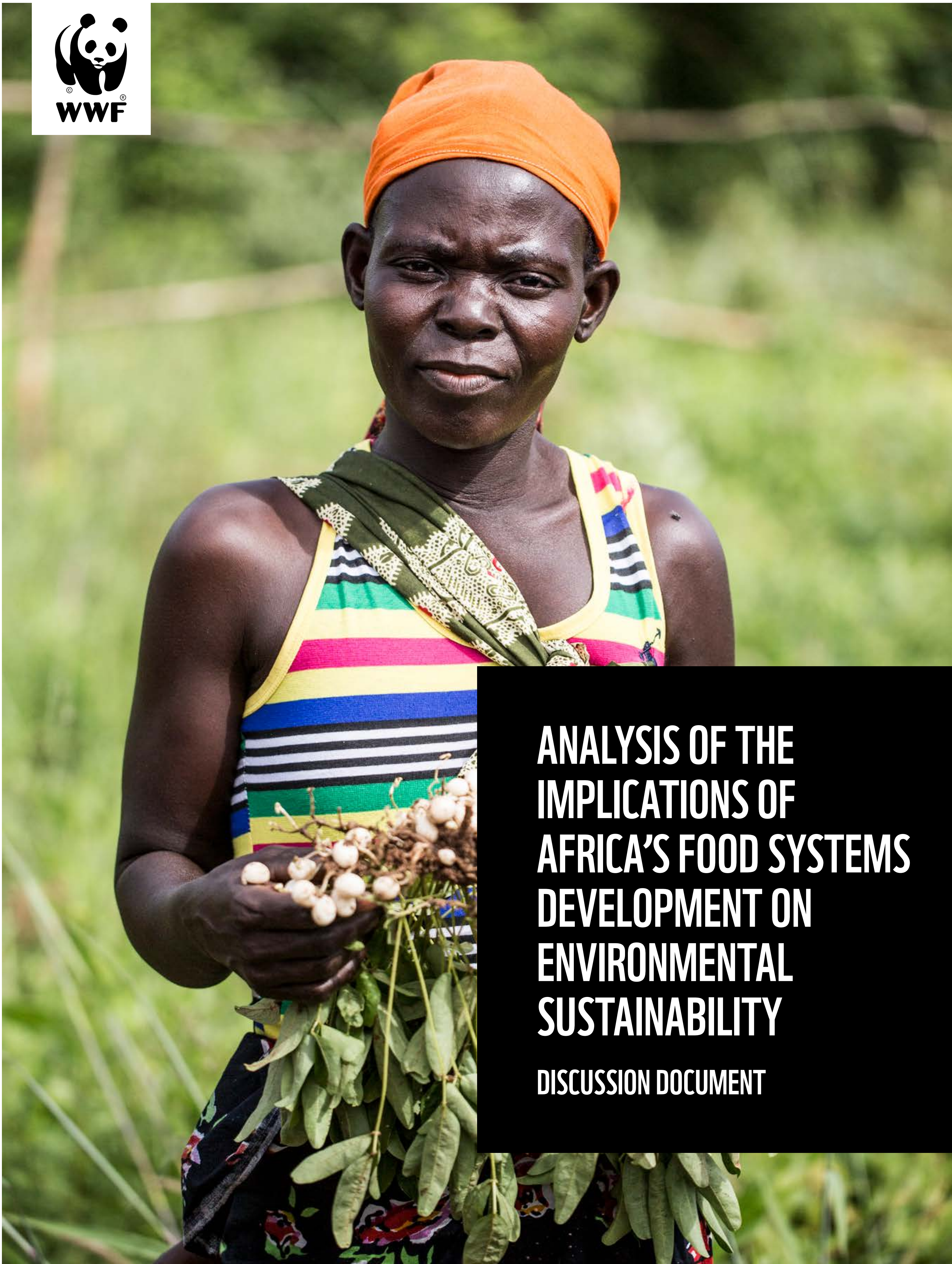
WWF



ANALYSIS OF THE IMPLICATIONS OF AFRICA'S FOOD SYSTEMS DEVELOPMENT ON ENVIRONMENTAL SUSTAINABILITY

DISCUSSION DOCUMENT

WWF is working with partners to secure sustainable food systems development in Africa

CGIAR Initiative on Nature-Positive Solutions | Alliance Bioversity & CIAT | iied International Institute for Environment and Development | African Development Bank Group / Groupe de la Banque Africaine de Développement | IFPRI International Food Policy Research Institute

This study was commissioned by the Worldwide Fund for Nature (WWF) in partnership with the Alliance of Biodiversity International, the International Center for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI) of the CGIAR (formally known as the Consultative Group on International Agricultural Research), and the African Development Bank (AfDB).

WWF wishes to acknowledge the tremendous efforts made by the lead researchers and authors of this report: Barbara Adolph, Geoff Griffiths and Xiaoting Hou-Jones of the International Institute for Environment and Development (IIED). We furthermore wish to thank the WWF project team that has guided this process, Peter Scheren, Nancy Rapando and Karen Luz. Finally, we wish to thank the members of the Steering Group who have provided valuable guidance, inputs and perspectives for this study, in particular Carlo Fadda (Alliance Bioversity-CIAT), Kristin Davis and Keith Wiebe (IFPRI), Durrel Nzene Halleson and Jeff Worden (WWF), and Philip Boahen and Innocent Onah (AfDB).

This discussion paper is intended to provide an analysis of the main trends and developments in terrestrial food production systems in Africa as they relate to potential implications for the long-term ecological futures of the continent. Any opinions expressed and arguments advanced herein are those of the authors and do not necessarily represent those of the individual partner organizations.

Authors:

Barbara Adolph, Senior Associate
Geoffrey Griffiths, consultant
Xiaoting Hou-Jones, Senior Researcher

International Institute for Environment and Development (IIED)

Final report, 17 November 2023

© Gareth Bentley / WWF-US

WWF, 28 rue Mauverney, 1196 Gland, Switzerland.
Tel. +41 22 364 9111 CH-550.0.128.920-7

For contact details and further information, please visit our international website at
www.panda.org

Front cover photography: © James Morgan / WWF-US

Back cover photography: © WWF-US / Julie Pudlowski

CONTENTS

TABLE

FIGURE

BOX


© Gareth Bentley / WWF-US

EXECUTIVE SUMMARY

INTRODUCTION

Africa's food systems need to provide sufficient affordable, nutritious food for Africa's population, whilst generating income and employment to support the continent's economic and social development. However, the long-term functioning of food systems relies on natural capital – the natural resources and ecosystems that provide the inputs needed for food production. These resources are currently being depleted and degraded at an alarming rate, with significant impacts on biodiversity, climate change, and ultimately, on the ability of food systems to fulfil their functions.

This study was commissioned jointly by the Worldwide Fund for Nature (WWF), in cooperation with the Alliance of Bioversity International, the International Center for Tropical Agriculture (CIAT) and the International Food Policy Research Institute (IFPRI) of the CGIAR (formally known as the Consultative Group on International Agricultural Research), and the African Development Bank (AfDB), to inform their engagement with key stakeholders in Africa and elsewhere, whose decisions today will influence the future of Africa's food systems – and with that, the future of the continent overall.

The report analyses the main trends and drivers of Africa's food systems, how food systems have responded to these drivers, and what the resulting environmental impacts of these responses have been across the continent. It identifies policy-levers for engagement in the food systems space and concludes with recommendations on how to move away from an unsustainable "business as usual" trajectory. The analysis was largely based on a review and analysis of publicly available literature and data.

FOOD SYSTEMS DRIVERS

Food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and food industries. They also include the broader economic, societal and natural environments in which these actors are embedded. The actors are influenced by local, national, continental and global trends and drivers, which affect the food system context. A review of six forward-looking reports[1] on African agriculture and food systems identified the following main drivers and their trends impacting on food systems:

- **Population growth** - increasing food demand overall and thereby increasing pressures on natural resources (land, water, energy).
- **Urbanization –** linked to dietary changes, in particular an increasing consumption of processed foods and food of animal origin, but also changes in employment patterns, away from agriculture-based livelihoods.
- **A growing middle class -** with increased incomes, driving the dietary shift and changing food distribution systems away from informal to more formal outlets.
- **Increasing regional trade within Africa –** enabling countries that are unable to meet their food demand from domestic production to access food via regional rather than global imports.
- **Climate change –** reducing agricultural productivity and increasing the risk of crop and livestock production, and thereby accelerating further agricultural expansion.
- **Technological innovations** and change in all sectors - including information and communication technology (ICT) and agricultural value chains – providing opportunities to monitor and reduce environmental impacts.
- **Sources of capital and investment –** with an increase in the proportion of foreign direct investment in Africa as compared to development aid.
- **Governance factors** (policies, institutions, markets) – determining the willingness and ability to regulate the sector effectively.
- **Global disruptions** (conflicts, pandemics, etc.) - disrupting supply chains and forcing people into unsustainable, environmentally harmful livelihoods.

For most of these drivers, their direction is known, but not their future magnitude. The last two drivers are particularly uncertain, but also highly influential, with governance-related factors providing the main levers for influencing food systems.

FOOD SYSTEMS RESPONSES

African food systems have adapted to these drivers in different ways, depending on context-specific opportunities and challenges. The main responses at continental level are manifested in cropland and pasture expansion, changes to farming practices (including increasing use of external inputs, mechanization, and irrigation), and development of agricultural value chains through investments in food processing and distribution.

Agricultural expansion is primarily driven by increases in demand for agricultural commodities because of domestic population and consumption growth, reinforced by changes in diets and lifestyles, trade, climate change and land degradation (driven by unsustainable farming methods), and lack of alternative income and employment opportunities. Unlike in other parts of the developing world, most of the land use change and deforestation in Africa during the past two decades, both in protected areas and overall, has been the result of food crop production for subsistence and for the local market, with only a small proportion resulting from export-oriented agriculture (although export crop production is an important driver of land use change in some countries).

The opportunities for further cropland expansion are limited, with most available land concentrated in a few countries. African governments have committed to ambitious targets to reverse land degradation and protect natural habitats, and hence supporting agricultural intensification is the main policy response to increasing food demand. However, attempts to increase agricultural productivity have often been associated with the adoption of unsustainable farming practices that contribute to land degradation, negative off-site impacts from agrochemicals, the extraction of water for irrigation, and reduced agrobiodiversity. While agroecological and regenerative farming practices have been promoted for decades, these are receiving limited technical, financial and policy support, and adoption rates remain low.

1 Key sources being the Africa Agricultural status report (AGRA 2022), Food systems transformations in the Sahel and West Africa (OECD 2021), Africa common position on food systems (AU 2021), Food systems in Southern Africa - Drivers of change (WFP 2021), People, Health and Nature: A SSA Transformation Agenda (FOLU 2019), and the African Ecological Futures report (WWF 2015, annex 6).

Agricultural mechanization levels are still very low across the continent, but are likely to increase in the future, with potentially negative impacts on emissions and soil properties – unless investments in renewable solutions are stepped up significantly. Irrigation is considered by many African governments to be a key strategy for increasing agricultural productivity. However, extraction of water for irrigation and clearing land near water bodies can also alter the natural patterns of water quality and quantity and disrupt morphological features of water systems, to the detriment of aquatic biodiversity.

Food processing and distribution on the continent are still largely carried out by informal sector actors, but this is changing rapidly – in particular in urban areas. Initiatives such as the African Union's Common Africa Agro-Parks (CAAPs) aim to attract private investments to establish transboundary mega agro-industrial hubs – but the potential environmental impacts of these investments are yet to be assessed.

ENVIRONMENTAL IMPACTS OF FOOD SYSTEM RESPONSES

Cropland and pasture expansion, combined with the use of unsustainable farming practices, contribute significantly to the loss, fragmentation, and degradation of habitats and thus to biodiversity loss. The specific environmental impacts of cropland expansion depend on the importance (in terms of biodiversity and ecosystem services - other than agriculture) of the land use that is being replaced and the characteristics of the farming practices used in the new cropland. It also depends on the speed at which cropland expansion happens, and the resulting spatial pattern of land use. Patchy conversion patterns lead to the fragmentation of existing forests and natural habitats, and hence to a reduction in the number and abundance of species that can be supported on unconverted land.

Food systems are both a contributor to and a victim of climate change, with agricultural productivity being negatively affected by changes in rainfall and temperatures. Agriculture is a main contributor of greenhouse gas emissions worldwide. In Africa, food systems emissions have so far mainly (to the extent of 55%) been the result of land use changes – but emissions from agricultural mechanization, production and use of inputs (in particular fertilizer), processing and transport are on the rise. On the other hand, there are also significant opportunities for the use of renewable energy in food systems that could counter this trend.

SPATIAL PATTERN OF IMPACT

Cropland expansion is a major factor in the loss and fragmentation of habitats with a spatial impact that varies significantly across the continent, depending on soil type, relief, and climate, among other factors. The report provides examples of cropland expansion at the continental scale, with illustrations of its impact in relation to areas of forest loss and impacts on Key Biodiversity Areas at a more detailed scale. The results indicate that, whilst in some areas forest loss is a consequence of cropland expansion, significant areas of forest loss are outside areas of cropland expansion, suggesting that other factors, such as logging, mining, infrastructure development and human settlements are also responsible.

LEVERS FOR CHANGE – TRANSFORMING FOOD SYSTEMS SUSTAINABLY

Intervention options to steer away from BAU and support a trajectory towards sustainable food systems, which bring about economic, social and environmental benefits to producers and consumers, exist in three main areas:

(a) Changing food production. This includes interventions to change the way farming is done, to include increased carbon storage, agrobiodiversity, and productivity. Specific levers include policies to secure land rights for small scale farmers to incentivize sustainable land management, and investments in appropriate green technology and infrastructure. It also includes the redirection of subsidies towards locally led innovation and adaptation, to generate solutions that work in the local context. Specific considerations related to agricultural production pathways are:

- Sustainable agriculture could deliver on productivity increase to avoid excessive farmland expansion. However, there are often trade-offs between intensification and conservation objectives.
- The proportion of medium- to larger farms is likely to continue to grow and export-oriented production will probably increase – posing increasing environmental threats, but also opportunities for the development, adaptation and scaling out of sustainable practices.
- Poverty is driving unsustainable agricultural practices and cropland expansion in most of Africa, hence improving the livelihoods of poor farmers is an important component of a more sustainable pathway.

