T., Songwe, V., 2014. Identifying and addressing land governance constraints to support intensification and land market operation: Evidence from 10 African countries. Food Policy 48, 76–87.
Deininger, K., Savastano, S., Xia, F., 2017. Smallholders' land access in Sub-Saharan Africa: A new landscape? Food Policy 67, 78–92.
Demeke, M., Kiermeier, M., Sow, M., Antonaci, L., 2016. Agriculture and Food Insecurity Risk Management in Africa. Food and Agriculture Organization of the United Nations, Rome.
Demirguc-Kunt, A., Klapper, L., Singer, D., Van Oudheusden, P., 2015. The Global Findex Database 2014: Measuring Financial Inclusion around the World, Policy Research Working Papers. The World Bank, Washington D.C.
Demmler, K., Klasen, S., Nzuma, J.M., Qaim, M., 2017. Supermarket purchase contributes to nutrition-related non-communicable diseases in urban Kenya. PloS one 12, e0185148.
Demmler, K.M., Ecker, O., Qaim, M., 2018. Supermarket Shopping and Nutritional Outcomes: A Panel Data Analysis for Urban Kenya. World Development 102, 292–303.
Diao, X., Cossar, F., Houssou, N., Kolavalli, S., 2014. Mechanization in Ghana: Emerging demand, and the search for alternative supply models. Food Policy, Boserup and Beyond: Mounting Land Pressures and Development Strategies in Africa 48, 168–181.
Diao, X., Harttgen, K., McMillan, M., 2017. The Changing Structure of Africa's Economies. World Bank Econ Rev 31, 412–433.
Diao, X., Silver, J., Takeshima, H., 2016. Agricultural Mechanization and Agricultural Transformation. International Food Policy Research Institute, IFPRI discussion papers 01527, 56.
Do, H., Luedeling, E., Whitney, C., 2020. Decision analysis of agroforestry options reveals adoption risks for resource-poor farmers. Agron. Sustain. Dev. 40, 12.
Dolan, C., Humphrey, J., 2004. Changing Governance Patterns in the Trade in Fresh Vegetables between Africa and the United Kingdom. Environ Plan A 36, 491–509.
Dolislager, M., Arslan, A., Tschirley, D., Reardon, T.A., Fox, L., Liverpool-Tasie, L.S., Christine, S., 2019. Youth Agri-food System Employment in Developing Countries: A Gender-Differentiated Spatial Approach (No. 43), IFAD Research Series. International Fund for Agricultural Development, Washington D.C.
Dongyu, Q., 2019. Moving forward on reducing food loss and waste.
Doss, C., Meinzen-Dick, R., Quisumbing, A., Theis, S., 2018. Women in agriculture: Four myths. Global Food Security 16, 69–74.
Doss, C., Morris, M.L., 2001. How does gender affect the adoption of agricultural innovations?: The case of improved maize technology in Ghana. Agricultural Economics 25, 27–39.
Doss, C.R., 2018. Women and agricultural productivity: Reframing the Issues. Development Policy Review 36, 35–50.
Dubbert, C., 2019. Participation in contract farming and farm performance: Insights from cashew farmers in Ghana. Agricultural Economics 50, 749–763.
Dumont, E.S., Bonhomme, S., Pagella, T.F., Sinclair, F.L., 2019. Structured stakeholder engagement leads to development of more diverse and inclusive agroforestry options. Experimental Agriculture 55, 252–274.
Eaton, C., Shepherd, A.W., 2001. Contract farming: Partnerships for growth. Food and Agriculture Organization of the United Nations, Rome.
Ebong, C., Byenkya, S.G., Ndikumana, J., 1999. Effects of Substituting Calliandra Leaf Meal for Soybean Meal on Intake, Digestibility, Growth and Feed Efficiency in Goats. Journal of Applied Animal Research 16, 211–216.
Eicker, F., Haseloff, G., Lennartz, B. (Eds.), 2017. Vocational Education and Training in Sub-Saharan Africa. wbv Media, Bielefeld.
Elder, S., Kring, S., 2016. Young and female – A double strike? International Labour Organization, Geneva.
Enahoro, D., Herrero, M., Johnson, N., 2019. Promising options for improving livestock production and productivity in developing countries (ILRI Project Report). International Livestock Research Institute, Nairobi.

Endamana, D., Angu, K.A., Akwah, G.N., Shepherd, G., Ntumwel, B.C., 2016. Contribution of non-timber forest products to cash and non-cash income of remote forest communities in Central Africa. Int. Forest. Rev. 18, 280–295.

European Commission, 2017. Rice value chain analysis in Mali. European Commission, Brussels.

Eurostat, 2020. Glossary: Livestock unit (LSU) [WWW Document]. Eurostat: Statistics Explained. URL https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Livestock_unit_(LSU) (accessed 8.13.20).

Evenson, R.E., Gollin, D., 2003. Crop variety improvement and its effect on productivity. CABI Pub., New Haven.

Ezeanya-Esiobu, C., 2019. Africa's Indigenous Knowledge: From Education to Practice, in: Ezeanya-Esiobu, C. (Ed.), Indigenous Knowledge and Education in Africa, Frontiers in African Business Research. Springer, Singapore, pp. 55–80.

Falck-Zepeda, J.B., Zambrano, P., 2013. Estimates and implications of the costs of compliance with biosafety regulations for African agriculture, in: Falck-Zepeda, J.B., Gruère, G., Sithole-Niang, I. (Eds.), Genetically Modified Crops in Africa: Economic and Policy Lessons from Countries South of the Sahara. International Food Policy Research Institute, Washington D.C., pp. 159–182.

Fan, S. (Ed.), 2008. Public expenditures, growth, and poverty: lessons from developing countries. Johns Hopkins University Press, Baltimore.

FAO, 2020a. FAOSTAT [WWW Document]. URL http://www.fao.org/faostat/en/

FAO, 2020b. Why we do it | Conservation Agriculture | Food and Agriculture Organization of the United Nations [WWW Document]. Food and Agriculture Organisation of the United Nations. URL http://www.fao.org/conservation-agriculture/overview/why-we-do-it/en/ (accessed 8.31.20).

FAO, 2020c. The State of World Fisheries and Aquaculture 2020: Sustainability in action. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2020d. Intra-African trade, the African Continental Free Trade Area (AfCFTA) and the COVID-19 pandemic. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2020e. FAO Regional Conference for Asia and the Pacific: Thirty-Fifth Session: 1-4 September 2020, UN Food Systems Summit (No. APRC/20/INF/25 Rev.1). Food and Agriculture Organization of the United Nations, Rome.

FAO, 2019a. The State of Food and Agriculture: Moving Forward on Food Loss and Waste Reduction. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2019b. Livestock sector development in Asia and sub-Saharan Africa: A comparative analysis of public health impacts (No. CA3610EN/1/03.19), Africa Sustainable Livestock 2050. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2019c. Land and water governance to achieve the SDGs in fragile systems. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2018a. Pastoralism in Africa's drylands: reducing risks, addressing vulnerability and enhancing resilience. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2018b. Livestock production systems spotlight: Nigeria. Dairy cattle and poultry (chicken) sectors, Africa Sustainable Livestock 2050. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2018c. Shaping the future of livestock: sustainably, responsibly, efficiently. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2018d. The monetary impact of zoonotic diseases on society: Kenya. Evidence from three zoonoses (No. I8968EN/1/04.18), Africa Sustainable Livestock 2050. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2018e. The State of World Fisheries and Aquaculture 2018: Meeting the sustainable development goals. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2017a. The Future of Food and Agriculture 2017: Trends and Challenges. Food and Agriculture Organization of the United Nations, Rome.

FAO (Ed.), 2017b. Leveraging food systems for inclusive rural transformation, The state of food and agriculture. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2017c. The State of Food and Agriculture 2017: Leveraging food systems for inclusive rural transformation. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2016a. The State of World Fisheries and Aquaculture 2016: Contributing to food security and nutrition for all. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2016b. How does agricultural trade impact food security? (No. 17), Trade Policy Briefs. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2014. Contribution to the 2014 United Nations Economic and Social Council (ECOSOC) Integration Segment. Presented at the 014 ECOSOC Integration Segment, Food and Agriculture Organization of the United Nations.

FAO, 2012. The State of Food and Agriculture 2012: Investing in agriculture for a better future. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2011. The State of Food and Agriculture 2010-2011: Women in agriculture: closing the gender gap for development. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2006. Quality Declared Seed System. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2005. The State of Food Insecurity in the World (SOFI) 2005. Food and Agriculture Organization of the United Nations, Rome.

FAO, n.d. Pastoralism [WWW Document]. Food and Agriculture Organisation of the United Nations.

FAO, IAEA, 2017a. Enhancing livestock productivity - through better reproduction and breeding management [WWW Document]. Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. URL http://www-naweb.iaea.org/nafa/aph/topic-animal-breeding.html (accessed 8.21.20).

FAO, IAEA, 2017b. The Artificial Insemination Centre in Cameroon [WWW Document]. Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. URL http://www-naweb.iaea.org/nafa/news/2010-artificial-insemination.html (accessed 8.21.20).

FAO, IFAD, UNICEF, WFP, WHO, 2020. The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets. Food and Agriculture Organization of the United Nations, Rome.

FAO, IFAD, UNICEF, WFP, WHO, 2019. The State of Food Security and Nutrition in the World 2019: Safeguarding against economic slowdowns and downturns. Food and Agriculture Organization of the United Nations, Rome.

FAO, IFAD, UNICEF, WFP, WHO, 2018. The State of Food Security and Nutrition in the World 2018: Building climate resilience for food security and nutrition. Food and Agriculture Organization of the United Nations, Rome.

FAO, IFAD, UNICEF, WFP, WHO, 2017. The State of Food Security and Nutrition in the World 2017: Building resilience for peace and food security. Food and Agriculture Organization of the United Nations, Rome.

FAO, IFAD, WFP, 2015. Achieving Zero Hunger: the critical role of investments in social protection and agriculture. Food and Agriculture Organization of the United Nations, Rome.

FAO, IGAD, 2019. East Africa Animal Feed Action Plan: Sustainably developing livestock-dependent livelihoods in East Africa. Food and Agriculture Organization of the United Nations and e Intergovernmental Authority on Development, Rome.

Fay, K., 2019. Towards a Sustainable Global Food Supply and the Cold Chain.

Faye, A., Wouterse, F., 2020. Institutions of Collective Action and Smallholder Performance: Evidence from Senegal, in: Diao, X., Resnick, D., Tadesse, G. (Eds.), Sustaining Africa's Agrifood System Transformation: The Role of Public Policies. ReSAKSS Annual Trends and Outlook Reports 2020. International Food Policy Research Institute, Washington D.C.

Fiedler, Y., Lafrate, M., 2017. Trends in Foreign Direct Investment in Food, Beverages and Tobacco. Food and Agriculture Organization of the United Nations, Rome.

Filmer, D., Fox, L., 2014. Youth Employment in Sub-Saharan Africa. The World Bank, Washington D.C.

Fischer, E., Qaim, M., 2012a. Linking Smallholders to Markets: Determinants and Impacts of Farmer Collective Action in Kenya. World Development 40, 1255–1268.

Fischer, E., Qaim, M., 2012b. Gender, agricultural commercialization, and collective action in Kenya. Food Sec. 4, 441–453.

Fisher, B., 2010. African exception to drivers of deforestation. Nature Geoscience 3, 375–376.

Flor, R., 2019. Eliminating Food Waste: A Country Diagnostics Perspective.

Fortman, L., 1985. The tree tenure factor in agroforestry with particular reference to Africa. Agroforestry Systems 2, 229–251.

Fox, L., Santibañez, L., Nguyen, V., André, P., 2012. Education Reform in Mozambique. Lessons and Challenges. World Bank Publications, Washington D.C.

Francesconi, G.N., Wouterse, F., 2015. The Health of Farmer-Based Organisations in Ghana: Organisational Diagnostics and Governance Implications. The Journal of Development Studies 51, 262–273.

Francis, G., Makkar, H.P.S., Becker, K., 2001. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture 199, 197–227.

Franzel, S., Wambugu, C., 2007. The Uptake of Fodder Shrubs among Smallholders in East Africa:, in: Hare, M.D., Wongpichet, K. (Eds.), Proceedings of an International Symposium. Presented at the Forages: A pathway to prosperity for smallholder farmers, Faculty of Agriculture, Ubon Ratchathani University, Ubon Ratchathani, pp. 203–222.

Fuglie, K., Rada, N., 2013. Resources, Policies, and Agricultural Productivity in Sub-Saharan Africa (Economic Research Report No. 145). United States Department of Agriculture, Washington D.C.

GAFRD, 2014. The general authority for fishery resources development: summary production statistics. General Authority For Fish Resources Development, Cairo.

GALVmed, n.d. Livestock diseases. GALVmed. URL https://www.galvmed.org/livestock-and-diseases/livestock-diseases/ (accessed 8.21.20).

Ganguly, K., Gulati, A., von Braun, J., 2017. Innovations spearheading the next transformations in India's agriculture (Working Paper No. 159). Center for Development Research, University of Bonn, Bonn.

Garcia, M. del M.H., 2013. The Role of Women in Food Security. Cuadernos de estrategia 161, 82–96.

Gardner, B.L., Evenson, R.E., Rausser, G.C., Pingali, P., 2001. Handbook of Agricultural Economics: Agricultural Development: Farmers, Farm Production and Farm Markets. Elsevier.