(b) Planning where to grow, including restoring and protecting ecosystems. This includes setting aside land for biodiversity, improving the governance and management of, and sharing of benefits from protected areas, and restoring degraded landscapes (as land degradation contributes to cropland expansion). There is a risk that value chain investments near KBA / biodiversity hotspots / protected areas may attract more farmers to these areas, increasing the pressure overall. Also, the environmental impact of value chain development (from pollution, water use etc.) can be locally significant, unless appropriate safeguards are in place.

(c) Influencing food demand and consumption. This involves bringing about dietary changes through public awareness, appropriate food imports and regulations on food quality. It also includes a strong commitment to and investments in reducing food waste and losses and increasing recycling.

These levers relate to the following realities with regards to food demand and cropland expansion:

- Domestic food demand (as opposed to export-oriented production) is and will remain the main driver for cropland expansion in most of SSA.
- Most cropland expansion has so far been driven by smallholder farmers and not by commercial farms. However, the proportion of medium- to larger farms is likely to continue to grow and export-oriented production will probably increase.
- Cropland expansion will undoubtedly continue (and likely along the currently observed frontiers).
- Ambitions to achieve national food self-sufficiency have not always considered comparative advantages for food and nature – for example, the extent to which a country's natural resources are better suited for food grain production, cash crop production or ecotourism.
- Urban diets (and, increasingly, rural diets) in Africa are becoming unhealthier, whilst food waste and losses indirectly contribute to cropland expansion.
- Land degradation also contributes to cropland expansion – by taking land out of production.

As a crosscutting theme, policy incoherences at national level contribute to competition for land and a lack of strategic interventions for land use. Hence there is a need to harmonize policies and address trade-offs resulting from competing policy objectives.

If food system responses continued along the existing trajectories, the threats to biodiversity and natural capital would mount further, with far reaching consequences. Scenario development can be used to explore alternatives to a "business as usual" (BAU) trajectory – either in a participatory way with stakeholders, or as a quantitative research tool to inform modelling. The report presents an example for a generic (continental) scenario process including an example from Zambia.

RECOMMENDATIONS

Several general recommendations can be drawn from this report. These are necessarily broad, addressing sustainable food systems development for a whole continent with vastly different socioeconomic and natural resources. They are meant as a starting point for more nuanced discussions at country level:

- Develop and implement coherent policies that acknowledge and manage trade-offs and bridge the gap between sectoral silos;
- Invest in increasing agricultural productivity in a sustainable way;
- Support poor farmers in a transition to sustainable agricultural (or, in some cases, non-agricultural) livelihoods;
- Invest in environmentally and socially responsible value chain development; and
- Increase awareness of healthy sustainable diets.


© Danielle Brigida / WWF-US

ACRONYMS

AEF	African Ecological Futures
AFAAS	African Forum for Agricultural Advisory Services
AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
AFFI	Africa Food Future Initiative
AMCEN	African Ministerial Conference on the Environment
ANAFE	African Network for Agriculture, Agroforestry and Natural Resources Education
AU	African Union
BAU	business as usual
CAAP	Common Africa Agro-Park
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CGIAR	Formerly known as the Consultative Group on International Agricultural Research, CGIAR is a global research network of 15 centers and their partners for a food-secure future, dedicated to transforming food, land, and water systems in a climate crisis.
CIAT	International Center for Tropical Agriculture
CSA	climate smart agriculture
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
GEF	Global Environment Facility
GHG	greenhouse gas
GVC	global value chain
ICT	information and communication technology
IFPRI	International Food Policy Research Institute
KBA	key biodiversity area
MHa	million hectares
Prolinnova	promoting local innovation in ecological agriculture and natural resource management
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture
SDG	Sustainable Development Goal
SME	Small and Medium Enterprise
SOKNOT	Southern Kenya Northern Tanzania
SSA	Sub-Saharan Africa
TFCA	Transfrontier Conservation Area
UNCTAD	United Nations Conference on Trade and Development
WWF	World Wide Fund for Nature

© James Morgan / WWF-US

1. INTRODUCTION

1. BACKGROUND AND PURPOSE OF THE STUDY

Africa's food systems face many challenges and opportunities. Feeding a growing and increasingly urbanized population – and feeding it better than currently, with a fifth of Africa's population being chronically undernourished – is a monumental task. A task that does not only involve producing food, but also generating employment and income for rural and urban people alike through (ideally) sustainable, productive, and equitable production systems and value chains.

Crop yields in Africa have been increasing (Djoumessi 2022), using both agroecological, regenerative approaches and, increasingly, external inputs (improved crop varieties and fertilizer). But food imports have also increased and are expected to increase further (from US $35 billion in 2015 to over US $110 billion by 2025[2]), putting African governments and citizens at risk of food price spikes during times of global crises. Climate change is threatening both crop and livestock production and, combined with other causes of land degradation, forces many farmers to open new farmland in areas not previously cultivated. But with Africa being the last continent where cropland expansion is still possible, it is attracting investors from within and outside the continent. Hence its food systems are not only fundamental to the health and well-being of Africa's population but are also providing the rest of the world with agricultural commodities.

Unfortunately, however, the way food is produced, distributed, and consumed in Africa is often at odds with sustaining the natural capital that people and wildlife depend on. Unsustainable agricultural practices are threatening the ecological integrity of the natural landscapes and the resilience of smallholder farming communities. If not adequately managed, therefore, Africa's much needed agricultural development may come at a dramatic cost to the continents' critical ecological infrastructure, its land, its forests and savannah landscapes, and its water resources. Already, in many parts of the continent, the limitations to growth are becoming apparent, with water scarcity and land degradation due to unsustainable agricultural practices and climate change being key factors.

For the future development of the agricultural sector in Africa, it is therefore crucial that the longer-term implications of this development on Africa's ecological base are adequately considered. The food systems in Africa must be transformed to sustainably provide reliable and nutritious food for people in urban and rural areas, as well as to meet Africa's export potential, while mitigating greenhouse gas emissions and preserving Africa's natural capital.

WWF's Africa's Food Future Initiative (AFFI) was created on the notion that Africa food production systems are not sustainable, delivering neither on socioeconomic nor environmental objectives. If current trends of land degradation, cropland expansion and overuse of water resources continued, the ecological integrity of Africa's rich conservation areas would be jeopardized. At the same time, improving food and nutrition security of Africa's populations needs to be improved. To address these trade-offs, AFFI aims to establish scalable models of productive and sustainable food systems and support resilient livelihoods via three workstreams: (i) integrated land- and water-use planning and management; (ii) agroecology; and (iii) sustainable and inclusive value chains, with a cross cutting theme on policy enhancement at country and continental level.

The policy work of the initiative aims to transform Africa policy processes by ensuring increased investments in food system approaches that are ecologically responsive. This work builds on the earlier African Ecological Futures (AEF) report, published by the African Development Bank (AfDB) and WWF in 2015, which was designed to guide policy and investment decisions of governments, inter-governmental organizations, development banks, bilateral and multilateral agencies, amongst others (Scheren et al., 2021). This report highlighted the importance of understanding Africa's ecological future and how it can be fundamentally altered by economic and development decisions taken today.

The results of this study will provide the basis for engagement with key stakeholders around futures scenarios that will guide Africa on its road towards long-term ecologically sustainable development path. The momentum for such dialogue is stronger than ever. Building on the call for post-COVID-19 Green Recovery, there is a potential to shape a range of development parameters and influence policies and initiatives to be consistent with Africa's sustainability goals, as articulated by the African Union Green Recovery Action Plan, the Green Stimulus Program of the African Ministerial Conference on the Environment (AMCEN), the CAADP (Comprehensive African Agricultural Development Program) process, as well as more broadly the Sustainable Development Goals (SDGs) and the Plan of Action for "people, planet and prosperity" under the 2030 Agenda for Sustainable Development. The analysis is also intended to inform the African Development Bank Group's 'Feed Africa' strategy and similar investment strategies for other major development banks.

2 https://www.afdb.org/en/the-high-5/feed-africa, accessed 20 September 2023. At the same time, the ADB aims to make Africa a net exporter of food by 2025 under its "Feed Africa" objective.

© Gareth Bentley / WWF-US

The study adds two key dimensions to the 2015 AEF report (which included an analysis of key pressures on Africa's ecosystems in the Appendix):

- Using a food systems lens for pressures and impacts throughout (so considering all the drivers and impacts identified in the original AEF report – direct and indirect ones –, and potentially some additional ones based on selected recent reports and events such as the COVID pandemic, but with a focus on food systems),
- Proposing next steps towards developing a more action-oriented set of options and recommendations than the 2015 report, to inform national and continental food policies and investments that acknowledge trade-offs between food and environmental objectives and propose pathways to managing these.

This report includes five main sections:

- **Section 1** presents the objectives, key concepts and methods used for this study.
- **Section 2** analyses the main drivers of agrifood systems in Africa that have resulted in the current patterns of impact, and the main trends for these drivers.
- **Section 3** analyses the current (and potential future) environmental impacts of African agrifood systems and their spatial pattern, in response to the trends of the main drivers. This analysis is primarily focusing on past and current impacts, with some reflections on potential future impacts.
- **Section 4** introduces the potential use of participatory scenario building as a tool to explore alternative plausible agrifood system futures. It presents a set of example scenarios based on decisions on choices about national food self-sufficiency strategies and agricultural production systems that could be used for such a process.
- **Section 5** concludes with the main challenges and opportunities to steer Africa's food systems development towards an ecologically sustainable pathway.

The report is based on a review of publicly available data and literature. Because of the breath of both thematic and geographic scope, depth and context specificity are inevitably low.

Whilst recognizing that fish and sea foods are an important source of food and income for many coastal and inland communities in Africa, fisheries was not included in this report. Seafood, both wild capture and farmed, is a vital part of the food system and an important protein source for many coastal and inland communities in Africa. Both wild capture fisheries and aquaculture can cause significant damage to ecosystems. Because of limited resources, this study was not able to include an analysis of the trends in seafood production nor the expected environmental impacts, a gap that we hope can be filled in the future.

2. KEY CONCEPTS AND METHODS

2.1. GLOSSARY OF TERMS AND CONCEPTS

This section defines the main concepts and terms used in this report. Where possible, definitions from internationally recognized sources are used. However, for some concepts, no globally agreed definition exists, or definitions are contested.

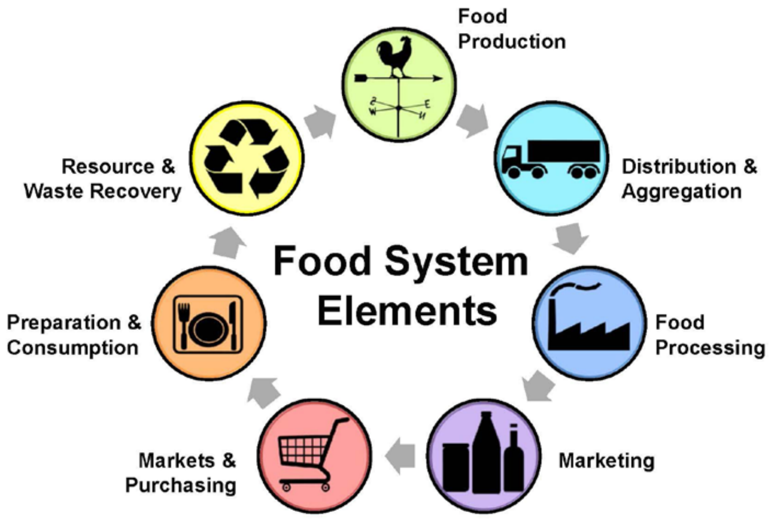
FOOD SYSTEMS

Food systems have been defined[3] as *"the sum of actors and interactions along the food value chain—from input supply and production of crops, livestock, fish, and other agricultural commodities to transportation, processing, retailing, wholesaling, preparation of foods, consumption and disposal. Food systems also include the enabling policy environments and cultural norms around food".*

Similarly, the Braun et al. (2021) defined food systems (for the UN Food Systems Summit) as *"encompassing the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and food industries, and the broader economic, societal and natural environments in which they are embedded."* Recent attention has focused on transforming food systems for greater sustainability, resilience, and inclusion. At every stage, food systems rely on natural resources, many of which are non-renewable. There is a growing awareness that food systems must use these resources sustainably and avoid destabilizing the ecosystems upon which such systems depend (AGRA 2022).

Food systems are connected to all SDGs, as shown in Figure 2, and are therefore at the heart of a wide range of development interventions related to poverty reduction, health, sustainable livelihoods, gender, etc.

Figure 1. *Food system elements*



Elements and dimensions of sustainable food systems are often depicted in a circular manner, with food waste feeding back into the production cycle. The seven elements shown in this version are often grouped together into four main categories: Production, transformation, distribution, and consumption.

Source: https://www.canr.msu.edu/news/modeling-an-equitable-michigan-food-system

NATURE-POSITIVE FOOD SYSTEMS

They are characterized by a regenerative, non-depleting and non-destructive use of natural resources. They are based on stewardship of the environment and biodiversity as the foundation of critical ecosystem services, including carbon sequestration and soil, water, and climate regulation.

Nature Positive Food Systems refer to protection, sustainable management and restoration of productive systems. Finally, nature positive food systems aim to meet the growing demand for sustainably produced food and healthy nutrition. (Hodson et al. 2021).