Garrity, D.P., Akinnifesi, F.K., Ajayi, O.C., Weldesemayat, S.G., Mowo, J.G., Kalinganire, A., Larwanou, M., Bayala, J., 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Sec. 2, 197–214. Gatiso, T.T., Wossen, T., 2015. Forest dependence and income inequality in rural Ethiopia: evidence from Chilimo-Gaji community forest users. International Journal of Sustainable Development & World Ecology 22, 14–24.

Gatzweiler, F., von Braun, J., 2016. Innovation for Marginalized Smallholder Farmers and Development: An Overview and Implications for Policy and Research, in: Gatzweiler, F., von Braun, J. (Eds.), Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development. Springer, Heidelberg, pp. 1–22.

Gavian, S., Ehui, S., 1999. Measuring the production efficiency of alternative land tenure contracts in a mixed crop-livestock system in Ethiopia. Agricultural Economics 20, 37–49.

Gebregziabher, G., Giordano, M.A., Langan, S., Namara, R.E., 2014. Economics Analysis of Factors Influencing Adoption

of Motor Pumps in Ethiopia. Journal of Development and Agricultural Economics 6, 490–500.
Gebreselassie, S., Kirui, O.K., Mirzabaev, A., 2016. Economics of Land Degradation and Improvement in Ethiopia, in: Nkonya, E., Mirzabaev, A., von Braun, J. (Eds.), Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer International Publishing, Cham, pp. 401–430.
Gerber, N., von Braun, J., Usman, M.A., Hasan, M.M., Okyere, C.Y., Vangani, R., Wiesmann, D., 2019. Water, Sanitation and Agriculture Linkages with Health and Nutrition Improvement (No. 282), ZEF Discussion Papers on Development Policy. Center for Development Research, University of Bonn, Bonn.
Getahun, T., Baumüller, H., Nigussie, Y., 2018. From Agricultural to Economic Growth: Targeting Investments Across Africa (Discussion Papers on Development Policy No. 252). Center for Development Research, University of Bonn, Bonn.
Ghimire, S.R., Njarui, D.M.G., Mutimura, M., Cardoso, J.A., Johnson, L.J., Gichangi, E.M., Teasdale, S.E., Odokonyero, K., Caradus, J.R., Rao, I.M., Djikeng, A., 2015. Climate-Smart Brachiaria for Improving Livestock Production in East Africa: Emerging Opportunities, in: Keynote Lectures. Presented at the 23rd International Grassland Congress 2015, New Delhi.
Global Nutrition Report, 2020. Global Nutrition Report 2020: Action on equity to end malnutrition. Development Initiatives Poverty Research Ltd., Bristol.
Goldsmith, P.D., Martins, A.G., de Moura, A.D., 2015. The economics of post-harvest loss: a case study of the new large soybean-maize producers in tropical Brazil. Food Security 7.
Gollin, D., 2018. Structural Transformation and Growth without Industrialisation (Background Paper Series No. 2). Pathways for Prosperity Commission, Oxford.
Gollin, D., Lagakos, D., Waugh, M.E., 2014. The Agricultural Productivity Gap. Q J Econ 129, 939–993.
Gong, B., 2020. New Growth Accounting. American Journal of Agricultural Economics 102, 641–661.
Gonzáles, C., Schiek, B., Mwendia, S., Prager, S.D., 2016. Improved forages and milk production in East Africa. A case study in the series: Economic foresight for understanding the role of investments in agriculture for the global food system. Centro Internacional de Agricultura Tropical, Cali.
Goodhue, R.E., 2011. Food Quality: The Design of Incentive Contracts. Annual Review of Resource Economics 3, 119–140.
Gottlieb, C., Grobovšek, J., 2019. Communal land and agricultural productivity. Journal of Development Economics 138, 135–152.
Goundan, A., Fall, C.S., 2017. Regional trade patterns, in: Badiane, O., Odjo, S.P. (Eds.), African Agricultural Trade Status Report 2017. International Food Policy Research Institute and CTA, Washington.
GPFI, 2015. Synthesis Report: New Trends in Agricultural Finance. Global Partnership for Financial Inclusion.
Guthiga, P., Karugia, J., Massawe, S., Ogada, M., Mugweru, L., Ongudi, S., Mbo'o-Tchouawou, M., Mulei, L., 2019. Mapping livestock value chains in the IGAD region, CTA Discussion Paper. CTA, Wageningen.
GwA, n.d. About the Compact with Africa [WWW Document]. G20 Compact with Africa. URL https://www.compactwithafrica.org/content/compactwithafrica/home/about.html (accessed 9.14.20).
GWP, 2014. "Coordinating land and water governance–An essential part of achieving food security." Stockholm, Sweden (2014).
Haggblade, S., Hazell, P., Reardon, T., 2010. The Rural Nonfarm Economy: Prospects for Growth and Poverty Reduction. World Development, The Future of Small Farms 38, 1429–1441.
Haile, A., Gizaw, S., Getachew, T., Mueller, J.P., Amer, P., Rekik, M., Rischkowsky, B., 2019. Community-based breeding programmes are a viable solution for Ethiopian small ruminant genetic improvement but require public and private investments. Journal of Animal Breeding and Genetics 136, 319–328.
Hall, M.H., Kuiper, D., 1998. Commercialization and Privatization of Agricultural Extension: The New Zealand Experience. Journal of Production Agriculture 11, 135–140.
Halwart, M., 2020. Fish farming high on the global food system agenda in 2020. FAO Aquaculture Newsletter 61, II–III.
Halwart, M., Moehl, J., 2004. FAO Regional Technical Expert Workshop on Cage Culture in Africa. Food and Agriculture Organization of the United Nations, Rome.
Hatibu, N.H., 2019. Role of SMEs (the Hidden Middle) in the Reduction of Food Loss and Waste in SSA.
Hazell, P.B.R., Rahman, A., 2014. New Directions for Smallholder Agriculture, New Directions for Smallholder Agriculture. Oxford University Press, United Kingdom.
Headey, D., Hirvonen, K., Hoddinott, J., 2018. Animal Sourced Foods and Child Stunting. American Journal of Agricultural Economics 100, 1302–1319.
Hegre, H., Nygård, H.M., 2015. Governance and Conflict Relapse. Journal of Conflict Resolution 59, 984–1016.
Henson, S., Masakure, O., Boselie, D., 2005. Private food safety and quality standards for fresh produce exporters: The case of Hortico Agrisystems, Zimbabwe. Food Policy 30, 371–384.
Herrero, M., Thornton, P.K., Power, B., Bogard, J.R., Remans, R., et al., 2017. Farming and the geography of nutrient production for human use: a transdisciplinary analysis. The Lancet Planetary Health 1, e33–e42.
Herrmann, R., Nkonya, E., Faße, A., 2018. Food value chain linkages and household food security in Tanzania. Food Sec. 10, 827–839.
Hertel, T.W., Baldos, U.L.C., 2018. Market integration and future food security in the context of spatially heterogeneous population and productivity growth. Presented at the The New Malthusianism, Cambridge.
Hertrampf, J.W., Piedad-Pascual, F., 2012. Handbook on ingredients for aquaculture feeds. Springer Science & Business Media, Berlin Heidelberg.

Hicks, J.H., Kleemans, M., Li, N.Y., Miguel, E., 2017. Reevaluating Agricultural Productivity Gaps with Longitudinal Microdata (Working Paper No. 23253), Working Paper Series. National Bureau of Economic Research, Cambridge.
Hishamunda, N., Bueno, P., Menezes, A.M., Ridler, N., Wattage, P., Martone, E., 2014. Improving governance of aquaculture employment. Food and Agriculture Organization of the United Nations, Rome.
Hoang, V.-N., Coelli, T., 2011. Measurement of agricultural total factor productivity growth incorporating environmental factors: A nutrients balance approach. Journal of Environmental Economics and Management 62, 462–474.
Hoddinott, J., 2008. Social Safety Nets and Productivity Enhancing Investments in Agriculture. Presented at the Convergence between social services provision (SSP) and productivity enhancing investments in development strategies: How to maximize the impact of public expenditure on agricultural growth and poverty reduction, Pietermaritzburg, South Africa.
Hollinger, F., Gross, A., 2019. Crop Receipts: A new financing instrument for Africa. International Finance Corporation and Food and Agriculture Organization of the United Nations, Washington D.C. and Rome.
Horemans, B., Kébé, M., 2006. Enhancing the economic contribution of fisheries to west and central African nations. Presented at the IIFET 2006 Portsmouth: Rebuilding Fisheries in an Uncertain Environment, International Institute of Fisheries Economics & Trade, Portsmouth, UK.
Houngbo, G., 2019. IFAD's experience minimizing food loss in developing countries.
Hounmanou, Y.M.G., Mdegela, R.H., Dougnon, T.V., Achoh, M.E., Mhongole, O.J., Agadjihouèdé, H., Gangbè, L., Dalsgaard, A., 2018. Tilapia lake virus threatens tilapiines farming and food security: Socio-economic challenges and preventive measures in Sub-Saharan Africa. Aquaculture 493, 123–129.
Houssou, N., Diao, X., Cossar, F., Kolavalli, S., Jimah, K., Aboagye, P.O., 2013. Agricultural Mechanization in Ghana: Is Specialized Agricultural Mechanization Service Provision a Viable Business Model? American Journal of Agricultural Economics 95, 1237–1244.
Huisman, L., Vink, M., van Eerdt, M., 2016. African Food Supply in Perspective: National-level food supply and land-use dynamics in 10 African countries under a growing demand for food (No. 1724). PBL Netherlands Environmental Assessment Agency, The Hague.
Husmann, C., Abiodun, F.O., Virchow, D., von Braun, J., Badiane, O., Akinbamijo, Y., 2015. Tapping Potentials of Innovation for Food Security and Sustainable Agricultural Growth - an Africa-wide Perspective. Center for Development Research, University of Bonn, Bonn.
Husmann, C., Kubik, Z., 2019. Foreign Direct Investment in the African Food and Agriculture Sector: Trends, Determinants and Impacts (No. 274), Discussion Papers Series. Center for Development Research, University of Bonn, Bonn.
Huyer, S., 2016. Closing the Gender Gap in Agriculture. Gender, Technology and Development 20, 105–116.
IAP, 2019. Harnessing Science, Engineering and Medicine to Address Africa's Challenges: The Role of African National Academies. The InterAcademy Partnership.
ICRISAT, 2009. Fertilizer Microdosing: Boosting Production in Unproductive Lands. International Crops Research Institute for the Semi-Arid Tropics, Patancheru.
IDRC, 2020. Livestock Vaccine Innovation Fund [WWW Document]. IDRC - International Development Research Centre. URL https://www.idrc.ca/en/initiative/livestock-vaccine-innovation-fund (accessed 8.21.20).
IEA, 2019. Africa Energy Outlook 2019. International Energy Agency, Vienna.
IFAD, 2018. How to do note: Design of gender transformative smallholder agriculture adaptation programmes.
IFC, 2020. MSME Finance Gap. International Finance Corporation, Washington D.C.
IFC, 2012. Innovative Farmer and Agricultural SME Financing Models, in: Innovative Agricultural SME Finance Models. International Finance Corporation, Washington, D.C, pp. 30–31.
IFPRI, 2019. 2019 Global food policy report, Global Food Policy Report. International Food Policy Research Institute, Washington D.C.
IFPRI, 2016. Global Nutrition Report 2016: From Promise to Impact: Ending Malnutrition by 2030. International Food Policy Research Institute, Washington D.C.
IFPRI, 2015. Global Nutrition Report 2015: Actions and Accountability to Advance Nutrition and Sustainable Development. International Food Policy Research Institute, Washington D.C.
IFPRI, 2011. Leveraging Agriculture for Improving Nutrition and Health. International Food Policy Research Institute, Washington D.C.
Ignatowski, C., 2017. What works in soft skills development for youth employment. A donor's perspective. Youth Employment Funders Group.
ILO, 2020. Global employment trends for the youth 2020: technology and the future of jobs. International Labour Organization, Geneva.
ILO, 2019. Work for a brighter future – Global Commission on the Future of Work. International Labour Organization, Geneva.
ILO, 2015. Global Employment Trends for Youth 2015. International Labour Organization, Geneva.
IMF, 2020. IMF DataMapper [WWW Document]. URL https://www.imf.org/external/datamapper/datasets (accessed 8.13.20).
Ismail, A., AHassarn, R., Abu Bakar, A., Hussin, H., Mat Hanafiah, M.A. and Asary, L.H., 2018. The development of TVET educator competencies for quality educator. JTET 10.
Isyagi, N.A., Veverica, K.L., Asiimwe, R., Daniels, W.H., 2009. Manual for the Commercial Pond Production of the African Catfish in Uganda. Walimi Fish Co-op Society Ltd., Kampala.

Iwuoha, J.-P., 2013. More meat, more feed – How entrepreneurs can exploit the huge market for animal feed in Africa. Smallstarter Africa. URL https://www.smallstarter.com/browse-ideas/animal-feed-supply-business/ (accessed 8.21.20).

Iyigun, M., Nunn, N., Qian, N., 2017. The Long-run Effects of Agricultural Productivity on Conflict, 1400-1900 (Working Paper No. 24066), Working Paper Series. National Bureau of Economic Research, Cambridge.

Jaffee, S., Henson, S., Diaz Rios, L., 2011. Making the Grade: Smallholder Farmers, Emerging Standards, and Development Assistance Programs in Africa - A Research Program Synthesis. The World Bank, Washington D.C.

Jamu, D.M., Ayinla, O.A., 2003. Potential for the development of aquaculture in Africa. Naga 26, 9–13.

Janoski, T., Luke, D., Oliver, C., 2014. The causes of structural unemployment: four factors that keep people from the jobs they deserve. Wiley, Hoboken.

Jayachandran, S., Laat, J., de Lambin, E.F., Stanton, C.Y., Audy, R., Thomas, N.E., 2017. Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation | Science. Science 357, 267–273.

Jayne, T.S., Muyanga, M., Wineman, A., Ghebru, H., Stevens, C., Stickler, M., Chapoto, A., Anseeuw, W., Westhuizen, D. van der, Nyange, D., 2019. Are medium-scale farms driving agricultural transformation in sub-Saharan Africa? Agricultural Economics 50, 75–95.

Jayne, T.S., Rashid, S., 2013. Input subsidy programs in sub-Saharan Africa: a synthesis of recent evidence. Agricultural Economics 44, 547–562.

Jayne, T.S., Yeboah, F.K., Henry, C., 2017. The future of work in African agriculture: Trends and drivers of change (Working Paper No. 25). International Labour Organization, Geneva.

Jenet, A., Buono, N., Lello, S.D., Gomarasca, M., Heine, C., Mason, S., Nori, M., Saavedra, R., Troos, K.V., 2016. The path to greener pastures. Pastoralism, the backbone of the world's drylands. Vétérinaires Sans Frontières International, Brussels.

Jensen, N.M., 2006. Nation-States and the Multinational Corporation: A Political Economy of Foreign Direct Investment. Princeton University Press, Princeton.

Jera, R., Ajayi, O.C., 2008. Logistic modelling of smallholder livestock farmers' adoption of tree-based fodder technology in Zimbabwe. Agrekon 47, 379–392.

Jeuland, M.A., Pattanayak, S.K., 2012. Benefits and Costs of Improved Cookstoves: Assessing the Implications of Variability in Health, Forest and Climate Impacts. PLOS ONE 7, e30338.

Jia, Z., Cai, Y., Chen, Y., Zeng, W., 2018. Regionalization of water environmental carrying capacity for supporting the sustainable water resources management and development in China. Resources, Conservation and Recycling 134, 282–293.

Jin, S.L., Schure, J., Ingram, V., Yoo, B.I., 2017. Sustainable woodfuel for food security: a smart choice: green, renewable and affordable. Food and Agriculture Organization of the United Nations, Rome.

Jobling, M., 2016. Fish nutrition research: past, present and future. Aquacult Int 24, 767–786.

Jones, K., 2013. The Role of Agricultural Technical and Vocational Education and Training in Developing Countries: A Review of Literature, Issues and Recommendations for Action. USAID, Washington D.C.

Juma, C., 2015. How to improve Africa's seed industry. World Economic Forum. URL https://www.weforum.org/agenda/2015/09/how-to-improve-africas-seed-industry/ (accessed 8.24.20).

Justino, P., 2012. Resilience in protracted crises: exploring coping mechanisms and resilience in households, communities and local institutions. Presented at the High Level Expert Forum on Food Security in Protracted Crises, Food and Agriculture Organization of the United Nations, Rome.

Kabirizi, J., Njarui, D.M.G., Itabari, J.K., Mugerwa, S., Nanyennya, W., Kaganda, S., Nakiganda, A., Nizigama, J., Namagembe, A., Namazzi, Mwilawa, A.J., 2012. Crop-livestock integration for sustainable management of natural resources in ECA region, in: Feeding Our Region in the 21st Century. Presented at the First ASARECA General Assembly, 14-16 December 2011, Association for Strengthening Agricultural Research in Eastern and Central Africa, Entebbe, pp. 84–85.

Kahan, D., 2013. Entrepreneurship in farming. Food and Agriculture Organization of the United Nations, Rome.

Kahan, D., Worth, S., 2015. Introducing the farm business school: a training package. Food and Agriculture Organization of the United Nations, Rome.

Kaiser, B., Roumasset, J., 2002. Valuing indirect ecosystem services: the case of tropical watersheds. Envir. Dev. Econ. 7.

Kaminski, A.M., Genschick, S., Kefi, A.S., Kruijssen, F., 2018. Commercialization and upgrading in the aquaculture value chain in Zambia. Aquaculture 493, 355–364.

Kampmann, W., Kirui, O.K., forthcoming. Role of Farmers' Organizations (FOs) in Agricultural Transformation in Africa: the Case of Senegal, Uganda, and Zambia (Discussion Paper). Center for Development Research, University of Bonn, Bonn.

Kanwar, A., Balasubramanian, K., Carr, A., 2019. Changing the TVET paradigm: new models for lifelong learning. International Journal of Training Research 17, 54–68.

Kappel, R., Reisen, H., 2019. G20 Compact with Africa: The Audacity of Hope. Friedrich-Ebert-Stiftung, Bonn.

Karamba, R.W., Winters, P.C., 2015. Gender and agricultural productivity: implications of the Farm Input Subsidy Program in Malawi. Agricultural Economics 46, 357–374.

Kariuki, J.G., 2011. The Future of Agriculture in Africa. Boston University, Boston.

Katchova, A.L., Ahearn, M.C., 2016. Dynamics of Farmland Ownership and Leasing: Implications for Young and Beginning Farmers. Appl Econ Perspect Policy 38, 334–350.

Kaufmann, D., Kraay, A., Mastruzzi, M., 2005. Governance Matters IV: Governance Indicators for 1996-2004. The World Bank, Washington D.C.
Kaufmann, D., Kraay, A., Mastruzzi, M., 2004. Governance Matters III: Governance Indicators for 1996, 1998, 2000, and 2002. The World Bank Economic Review 18, 253–287.
Khan, M.H., 2005. Agricultural taxation in developing countries: a survey of issues and policy. Agricultural Economics 24, 315–328.
Kibaara, B., 2019. What needs to happen next.
Kienzle, J., 2013. Precision Agriculture for Smallholder Farmers. Agriculture for Development 19, 12–15.
Kilimo Trust, 2017. Characteristics of Markets for Animal Feeds Raw Materials in the East African Community: Focus on Maize Bran and Sunflower Oil Cake. Kilimo Trust, Kampala.
Kim, J., Hanotte, O., Mwai, O.A., Dessie, T., Bashir, S., et al., 2017. The genome landscape of indigenous African cattle. Genome Biol 18, 34.
King, L., 2011. Neglected Zoonotic Diseases, in: Insitute of Medicine (Ed.), The Causes and Impacts of Neglected Tropical and Zoonotic Diseases: Opportunities for Integrated Intervention Strategies. National Academies Press (US), Washington D.C.
Kirui, O., 2019. The Agricultural Mechanization in Africa: Micro-Level Analysis of State Drivers and Effects (272), Discussion Papers on Development Policy. Center for Development Research, University of Bonn, Bonn.
Kirui, O., Kozicka, M., 2018. Vocational Education and Training for Farmers and Other Actors in the Agri-Food Value Chain in Africa (No. 164), Working Paper. Center for Development Research, University of Bonn, Bonn.
Koobonye, S., 2020. TVET in Botswana : a case study on its ability to develop demand-driven and competence-based skills for the labour market. Bundesinstitut für Berufsbildung, Bonn.
Kornher, L., 2018. Maize markets in Eastern and Southern Africa (ESA) in the Context of Climate Change—Background Paper for The State of Agricultural Commodity Markets (SOCO) 2018. Food and Agriculture Organization of the United Nations, Rome.
Kornher, L., Kalkuhl, M., 2019. The gains of coordination - When does regional cooperation for food security make sense? Global Food Security 22, 37–45.
Kornher, L., von Braun, J., 2020. EU Common Agricultural Policy - Impacts on Trade with Africa and African Agricultural Development, ZEF Discussion Papers. Center for Development Research, University of Bonn, Bonn.
Kosec, K., Ghebru, H., Holtemeyer, B., Mueller, V., Schmidt, E., 2017. The Effect of Land Access on Youth Employment and Migration Decisions: Evidence from Rural Ethiopia - Kosec - 2018 - American Journal of Agricultural Economics - Wiley Online Library. American Journal of Agricultural Economics 100, 931–954.
Kosec, K., Ragasa, C., 2019. How to improve rural service delivery in developing countries: Complementarities, information, and incentives. International Food Policy Research Institute, Washington D.C.
Kowalski, P., Gonzalez, J.L., Ragoussis, A., Ugarte, C., 2015. Participation of Developing Countries in Global Value Chains: Implications for Trade and Trade-Related Policies. Organisation for Economic Co-operation and Development, Paris.
Kristjanson, P., Okike, I., Tarawali, S., Singh, B.B., Manyong, V.M., 2005. Farmers' perceptions of benefits and factors affecting the adoption of improved dual-purpose cowpea in the dry savannas of Nigeria. Agricultural Economics 32, 195–201.
Kubik, Z., 2020. Rural youth and productive employment in Sub-Saharan Africa: A review. Unpublished working paper.
Kubik, Z., Odubote, I., Getahun, T., Oueslati-Zlaoui, M., forthcoming. Employment in agroprocessing sector: Evidence from Ethiopia, Ghana and Tunisia. Center for Development Research, University of Bonn, Bonn.
Kuma, T., Dereje, M., Hirvonen, K., Minten, B., 2019. Cash Crops and Food Security: Evidence from Ethiopian Smallholder Coffee Producers. The Journal of Development Studies 55, 1267–1284.
Kuyah, S., Öborn, I., Jonsson, M., 2017. Regulating Ecosystem Services Delivered in Agroforestry Systems, in: Dagar, J.C., Tewari, V.P. (Eds.), Agroforestry: Anecdotal to Modern Science. Springer, Singapore, pp. 797–815.
Kuyah, S., Whitney, C.W., Jonsson, M., Sileshi, G.W., Öborn, I., Muthuri, C.W., Luedeling, E., 2019. Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa. A meta-analysis. Agron. Sustain. Dev. 39, 47.
Kwon, H.-Y., Nkonya, E., Johnson, T., Graw, V., Kato, E., Kihiu, E., 2016. Global Estimates of the Impacts of Grassland Degradation on Livestock Productivity from 2001 to 2011, in: Nkonya, E., Mirzabaev, A., von Braun, J. (Eds.), Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer International Publishing, Cham, pp. 197–214.
La Porta, R., 1999. The quality of government. Journal of Law, Economics, and Organization 15, 222–279.
Laajaj, R., Macours, K., 2017. Measuring skills in developing countries. The World Bank, Washington D.C.
Laffoley, D., Grimsditch, G., 2009. The Management of Natural Coastal Carbon Sinks. International Union for Conservation of Nature and Natural Resources, Gland.
Lallemand, T., Rycx, F., 2016. Are Young and Old Workers Harmful for Firm Productivity? (Discussion Paper No. 3938). Institute for the Study of Labor, Bonn.
Lankford, B., Makin, I., Matthews, N., McCornick, P.G., Noble, A., Shah, T., 2016. A Compact to Revitalise Large-Scale Irrigation Systems Using a Leadership-Partnership-Ownership "Theory of Change." Water Alternatives 9, 1–32.
Latchem, C., 2017. Using ICTs and Blended Learning in Transforming TVET. Perspectives on Open and Distance Learning. United Nations Educational, Scientific, and Cultural Organization and Commonwealth of Learning, Paris and Burnaby.

Le, Q.B., Nkonya, E., Mirzabaev, A., 2016. Biomass Productivity-Based Mapping of Global Land Degradation Hotspots, in: Nkonya, E., Mirzabaev, A., von Braun, J. (Eds.), Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer, Cham, pp. 55–84.

Lefore, N., Giordano, M., Ringler, C., Barron, J., 2019. Sustainable and equitable growth in farmer-led irrigation in Sub-Saharan Africa: What will it take? Water Alternatives 12, 156–168.

Lele, U., Pretty, J., Terry, E., Trigo, E., 2010. Transforming Agricultural Research for Development: Report for the Global Conference on Agricultural Research (GCARD) 2010. Global Forum on Agricultural Research, Rome.

Lerman, R., 2019. Do firms benefit from apprenticeship investments? IZA World of Labor 55, 1–10.

Levison, D., DeGraff, D.S., Dungumaro, E.W., 2018. Implications of Environmental Chores for Schooling: Children's Time Fetching Water and Firewood in Tanzania. Eur J Dev Res 30, 217–234.

Lewis, W.A., 1954. Economic Development with Unlimited Supplies of Labour. The Manchester School 22, 139–191.

Li, H., Zhang, X., 2017. A spatial explicit assessment of food security in Africa based on simulated crop production and distribution. Journal of Cleaner Production 147, 628–636.

Li, W., Ahmed, M., Khan, Q., Hongwei, M., 2016. Education and Training for Rural Transformation: Skills, Jobs, Food and Green Future to Combat Poverty. SAGE Publications India, New Delhi.

Li, Y., Kalnay, E., Motesharrei, S., Rivas, J., Kucharski, F., Kirk-Davidoff, D., Bach, E., Zeng, N., 2018. Climate model shows large-scale wind and solar farms in the Sahara increase rain and vegetation. Science 361, 1019–1022.