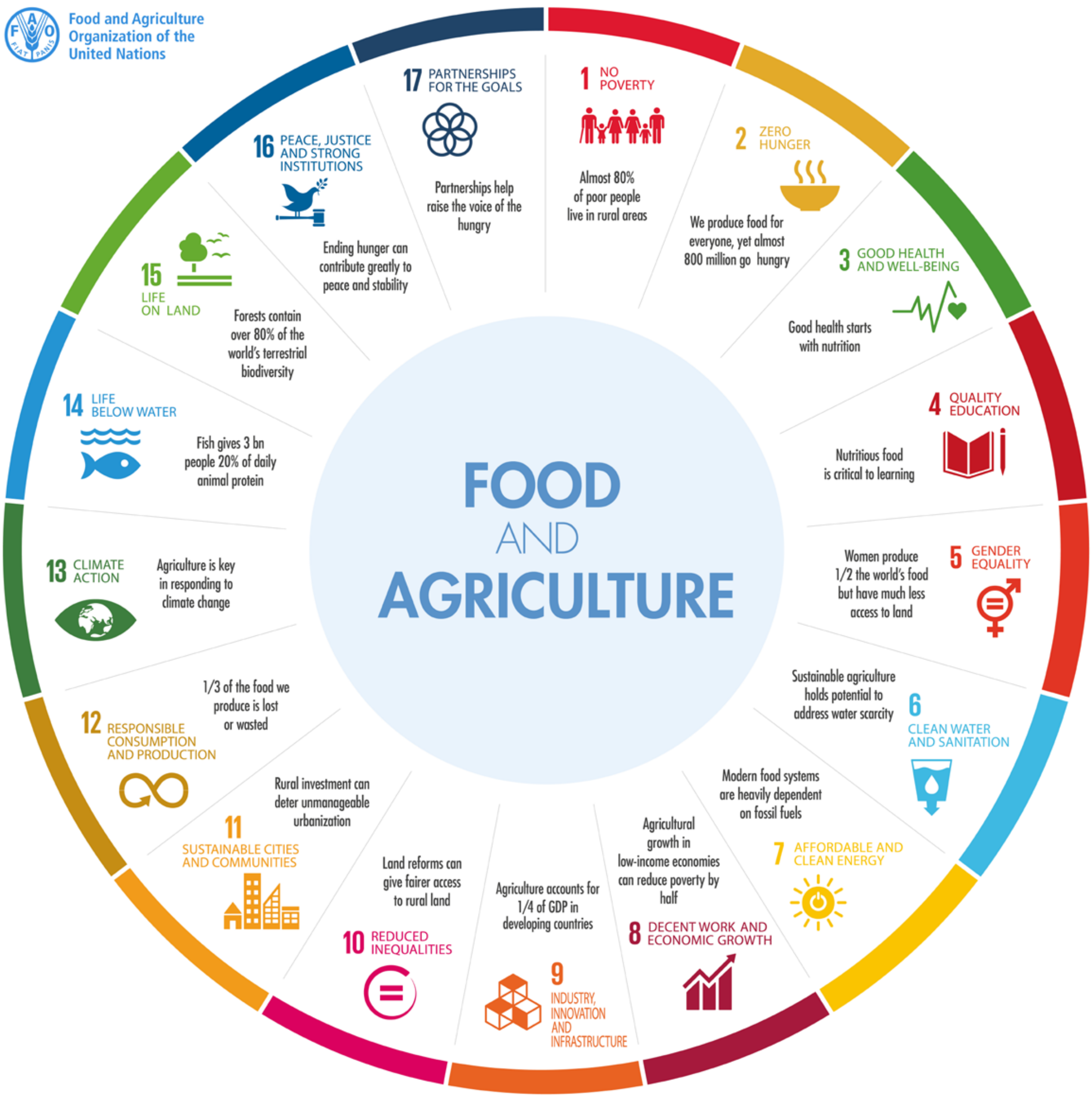
3 https://www.ifpri.org/topic/food-systems

AGRI-FOOD SYSTEM

Agrifood systems (AFS) *"encompass the entire range of actors, and their interlinked value-adding activities, engaged in the primary production of food and nonfood agricultural products, as well as in storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, disposal and consumption of all food products, including those of non-agricultural origin"* (FAO 2022). Thus, the agri-food system includes agricultural produce that is not used for food, such as feed, fiber, and raw materials for industry (including oil crops and biofuel).

For the purpose of this study, the focus is primarily on the production and consumption sides of agri-food systems, as we consider these dimensions to have currently more significant and widespread environmental impacts in Africa than food processing and distribution. Whilst recognizing the importance of fish and seafood in the diets of a large proportion of the African population, fisheries has not been included in this study, because it has limited links to terrestrial ecosystems.

Figure 2. *Food systems and the SDGs*



Source: FAO, https://www.fao.org/fileadmin/user_upload/codexalimentarius/photo-archive/Infographics/SDG-Wheel.jpg

FOOD SYSTEMS IMPACTS

The main purpose of food systems are to deliver sufficient affordable and health food, whilst creating employment and other livelihoods opportunities for rural and urban people. In this report, the emphasis is on the main impacts that food systems have on the environment. In the African context, where processing of food is still predominantly done at household level and by small and medium enterprises (SMEs), and where most of the food is consumed relatively closely to where it is produced, the main environmental impacts are related to food production. These include primarily:

- Greenhouse gas emissions along the value chain (in Africa, this is primarily from production of crops, livestock, and aquaculture).
- Land use changes (conversion of natural habitats into farmland – agricultural sprawl/expansion), contributing to greenhouse gas (GHG) emissions, land degradation and biodiversity loss.
- Reduction in waterflow and alteration of environmental flows in rivers and wetlands, and groundwater depletion as a result of land degradation, soil erosion, and water extraction for irrigation, affecting aquatic ecosystems and wetland ecology downstream (as well as rural and urban livelihoods requiring water).
- Pollution or degradation of land, water and air from agricultural production such as eutrophication of water bodies from fertilizer and reduced agrobiodiversity from pesticide use – but also from agricultural processing and distribution, and this may well increase in the longer term, as value chains become more industrialized.

However, food system impacts from processing are expected to increase in the future as a result of an increase in large scale production and processing of food, in particular in medium-income countries. USAID estimated in 2015 that Africa's food processing industry holds huge potential for growth and that, by 2040, the value of food purchased in East and Southern Africa will grow seven-fold (Technoserve 2017).

ECOSYSTEMS

WWF defines ecosystems as *"a community of animals and plants interacting with each other and with their physical environment such as soils, water, nutrients, and all types of living organisms. Healthy ecosystems have always performed a multitude of essential functions for human communities – ecosystem services".*[4]

ECOREGIONS

African ecosystems have been classified spatially into ecoregions, based on the typology designed by Olson et al. (2001). Ecoregions are defined as *"relatively large units of land or water containing a distinct assemblage of natural communities sharing a large majority of species, dynamics, and environmental conditions".*[5] Globally, there are 867 terrestrial ecoregions, classified into 14 different biomes such as forests, grasslands, or deserts. WWF Africa is particularly interested in those ecoregions that have a high level of biodiversity and provision of ecosystem services, and that are threatened by human actions including urbanization, mining, and agriculture.

SUSTAINABLE AGRICULTURE

This is a broad term that refers to agriculture *"that meets the needs of existing and future generations, while also ensuring profitability, environmental health and social and economic equity."*[6] In this report, we use the term to group together the different concepts below (sustainable intensification, agroecology, regenerative agriculture, nature positive agriculture and climate smart agriculture), as they strongly overlap – especially when applied to identify specific agricultural practices in specific contexts.

SUSTAINABLE INTENSIFICATION

This concept emphasizes the productivity and efficiency dimensions of sustainable agriculture, i.e., increasing production volume per unit area (or other productive resources such as water or labor). The focus is on "doing no harm" (e.g., by using agrochemicals and fertilizers in a responsible way that reduces negative environmental impacts). This may well involve agroecological and regenerative principles and practices, but also the use of improved inputs such as high yielding crop varieties.

4 https://wwf.panda.org/discover/knowledge_hub/where_we_work/baltic/area/ecosystem_services/

5 https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

6 https://www.unep.org/news-and-stories/story/beginners-guide-sustainable-farming

© Brent Stirton / Reportage for Getty Images / WWF

AGROECOLOGY

Agroecology has been defined variously as a science, a set of practices and a social movement (Silici 2014). FAO published a set of 10 "elements" of agroecology[7] (FAO 2018), which focus primarily on the socio-economic rather than the environmental aspects of agroecology, hence more in line with the idea of agroecology as a social movement that uses specific governance and collaboration processes. According to FAO, agroecology is *"a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems. It seeks to optimize the interactions between plants, animals, humans and the environment, while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced"*[8]. For the purpose of this study, we use a definition that emphasizes the first two dimensions: Agroecology as the application of ecological concepts and principles to the design and management of sustainable agroecosystems (Altieri 1995). This does not exclude the use of inorganic fertilizer or agrochemicals as part of an integrated soil fertility or pest management strategy. There is no agreed set of agroecological practices, as these are context specific.

REGENERATIVE AGRICULTURE

Similar to "agroecology", there are a range of definitions of regenerative agriculture. "'Regenerative Agriculture' describes farming and grazing practices that, among other benefits, reverse climate change by rebuilding soil organic matter and restoring degraded soil biodiversity – resulting in both carbon drawdown and improving the water cycle. Specifically, Regenerative Agriculture is a holistic land management practice that leverages the power of photosynthesis in plants to close the carbon cycle, and build soil health, crop resilience and nutrient density." (Regenerative agriculture initiative 2017). Hence it includes agroecological principles and practices, but with a focus on soil.

CLIMATE SMART AGRICULTURE

FAO (2010) defined CSA as "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals." It hence combines aspects of regenerative agriculture (with sustainable land management supporting productivity, resilience, and carbon sequestration), sustainable intensification (to increase productivity) and agroecology (to increase resilience).

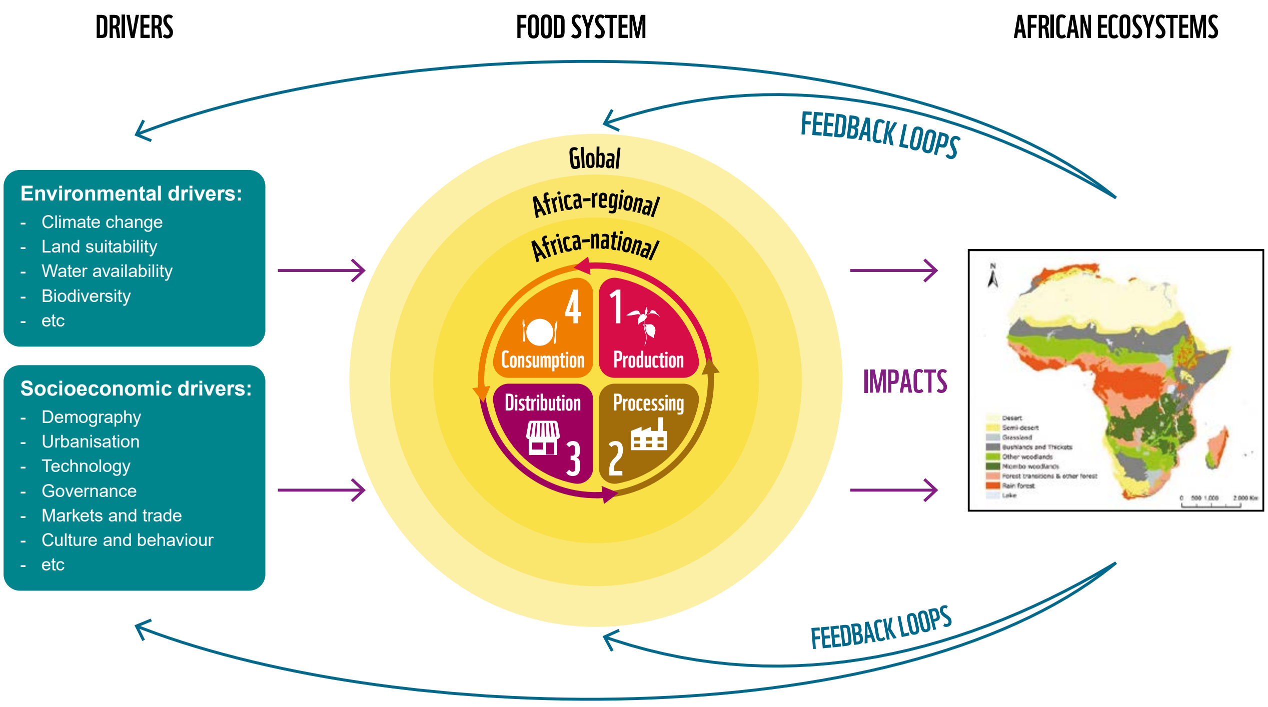
---

7 These are: diversity, synergies, efficiency, resilience, recycling, co-creation and sharing of knowledge, human and social values, culture and food traditions (context features), responsible governance, circular and solidarity economy.

8 https://www.fao.org/agroecology/home/en/, accessed 20/09.23

2.2. CONCEPTUAL FRAMEWORK, METHODS AND LIMITATIONS

Figure 3. *Conceptual framework (simplified)*



Source: authors' own

Figure 3 conceptualizes the scope of this study: We are exploring the drivers that influence African food systems, to assess the current and plausible future impacts of these food systems on African ecosystems. Changes in ecosystems affect food systems directly (e.g., when cropland expansion reduces beneficial ecosystem services such as pollination), and indirectly by changing the drivers (e.g., when environmental changes in Africa result in changes to culture and behavior of people in both Africa and globally).

This study used (largely publicly available) literature and datasets on African food systems, food system transformation, food system impacts and related policies and initiatives. The focus was on recent literature on Africa, and in particular sub-Saharan Africa (SSA). However, no comprehensive literature review was carried out due to the broad scope of this report in relation to the amount of time and resources available to produce it.

Specifically, the different steps were as follows:

- Review of agri-food system drivers and responses for Africa (based on the literature, but focusing on six studies with a forward-looking perspective)
- Analysis of food system responses to these drivers, and their past and current environmental impacts (again based on the literature)
- Spatial distribution of food system responses, by overlaying proxies for "food system pressure" with key biodiversity areas, biodiversity hotspots and protected areas.
- Discussion of potential future impacts based on some of the literature and data available.

The main limitations are related to (a) the range of literature and data used, which was limited, and (b) the availability of spatial data and data at sub-country level for food system characteristics in Africa.

© James Morgan / WWF-US

2. FOOD SYSTEM DRIVERS

The WWF (2015) "African Ecological Futures" report included a review of the main pressures on ecosystems, including pressures from the agri-food system. To update these findings, a review of key documents (see below) was undertaken for the analysis of key food system drivers shown in Table 1.

- Africa Agricultural status report (AGRA 2022)
- Food systems transformations in the Sahel and West Africa - Implications for people and policies (OECD 2021)
- Africa common position on food systems - Regional Submission to the UN Food Systems Summit (AU 2021)
- Food systems in Southern Africa - Drivers of change and opportunities for influence (WFP 2021)
- People, Health and Nature: A Sub-Saharan African Transformation Agenda (FOLU 2019)
- African Ecological Futures report (WWF 2015, annex 6)

The reviewed reports broadly agree on the key drivers of food system change in Africa (and their potential impact on ecosystems):

- **Population growth -** increasing food demand overall and pressures on natural resources (land, water, energy). This is particularly pronounced in SSA, where food demand is projected to nearly triple between 2010 and 2050 (van Ittersum et al. 2016), as compared to a total global food demand increase during the same period of 35% to 56%, depending on projections (van Dijk et al. 2021).
- **Urbanization –** linked to dietary changes (in particular an increasing consumption of processed foods and food of animal origin), but also changes in employment patterns, away from agriculture-based livelihoods.
- **A growing middle class** with increased incomes - driving the dietary shift and changing food distribution systems away from informal (street vendor, markets) to more formal outlets (supermarkets / shops).
- **Increasing regional trade** within Africa – enabling countries that are unable to meet their food demand from domestic production to access food via regional imports.
- **Technological innovations** and change in all sectors - including information and communication technology (ICT) and agricultural value chains – providing opportunities to monitor and reduce environmental impacts.
- **Governance factors** (policies, institutions, markets) – determining the willingness and ability to regulate the sector effectively.
- **Climate change** – reducing agricultural productivity (because of increasing temperatures and droughts, as well as unpredictable weather patterns) and thereby increasing the risk of further agricultural expansion.
- **Global disruptions** (conflicts, pandemics, etc.) - disrupting supply chains and forcing people into unsustainable, environmentally harmful livelihoods.

© Arnold Mugasha / WWF

Table 1. Recent studies on long-term pressures on / drivers of African food systems

<table>
<thead>
<tr><th>Main driver category</th><th>Africa Agricultural status report (AGRA 2022)</th><th>Food systems transformations in the Sahel and West Africa (OECD 2021)</th><th>Africa common position on food systems (AU 2021)</th><th>Food systems in Southern Africa - Drivers of change (WFP 2021)</th><th>People, Health and Nature: A SSA Transformation Agenda (FOLU 2019)</th><th>African Ecological Futures report (WWF 2015, annex 6)</th></tr>
</thead>
<tbody>
<tr><td rowspan="2">Demography</td><td>Rural population growth and associated rising land scarcity</td><td>Population growth</td><td>Not explicitly considered, other than urbanization</td><td>Population growth</td><td>Population growth and increasing number of rural poor</td><td>Population growth and its constraint on energy, water, and agricultural sectors</td></tr>
<tr><td>Rapidly rising urban populations, fueling a stable and constantly increasing demand for food</td><td>Urbanization (focus on coastal cities in West Africa)</td><td>Rapid urbanization and consequent shifts in food demand and downstream modernization of the food systems</td><td>Urbanization</td><td>Urbanization</td><td>Urbanization</td></tr>
<tr><td>Socio-cultural drivers</td><td>Not explicitly considered</td><td>Diversity of food systems, changing diets, tastes, lifestyle, food innovation</td><td>A rise in the youth-driven consumption of processed foods and rising demand for animal source foods</td><td>Dietary choices (and associated health problems / double burden of malnutrition)</td><td rowspan="2">Expanding middle class, dietary shift (and double burden of malnutrition)</td><td>Not explicitly considered</td></tr>
<tr><td rowspan="4">Economic drivers: Income, prices and trade</td><td>Economic transformation, whose main features include rising wage rates and per capita incomes (and increasing demand for processed and livestock-based food)</td><td>Increasing household incomes, driving transformation of the food sector from subsistence to commercial</td><td>The rise of the African middle class, linked to...</td><td>Changes in food acquisition patterns and diets</td><td>Changing consumption patterns sparked by growing affluence and higher incomes (growing middle class) – means changes in food and energy demand</td></tr>
<tr><td rowspan="3">Remaining land suitable for farming is highly unevenly distributed between countries.</td><td rowspan="3">Increasing regional trade within (West) Africa - African Continental Free Trade Area (AfCFTA)</td><td>Global food markets and trade and implications for the AfCFTA and Africa's local & trans-national food markets and trade</td><td rowspan="3">Not explicitly considered</td><td rowspan="3">Increasing trade within Africa</td><td rowspan="3">Increasing global resource demand - Africa as the last place where farmland expansion is still possible.</td></tr>
<tr><td>A rapid shift in the labor force from farming to non-farm jobs</td></tr>
<tr><td>Rising competition over African farmland</td></tr>
</tbody>
</table>

Main driver category	Africa Agricultural status report (AGRA 2022)	Food systems transformations in the Sahel and West Africa (OECD 2021)	Africa common position on food systems (AU 2021)	Food systems in Southern Africa - Drivers of change (WFP 2021)	People, Health and Nature: A SSA Transformation Agenda (FOLU 2019)	African Ecological Futures report (WWF 2015, annex 6)
Innovation, technology, and infrastructure	Accelerated pace of technical innovation in communications, information, and supply chains	Internet access, e-commerce, post-harvest innovations, digital technologies for agricultural advisory services etc.	Rise of the staples processing sector	Agricultural intensification through modernization and investment	Infrastructure investment	Changes in investment patterns (including infrastructure and agricultural value chains)
			Technology advances, especially digitalization		Technological innovation (mobile phone connectivity, mechanization, access to markets)	
Conflicts (global and local) and disruptions	Ongoing global health crises, regional conflicts, and economic disruptions	Not explicitly considered	COVID-19 pandemic	Not explicitly considered	Impacts of global disruptions on food availability (high imports)	Conflicts and epidemics (Ebola, COVID-19,) have a negative impact on development
Policies, regulations and governance	Not explicitly considered, but included in some of the other drivers	Taxation, (food) standards, policy coherence across sectors, trade-off management		Tackling inequality	Improved institutional capacity	The opportunities and implications in Africa's democratization and inclusivity
Biophysical & environmental drivers	Climate change and increasing incidence of extreme weather events	Climate change	Climate change	Climate change and resulting water shortage / stress	Climate change and its impact on yields	Climate change and disasters exacerbate challenges

© naturepl.com / Nick Garbutt / WWF

From the reports reviewed, only the WWF (2015) report explicitly mentions the threats and opportunities resulting from Africa being the only continent where agricultural land use can still expand. The World Bank report "Awakening Africa's Sleeping Giant", published in 2009, suggested that there was huge potential for the expansion of commercial agriculture in Africa. Since then, the notion of large tracts of unutilized land in Africa has been challenged (Future Agricultures 2010, The Economist 2018[9]), pointing to the concentration of potential farmland in only a few countries in Africa, the socio-economic and physical constraints to expanding agriculture in these areas, and the potential negative impacts on local people and the environment. In most parts of Africa, there is a shortage of suitable farmland, with many young people struggling to access land, and some of them opting to encroach on forests, wetlands or other natural habitats and protected areas. Land shortage has been identified as a major driver of farmland expansion (Jellason et al. 2021).

Uncertainties continue to exist with regards to policy choices – and, not surprisingly, scenarios developed for Africa during the period between 2013 and 2016 (see Table 3) all build on uncertainties with regards to policies and governance. However, they reflect the context at the time and the specific purpose for which they were developed with for example, the WWF 2015 report focusing on investment trends overall, not only with regards to agriculture.

Since the production of the reports reviewed, several major developments have happened:

- Both the covid pandemic and the Ukraine war have contributed to global food and energy price increases, which have affected African countries that are net importers of grain, fertilizer, and other agricultural inputs from outside the continent. This has strengthened calls for national self-sufficiency in staple food crops (cereals and root / tubers), with many SSA countries having committed to self-sufficiency in staple food crops before the pandemic (Jeary et al. 2022). This choice has land use implications.
- African regional trade continues to strengthen, with the African Continental Free Trade Area (AfCFTA) providing a platform for this that is likely to grow in the future. Increased regional trade is expected to replace some intercontinental trade in the future.
- There is perhaps more agreement, across African nations, on the type of food system transformation wanted (as shown in the Africa common position on food systems, AU 2021), and the Dakar2 declaration on Food Sovereignty and Resilience (AU 2023).
- There is a growing recognition, both in Africa and globally, that the increasing consumption by Africans of food produced on the continent will drive growth of the agricultural land use footprint, and this poses challenges to remaining natural habitats. This will likely be a greater challenge than that posed by export crops.
- The emergence of medium-size farms, often owned by wealthier individuals from within Africa, has been identified as an important driver of deforestation – perhaps more important than deforestation by large-scale entities (Wineman et al. 2021).
- The increasing call for Africa's export diversification and the need to invest in value addition to increase export revenue (UNCTAD 2022, Bouët et al. 2022) and thereby potentially reducing the land use footprint of export crop production. Martin 2018 emphasizes opportunities to further grow African high-value agricultural exports, which provide higher returns, but with a lower land use impact per unit of export earnings.
- The shift from donor-funded investments in food systems to private sector investments (UNECA 2020, Rhode and Stitteneder 2020).

There are thus three types of drivers to consider when looking forward:

1. (Relative) certainties, where it is possible to some extent to predict or model their impact on food systems. These include the growing demand for food in Africa and globally, resulting from the combination of population growth, urbanization, and income increase, but also the demand for food commodities by the export market. It also includes climate change's impacts on major crops. These factors are already explicitly included in models of food demand and supply, such as the IFPRI IMPACT model.[10] However, for many of these trends there are currently no projections available.
2. Uncertainties that are the result of geopolitical or other events that result in instability or conflicts and that severely limit the space for decision-making at national and potentially regional level. Examples include the recent conflicts in Sudan and Niger.
3. Uncertainties, whereby future impacts are the result of political will, priorities and effective policies and institutions to implement these. These create the decision space for food system transformation and will be discussed in section 4.

9 https://www.economist.com/middle-east-and-africa/2018/04/28/africa-has-plenty-of-land-why-is-it-so-hard-to-make-a-living-from-it

10 IMPACT 3 is an integrated modeling system that links information from climate models (Earth System Models), crop simulation models (for example, Decision Support System for Agrotechnology Transfer), and water models to a core global, partial equilibrium, multimarket model focused on the agriculture sector. https://dataverse.harvard.edu/dataverse/impact

It is the uncertain drivers under 3. above, which are at least partially related to political and investment choices, that provide the decision-space for governments to avoid a 'business as usual' scenario (which would almost certainly result in irreversible damage or loss of significant parts of Africa's ecosystems).

Table 2. *Main food system drivers, trends and projections for 2050 (where available)*

Main driver	Trend	Projection for 2050	Implications for food system impacts
Population	Increasing	2.4 billion	Necessitates either increased domestic food production or increased imports or both
Urbanization	Increasing	1.34 billion	Linked to dietary changes, in particular an increasing consumption of processed foods and food of animal origin
Proportion of middle class with higher incomes	Increasing	1.2 billion by 2060[11]	Driving the dietary shift and changing food distribution systems away from informal (street vendor, markets) to more formal outlets (supermarkets / shops)
Regional trade within Africa	Increasing	?	Reducing the need to import food from outside Africa and potentially reducing the desire of African countries to be food self-sufficient
Agricultural commodity exports from Africa	Increasing	?	Further land use changes and deforestation, but not necessarily accompanied by significant economic benefits in terms of employment and revenue (as compared to adding value to existing export)[12]
Technological innovations and change in all sectors	Increasing		Providing new opportunities along the value chain (processing, storage, reduction of waste) and potentially enabling more efficient dosage of agro-inputs; digital advisory services could help scale up sustainable agriculture
Climate change	Increasing	Various CC scenarios for Africa have been developed and are included in e.g., the IFPRI IMPACT model (projections) of future crop production (IFPRI 2022)	Reducing agricultural productivity and increasing the risk of further agricultural expansion; damaging infrastructure; increasing pressure on land locally due to migration
Governance factors (policies, institutions, markets)	Uncertain	Uncertain	Can work in many directions – main uncertainty, but also main leverage point for change, to move away from BAU.
Global disruptions (conflicts, pandemics, etc.)	Uncertain	Uncertain, but perhaps likely to increase?	Can work in many directions, but most likely negative impacts, if food prices increase and widespread poverty triggers environmentally and socially damaging coping strategies.

11 United Nations (2023). "The African Development Bank (AFDB) has defined the middle class as the share of the population that can afford to spend between $2 and $20 per day. In 2010, around 326 million people or 34.3% of Africa's population were in this group, a threefold increase from 1980. Some estimates indicate that the middleclass population in Africa could increase to 1.1 billion (42% of the total population) by 2060."

12 For example, cocoa has been the fastest expanding export-oriented crop across SSA, accounted for 57% of global expansion in 2000–2013 at a rate of 132 thousand ha yr−1. However, cocoa only amounted to 0.89% of foreign land investment (Ordway et al. 2017) and cocoa farmers still live largely below the poverty line (Kalisheck et al. 2023)

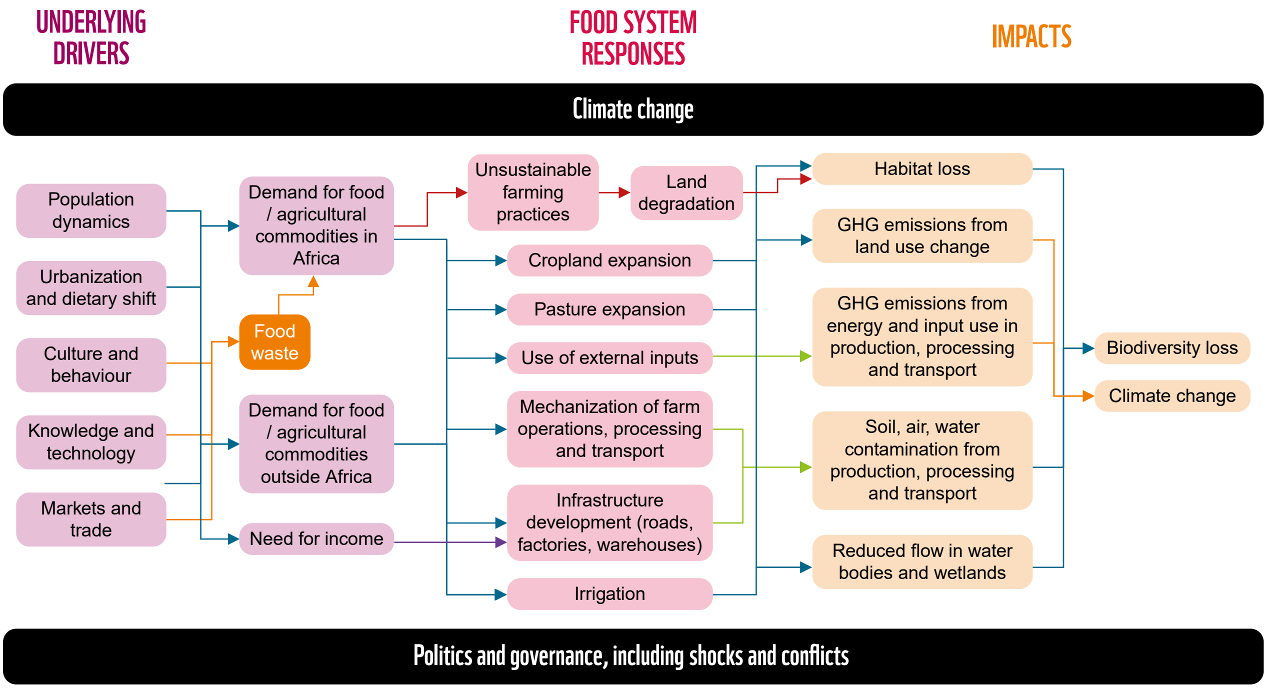
3. ENVIRONMENTAL IMPACTS OF AFRICAN FOOD SYSTEMS

1. TYPES AND SCALE OF IMPACTS

The drivers outlined in section 2 above result in food system responses, which in turn affect African ecosystems in different ways, resulting in a complicated web of factors with multiple causes and effects, as shown in Figure 4 below. A wide range of case studies, often focusing on a specific landscape, ecosystem, or sub-national location, have been carried out on each of the relationships shown in the diagram. The objective of this section is not to exhaustively analyze this vast body of knowledge, but to highlight the main types of food system impacts.