Lillesø, J.P.B., Harwood, C., Derero, A., Graudal, L., Roshetko, J.M., et al., 2018. Why institutional environments for agroforestry seed systems matter. Development Policy Review 36, O89–O112.

Lind, C.E., Brummett, R.E., Ponzoni, R.W., 2012. Exploitation and conservation of fish genetic resources in Africa: issues and priorities for aquaculture development and research. Reviews in Aquaculture 4, 125–141.

Lio, M., Liu, M.-C., 2008. Governance and agricultural productivity: A cross-national analysis. Food Policy 33, 504–512.

Lippmann, L.H., Ryberg, R., Carney, R., Moore, K.A., 2015. Workforce Connections: Key "soft skills" that foster youth workforce success: toward a consensus across fields. Child Trends, Washington D.C.

Lobell, D.B., Cassman, K.G., Field, C.B., 2009. Crop yield gaps: their importance, magnitudes, and causes. Annual Review of Environment and Resources 34, 179–294.

Lordkipanidze, N., Tauer, L.W., 2000. Farmer Efficiency and Technology Use with Age. Agricultural and Resource Economics Review 29, 24–31.

Lowder, S.K., Skoet, J., Raney, T., 2016. The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. World Development 87, 16–29.

Lowore, J., 2020. Understanding the Livelihood Implications of Reliable Honey Trade in the Miombo Woodlands in Zambia. Front. For. Glob. Change 3, 28.

Ludwig, T., 2018. An Egg for an Egg and a Bean for a Bean? How Production Diversity Determines Dietary Diversity of Smallholder Farmers in Rural India (Discussion Papers on Development Policy No. 247). Center for Development Research, University of Bonn, Bonn.

Luedeling, E., Kindt, R., Huth, N.I., Koenig, K., 2014. Agroforestry systems in a changing climate—challenges in projecting future performance. Current Opinion in Environmental Sustainability, Sustainability challenges 6, 1–7.

Luedeling, E., Shepherd, K., 2016. Decision-Focused Agricultural Research. Solutions 7, 46–54.

Luedeling, E., Sileshi, G., Beedy, T., Dietz, J., 2011. Carbon Sequestration Potential of Agroforestry Systems in Africa, in: Kumar, B.M., Nair, P.K.R. (Eds.), Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges, Advances in Agroforestry. Springer Netherlands, Dordrecht, pp. 61–83.

Lukkainen, J., 2012. A Comparison of Extension Methods Used by Different Agricultural Extension Service Providers in Nyandarua County, Kenya. HAMK University of Applied Sciences, Evo.

Lukumbuzya, K., Sianga, C., 2017. Overview of the Timber Trade in East and Southern Africa: National Persepctives and Regional Trade Linkages. TRAFFIC and WWF, Cambridge.

Lunduka, R., Ricker-Gilbert, J., Fisher, M., 2013. What are the farm-level impacts of Malawi's farm input subsidy program? A critical review. Agricultural Economics 44, 563–579.

Lusigi, A., Thirtle, C., 1997. Total Factor Productivity and the Effects of R&d in African Agriculture. Journal of International Development 9, 529–538.

Lynam, J., Beintema, N., Roseboom, J., Badiane, O., 2016. Agricultural research in Africa: Investing in future harvests. International Food Policy Research Institute, Washington D.C.

Ma, W., Abdulai, A., 2016. Does cooperative membership improve household welfare? Evidence from apple farmers in China. Food Policy 58, 94–102. Mabaya, E., Cramer, L., 2014. Growth in a Globalized Industry: The Case of Hillside Green Growers & Exporters Ltd. International Food and Agribusiness Management Review 17, 1–5.

Mabaya, E., Diack Ba, M.M., Ndiaye, M., Mugoya, M., 2017. Senegal Brief 2017 – The African Seed Access Index. The African Seed Access Index, Nairobi.

Mabaya, E., Mugoya, M., 2017. 2017 Ten Emerging Lessons from TASAI. The African Seed Access Index, Nairobi.

Maertens, M., Vande Velde, K., 2017. Contract-farming in Staple Food Chains: The Case of Rice in Benin. World Development 95, 73–87.

Maiangwa, M., Adeniji, O., Omolehin, R., Mohammed, U., 2011. Food insecurity: challenges of agricultural extension in developing countries. J. Ag. For. Soc. Sci. 7, 73–105.

Maïga, E., Christiaensen, L., Palacios-Lopez, A., 2015. Are the youth exiting agricultureen masse? Presented at the CSAE Conference 2016: Economic Development in Africa, Center for the Study of African Economies, Oxford, UK.
Makochekanwa, A., 2014. Welfare Implications of COMESA-EAC-SADC Tripartite Free Trade Area. African Development Review 26, 186–202.
Makoni, N., Mwai, R., Redda, T., 2014. White gold: Opportunities for Dairy Sector Development Collaboration in East Africa (No. CDI-14-006), CDI report. Center for Development Innovation, Wageningen University, Wageningen.
Malabo Montpellier Panel, 2020. Meat, milk and more: Policy innovations to shepherd inclusive and sustainable livestock systems in Africa. Malabo Montpellier Panel, Dakar.
Malabo Montpellier Panel, 2019a. Byte by Byte: Policy Innovation for Transforming Africa's Food System with Digital Technologies. Malabo Montpellier Panel, Dakar.
Malabo Montpellier Panel, 2019b. Energized: Policy Innovations to Power the Transformation of Africa's Agriculture and Food System. Malabo Montpellier Panel, Dakar.
Malabo Montpellier Panel, 2018a. Water-Wise: Smart Irrigation Strategies for Africa. Malabo Montpellier Panel, Dakar.
Malabo Montpellier Panel, 2018b. Mechanized: Transforming Africa's agriculture value chains | IFPRI : International Food Policy Research Institute. Malabo Montpellier Panel, Dakar.
Malabo Montpellier Panel, 2017. Nourished: How Africa Can Build a Future Free from Hunger and Malnutrition. Malabo Montpellier Panel, Dakar.
Malan, M., Berkhout, E., Bouma, J., 2016. The impact of taxes and subsidies on crop yields - Agricultural price distortions in Africa. PBL Netherlands Environmental Assessment Agency, The Hague.
Mangisoni, J.H., 2008. Impact of treadle pump irrigation technology on smallholder poverty and food security in Malawi: a case study of Blantyre and Mchinji districts. International Journal of Agricultural Sustainability 6, 248–266.
Mango, N., Makate, C., Tamene, L., Mponela, P., Ndengu, G., 2018. Adoption of Small-Scale Irrigation Farming as a Climate-Smart Agriculture Practice and Its Influence on Household Income in the Chinyanja Triangle, Southern Africa. Land 7, 1–19.
Maredia, M.K., Byerlee, D., Pee, P., 2000. Impacts of food crop improvement research: evidence from sub-Saharan Africa. Food Policy 25, 531–559.
Markel, E., Gettliffe, E., Jones, L., Kim, L., Miller, E., 2016. The social norms factor: How gendered social norms influence how we empower women in market systems development. The BEAM Exchange, London.
Marshall, K., 2014. Optimizing the use of breed types in developing country livestock production systems: a neglected research area. J. Anim. Breed. Genet. 131, 329–340.
Marshall, K., Gibson, J.P., Mwai, O., Mwacharo, J.M., Haile, A., Getachew, T., Mrode, R., Kemp, S.J., 2019. Livestock Genomics for Developing Countries – African Examples in Practice. Front. Genet. 10, 297.
Mastercard Foundation, 2020. Farmer Organizations [WWW Document]. URL https://www.raflearning.org/topics/farmer-organizations (accessed 8.13.20).
Matthews, A., Soldi, R., 2019. Evaluation of the impact of the current CAP on the agriculture of developing countries. European Committee of the Region, Brussels.
Mattiello, S., Caroprese, M., Crovetto, G.M., Riccardo, F., 2017. Typical dairy products in Africa from local animal resources. Italian Journal of Animal Science 17, 1–15.
Mbaabu, A., Alela, R., 2019. Lessons and recommended strategies for scale-out of Yieldwise-Tanzania beyond maize value chains (unpublished report). Alliance for a Green Revolution in Africa, Nairobi.
Mbengue, M.M., 2018. Facilitating Investment for Sustainable Development: It Matters for Africa (Columbia FDI Perspectives No. 222). Columbia Center on Sustainable Development, New York.
Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P.A., Kowero, G., 2014. Agroforestry solutions to address food security and climate change challenges in Africa. Current Opinion in Environmental Sustainability, Sustainability challenges 6, 61–67.
McGuire, S., Sperling, L., 2016. Seed systems smallholder farmers use. Food Sec. 8, 179–195.
McInerney, E., 2014. Cooperatives key to achieving sustainable agricultural Development. Department of Economic and Social Affairs, United Nations, New York.
McIntyre, B.D., Herren, H.R., Wakhungu, J., Watson, R.T., 2009. Synthesis report: a synthesis of the global and sub-global IAASTD reports. Island Press, Washington D.C.
McLeod Rivera, W., Qamar, M.K., 2003. Agricultural Extension, Rural Development and the Food Security Challenge. Food and Agriculture Organization of the United Nations, Rome.
McNamara, P., Bohn, A., Moore, A., Alvarez-Mingote, C., Childress, A., 2016. Modernizing Extension and Advisory Services (MEAS) Final Project Report. USAID, Washington D.C.
Meemken, E.-M., Sellare, J., Kouame, C.N., Qaim, M., 2019. Effects of Fairtrade on the livelihoods of poor rural workers. Nature Sustainability 2, 635–642.
Meinzen-Dick, R., Johnson, N., Quisumbing, A., Njuki, J., Behrman, J., Rubin, D., Peterman, A., Waithanji, E., 2011. Gender, Assets, and Agricultural Development Programs: A Conceptual Framework. International Food Policy Research Institute, Washington D.C.
Melitz, M.J., 2003. The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. Econometrica 71, 1695–1725.
Meon, P.-G., Weill, L., 2005. Does better governance foster efficiency? An aggregate frontier analysis. Economics of Governance 6, 75–90.
Migot-Adholla, S., Hazell, P., Blarel, B., Place, F., 1991. Indigenous Land Rights Systems in Sub-Saharan Africa:

A Constraint on Productivity? The World Bank Economic Review 5, 155–175.
Miguel, E., Hamory, J., 2009. Individual Ability and Selection into Migration in Kenya (No. 2009/45), Human Development Research Paper. United Nations Development Programme, New York.
Mikalsen, K.H., Hernes, H.-K., Jentoft, S., 2007. Leaning on user-groups: The role of civil society in fisheries governance. Marine Policy 31, 201–209.
Miller, C., Jones, L., 2010. Agricultural Value Chain Finance: Tools and Lessons. Food and Agriculture Organization of the United Nations and Practical Action Publishing, Rome and Rugby.
Minot, N., 2011. Contract Farming in sub-Saharan Africa: Opportunities and Challenges. Presented at the Smallholder-led Agricultural Commercialization and Poverty Reduction: How to Achieve It?, International Food Policy Research Institute, Kigali.
Minten, B., Randrianarison, L., Swinnen, J.F.M., 2009. Global Retail Chains and Poor Farmers: Evidence from Madagascar. World Development, Agrifood Industry Transformation and Small Farmers in Developing Countries 37, 1728–1741.
Minten, B., Reardon, T., Chen, K., 2017. Agricultural value chains: How cities reshape food systems, in: IFPRI (Ed.), 2017 Global Food Policy Report. International Food Policy Research Institute, Washington D.C., pp. 42–49.
Mirzabaev, A., Wambui Njiraini, G., Gebremariam, G., Jourdain, D., Magaia, E., et al., 2015. Transboundary Water Resources for People and Nature: Challenges and Opportunities in the Olifants River Basin (Working Paper No. 77). Center for Development Research, University of Bonn, Bonn.
Mirzabaev, A., Wu, J., Evans, J., Garcia-Oliva, F., Hussein, I., et al., 2019. Desertification, in: Shukla, P.R., et al. (Eds.), Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. World Meteorological Organization and United Nations Environment Programme, Geneva and Nairobi, pp. 249–343.
Mishra, A.K., Kumar, A., Joshi, P.K., D'Souza, A., 2018. Cooperatives, contract farming, and farm size: The case of tomato producers in Nepal. Agribusiness 34, 865–886.
Mogues, T., Fan, S., Benin, S., 2015. Public Investments in and for Agriculture. Eur J Dev Res 27, 337–352.
Mogues, T., Yu, B., Fan, S., McBride, L., 2012. The impacts of public investment in and for agriculture: Synthesis of the existing evidence (Working Paper No. 12– 07). Food and Agriculture Organization of the United Nations, Rome.
Mohrenweiser, J., Zwick, T., Backes-Gellner, U., 2019. Poaching and firm-sponsored training. British Journal of Industrial Relations 57, 143–181.
Montagnini, F., Nair, P.K.R., 2004. Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agroforestry Systems 61, 281.
Morris, S.S., Beesabathuni, K., Headey, D., 2018. An egg for everyone: Pathways to universal access to one of nature's most nutritious foods. Matern Child Nutr 14, e12679.
Morton, J., Matthewman, R., 1996. Improving livestock production through extension: Information needs, institutions and opportunities. Natural Resource Persepectives 12, 8.
Moussa, B., Nkonya, E., Meyer, S., Kato, E., Johnson, T., Hawking, J., 2016. Cost, Drivers and Action Against Land Degradation in Senegal, in: Nkonya, E., Mirzabaev, A., von Braun, J. (Eds.), Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer International Publishing, Cham, pp. 499–539.
Mrode, R., Ekine Dzivenu, C., Marshall, K., Chagunda, M.G.G., Muasa, B.S., Ojango, J., Okeyo, A.M., 2020. Phenomics and its potential impact on livestock development in low-income countries: innovative applications of emerging related digital technology. Animal Frontiers 10, 6–11.
Mueller, J.P., Rischkowsky, B., Haile, A., Philipsson, J., Mwai, O., et al., 2015. Community-based livestock breeding programmes: essentials and examples. J. Anim. Breed. Genet. 132, 155–168.
Mueller, N.D., Gerber, J.S., Johnston, M., Ray, D.K., Ramankutty, N., Foley, J.A., 2012. Closing yield gaps through nutrient and water management. Nature 490, 254–257.
Muir, J., 2015. Fuel and energy use in the fisheries sector - Approaches, inventories and strategic implications. Food and Agriculture Organization of the United Nations, Rome.
Mujahid, I., Kalkuhl, M., 2016. Do Trade Agreements Increase Food Trade? World Economy 39, 22.
Muriithi, B.W., Matz, J.A., 2015. Welfare effects of vegetable commercialization: Evidence from smallholder producers in Kenya. Food Policy 50, 80–91.
Muriuki, H.G., 2011. Dairy Development in Kenya. Food and Agriculture Organization of the United Nations, Rome.
Murray, M., Clifford, D.J., Gettinby, G., Snow, W.F., McIntyre, W.I., 1981. Susceptibility to African trypanosomiasis of N'Dama and Zebu cattle in an area of Glossina morsitans submorsitans challenge. Veterinary Record 109, 503–510.
Musinguzi, L., Lugya, J., Rwezawula, P., Kamya, A., Nuwahereza, C., Halafo, J., Kamondo, S., Njaya, F., Aura, C., Shoko, A.P., Osinde, R., Natugonza, V., Ogutu-Ohwayo, R., 2019. The extent of cage aquaculture, adherence to best practices and reflections for sustainable aquaculture on African inland waters. Journal of Great Lakes Research 45, 1340–1347.
Mutonyi, S., 2019. The effect of collective action on smallholder income and asset holdings in Kenya. World Development Perspectives 14, 100099.
Mwai, O., Hanotte, O., Kwon, Y.-J., Cho, S., 2015. African Indigenous Cattle: Unique Genetic Resources in a Rapidly Changing World. Asian Australas. J. Anim. Sci 28, 911–921.
Nagoli, J., Mwendo Phiri, E., Kambewa, E., Jamu, D., 2009. Adapting integrated agriculture aquaculture for HIV and AIDS-affected households: the case of Malawi. WorldFish, Penang.