The nature and extent of the environmental impact of food systems depends on the nature and constellation of drivers. For example, whilst increased incomes, urbanization and dietary shift will normally increase food demand and hence trigger cropland expansion or potentially unsustainable intensification, it is also possible that increased levels of education associated with urbanization and income could lead to more sustainable food choices in the longer term (as observed in Europe with the increasing proportion of vegan and vegetarian consumers, in particular amongst the youths, BEUC 2020). Similarly, cultural and behavioral factors could favor a shift towards more sustainable farming practices.

Figure 4. *Links between drivers, food system responses and negative environmental impacts*



Source: Authors' own

Note: The colors of the arrows are for clarity only (to distinguish different linkages) and do not have any further significance.

Food system activities will nearly always have negative impacts on ecosystems, as no agricultural production system will have the same properties as the ecosystem it replaces, for example in terms of soil health and biodiversity. But the use of nature-based solutions can mimic natural processes to some extent, and the concept of biomimicry is gaining traction in recent years, with regenerative agriculture considered by some to be a biomimetic technology, and an example of the '(re)turn to nature' paradigm. (Sumberg 2020, Gremmen 2022)

Large parts of the African continent have already been affected by human activities such as urbanization and infrastructure development, mining and quarrying, crop and livestock production / grazing, etc. Some of the negative environmental impacts of these developments can be reversed through careful rehabilitation activities, using a combination of decontamination, soil and water conservation, natural regeneration, planting and sowing of suitable trees and other plants, and protection from exploitation. African countries have committed to ambitious targets for land rehabilitation under the Land Degradation Neutrality Target Setting Programme (LDN TSP) of the United Nations Convention to Combat Desertification (UNCCD)[13].

Reversing land degradation (including soil erosion and soil fertility loss) caused by unsustainable farming practices could either reduce the speed of cropland expansion (if the land was subsequently used for farming) or return land to nature – both of which would have significant benefits for the environment.

Other efforts to reduce negative impacts of the food system along the value chain range from bans on plastic bags in some African countries[14] to using renewable energy resources for agri-processing[15]. However, it was not possible to review the entire literature on environmentally sound food system technologies and policies for this report, and interested readers are referred to other sources for this (see e.g., Herrero et al. 2020 and others).[16]

Impacts occur at different spatial scales, as shown in Table 3 below. Africa's agri-food systems produce agricultural products for both domestic consumption and export. According to a recent analysis of the impact of COVID-19 on African agriculture[17], the continent exports $35-40 billion worth of agricultural products, whilst importing $45-50 billion.[18]

13 See https://www.unccd.int/our-work/country-profiles/voluntary-ldn-targets for details of the country targets.

14 https://www.greenpeace.org/africa/en/blogs/11156/34-plastic-bans-in-africa/, accessed 21 September 2023

15 https://energycapitalpower.com/transforming-africas-food-systems-through-renewable-energy/, accessed 21 September 2023

16 See also https://climatechampions.unfccc.int/call-to-action-for-climate-resilient-sustainable-food-systems-in-africa/, accessed 22 September 2023)

17 https://www.mckinsey.com/featured-insights/middle-east-and-africa/safeguarding-africas-food-systems-through-and-beyond-the-crisis#/

18 This is in addition to approximately $8 billion of internal trade of agricultural products within the continent.

Table 3. *Food system impacts by food system component and driver*

Food system responses to pressures	**Type of impact**	**Region typically affected by the impact**			
		Africa-local	Africa-(sub) national	Africa-regional	Global/ outside Africa
1. Crop, food and livestock production for domestic consumption and export					
Expansion of farmland and grazing land	Greenhouse gas emissions	Dark green	Dark green	Dark green	Dark green
	Biodiversity loss	Dark green	Dark green	Dark green	Light green
Use of unsustainable farming practices	Land degradation, habitat- and biodiversity loss	Dark green	Dark green	Light green	
Withdrawal and alteration of surface water flows or groundwater for irrigation	Reduced river flow and springs drying up, affecting downstream ecosystems (wetlands)	Dark green	Dark green	Light green	
Mechanization of farm operations	Greenhouse gas emissions*	Dark green	Dark green	Dark green	Dark green
	Soil, water, and air pollution contributing to biodiversity loss	Dark green	Dark green	Light green	
Pollution from agricultural operations / input use		Dark green	Dark green	Light green	
2. Food transformation and distribution for domestic consumption and export					
Transformation and transport	Greenhouse gas emissions*	Dark green	Dark green	Dark green	Dark green
Processing and packaging materials	Soil, water and air pollution	Dark green	Dark green	Light green	
Physical infrastructure for transformation and distribution	Land use change, GHG emissions, pollution	Dark green	Light green		
3. Consumption, including quantitative and qualitative dimensions. Food demand at the national level is a function of population size and dietary preferences					
If met from domestic production: See production and transformation under 1. and 2. above					
If met by import of food from outside** the continent:					
Expansion of farmland and grazing land outside Africa	Greenhouse gas emissions				Dark green
	Biodiversity loss				Dark green
Withdrawal of surface water or groundwater for irrigation outside Africa	Reduced river flow, springs drying up, affecting downstream ecosystems				Dark green
Energy consumption and pollution from farm operations & processing / distribution outside Africa	Greenhouse gas emissions*				Dark green
	Soil, water and air pollution				Dark green

Source: Authors' own.

Notes:

Shading indicates the anticipated geographic scale of the impacts:
dark green implies strong convergence; light green implies weaker convergence

* Unless powered by renewable energy

** Main countries (by value) from which Africa imports food: Brazil, China, India, Europe (various countries), USA – see https://wits.worldbank.org/CountryProfile/en/Country/SSF/Year/2020/TradeFlow/Import/Partner/by-country/Product/16-24_FoodProd for details.

Most agricultural products leave Africa without significant processing, reducing the revenue that the continent overall obtains from its agricultural exports. The annual Africa Agriculture Trade Monitor published by IFPRI (Bouët et al. 2022) indicates that Africa captures only a small share of the global trade in value added, despite an increasing level of participation in global value chains (GVCs).

The environmental impacts of each agricultural export commodity differ – and can be location-specific. Some commodities have specific environmental impacts because of their agroecological zone and production system. For example, both cocoa and palm oil production are concentrated in tropical forest areas in West and Central Africa, threatening forest ecosystems in that region.

However, domestic demand for commodity crops has been associated with most agricultural expansion in SSA in recent years, which includes soy and oil palm (Ordway et al. 2017).

Via food imports, agricultural trade with Africa also affects ecosystems outside the continent. A large proportion of food consumed in Africa is imported from other parts of the world, with a net import of cereals alone of 58.6 million metric tons in 2010.[19] This is projected to increase by 180% to 164.2 million tons by 2050. Assuming average cereal yields of 3t / ha in the countries of production, producing this grain in 2050 would require an area of cropland equivalent to the size of France or Kenya. Hence, the environmental impacts of Africa's food system expand beyond the continent, affecting land and water use in other parts of the world. The current study, however, focuses on the impacts on the African continent.

2. FOOD SYSTEM RESPONSES

This section outlines the different ways in which food systems and their components "react" to drivers. It is these responses or reactions that ultimately impact the environment.

2.1. CROPLAND AND PASTURE EXPANSION

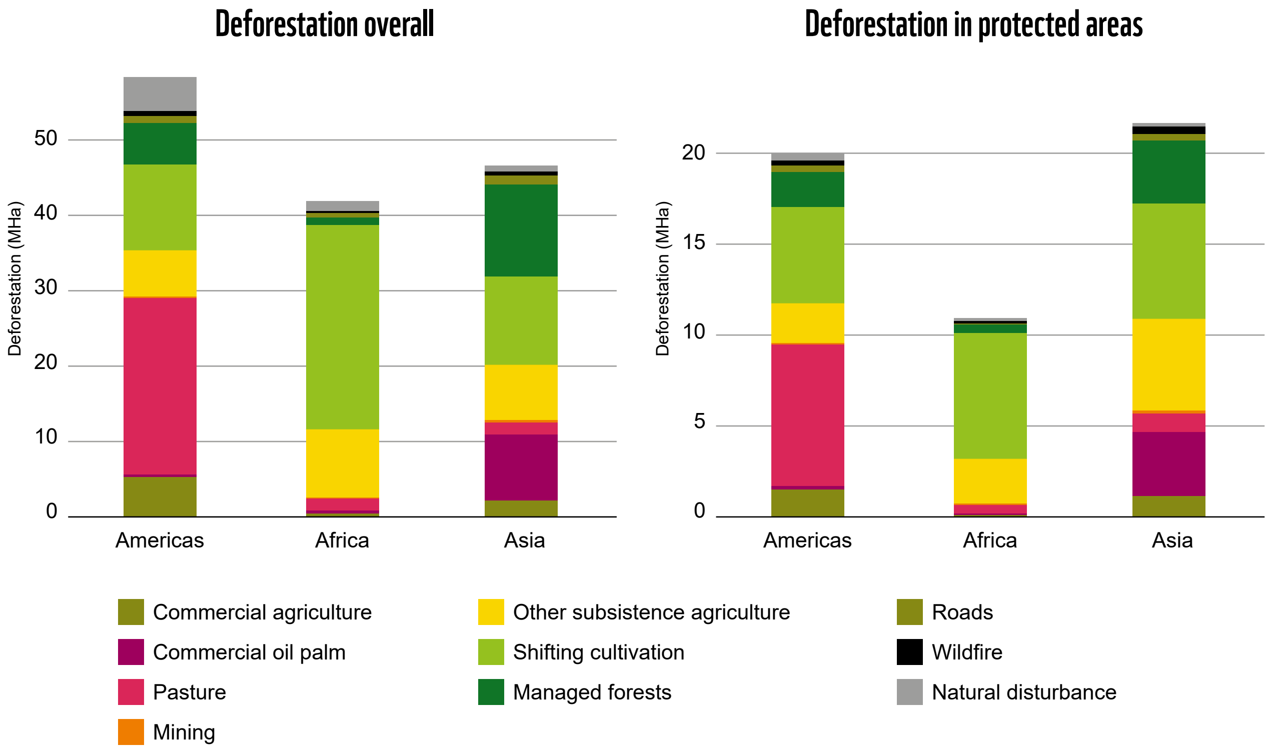
From a wildlife and biodiversity conservation perspective, land use change (conversion of forests and other natural habitats into crop- or grazing lands) constitutes by far the most serious impact that affects ecosystems at local, national, and continental level. According to Potapov et al. (2022), cropland has expanded in Africa between 2000 and 2019 by approximately 50Mha or 34%. Conversion of natural vegetation accounts for 79% of this expansion, with the remaining 21% resulting from replacing pastures, recultivation of abandoned agricultural lands and dryland irrigation.


© Jonathan Caramanus / Green Renaissance / WWF-UK

Cropland expansion has been identified as the main driver of deforestation in Africa between 2000 and 2019. Unlike in other parts of the developing world, most of the land use change and deforestation in Africa during the past two decades, both in protected areas and overall, has been the result of shifting cultivation and other subsistence agriculture activities, with only a small proportion resulting from commercial agriculture (Figure 5 and Pacheco et al. 2021). This pattern reflects the increases in food demand over that period as a result of population growth and changes in diets, in particular for the urban middle class (see e.g., de Bruin and Dengerink 2020 for West- and Central Africa).

19 IMPACT projections of cereal production, consumption, and net trade to 2050 with and without climate change, https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/WTWRMH

Figure 5. The amount of deforestation (in MHa) by driver in the Americas, Africa, and Asia in the area 30° latitude north and south of the equator



Source: Fritz et al. (2022)

In Africa overall, cropland expansion for domestic production has by far outstripped expansion for export crops (Ordway et al. 2017). However, at national and local level, the production of export crops by both smallholder farmers and commercial agriculture can be a major driver of deforestation. Recent research by Kalischek et al. (2023) showed that cocoa cultivation is an underlying driver of over 37% of forest loss in protected areas in Côte d'Ivoire and over 13% in Ghana. However, unlike in South America, most export crops in Africa are grown by small- to medium sized farms (Ordway et al. 2017).

The reasons for smallholder cropland expansion are complex and context specific. Jellason et al. (2021) identified population dynamics and government policies to be the main underlying drivers, leading to high levels of food demand and hence pressure on land. Economic opportunities (such as agricultural mechanization and cash crops production) as well as soil fertility decline, and climate change are key proximate drivers for expansion.

It is much more difficult to assess changes in grazing lands in Africa because most livestock are not grazed on permanent pastures, but on a mix of natural vegetation (savanna, woodlands) and crop fields (after harvesting). The land under pastures has globally declined since 2000 because of livestock intensification. In Africa, pastures increased until 2010, but have since declined there as well.[20] This is largely the result of conversion of pastures and grazing lands into cropland, making up 17% of cropland gains in Africa (Potapov et al. 2022), often leading to conflicts between herders and farmers. At the same time, livestock is grazed on cropland that has been abandoned because of land degradation.

20 https://thebreakthrough.org/issues/food-agriculture-environment/livestock-revolution, based on FAO data.

BOX 1. WHAT IS THE POTENTIAL FOR CROPLAND EXPANSION IN AFRICA?