Nair, R. das, Chisoro, S., Ziba, F., 2018. The implications for suppliers of the spread of supermarkets in southern Africa. Development Southern Africa 35, 334–350.
Nair, P.K.R., 1993. An Introduction to Agroforestry. Springer Netherlands, Dordrecht.
Namulawa, V.T., Mutiga, S., Musimbi, F., Akello, S., Ngángá, F., Kago, L., Kyallo, M., Harvey, J., Ghimire, S., 2020. Assessment of Fungal Contamination in Fish Feed from the Lake Victoria Basin, Uganda. Toxins 12, 233.
NASAC, 2018. Opportunities and challenges for research on food and nutrition security and agriculture in Africa. The Network of African Science Academies, Nairobi.
National Veterinary Institute, n.d. History of NVI [WWW Document]. National Veterinary Institute. URL https://www.nvi.com.et/about-us/history-of-nvi/ (accessed 8.21.20).
Ncube, P., 2018. The southern African poultry value chain: Corporate strategies, investments and agro-industrial policies. Development Southern Africa 35, 369–387.
Ndambi, O.A., Pelster, D.E., Owino, J.O., de Buisonjé, F., Vellinga, T., 2019. Manure Management Practices and Policies in Sub-Saharan Africa: Implications on Manure Quality as a Fertilizer. Front. Sustain. Food Syst. 3, 29.
Neate, P.J.H., Guéi, R.G., 2010. Promoting the growth and development of smallholder seed enterprises for food security crops: best practices and options for decision making. Food and Agriculture Organization of the United Nations, Rome.
Neely, C., Bunning, S., Wilkes, A., 2009. Review of evidence on drylands pastoral systems and climate change: Implications and opportunities for mitigation and adaptation. Food and Agriculture Organization of the United Nations, Rome.
Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T.B., et al., 2009. Climate Change: Impact on Agriculture and Costs of Adaptation. International Food Policy Research Institute, Washington, D.C.
NEPAD, 2019. Overview of Nutrition in Africa as a response to the Malabo/CAADP Commitments to end hunger and malnutrition by 2025 [WWW Document]. AUDA-NEPAD. URL https://www.nepad.org/publication/overview-of-nutrition-africa-response-malabocaadp-commitments-end-hunger-and (accessed 9.14.20).
NEPAD, 2014. Agriculture in Africa. Transformation and outlook [WWW Document]. URL https://www.tralac.org/images/docs/6460/agriculture-in-africa-transformation-and-outlook.pdf (accessed 8.12.20).
Ngarava, S., Mushunje, A., Chaminuka, P., 2018. Impact Of Livestock Development Programmes On Production & Risk: Case Of The Kaonafatso Ya Dikgomo (KyD) Programme. Presented at the 56th Annual Conference of the Agricultural Economics Association of South Africa, Agricultural Economics Association of South Africa (AEASA), Cape Town, South Africa.
Ngarava, S., Phetshe, M., Mushunje, A., 2019. Market Awareness and Participation for Cattle Farmers in the Kaonafatso ya Dikgomo (KyD) Scheme in KwaZulu-Natal Province, South Africa. Agriculture 9, 1–12.
Ngepah, N., 2017. A review of theories and evidence of inclusive growth: an economic perspective for Africa. Current Opinion in Environmental Sustainability, Sustainability science 24, 52–57.
Niasse, M., Cherlet, J., 2014. Coordinating land and water governance–An essential part of achieving food security. Global Water Partnership, Stockholm.
Nilsson, P., 2019. The Role of Land Use Consolidation in Improving Crop Yields among Farm Households in Rwanda. The Journal of Development Studies 55, 1726–1740.
Nin-Pratt, A., McBride, L., 2014. Agricultural intensification in Ghana: Evaluating the optimist's case for a Green Revolution. Food Policy, Boserup and Beyond: Mounting Land Pressures and Development Strategies in Africa 48, 153–167.
Njarui, D.M.G., Kabirizi, J., Itabari, J.K., Gatheru, M., Nakiganda, A., Mugerwa, S., 2012. Production characteristics and gender roles in dairy farming in peri-urban areas of Eastern and Central Africa. Livestock Research for Rural Development 24.
Njiraini, G., Ngigi, M., Baraké, E., 2018. Women in African Agriculture: Integrating Women into Value Chains to Build a Stronger Sector (No. 175), Working Papers. Center for Development Research, University of Bonn, Bonn.
Nkonya, E., Mirzabaev, A., von Braun, J., 2016. Economics of Land Degradation in Sub-Saharan Africa, in: Nkonya, E., Mirzabaev, A., von Braun, J. (Eds.), Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer International Publishing, Cham, pp. 215–259.
Nonvide, G.M.A., 2018. Irrigation adoption: A potential avenue for reducing food insecurity among rice farmers in Benin. Water Resources and Economics 24, 40–52.
Norton, G.W., Alwang, J., 2020. Changes in Agricultural Extension and Implications for Farmer Adoption of New Practices. Applied Economic Perspectives and Policy 42, 8–20.
Obayelu, A.E., 2014. Postharvest Losses and Food Waste: The Key Contributing Factors to African Food Insecurity and Environ mental Challenge. African Journal of Food, Agriculture, Nutrition and Development 14.
Ochieng, J., Knerr, B., Owuor, G., Ouma, E., 2016. Commercialisation of Food Crops and Farm Productivity: Evidence from Smallholders in Central Africa. Agrekon 55, 458–482.
Odhiambo, B., 2016. New Drought-Resistant Pasture Grass to boost African livestock farmers yields, income [WWW Document]. Africa Science News. URL https://africasciencenews.org/new-drought-resistant-pasture-grass-to-boost-african-livestock-farmers-yields-income/ (accessed 8.21.20).
Odhiambo, W., 2007. Financing African Agriculture: Issues and Challenges. Presented at the Second African Economic Conference at the United Nations Conference Centre (UNCC), Addis Ababa, Ethiopia.
Odijie, M.E., 2019. The need for industrial policy coordination in the African Continental Free Trade Area. Afr Aff (Lond) 118, 182–193.

OECD, 2020. OECD.stat. [WWW Document]. OECD.stat. URL https://stats.oecd.org/

OECD, 2017. Youth Aspirations and the Reality of Jobs in Developing Countries: Mind the Gap | en | OECD. Organisation for Economic Co-operation and Development, Paris.

OECD, 2013. Agricultural Innovation Systems: A Framework for Analysing the Role of the Government. Organisation for Economic Co-operation and Development, Paris.

OECD, 2012. Livestock Diseases: Prevention, Control and Compensation Schemes. Organisation for Economic Co-operation and Development, Paris.

OECD, FAO, 2020. OECD-FAO Agricultural Outlook 2020-2029, OECD-FAO Agricultural Outlook. Organisation for Economic Co-operation and Development and Food and Agriculture Organization of the United Nations, Paris and Rome.

OECD, WTO, 2019. Aid for Trade at a Glance 2019: Economic Diversification and Empowerment, Aid for Trade at a Glance. Organisation for Economic Co-operation and Development and World Trade Organization, Paris and Geneva.

Ogunlela, V., Ogungbila, A.O., 2006. Alleviating rural poverty in Nigeria. A challenge for National agricultural research system. Journal of Food, Agriculture and Environment 6, 3–4.

Ogutu, S.O., Okello, J.J., Otieno, D.J., 2014. Impact of Information and Communication Technology-Based Market Information Services on Smallholder Farm Input Use and Productivity: The Case of Kenya. World Development 64, 311–321.

O'Higgins, N., 2017. Rising to the youth employment challenge: new evidence on key policy issues. International Labour Office, Geneva.

OIE, 2019. The OIE PPP Handbook: Guidelines for Public-Private Partnerships in the veterinary domain. World Organisation for Animal Health (OIE), Paris.

Okebalama, C.B., Ibrahim, A., Safo, E.Y., Yeboah, E., Abaidoo, R.C., Logah, V., Uzoh, I.M., 2017. Fertilizer micro-dosing in West African low-input cereals cropping: Benefits, challenges and improvement strategies. African Journal of Agricultural Research 12, 1169–1176.

Oladele, O.I., 2011. Features of agricultural extension models and policy in selected sub - Saharan Africa countries. Journal of Agriculture and Environment for International Development (JAEID) 105, 35–44.

Olagunju, A., Thondhlana, G., Chilima, J.S., Sène-Harper, A., Compaoré, W.R.N., Ohiozebau, E., 2019. Water governance research in Africa: progress, challenges and an agenda for research and action. Water International 44, 382–407.

Olsson, L., Barbosa, H., Bhadawal, S., Cowie, A., Delusca, K., Flores-Renteria, D., Hermans, K., Jobbagy, E., Kurz, W., Li, D., Sonwa, D.J., Stringer, L., 2019. Land Degradation, in: Shukla, P.R., et al. (Eds.), Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. World Meteorological Organization and United Nations Environment Programme, Geneva and Nairobi, pp. 345–436.

Omondi, I.A., Zander, K.K., Bauer, S., Baltenweck, I., 2017. Understanding farmers' preferences for artificial insemination services provided through dairy hubs. Animal 11, 677–686.

Omoregbee, F.E., Ojogho, O., Isikhuemen, E.M., Orhue, E.R., Ewansiha, S.I., Omoyakhi, M., Aliu, B.S., Ebabhamiegbebho, P.A., 2016. Outreach Program to University of Benin Host Communities. unpublished manuscript.

Ortega, D.L., Bro, A.S., Clay, D.C., Lopez, M.C., Tuyisenge, E., Church, R.A., Bizoza, A.R., 2019. Cooperative membership and coffee productivity in Rwanda's specialty coffee sector. Food Sec. 11, 967–979.

Otte, M.J., Chilonda, P., 2002. Cattle and small ruminant production systems in sub-Saharan Africa: A systematic review. Food and Agriculture Organization of the United Nations, Rome.

Palacios-Lopez, A., Christiaensen, L., Kilic, T., 2017. How much of the labor in African agriculture is provided by women? Food Policy, Agriculture in Africa – Telling Myths from Facts 67, 52–63.

Palmer, R., 2020. Lifelong Learning in the Informal Economy. International Labour Organization, Geneva.

Passarelli, S., Mekonnen, D., Bryan, E., Ringler, C., 2018. Evaluating the pathways from small-scale irrigation to dietary diversity: evidence from Ethiopia and Tanzania. Food Sec. 10, 981–997.

Patel, E., 2019. Building capacity of African researchers in genomics to play key role in boosting productivity of livestock systems. ILRI news. URL https://news.ilri.org/2019/11/20/genomics-capacities/ (accessed 8.21.20).