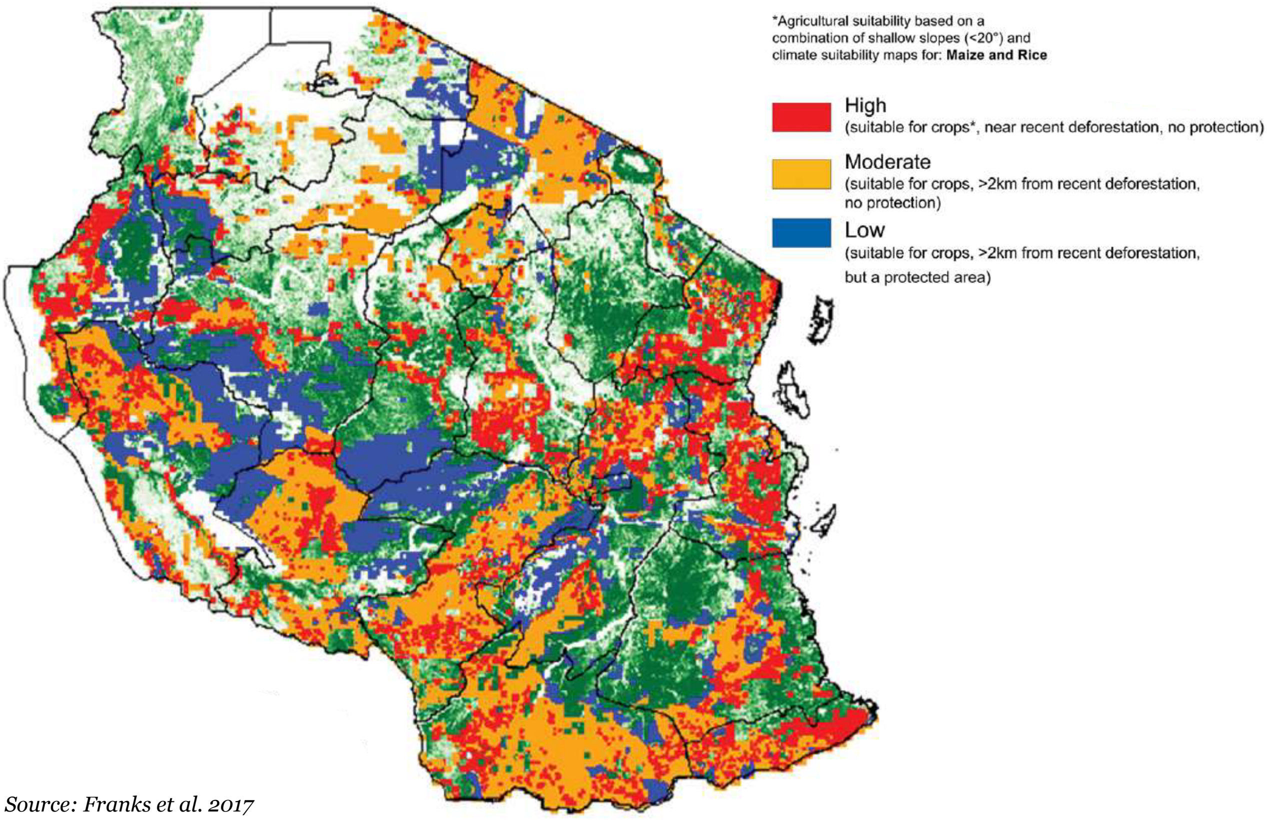
It is very difficult to obtain a clear picture of the extent and location of land that would be suitable for different types of crops and is hence at risk of future cropland expansion. This is because "suitability" has multiple dimensions, including environmental factors (humidity / rainfall, soil properties, topography etc.) and socio-economic (proximity to roads, security, economic viability etc.). These factors are location specific. In addition, classifications that use fixed thresholds, based on best agronomic practices (e.g., assuming that land with slope of more than 20% is not suitable for cereal cultivation) do not reflect farmers' coping strategies, which may include cultivating steeper slopes if no other livelihood options are available to them.

Attempts to estimate potentially available cropland in Africa include the following:

- ISDA[21] provides spatial data on soil fertility for Africa, showing the number of (soil fertility related) constraints – but without information on rainfall, slope etc., this is of limited use to assess potential future cropland expansion.
- Focusing only on cereals, IIED and partners analyzed land capability for crop production in Ethiopia, Ghana and Tanzania, considering climate suitability and slope (Franks et al. 2017). By adding "proximity to recent deforestation" and "protection" (i.e., whether location is within a protected area), they developed maps of likelihood of cereal expansion (see an example for Tanzania in Figure 6).
- Van Ittersum et al. (2016), in their study on the potential of SSA countries to achieve national self-sufficiency in cereals, used estimates of potentially available cropland from Chamberlin et al. (2014), which is reproduced in Annex 2.

Whilst useful in providing a general picture, such estimates and models are not sufficiently detailed to inform local or even national level land use planning.

Figure 6. *Likelihood of cereal crop (maize and rice) expansion into forest in Tanzania*



Source: Franks et al. 2017

21 https://www.isda-africa.com/isdasoil/

Van Ittersum et al. (2016) analyzed the land use implications of likely future cereal demand and yield gap closure (the difference between actual yields and potential yields in a given agroecological zone) for 10 African countries that together make up over 50% of the population and the crop land in Africa. Their results show that, with a yield gap closure of 50%, by 2050, seven out of the ten countries (including Nigeria) would not be self-sufficient with cereals even when converting all land suitable for cereal cultivation into crop land. Hence the pressure on natural habitats in Africa from farmland expansion is likely to continue for the next decades.

2.2. USE OF UNSUSTAINABLE FARMING PRACTICES

The specific environmental impacts of agricultural production depend on the nature of the farming system and associated practices. Across Africa, a large variability exists in the types of crops grown, the agronomic practices (from land preparation to harvesting) and the types of inputs used. All of these can vary even at farm level, with farmers often growing multiple crops on multiple plots with different practices. For example, farmers in West Africa often grow hybrid or improved maize seed and fertilizer to grow maize for sale, but grow local varieties of sorghum or millet, intercropped with a range of other food crops such as beans, pumpkins, and yams, for home consumption.[22]

Many case studies have been carried out on farming practices in different parts of Africa, but there is no comprehensive data available about the geographic scale of specific unsustainable practices by country or region, which include (but are not limited to):

- Burning of crop residues on the field (bush fires) to clear the land, promote the growth of young grass and facilitate hunting of small wildlife. But burning reduces water retention and soil fertility by 25 to 30 per cent[23], causes significant emissions of GHGs (Ramo et al. 2021) and destroys natural habitats.
- Irresponsible use of agrochemicals – using banned or hazardous substances or using permitted chemicals incorrectly (close to water sources, during windy conditions or before rainfall, in dosages above the recommended ones etc.) with negative impacts on human, animal, plant and soil health (Tostado 2022).
- Use of agronomic practices that lead to soil erosion, soil compaction, soil fertility loss and ultimately land degradation (e.g., ploughing shallow soils too deeply or with heavy equipment, leaving the soil unprotected / uncovered for periods of time and hence reducing infiltration, cultivating on steep slopes, removal of crop residues from fields, shortening fallow periods without adding soil amendments, etc.) (ELD Initiative 2015)
- Land management practices that reduce agrobiodiversity by growing a limited number of crops and crop varieties, removing natural vegetation from fields and field boundaries and thus reducing habitats for predators of crop pests and for pollinators. (Kaihura and Stocking 2015)

To address some of these challenges, “sustainable land management” has been promoted for close to a century, promising socioeconomic and environmental benefits (TerrAfrica 2009). Soil and water conservation measures on cropland can reduce the extent of soil erosion and increase infiltration, thus reducing some of the negative impacts on downstream land and water bodies. Fertilizer use can be optimized through micro-dosage as part of integrated soil fertility management that combines the use of organic and inorganic fertilizers with careful crop rotation. The integration of trees and livestock can reduce the reliance on fertilizers but may, in some contexts, reduce crop yields (due to competition with crops for space, light, water and nutrients).

The emergence of different concepts of sustainable agriculture in recent years, each with a slightly different focus (see section ☐1.2.1 for details), may be helpful for academic or advocacy purposes, but does little to address the key challenges of scaling out sustainable practices in vastly different contexts. There is a large body of research and practice on the promotion, use, benefits and challenges of agroecology, nature-positive agriculture, regenerative agriculture, climate smart agriculture and sustainable agriculture. These approaches aim to manage farmland in an integrated way that relies primarily on ecological processes and less on external inputs, in order to increase resilience to climate change induced shocks. They are considered by many as an alternative to “conventional” or “industrial” agriculture, which relies on external inputs to maximize productivity (often at the expense of environmental and social sustainability). However, large, market-oriented farms can integrate agroecological principles and can be run in a socially responsible way.

It does not help that the debates on the pros and cons of different farming approaches are led by academics, activists and corporations and not by African farmers, who generally use a combination of agroecological, conventional and perhaps (more or less sustainable) indigenous farming practices to suit their contexts and objectives. For example, farmers in Upper West Region of Ghana use legume-cereal rotations and farmyard manure to manage soil fertility, but also apply inorganic fertilizer and use tractors for land preparation (Dakyaga et al. 2020). Similarly, farmers in Central Malawi grow modern varieties of groundnuts in monoculture for the market but practice some elements of conservation agriculture (Bwanausi Kabuye and Adolph 2020). Most farmers in SSA already consider the economic, environmental, and social costs and benefits of different practices, making an informed choice for their specific context (Adolph et al. 2021).

22 Authors’ own observations from field research in Ghana and Burkina Faso between 2012 and 2016.

23 https://www.unep.org/news-and-stories/story/toxic-blaze-true-cost-crop-burning

This context includes constraints such as climate change (necessitating rapid land preparation), shortage of labor and organic matter, market preferences and prices for produce and inputs, and access to appropriate inputs and technologies. Whilst many technical solutions for sustainable agriculture exist - often as a result of a successful integration of farmers' and researchers' knowledge, these are not always economically viable for smallholder farmers operating in a specific context. This context is at least partly shaped by national and regional agricultural and trade policies.

The promotion of sustainable agriculture is a declared objective of national agricultural policies across the African continent, but policies and incentives do not normally provide a conducive context for large-scale adoption of sustainable practices that tend to be knowledge- and labor-intensive and offer fewer opportunities for corporate profits from the production and sale of agricultural inputs. The economic, social and political barriers to widespread adoption of sustainable farming practices have been widely analyzed and documented (see e.g. Piñeiro et al 2020). They include the lack of secure and equitable access to resources (land, water, labor, technology, farm inputs and infrastructure), and markets that do not consider externalities and therefore do not incentivize the use of sustainable practices. Most national agricultural policies and donor-funded agricultural development programs do not provide significant incentives for the development, adaptation and adoption of sustainable farming practices at scale.

From an environmental impact perspective, the use of sustainable agricultural practices is desirable – but it could potentially contribute to further farmland expansion, if productivity with such practices was low, e.g., due to a reliance on organic soil amendments alone (Adjei-Nsiah et al. 2022). Promotors of the 'land sparing' paradigm suggest that the only way of protecting natural habitats (and living up to commitments on habitat conservation and climate change mitigation made by governments globally and in SSA) is to increase agricultural productivity in areas with a high potential for agriculture, but low biodiversity value. This argument was summarized by Benton and Harwatt (2022) as follows: *"Food production must increase to satisfy growing demand. Efficiency gains – primarily through the use of technology – will allow biodiversity-rich land to be protected from agricultural expansion, and ecosystems to be restored on unused land."*

'Land sharing' has been promoted as an alternative paradigm. Supporters propose using environmentally sustainable farming methods so that land can provide provisioning, regulating and supporting ecosystem services at the same time. This involves farming based on agroecological and regenerative principles, such as agroforestry and biological control of pests and diseases, so that agricultural land can maintain many of its important environmental benefits.

© WWF / Martina Lippuner

Others propose that a systems perspective, which includes shifting food demand through changes in consumption patterns, in particular amongst the wealthier, can reduce food demand and hence the pressure on natural resources (e.g., by reducing the consumption of meat). Benton and Harwatt (2022) summarize the underlying logic as follows: *"Changing consumption patterns can improve public health and reduce demand. This reduces pressure on land, allowing for the widespread adoption of agroecological farming to make the food system sustainable."* However, whilst there is now a general agreement on the components of a healthy and sustainable diets[24], most people in SSA are not currently consuming enough protein and very little animal-based foods (FAO, ECA and AUC 2021), contributing to malnutrition. And even a "sustainable" diet that has a low animal-calorie share would not enable most countries in Africa to be food self-sufficient, according to Beltran-Peña et al. (2020). They developed food self-sufficiency scenarios for 2100, based on alternative future food consumption patterns and crop yields under different climate change and irrigation assumptions. The results show that the majority of countries in SSA would not be able to achieve food self-sufficiency in any of the three scenarios, including a "sustainable" scenario, with a diet that is low in animal-based calories.

The 'land sharing' and 'land sparing' paradigms sit on opposite ends of a spectrum, and in practices, most countries would aim for a spatial pattern of food production systems that include more intensively farmed land (where no important ecosystem services are compromised by this use), less intensively farmed land using nature-based solutions (where biodiversity conservation is a priority) and areas under protection with very limited human activities and no farming. This can be achieved through appropriate land use planning – one of the key tools for managing land-use trade-offs discussed in section 5.

24 See e.g. the WWF position paper on healthy and sustainable diets at https://wwfint.awsassets.panda.org/downloads/wwf_position_on_healthy_and_sustainable_diets.pdf and the Planetary Health Diet of the EAT-Lancet Commission on Food, Planet, Health at https://eatforum.org/eat-lancet-commission/the-planetary-health-diet-and-you/.

2.3. AGRICULTURAL MECHANIZATION

Mechanization levels in African agriculture are below those on other continents. Various data sources suggest that between 1% and 12% of households in SSA have access to a tractor, while only 5% of agricultural land is actually cultivated by tractor (Daum and Birner 2020). Threshers and power tillers are used by even fewer farmers (except for Egypt and South Africa), with threshing done manually and largely by family labor.

Land preparation and threshing are hard work and increase the burden on women and children. Increasing agricultural mechanization is a declared objective of national agricultural policies in order to address seasonal labor shortages, speed up land preparation in the face of climate variability, and reduce production costs.

The equipment used by African farmers is often purchased second-hand (imported from Europe, Asia or, less frequently, America) and is normally not very fuel efficient. However, considering the small proportion of land cultivated with powered equipment, the GHG emissions from mechanization are still low. The development of small-scale machinery adapted to the African context, in particular for land preparation and threshing, is increasing (Kirui and von Braun 2018). Conservation agriculture and other low / zero tillage systems have been promoted in many parts of SSA, but adoption has been slow due to several factors, including the initial yield decrease, a competition for crop residues from livestock feed and fuel requirements, increased labor demand and high initial investment costs (Lee and Gambiza 2022).

Because of the high costs of tractors, the risk of compacting soils when using them, and the need to clear most trees from the plot to plough with a tractor, animal traction has been promoted in SSA for decades (Blench 1999). This includes both the promotion of livestock breeding and health programs, and the development and promotion of appropriate implements for different soil types and draught animals (including donkeys).

2.4. WITHDRAWAL / USE OF SURFACE WATER OR GROUNDWATER FOR IRRIGATION

Changes to surface water bodies and wetlands, as well as to groundwater levels, have significant impacts on people and the planet. Urbanization and industrialization contribute to a growing competition for water. Land use changes (replacing forests with cropland or pastures) on their own can have significant impacts on water cycles, even without extraction of water for crop irrigation, as surface runoff increases with the removal of permanent vegetation. When adding extraction of water for crop irrigation and the effects of prolonged droughts due to climate change, the environmental impacts become significant. Use of water for irrigation and clearing land near water bodies can also alter the natural patterns of water quality and quantity (environmental flows) and disrupt morphological features of water systems, to the detriment of aquatic biodiversity.

With 7%, Africa has the lowest proportion of irrigation cropland worldwide (Nkiaka et al. 2021) – but developing irrigation is a key objective of the agricultural policies of many countries, to increase crop yields, whilst also reining in cropland expansion. Hence there is a trade-off between the objective of reducing cropland expansion through agricultural intensification, including irrigation, in order to preserve natural habitats, and the objective of reducing water extraction for agriculture in order to preserve water bodies and wetlands.

An alternative could be irrigation using renewable groundwater, the potential of which is considered very large by some. Altchenko and Villholth (2015) calculated that *"the total area of cropland irrigable with renewable groundwater ranges from 44.6 to 105.3 × 106 ha, corresponding to 20.5 to 48.6 % of the cropland over the continent. In particular, significant potential exists in the semiarid Sahel and eastern African regions which could support poverty alleviation if developed sustainably and equitably."*

2.5. FOOD PROCESSING AND DISTRIBUTION

The processing and distribution of food and agricultural commodities enables reaching those food consumers who are not also food producers and hence plays an important role within the food system. However, food processing and distribution increasingly involves mechanization, the use of often hazardous materials or the production of waste and effluents that can have negative environmental impacts locally. Africa's food value chains are still largely informal, with much of the processing done at farm and household level or via small SMEs – with environmental impacts that are limited in scale and severity. To increase income and employment from the agricultural sector and to gain much-needed revenue for government spending, it is essential to develop agricultural value chains both for import substitution and for export. This could also potentially reduce pressures on land, if higher value, processed commodities were exported instead of raw materials – but this assumption has not been tested and increasing the value of agricultural produce may well incentivize further cropland expansion.

There is limited information available about food processing in Africa overall – most research is in the form of case studies (for example, focused on specific commodities in specific countries). Whilst the impact on biodiversity hotspots may be limited, with most of the processing happening in urban areas, the impacts can be significant locally through pollution of air, soil and water from fuels and refuse, and disturbance from noise and vibrations from machinery. In most African countries there are no environmental impact assessments of food processing facilities, and the pressure to keep costs low in order to compete with cheap imports may result in unsustainable shortcuts being used for sourcing of processing materials and equipment, packaging and waste disposal. There is very limited data available about waste disposal from food processing for the continent overall.

An example for food processing and consumption waste is plastic. Plastic waste emissions from rivers into the oceans are significant (and exceeds such emissions in most of Europe and North America) along the coast of West Africa, the Mediterranean coast of Morocco and Algeria, and the Southeastern part of South Africa – all areas of high population density and urbanization (Lebreton et al. 2018).

Inefficient food processing and distribution systems can contribute to food losses and waste. The World Resources Institute (WRI) estimates[25] that around 37% of food produced in SSA is lost or wasted, including an estimated $4 billion worth for grains alone. This exceeds the value of the total food aid received in sub-Saharan Africa over the past decade and equates to the annual value of cereal imports.

Three strategies for reducing losses and waste are proposed:

- Producing food in a way that commonly wasted resources (such as phosphates) are sustainably used and recycled,
- transforming by-products into useful agricultural products,
- and improving transport and storage facilities to prevent food loss.

All of these require political commitment and substantive investments.

2.6. PHYSICAL INFRASTRUCTURE FOR TRANSFORMATION AND DISTRIBUTION

Infrastructure for food transformation and distribution includes roads, storage facilities and processing facilities, as well as associated water and power supply and waste disposal. There is no comprehensive data available about the scale of food processing infrastructure, but there appears to be general agreement that the potential for this sector is large, and, with the right investments and support, infrastructure is likely to increase significantly in the future (Technoserve 2017). Recently, the African Union's Common Africa Agro-Parks (CAAPs) Initiative aims to attract private investments in establishing transboundary mega agro-industrial hubs in order to transform the continent's agriculture and boost the continent's integration through trade and industrialization.[26] It is not clear how and to what extent any negative environmental impacts of such hubs will be assessed and mitigated.

From an environmental perspective, the main concerns relate to

- Land use impacts, with processing infrastructure contributing to urban sprawl, including into farmland (which may lead to farmland expansion elsewhere), wetlands or other natural habitats
- Pollution from effluents and waste
- GHG emissions from the use of fossil fuels.

25 https://www.wri.org/insights/3-ways-reduce-food-loss-waste-africa, accessed 22 September 2023 and WWF (2021)

26 https://au.int/en/pressreleases/20230222/common-africa-agro-parks-caaps-implementation-boost-acceleration-afcfta-and, accessed 22 September 2023

The spatial impacts of these developments may well go far beyond the location of processing facilities. To some extent, they are an inevitable consequence of economic development – especially considering that, in comparison with wealthier nations in the global north, Africa's infrastructure is still very modest in size. Improvements to infrastructure are urgently needed to generate the economic growth and employment needed to overcome poverty (which on its own has negative environmental impacts, when people are forced to use destructive livelihood strategies such as artisanal mining or unsustainable farming practices).

There are also huge opportunities in Africa to develop those physical infrastructure in a nature friendly way - for example, using renewable power for processing facilities.[27] However, there are many indirect effects of infrastructure development that need to be considered. For example, making areas more accessible could accelerate land use changes (through land conversion for agriculture, settlements and other purposes) and other forms of resource extraction, such as for firewood and charcoal, as well as bushmeat.

3. NATURE AND SCALE OF ENVIRONMENTAL IMPACTS

3.1. FOOD SYSTEMS AS A CONTRIBUTOR TO AND VICTIM OF CLIMATE CHANGE

Agriculture is a main contributor of greenhouse gas emissions worldwide. The IPCC's Special Report on Climate Change and Land (2019) estimates that agriculture is directly responsible for up to 8.5% of all greenhouse gas emissions, with a further 14.5% coming from land use change (mainly deforestation in the developing world to clear land for food production).

In Africa, the food system responses outlined in section 3.2 above contribute to GHG emissions largely through land use change – but emissions from agricultural mechanization, production, and use of inputs (in particular fertilizer), processing and transport are on the rise. Whilst Africa accounts for the smallest share of global greenhouse gas emissions, at just 3.8%, in contrast to 23% in China, 19% in the US, and 13% in the European Union (CDP 2020), emissions have been steadily rising overall. In SSA, the proportion of emissions originating from land use change, forestry and agriculture is significantly higher than in more developed economies, making up about 55% in 2020[28]. However, this proportion has been steadily declining, as emissions from energy and industry are increasing and this trend is likely to continue, as African economies grow and diversify.

Whilst the development of processing and manufacturing sectors are urgently needed to eradicate poverty, they will inevitably increase emissions from the continent. More affordable green energy technology has the potential to reduce emissions from those sectors in Africa. A recent report (IRENA and FAO 2021) on renewable energy for agri-food systems outlines how green energy can increase supplies of modern energy in low-access areas, minimize dependence on the volatility of fossil-fuel prices, reduce costs and losses along the agri-food chain, reduce the food sector's environmental impacts and meet the clean cooking challenge.

In addition, there is also an opportunity for Africa to expand the role of its forests as carbon sinks, whilst providing incomes and livelihoods for rural people. There are a growing number of initiatives to protect and restore forests, grasslands, and other ecosystems, in order to increase their ability to absorb and store carbon. When measuring this carbon and turning it into carbon credits, it can be "sold" to companies and individuals, and the income generated can be used for the benefit of the communities involved. There is a growing experience[29] with such initiatives, which could simultaneously restore degraded habitats, whilst providing the urgently needed resources for local development. However, carbon credit schemes have been criticized for providing limited benefits to local people.[30]

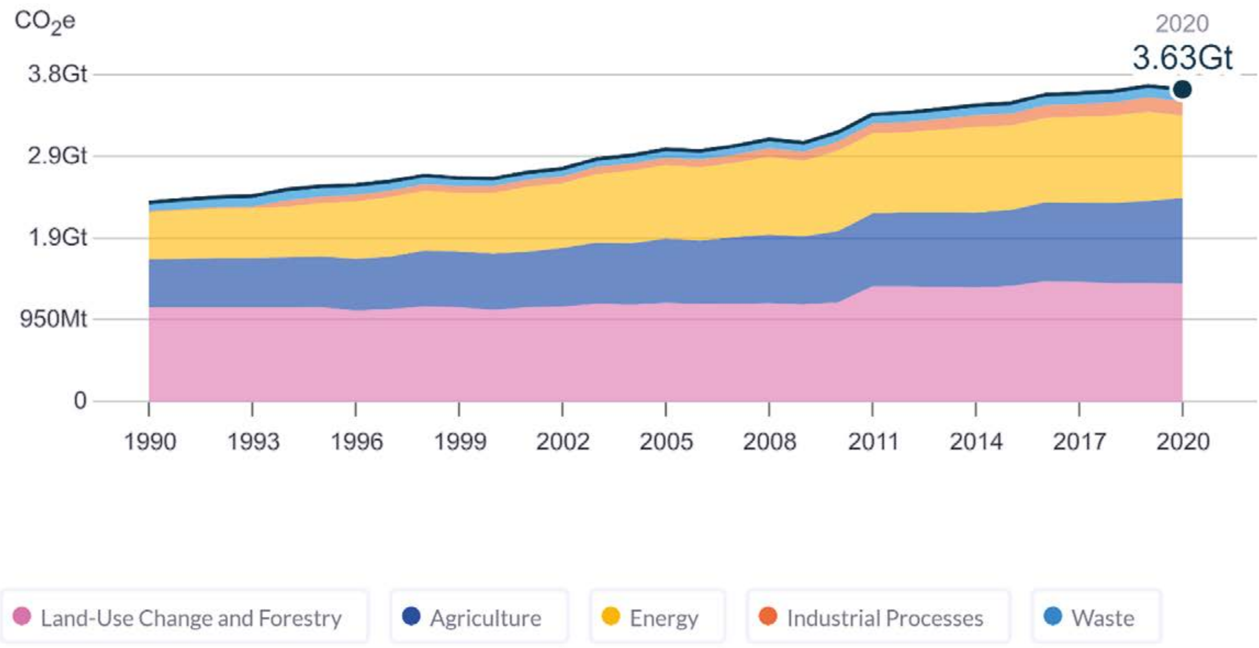
27 See for example https://energycapitalpower.com/transforming-africas-food-systems-through-renewable-energy/, accessed 1 October 2023

28 https://www.climatewatchdata.org/embed/ghg-emissions?breakBy=sector&chartType=percentage&end_year=2020&regions=SSA&start_year=1990, accessed 1 October 2023

29 See for example https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/africa-forest-carbon-projects-interview/, accessed 21 July 2023

30 https://blogs.lse.ac.uk/africaatlse/2023/06/12/carbon-credits-are-distorting-markets-and-destroying-local-businesses/

Figure 7. *Historical GHG emissions, Sub-Saharan Africa*



Source: https://www.climatewatchdata.org/embed/ghg-emissions?breakBy=sector&calculation=ABSOLUTE_VALUE&chartType=area&end_year=2020&regions=SSA&start_year=1990

Another aspect to consider are the impacts of Africa's food system on emissions outside the continent As Africa overall has been a net food importer for at least the past 20 years, it contributes to environmental impacts, including GHG emissions, of food production outside the continent – whilst exporting a growing quantity of agricultural commodities, which result in environmental impacts locally and on the African continent overall. Whilst some attempts have been made to calculate a GHG emission balance sheet for food systems outside Africa (e.g., Audsley et al 2009 for the United Kingdom), no such calculations have been made to our knowledge for the African continent. It is therefore not known whether emissions from African food imports exceed those from agricultural commodity exports.

However, considering that Africa's per capita GHG emissions are only about a sixth of global average[31], Africa's food systems are over-proportionately affected by climate change impacts. Temperature increases threaten crop yields, whilst rising sea levels – at a rate higher than the global average – threaten the densely populated coastal areas and their crucial infrastructure (Box 2 below). Hence food systems are both a cause and a victim of climate change.

31 https://www.wilsoncenter.org/article/battle-earths-climate-will-be-fought-africa, from World Bank data at https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=ZG (accessed 20 July 2023)

BOX 2. KEY OBSERVATIONS ABOUT CLIMATE IMPACTS ON FOOD SYSTEMS

The rate of sea-level rise along the African coastlines is higher than the global mean rate, in particular along the Red Sea and southwest Indian Ocean, where the rate is close to 4 mm/year. Relative sea-level rise is likely to continue in the future, contributing to an **increase in the frequency and severity of coastal flooding in low-lying cities and an increase in the salinity of groundwater due to sea-water intrusion.** By 2030, 108–116 million people in Africa are expected to be exposed to sea-level rise risk [affecting irrigation water availability and quality].

Increasing water consumption combined with more frequent droughts and heat events will increase **water demand and put additional pressure on already scarce water resources.** Disruptions in water availability will impede access to safe water. In addition, limited water availability and water scarcity are expected to trigger conflicts among people who are already contending with economic challenges.

East Africa suffered the effects of cumulative failed rainy seasons combined with heightened conflict endemic in the region, related population displacement, and COVID-19 restrictions. **High food prices impeded food availability and access, leaving more than 58 million people in conditions of acute food insecurity.**

Increased temperature has contributed to a 34% reduction in agricultural productivity growth in Africa since 1961. This is more than any other region. This trend is expected to continue in the future, increasing the risk of acute food insecurity and malnutrition. Global warming of 1.5 °C is projected to be accompanied by a decline of 9% of the maize yield in West Africa and a decline of 20%–60% of the wheat yield in Southern and North Africa.

Climate-related hazards continued to be a major driver of new displacement in Africa. Hydrometeorological hazards continued to fuel patterns of protracted, prolonged and repeated displacement. While most disaster displacement is internal, displacement across borders also occurs and may be linked to conflict or violence, with climate change acting as a vulnerability multiplier.