Paulos, H.B., 2019. The Water-Energy-Food Nexus in the Eastern Nile Basin: Transboundary Interlinkages, Climate Change and Scope for Cooperation (Doctoral thesis at Faculty of Agriculture, University of Bonn). University of Bonn, Bonn.

Paumgarten, F., 2005. The Role of non-timber forest products as safety-nets: A review of evidence with a focus on South Africa. GeoJournal 64, 189–197.

Pavelic, P., Villholth, K.G., Shu, Y., Rebelo, L.-M., Smakhtin, V., 2013. Smallholder groundwater irrigation in Sub-Saharan Africa: country-level estimates of development potential. Water International 38, 392–407.

PEN, 2016. CIFOR's Poverty and Environment Network (PEN) global dataset. URL https://data.cifor.org/dataset.xhtml?persistentId=doi:10.17528/CIFOR/DATA.00021 (accessed 9.09.20).

Penunia, E., 2011. The Role of Farmers' Organizations in Empowering Rural Women and Promoting Rural Women's Leadership 13.

Persha, L., Agrawal, A., Chhatre, A., 2011. Social and Ecological Synergy: Local Rulemaking, Forest Livelihoods, and Biodiversity Conservation. Science 331, 1606–1608.

Petry, N., Jallow, B., Sawo, Y., Darboe, M.K., Barrow, S., et al., 2019. Micronutrient Deficiencies, Nutritional Status and

the Determinants of Anemia in Children 0–59 Months of Age and Non-Pregnant Women of Reproductive Age in The Gambia. Nutrients 11, 2275.
Pica-Ciamarra, U., Baker, D., Morgan, N., Ly, C., Nouala, S., 2013. Investing in African Livestock: business opportunities in 2030-2050 (No. 86591). World Bank, FAO, ILRI, AU-IBAR, Washington D.C.
Pica-Ciamarra, U., Baker, D., Morgan, N., Zezza, A., Azzari, C., Ly, C., Nsiima, L., Nouala, S., Okello, P., Sserugga, J., 2014. Investing in the Livestock Sector: Why Good Numbers Matter. A Sourcebook for decision makers on how to improve livestock data (No. 85732- GLB). The World Bank, Washington D.C.
Pingali, P., 2007. Agricultural Mechanization: Adoption Patterns and Economic Impact, in: Handbook of Agricultural Economics. Elsevier, pp. 2779–2805.
Pingali, P.L., 1997. From Subsistence to Commercial Production Systems: The Transformation of Asian Agriculture. American Journal of Agricultural Economics 79, 628–634.
Pingali, P.L., Rosegrant, M.W., 1995. Agricultural commercialization and diversification: processes and policies. Food Policy, Agricultural Commercialization and Diversification 20, 171–185.
Place, F., 2009. Land Tenure and Agricultural Productivity in Africa: A Comparative Analysis of the Economics Literature and Recent Policy Strategies and Reforms. World Development 37, 1326–1336.
Popkin, B.M., 2003. The Nutrition Transition in the Developing World. Development Policy Review 27, 628– 646.
Pradhan, P., Fischer, G., van Velthuizen, H., Reusser, D.E., Kropp, J.P., 2015. Closing Yield Gaps: How Sustainable Can We Be? PLoS ONE 10, e0129487.
Punjabi, M., 2009. India: Increasing demand challenges the dairy sector, in: FAO Regional Office for Asia and the Pacific, Morgan, N. (Eds.), Smallholder Dairy Development: Lessons Learned in Asia, RAP Publication. FAO Regional Office for Asia and the Pacific, Bangkok.
Radchenko, N., Corral, P., 2018. Agricultural Commercialisation and Food Security in Rural Economies: Malawian Experience. The Journal of Development Studies 54, 256–270.
Ragasa, C., Andam, K., Kufoalor, D., Amewu, S., 2018a. A blue revolution in sub-Saharan Africa? Evidence from Ghana's tilapia value chain. International Food Policy Research Institute, Washington D.C.
Ragasa, C., Lambrecht, I., Kufoalor, D.S., 2018b. Limitations of Contract Farming as a Pro-poor Strategy: The Case of Maize Outgrower Schemes in Upper West Ghana. World Development 102, 30–56.
Rakotoarisoa, M.A., Iafrate, M., Paschali, M. (Eds.), 2012. Why has Africa become a net food importer? Explaining Africa agricultural and food trade deficits. Food and Agriculture Organization of the United Nations, Rome.
Ramirez, M., Clarke, I., Klerkx, L., 2018. Analysing intermediary organisations and their influence on upgrading in emerging agricultural clusters. Environ Plan A 50, 1314–1335.
Rangarajan, A., Chitja, J., 2020. Building human capacity to transform agriculture in Southern Africa, in: Sikora, R.A., Terry, E.R., Vlek, P.L.G., Chitja, J. (Eds.), Transforming Agriculture in Southern Africa: Constraints, Technologies, Policies and Processes. Routledge, Oxon, pp. 232–241.
Rao, B.S.S., 2012. Human Capital Development for the Management of F&A in India. International Food and Agribusiness Management Review 15, 4.
Reardon, T., Barrett, C.B., Berdegué, J.A., Swinnen, J.F.M., 2009. Agrifood Industry Transformation and Small Farmers in Developing Countries. World Development 37, 1717–1727.
Reardon, T., Echeverria, R., Berdegué, J., Minten, B., Liverpool-Tasie, S., Tschirley, D., Zilberman, D., 2019. Rapid transformation of food systems in developing regions: Highlighting the role of agricultural research & innovations. Agricultural Systems, Agricultural research for rural prosperity: Rethinking the pathways 172, 47–59.
Reardon, T., Timmer, C.P., Barrett, C.B., Berdegué, J., 2003. The Rise of Supermarkets in Africa, Asia, and Latin America. American Journal of Agricultural Economics 85, 1140–1146.
Reed, J., van Vianen, J., Foli, S., Clendenning, J., Yang, K., MacDonald, M., Petrokofsky, G., Padoch, C., Sunderland, T., 2017. Trees for life: The ecosystem service contribution of trees to food production and livelihoods in the tropics. Forest Policy and Economics 84, 62–71.
Reichhuber, A., Gerber, N., Mirzabaev, A., Svoboda, M., López Santos, A., Graw, V., Stefanski, R., Davies, J., Vuković, A., Fernández García, M.A., Fiati, C., Jia, X., 2019. The Land-Drought Nexus Enhancing the Role of Land-Based Interventions in Drought Mitigation and Risk Management. United Nations Convention to Combat Desertification, Bonn.
Reilly, A., 2018. Overview of food fraud in the fisheries sector. Food and Agriculture Organization of the United Nations, Rome.
Renault, D., Wallender, W.W., 2000. Nutritional water productivity and diets. Agricultural Water Management 45, 275–296.
République de Mali, 2013. Politique de Développement Agricole du Mali (PDA). République de Mali, Bamako.
Rezaei, E.E., Gaiser, T., 2017. Change in crop management strategies could double the maize yield in Africa (Discussion Papers on Development Policy No. 239). Center for Development Research, University of Bonn, Bonn.
Ricker-Gilbert, J., Mason, N.M., Darko, F.A., Tembo, S.T., 2013. What are the effects of input subsidy programs on maize prices? Evidence from Malawi and Zambia. Agricultural Economics 44, 671–686.
Ritchie, H., Roser, M., 2017. Meat and Dairy Production. Our World in Data.
Roseboom, J., Flaherty, K., 2016. The Evolution of Agricultural Research in Africa: Key Trends and Institutional Developments. Investing in Future Harvests 31.
Rosegrant, M.W., Koo, J., Cenacchi, N., Ringler, C., Robertson, R.D., Fisher, M., Cox, C.M., Garrett, K., Perez, N.D., Sab-

bagh, P., 2014. Food security in a world of natural resource scarcity: The role of agricultural technologies. International Food Policy Research Institute, Washington D.C.
Rosegrant, M.W., Magalhaes, E., Valmonte-Santos, R.A., Mason-D'Croz, D., 2016. Returns to Investment in Reducing Postharvest Food Losses and Increasing Agricultural Productivity Growth. Presented at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston.
Rosegrant, M.W., Ringler, C., Foster, V., Briceño-Garmendia, C., 2009. Irrigation: Tapping Potential, in: Africa Infrastructure: A Time for Transformation. Agence Française de Développement and the World Bank, Paris and Washington D.C., pp. 287–298.
Saenger, C., Torero, M., Qaim, M., 2014. Impact of third-party contract enforcement in agricultural markets—A field experiment in Vietnam. American Journal of Agricultural Economics 96, 1220–1238.
Sahel Capital, 2015. An Assessment of the Nigerian Poultry Sector. Sahel Capital Newsletter 11, 2.
Sakketa, T.G., 2018. Institutional bricolage as a new perspective to analyse institutions of communal irrigation: Implications towards meeting the water needs of the poor communities. World Development Perspectives 9, 1–11.
Salvatierra Rojas, A., Torres Toledo, V., Mrabet, F., Müller, J., 2018. Improving milk value chains through solar milk cooling (No. 276621), Working Papers, Working Papers. University of Bonn, Center for Development Research (ZEF), Bonn, Germany.
Salvatierra-Rojas, A., Nagle, M., Gummert, M., Bruin, T. de, Müller, J., 2017. Development of an inflatable solar dryer for improved postharvest handling of paddy rice in humid climates. International Journal of Agricultural and Biological Engineering 10, 269–282.
Samboko, P.C., Zulu-Mbata, O., Chapoto, A., 2018. Analysis of the animal feed to poultry value chain in Zambia. Development Southern Africa 35, 351–368.
Sarris, A., 2016. Financial needs and tools for agricultural development and transformation pertinent to low-income, food-insecure countries. FERDI, Clermont-Ferrand.
Sayer, J., Cassman, K.G., 2013. Agricultural innovation to protect the environment. PNAS 110, 8345–8348.
Saygili, M., Peters, R., Knebel, C., 2017. African Continental Free Trade Area: Challenges and Opportunities of Tariff Reductions (UNCTAD Research Paper No. 15). United Nations Conference on Trade and Development, Geneva.
Schelling, E., Bechir, M., Ahmed, M.A., Wyss, K., Randolph, T.F., Zinsstag, J., 2007. Human and Animal Vaccination Delivery to Remote Nomadic Families, Chad. Emerg. Infect. Dis. 13, 373–379.
Schmidhuber, J., Bruinsma, J., Boedeker, G., 2009. Capital requirements for agriculture in developing countries to 2050. Food and Agriculture Organization of the United Nations, Rome.
Schmieg, E., 2018. EU und Afrika: Investitionen, Handel, Entwicklung. SWP Aktuell 2018/A 70.
Schnegg, M., Bollig, M., 2016. Institutions put to the test: Community-based water management in Namibia during a drought. Journal of Arid Environments 124, 62–71.
Scholte, J.A., 2012. A More Inclusive Global Governance? The IMF and Civil Society in Africa. GG 18, 185–206.
SDC, 2019. Understanding and analysing vocational education and training systems – An introduction. Swiss Agency for Development and Cooperation, Bern.
SDC, 2013. Understanding and analysing vocational education and trainingsystems –An introduction. Swiss Agency for Development and Cooperation, Bern.
Seck, A., Cissokho, L., Makpayo, K., Haughton, J., 2010. How Important Are Non-Tariff Barriers to Agricultural Trade within ECOWAS? (No. 2010–3), Working Papers, Working Papers. Department of Economics, Suffolk University, Boston.
Seré, C., 2020. Investing Sustainably in African Livestock Development: Opportunities and Trade-Offs (Working Paper No. 194). Center for Development Research, University of Bonn, Bonn.
Shaw, A.P.M., Cecchi, G., Wint, G.R.W., Mattioli, R.C., Robinson, T.P., 2014. Mapping the economic benefits to livestock keepers from intervening against bovine trypanosomosis in Eastern Africa. Preventive Veterinary Medicine 113, 197–210.
Sheahan, M., Barrett, C.B., 2017. Ten striking facts about agricultural input use in Sub-Saharan Africa. Food Policy, Agriculture in Africa – Telling Myths from Facts 67, 12–25.
Shen, X., Lin, B., Wu, W., 2019. R&D Efforts, Total Factor Productivity, and the Energy Intensity in China. Emerging Markets Finance and Trade 55, 2566–2588.
Sheng, Y., Tian, X., Qiao, W., Peng, C., 2020. Measuring agricultural total factor productivity in China: pattern and drivers over the period of 1978-2016. Australian Journal of Agricultural and Resource Economics 64, 82–103.
Shiferaw, B., Hellin, J., Muricho, G., 2011. Improving market access and agricultural productivity growth in Africa: what role for producer organizations and collective action institutions? Food Sec. 3, 475–489.
Shukla, P., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., et al., 2019. Special Report on Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. International Panel on Climate Change, Geneva.
SIDA, 2015. Woman and Food Security, Gender Toolbox Brief. The Swedish International Development Cooperation Agency, Sweden.
Siebert, S., Döll, P., 2010. The Global Crop Water Model (GCWM): Documentation and First Results for Irrigated Crops. Food and Agriculture Organization of the United Nations, Rome.
Sigei, J., 2014. The Contribution Of Agricultural Extension Services To Food Security Of Smallholder Households In Nandi County, Kenya. University of Nairobi, Nairobi.

Silva, J.V., Baudron, F., Reidsma, P., Giller, K.E., 2019. Is labour a major determinant of yield gaps in sub-Saharan Africa? A study of cereal-based production systems in Southern Ethiopia. Agricultural Systems 174, 39–51.
Simelton, E.S., Catacutan, D.C., Dao, T.C., Dam, B.V., Le, T.D., 2017. Factors constraining and enabling agroforestry adoption in Viet Nam: a multi-level policy analysis. Agroforestry Systems 91, 51–67.
Sims, B.G., Hilmi, M., Kienzle, J., 2016. Agricultural mechanization: a key input for sub-Saharan Africa smallholders. Food and Agriculture Organization of the United Nations, Rome.
Singirankabo, U.A., Ertsen, M.W., 2020. Relations between Land Tenure Security and Agricultural Productivity: Exploring the Effect of Land Registration. Land 9, 138.
Sinyolo, S., Mudhara, M., 2018. Farmer groups and inorganic fertiliser use among smallholders in rural South Africa. South African Journal of Science 114.
Smethurst, P.J., Huth, N.I., Masikati, P., Sileshi, G.W., Akinnifesi, F.K., Wilson, J., Sinclair, F., 2017. Accurate crop yield predictions from modelling tree-crop interactions in gliricidia-maize agroforestry. Agricultural Systems 155, 70–77.
SOFA Team, Doss, C., 2011. The Role of Women in Agriculture (No. 11– 02), ESA Working Paper. Food and Agriculture Organization of the United Nations, Rome.
Sola, P., Ochieng, C., Yila, J., Iiyama, M., 2016. Links between energy access and food security in sub Saharan Africa: an exploratory review. Food Sec. 8, 635–642.
Soullier, G., Moustier, P., 2018. Impacts of contract farming in domestic grain chains on farmer income and food insecurity. Contrasted evidence from Senegal. Food Policy 79, 179–198.
Sow, S., Nkonya, E., Meyer, S., Kato, E., 2016. Cost, Drivers and Action Against Land Degradation in Senegal, in: Nkonya, E., Mirzabaev, A., von Braun, J. (Eds.), Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development. Springer International Publishing, Cham, pp. 577–608.
Spielman, D., 2020. Seed Policies and Regulatory Reforms, in: Diao, X., Resnick, D., Tadesse, G. (Eds.), Sustaining Africa's Agrifood System Transformation: The Role of Public Policies. ReSAKSS Annual Trends and Outlook Reports 2020., ReSAKSS Annual Trends and Outlook Reports 2020. International Food Policy Research Institute, Washington D.C.
Spielman, D.J., Davis, K., Negash, M., Ayele, G., 2011. Rural innovation systems and networks: findings from a study of Ethiopian smallholders. Agric Hum Values 28, 195–212.
Spielman, D.J., Smale, M., 2017. Policy Options to Accelerate Variety Change Among Smallholder Farmers in South Asia and Africa South of the Sahara (Discussion Paper No. 1666). International Food Policy Research Institute, Washington D.C.
Stockinger, B., Zwick, T., 2017. Apprentice poaching in regional labor markets (Discussion Paper No. 17– 013). Centre for European Economic Research, Mannheim.
Strange, A.M., Dreher, A., Fuchs, A., Parks, B., Tierney, M.J., 2017. Tracking Underreported Financial Flows: China's Development Finance and the Aid–Conflict Nexus Revisited. Journal of Conflict Resolution 61, 935–963.
Ströh de Martinez, C., Feddersen, M., Speicher, A., 2016. Food security in sub-Saharan Africa: a fresh look on agricultural mechanisation; how adapted financial solutions can make a difference. German Development Institute / Deutsches Institut für Entwicklungspolitik (DIE), Bonn.
Stutzman, E., Molnar, J., Atukunda, G., Walakira, J., 2017. Understanding the Role of Fish Farmer Associations as Intermediaries for the Commercialization of Aquaculture in Uganda. Fisheries and Aquaculture Journal 8, 1–12.
Sukati, M., 2016. COMESA's Revealed Comparative Advantage in Common Agricultural Commodities (MPRA Paper No. 69989). Munich Personal RePEc Archive, Munich.
Sunding, D., Zilberman, D., 2001. The agricultural innovation process: Research and technology adoption in a changing agricultural sector, in: Handbook of Agricultural Economics, Agricultural Production. Elsevier, Amsterdam, pp. 207–261.
Swinnen, J.F.M., Maertens, M., 2007. Globalization, privatization, and vertical coordination in food value chains in developing and transition countries. Agricultural Economics 37, 89–102.
Tadesse, G., Abate, G.T., Ergano, K., 2019. The Boundary of Smallholder Producers' Cooperatives: A Conceptual and Empirical Analysis. Journal of Agricultural Economics 70, 529–549.
Tadesse, G., Badiane, O., 2018. Determinants of African agricultural exports, in: Badiane, O., Odjo, S.P., Collins, J. (Eds.), Africa Agricultural Trade Monitor 2018. International Food Policy Research Institute, Washington D.C., pp. 85–109.
Tadesse, G., Badiane, O., forthcoming. Policy Responses to Rapidly Transforming Midstream Value Chains in Africa: The Case of the Millet Sector in Senegal, in: Sustaining Africa's Agrifood System Transformation: The Role of Public Policies. ReSAKSS Annual Trends and Outlook Reports 2020. International Food Policy Research Institute, Washington D.C.
Tadesse, G., Kassie, G.T., 2017. Measuring trust and commitment in collective actions: Evidence from farmers' marketing organizations in rural Ethiopia. International Journal of Social Economics 44, 980–996.
Tadesse, G., Zewdie, T., 2019. Grants vs. credits for improving the livelihoods of ultra-poor: Evidence from Ethiopia. World Development 113, 320–329.
Tambo, J.A., 2018. Recognizing farmer-generated innovations through contests: insights from four African countries. Food Sec. 10, 1237–1250.
Tambo, J.A., Wünscher, T., 2015. Identification and prioritization of farmers' innovations in northern Ghana. Renew. Agric. Food Syst. 30, 537–549.
Taneja, J., 2018. If You Build It, Will They Consume? Key Challenges for Universal, Reliable, and Low-Cost Electricity Delivery in Kenya (Working Paper No. 491). Center for Global Development, Washington D.C.

Tauer, L., 1995. Age and Farmer Productivity. Review of Agricultural Economics 17, 63–69.
Tauer, L.W., 2017. Farmer Productivity By Age Over Eight U.S. Census Years (Working Paper). Department of Applied Economics and Management, Cornell University, Ithaca.
Tauer, L.W., 1984. Productivity of Farmers at Various Ages. North Central Journal of Agricultural Economics 6, 81–87.
Tefera, D.A., Bijman, J., 2019. Cooperatives in Modern Food Supply Chains: A Case Study of the Malt Barley Sector in Ethiopia, in: Windsperger, J., Cliquet, G., Hendrikse, G., Srećković, M. (Eds.), Design and Management of Interfirm Networks., Contributions to Management Science. Springer International Publishing, Cham, pp. 217–237.
Tesfai, M., Njarui, D.M.G., Ghimire, S.R., 2019. Sustainable intensifications of African agriculture through legume-based cropping and Brachiaria forage systems. AJAR 14, 1138–1148.
TFRA, 2020. Prioritise for Africad's food and nutrition security post-Covid-19. A contribution from the Task Force Rural Africa (TFRA)to the AU-EU Summit, October 2020. Task Force Rural Africa.
TFRA, 2019. An Africa-Europe Agenda for rural transformation: Report by the Task Force Rural Africa. Task Force Rural Africa.
The Montpellier Panel, 2014. No Ordinary Matter: Conserving, Restoring and Enhancing Africa's Soils. Agriculture for Impact, Imperial College London, London.
The Montpellier Panel, 2013. Sustainable Intensification: A New Paradigm for African Agriculture. Agriculture for Impact, Imperial College London, London.
The Pontificial Academy of Science, 2019. Final Statement on Food Loss and Waste Reduction. Pontifical Academy of Sciences, The Vatican.
Thierfelder, C., Chivenge, P., Mupangwa, W., Rosenstock, T.S., Lamanna, C., Eyre, J.X., 2017. How climate-smart is conservation agriculture (CA)? – its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa. Food Sec. 9, 537–560.
Thoelen, J., Daum, T., 2019. How to keep Tractors running in Africa? Lessons for knowledge and skills development from Zambia, PARI Policy Brief. Center for Development Research, University of Bonn, Bonn.
Thorlakson, T., Neufeldt, H., 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. Agriculture & Food Security 1, 15.
Thornton, P.K., Herrero, M., 2015. Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. Nature Clim Change 5, 830–836.
Thornton, P.K., Rosenstock, T., Förch, W., Lamanna, C., Bell, P., Henderson, B., Herrero, M., 2018. A Qualitative Evaluation of CSA Options in Mixed Crop-Livestock Systems in Developing Countries, in: Lipper, L., McCarthy, N., Zilberman, D., Asfaw, S., Branca, G. (Eds.), Climate Smart Agriculture, Natural Resource Management and Policy. Springer International Publishing, Cham, pp. 385–423.
Thurlow, J., 2015. Youth Employment Prospects in Africa, in: Resnick, D., Thurlow, J. (Eds.), African Youth and the Persistence of Marginalization. Employment, Politics, and Prospects for Change. Routledge, Abingdon-on-Thames.
Thurstan, R.H., Roberts, C.M., 2014. The past and future of fish consumption: Can supplies meet healthy eating recommendations? Marine Pollution Bulletin 89, 5–11.
Tieguhong, J.C., Nkamgnia, E.M., 2012. Household dependence on forests around lobeke Nationa l Park, Cameroon. Int. Forest. Rev. 14, 196–212.
Timmer, C., 2009. A World Without Agriculture: The Structural Transformation in Historical Perspective (Books). American Enterprise Institute, Washington D.C.
Tolno, E., Kobayashi, H., Ichizen, M., Esham, M., Balde, B., 2015. Economic Analysis of the Role of Farmer Organizations in Enhancing Smallholder Potato Farmers' Income in Middle Guinea. Journal of Agricultural Science 7, p123.
Ton, G., Vellema, W., Desiere, S., Weituschat, S., D'Haese, M., 2018. Contract farming for improving smallholder incomes: What can we learn from effectiveness studies? World Development 104, 46–64.
Toth, G.G., Nair, P.K.R., Jacobson, M., Widyaningsih, Y., Duffy, C.P., 2019. Malawi's energy needs and agroforestry: Impact of woodlots on fuelwood sales. Energy for Sustainable Development 50, 101–108.
Tran, N., Chu, L., Chan, C.Y., Genschick, S., Phillips, M.J., Kefi, A.S., 2019. Fish supply and demand for food security in Sub-Saharan Africa: An analysis of the Zambian fish sector. Marine Policy 99, 343–350.
Triki, T., Faye, I., 2013. Financial Inclusion in Africa. African Development Bank, Abidjan.
Trimble, C.P., Kojima, M., Perez Arroyo, I., Mohammadzadeh, F., 2016. Financial viability of electricity sectors in Sub-Saharan Africa : quasi-fiscal deficits and hidden costs. The World Bank, Washington D.C.
Tripoli, M., Schmidhuber, J., 2018. Emerging Opportunities for the Application of Blockchain in the Agri-food Industry. International Centre for Trade and Sustainable Development, Geneva.
Tsan, M., Totapally, S., Hailu, M., Addom, B.A., 2019. The Digitalisation of African Agriculture Report 2018-2019. CTA, Wageningen.
Tschirley, D., Reardon, T., Dolislager, M., Snyder, J., 2015. The Rise of a Middle Class in East and Southern Africa: Implications for Food System Transformation. Journal of International Development 27, 628–646.
UN, 2016. World Economic and Social Survey 2016 – Climate Change Resilience: An Opportunity for Reducing Inequalities. United Nations, New York.
UN Women, 2018. The gender gap in agricultural productivity in sub-Saharan Africa: causes, costs and solutions, UN Woman Policy Brief. UN Women, New York.
UNCCD, 2020. The Great Green Wall Initiative [WWW Document]. United Nations Convention to Combat Desertification. URL https://www.unccd.int/actions/great-green-wall-initiative (accessed 8.18.20).

UNCTAD, 2020. https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?sCS_ChosenLang=en [WWW Document]. UNCTADStat.
UNCTAD, 2009. Economic Development in Africa Report 2009. United Nations Publications, New York.
UNDESA, 2019. World population prospects Highlights, 2019 revision Highlights, 2019 revision. Department of Economic and Social Affairs, United Nations, New York.
UNDESA, 2015. The world's women 2015: trends and statistics. Department of Economic and Social Affairs, United Nations, New York.
UNECA, AU, 2020. African Continental Free Trade Area - Updated Q&A. United Nations Economic Comission for Africa, Addis Ababa.
United Nations, 2020. Inter-agency Task Force on Financing for Development: Financing for Sustainable Development Report 2020. United Nations, New York.
Unruh, J.D., 2008. Carbon sequestration in Africa: The land tenure problem. Global Environmental Change, Local evidence on vulnerabilities and adaptations to global environmental change 18, 700–707.
Ute, C., Gold, E., Schneider, K., Rütters, K., 2014. Improving the Image of Technical and Vocational Education and Training. A syntesis. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Eschborn.
Valbuena, D., Erenstein, O., Homann-Kee Tui, S., Abdoulaye, T., Claessens, L., Duncan, A.J., Gerard, B.G., Rufino, M.C., Teufel, N., Rooyen, A.F. van, Wijk, M.T. van, 2012. Conservation agriculture in mixed crop-livestock systems: Scoping crop residue trade-offs in Sub-Saharan Africa and South Asia. Field Crops Research.
van den Broeck, G., Swinnen, J., Maertens, M., 2017. Global value chains, large-scale farming, and poverty: Long-term effects in Senegal. Food Policy 66, 97–107.
van Dijk, M., Vander Stichele, M., 2008. Is Foreign Investment Good for Development? A Literature Review. Centre for Research on Multinational Corporations, Amsterdam.
van Ittersum, M.K., van Bussel, L.G.J., Wolf, J., Grassini, P., van Wart, J., et al., 2016. Can sub-Saharan Africa feed itself? PNAS 113, 14964–14969.
van Koppen, B., 2003. Water reform in Sub-Saharan Africa: what is the difference? Physics and Chemistry of the Earth, Parts A/B/C 28, 1047–1053.
van Marle-Köster, E., Visser, C., 2018. Genetic Improvement in South African Livestock: Can Genomics Bridge the Gap Between the Developed and Developing Sectors? Front. Genet. 9, 331.
Van Noordwijk, M., Lusiana, B., 1999. WaNuLCAS, a model of water, nutrient and light capture in agroforestry systems, in: Auclair, D., Dupraz, C. (Eds.), Agroforestry for Sustainable Land-Use Fundamental Research and Modelling with Emphasis on Temperate and Mediterranean Applications: Selected Papers from a Workshop Held in Montpellier, France, 23–29 June 1997, Forestry Sciences. Springer Netherlands, Dordrecht, pp. 217–242.
Vandermeulen, S., Ramírez-Restrepo, C.A., Beckers, Y., Claessens, H., Bindelle, J., 2018. Agroforestry for ruminants: a review of trees and shrubs as fodder in silvopastoral temperate and tropical production systems. Anim. Prod. Sci. 58, 767.
Vanni, F., 2014. Agriculture and Public Goods: The Role of Collective Action. Springer Netherlands, Dordrecht.
Verhofstadt, E., Maertens, M., 2015. Can Agricultural Cooperatives Reduce Poverty? Heterogeneous Impact of Cooperative Membership on Farmers' Welfare in Rwanda. Appl Econ Perspect Policy 37, 86–106.
Verhofstadt, E., Maertens, M., 2014. Smallholder cooperatives and agricultural performance in Rwanda: do organizational differences matter? Agricultural Economics 45, 39–52.
Vignare, K., 2013. Options and strategies for information and communication technologies within agricultural extension and advisory services. Michigan State University, East Lansing.
Villholth, K.G., 2013. Groundwater irrigation for smallholders in Sub-Saharan Africa – a synthesis of current knowledge to guide sustainable outcomes. Water International 38, 369–391.
Villoria, N., 2019. Consequences of agricultural total factor productivity growth for the sustainability of global farming: accounting for direct and indirect land use effects. Environ. Res. Lett. 14, 125002.
von Braun, J., 2018. Innovations to Overcome the Increasingly Complex Problems of Hunger (Working Paper No. 167). Center for Development Research, University of Bonn, Bonn.
von Braun, J., 2017. Agricultural Change and Health and Nutrition in Emerging Economies, in: Pingali, P., Feder, G. (Eds.), Agriculture and Rural Development in a Globalizing World. Routledge, London, pp. 273–291.
von Braun, J., 1995. Agricultural commercialization: impacts on income and nutrition and implications for policy. Food Policy, Agricultural Commercialization and Diversification 20, 187–202.
von Grebmer, K., Bernstein, Patterson, F., Wiemers, M., Chéailleachair, R.N., Foley, C., Gitter, S., Ekstrom, K., Fritschel, H., Rupa, 2019. 2019 Global Hunger Index: The Challenge of Hunger and Climate Change. Deutsche Welthungerhilfe and Concern Worldwide, Bonn and Dublin.
Vorley, B., Cotula, L., Chan, M.-K., 2012. Tipping the Balance: Policies to shape agricultural investments and markets in favour of small-scale farmers. Oxfam, London.
Vos, R., 2019. Reducing food losses in developing countries: Simple technological solutions, complex adoption along supply chains.
Walakira, J., Akoll, P., Engole, M., Sserwadda, M., Nkambo, M., et al., 2014. Common fish diseases and parasites affecting wild and farmed Tilapia and catfish in Central and Western Uganda. Uganda Journal of Agricultural Sciences 15, 113–125.
Wamala, S.P., Mugimba, K.K., Mutoloki, S., Evensen, Ø., Mdegela, R., Byarugaba, D.K., Sørum, H., 2018. Occurrence and antibiotic susceptibility of fish bacteria isolated from

Oreochromis niloticus (Nile tilapia) and Clarias gariepinus (African catfish) in Uganda. Fish Aquatic Sci 21, 6.
Warshawsky, D.N., 2016. Civil Society and the Governance of Urban Food Systems in Sub-Saharan Africa: Local Food Organizations in Sub-Saharan Africa. Geography Compass 10, 293–306.
Warshawsky, D.N., 2014. Civil society and urban food insecurity: analyzing the roles of local food organizations in Johannesburg. Urban Geography 35, 109–132.
Wassie, S.B., Kusakari, H., Masahiro, S., 2019. Inclusiveness and effectiveness of agricultural cooperatives: recent evidence from Ethiopia. International Journal of Social Economics 46, 614–630.
Watson, J.E.M., Evans, T., Venter, O., Williams, B., Tulloch, A., et al., 2018. The exceptional value of intact forest ecosystems. Nature Ecology & Evolution 2, 599–610.
Whitney, C.W., Tabuti, J.R.S., Hensel, O., Yeh, C.-H., Gebauer, J., Luedeling, E., 2017. Homegardens and the future of food and nutrition security in southwest Uganda. Agricultural Systems 154, 133–144.
WHO, 2016. Obesity and Overweight Fact Sheet. World Health Organization, Geneva.
Wiebe, K.D., Sulser, T.B., Mason-D'Croz, D., Rosegrant, M.W., 2017. The effects of climate change on agriculture and food security in Africa, in: A Thriving Agricultural Sector in a Changing Climate: Meeting Malabo Declaration Goals through Climate-Smart Agriculture. ReSAKSS Annual Trends and Outlook Reports 2016. International Food Policy Research Institute, Washington D.C., pp. 5–21.
Wiggins, S., Henley, G., Keats, S., 2015. Competitive or complementary? Industrial crops and food security in sub-Saharan Africa, ODI Report. Overseas Development Institute, London.
Williams, S.B., Baributsa, D., Woloshuk, C., 2014. Assessing Purdue Improved Crop Storage (PICS) bags to mitigate fungal growth and aflatoxin contamination. Journal of Stored Products Research 59, 190–196.
Windsperger, J., Cliquet, G., Hendrikse, G., Srećković, M., 2019. Design and Management of Interfirm Networks. Springer, Heidelberg.
Winter-Nelson, A.E., Stack, J.L., Brighton, M.M., Pedzisa, T., Mazvimavi, K., 2016. Impact of Fertilizer Microdosing Research and Development in Semi-Arid Zimbabwe (Impact Brief No. 3). International Crops Research Institute for the Semi-Arid Tropics, Patancheru.
Wolfenson, K.D.M., 2013. Coping with the food and agriculture challenge: smallholders' agenda. Food and Agriculture Organization of the United Nations, Rome.
World Agroforestry Centre, n.d. Faidherbia Albida: Keystone of Evergreen Agriculture in Africa. World Agroforestry Centre, Nairobi.
World Bank, 2020f. The African Continental Free Trade Area: Economic and Distributional Effects. World Bank, Washington D.C.
World Bank, 2020a. Agriculture, forestry, and fishing, value added (constant 2010 US$) - Sub-Saharan Africa | Data [WWW Document]. World Bank Indicators. URL https://data.worldbank.org/indicator/NV.AGR.TOTL.KD?locations=ZG (accessed 9.14.20).
World Bank, 2020b. Employment in agriculture (% of total employment) (modeled ILO estimate) - Sub-Saharan Africa | Data [WWW Document]. World Bank Indicators. URL https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=ZG (accessed 9.14.20).
World Bank, 2020c. Rural population (% of total population) - | Data [WWW Document]. World Bank Indicators. URL https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZG (accessed 8.15.20).
World Bank, 2020d. Access to electricity (% of population) | Data [WWW Document]. World Bank Indicators. URL https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=1991&most_recent_year_desc=false&start=1990 (accessed 9.14.20).
World Bank, 2020e. Doing Business 2020: Comparing Business Regulation in 190 Economies. The World Bank, Washington D.C.
World Bank, 2019. Enabling the Business of Agriculture 2019. The World Bank, Washington D.C.
World Bank, 2017a. State of Electricity Access Report 2017. The World Bank, Washington D.C.
World Bank, 2017b. Doing Business 2017: Equal Opportunity for All, Doing Business. The World Bank, Washington D.C.
World Bank, 2016. Reaping Richer Returns: Public Spending Priorities for African Agriculture Productivity Growth. The World Bank, Washington D.C.
World Bank, 2015. Improving Livelihoods and Creating Wealth through Sustainable Fisheries. The World Bank, Washington D.C.
World Bank, 2013. Growing Africa: Unlocking the Potential of Agribusiness. The World Bank, Washington D.C.
World Bank, 2012. World Development Report 2012: Gender equality and development. The World Bank, Washington D.C.
World Bank, FAO, 2014. Business and Livelihoods in African Livestock: Investments to overcome information gaps (No. 86093- AFR). The World Bank, Washington D.C.
World Bank, IFAD, 2017. Rural youth employment. The World Bank and International Fund for Agricultural Development, Washington D.C.
World Bank, World Economic Forum, African Development Bank, 2017. The Africa competitiveness report 2017: addressing Africa's demographic dividend. World Economic Forum, Geneva.
Wortmann-Kolundžija, E., 2019. Empowering Smallholder Farmers through Farmer Organizations: Insights from Kenya and Burkina Faso. (Working Paper No. 190). Center for Development Research, University of Bonn, Bonn.
Wossen, T., Abdoulaye, T., Alene, A., Haile, M.G., Feleke, S., Olanrewaju, A., Manyong, V., 2017. Impacts of extension access and cooperative membership on technology adoption and household welfare. Journal of Rural Studies 54, 223–233.

WPP, 2010. Water sector governance in Africa. Volume 2. Assessment and guidelines. Water Partnership Program, African Development Bank, Tunis.
Wunder, S., Börner, J., Shively, G., Wyman, M., 2014. Safety Nets, Gap Filling and Forests: A Global-Comparative Perspective. World Development 64, 29–S42.
Xie, H., Perez, N., Anderson, W., Ringler, C., You, L., 2018. Can Sub-Saharan Africa feed itself? The role of irrigation development in the region's drylands for food security. Water International 43, 796–814.
Xie, H., You, L., Wielgosz, B., Ringler, C., 2014. Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. Agricultural Water Management 131, 183–193.
Xiong, J., Thenkabail, P.S., Teluguntla, P., Congalton, R.G., Yadav, K., Dungan, J., Oliphant, A., Poehnelt, J., Smith, C., Massey, R., 2017a. Global Food Security-support Analysis Data (GFSAD) Cropland Extent 2015 Africa 30 m V001.
Xiong, J., Thenkabail, P.S., Tilton, J.C., Gumma, M.K., Teluguntla, P., Oliphant, A., Congalton, R.G., Yadav, K., Gorelick, N., 2017b. Nominal 30-m Cropland Extent Map of Continental Africa by Integrating Pixel-Based and Object-Based Algorithms Using Sentinel-2 and Landsat-8 Data on Google Earth Engine. Remote Sensing 9, 1065.
Yeboah, F.K., Jayne, T.S., 2018. Africa's Evolving Employment Trends. The Journal of Development Studies 54, 803–832.
You, L., Ringler, C., Wood-Sichra, U., Robertson, R., Wood, S., Zhu, T., Nelson, G., Guo, Z., Sun, Y., 2011. What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. Food Policy, Between the Global and the Local, the Material and the Normative: Power struggles in India's Agrifood System 36, 770–782.
Young, A., 2013. Inequality, the Urban-Rural Gap, and Migration*. Q J Econ 128, 1727–1785.
Yumkella, K.K., 2011. Agribusiness for Africa's prosperity. United Nations Industrial Development Organization, Vienna.
Zenebe, A., Peterson, W., Wamisho, K., 2014. The Impact of the African Growth and Opportunity Act (AGOA): An Empirical Analysis of Sub-Saharan African Agricultural Exports, in: 2014 Annual Meeting, July 27-29, 2014, Minneapolis, Minnesota. Presented at the 2014 Annual Meeting of the Agricultural and Applied Economics Association, Minneapolis, USA.
Zhan, J., Mirza, H., Speller, W., 2018. Investment: International investment and local food security, in: IFPRI (Ed.), 2018 Global Food Policy Report. International Food Policy Research Institute, Washington D.C., pp. 30–37.
Zimmermann, R., Brüntrup, M., Kolavalli, S., Flaherty, K., 2009. Agricultural Policies in Sub-Saharan Africa. Deutsches Institut für Entwicklungspolitik, Bonn.

IMPRINT:

Center for Development Research (ZEF)
Genscherallee 3 | 53113 Bonn | Germany
E-Mail: presse.zef@uni-bonn.de
Phone: +49-(0)228 - 73 18 46