Source: WMO (2022)

3.2. HABITAT LOSS, DEGRADATION AND FRAGMENTATION, LEADING TO BIODIVERSITY EROSION OR LOSS

Cropland and pasture expansion (section 3.2.1) and Use of unsustainable farming practices (3.2.2) contribute significantly to the loss, fragmentation and degradation of habitats and thus to biodiversity loss.

The specific environmental impacts of cropland expansion depend on the importance (in terms of biodiversity and ecosystem services - other than agriculture) of the land use that is being replaced and the characteristics of the farming practices used in the new cropland. It also depends on the speed at which cropland expansion happens, and the resulting spatial pattern of land use. Patchy conversion patterns lead to the fragmentation of existing forests and natural habitats, and hence to a reduction in the number and abundance of species that can be supported on unconverted land (Perrings and Halkos 2015).

Farming systems that rely on agroecological, regenerative farming practices, including the judicious use of inorganic fertilizer (e.g., using micro-dosage as part of an integrated soil fertility management regime) and integration of trees can mimic some natural ecosystem functions, but may be less profitable (where agricultural labor costs are high).

Low intensity farming systems (which use neither external inputs, nor agroecological approaches) with low productivity can contribute to a higher pressure on remaining natural habitats, as more land is needed to produce the same amount of food. Farming systems designed to maximize yield by using highly efficient and productive methods may be more susceptible to climate change impacts and other shocks, and hence be less resilient.

© Martin Harvey / WWF

Perrings and Halkos (2015) analyzed the biodiversity impacts of agricultural productivity growth and agricultural land conversion in 27 countries on threats to mammal, bird, and plant species over two timescales: one covering the period since agricultural and environmental records began, the other covering the last decade. They found that the extensive growth of agriculture is associated with increasing threats to biodiversity at all time scales. Intensification was associated with a significant reduction in the threat to all species on long time scales, but it had no significant effect on shorter time scales. They conclude that, over longer time scales, agricultural intensification has offered conservation benefits in SSA, but there was little evidence that intensification reduces threats to biodiversity on shorter time scales. This is almost certainly because intensification works by slowing the rate of future land conversion.

The agri-food system contributes not only to habitat loss through cropland expansion, but also to land degradation of existing farmland (see 3.1). The Global Environment Facility (GEF) defines land degradation as *"the deterioration or loss of the productive capacity of the soils for present and future" and considers it "one of the world's most pressing environmental problems"*.[32] According to ISRIC (World Soil Information), cited in ELD Initiative and UNEP (2015), an estimated 494 million hectares of Africa's total land area of 2,966 million hectares was degraded.

Food system responses causing land degradation include unsustainable farming activities (see section 0), leading to soil erosion and soil fertility loss as well as pollution. This in turn affects downstream ecosystems, but also causes a vicious cycle of low productivity, land abandonment and further cropland expansion. There has been no comprehensive study of cropland abandonment in Africa, but case studies in South Africa suggest that it could be significant (Moyo and Ravhuhali 2022).

4. SPATIAL PATTERN OF IMPACT

4.1. DATA SOURCES AND CHALLENGES

There is a wide range of datasets available on agri-food systems and environmental dimensions, but most of it is not spatially explicit. Hence the main challenge when undertaking a spatial analysis of food system impacts is the fact that data for almost all relevant food system component indicators is only available as aggregate figures at the country level – i.e., one value for the whole country, without disaggregating it e.g., by urban and rural areas, different agroecological zones, or even different administrative units within the country (regions, districts, counties etc.). These aggregate figures originate from sub-national / local level data collection or estimations carried out by line ministries such as the ministries of agriculture or statistical offices. The resulting figures are then reported to agencies such as the Food and Agriculture Organization (FAO) of the United Nations, the African Union (AU) or the World Bank but are not available in the public domain. For some countries, disaggregated data (e.g., by district) is available for some indicators – but as this study covers the whole continent, only data available for all or the majority of countries could be included.

For the maps in this report, data derived from satellite images was used. The specific sources and definitions for each dataset are included below each map.

4.2. SPATIAL PATTERNS OF FOOD SYSTEMS DRIVERS AND RESPONSES

For those food system drivers and responses for which spatially explicit data is available, overlaying them with biodiversity indicators produces a pattern that is indicative of some of the current pressures on ecosystems. This shows possible 'flashpoints', where high food demand and cropland expansion intersect with areas important for biodiversity.

POPULATION DENSITY AND HUMAN SETTLEMENTS.

Relatively recent spatial data is available for population density and human settlement areas. Population density can be used as an indicator for food system pressures, with higher density suggesting higher food demand and environmental footprint of the food system. In the absence of spatially explicit timeline data of population density, changes in the sizes of human settlement areas can be used as a proxy for trends and patterns in population concentration, food demand and hence food system pressures on the environment.

32 https://www.thegef.org/what-we-do/topics/land-degradation

Figure 8. *Population density in Africa in 2019*[33]

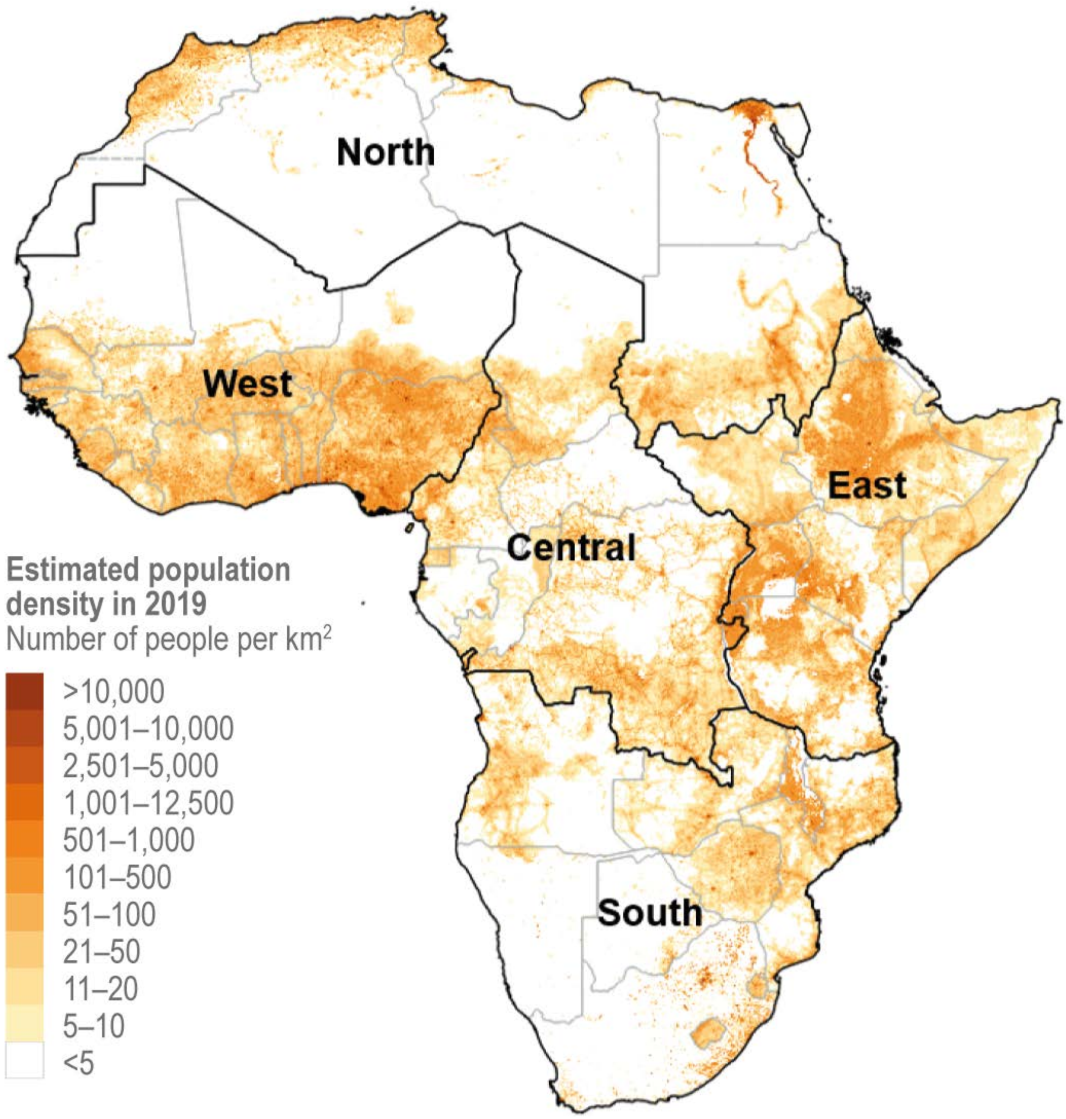


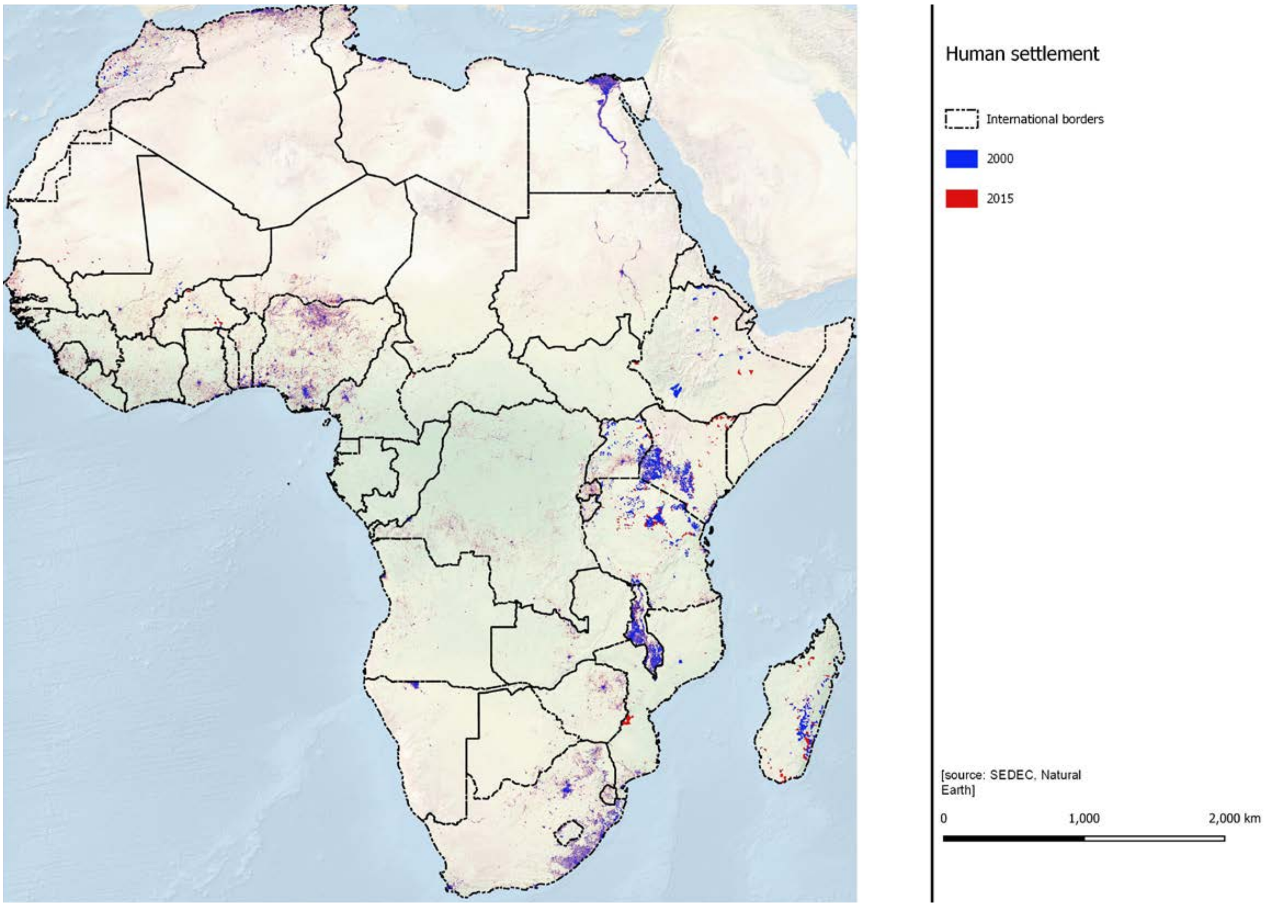
Figure 8 shows high concentrations of population along the Mediterranean coast, in West Africa, Ethiopia the great lakes region. In Figure 9, expansions of human settlements can be seen in Madagascar, Kenya, Tanzania, Malawi, Nigeria, and other parts of West Africa. This reflects the increase of human settlements in SSA alone (without North Africa) by nearly 85% during the period 2000 to 2015.[34]

These expansions do not appear to be very prominent on a continental scale. However, when "zooming in" to hotspots such as key transfrontier conservation areas (TFCAs), the threat to specific ecosystems becomes apparent.

33 Source: Figure 9.1 in Trisos, C.H., I.O. Adelekan, E. Totin, A. Ayanlade, J. Efitre, A. Gemeda, K. Kalaba, C. Lennard, C. Masao, Y. Mgaya, G. Ngaruiya, D. Olago, N.P. Simpson, and S. Zakieldeen, 2022: Africa. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1285–1455, doi:10.1017/9781009325844.011.

34 From 211 million to 390 million, https://data.worldbank.org/.

Figure 9. *Human settlements in Africa in 2000 and in 2015*



Data source: Joint Research Centre - JRC - European Commission, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2021. Global Human Settlement Layer: Population and Built-Up Estimates, and Degree of Urbanization Settlement Model Grid. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/h4154f0w. Accessed 10 October 2023.

Notes:

The Global Human Settlement Layer (GHSL) provides gridded data on human population (GHS-POP), built-up area (GHS-BUILT), and degree of urbanization (GHS-SMOD) across four time periods: 1975, 1990, 2000, and 2014 (BUILT) or 2015 (POP, SMOD). GHS-BUILT describes the percent built-up area for each 30 arc-second grid cell (approximately 1 km at the equator) based on Landsat imagery from each of the four time periods.

GHS-POP consists of census data from the 2010 round of global census from Gridded Population of the World, spatially allocated within census units based on the percent built-up areas from GHS-BUILT. GHS-SMOD uses GHS-BUILT and GHS-POP to develop a standardized classification of degree of urbanization grid.

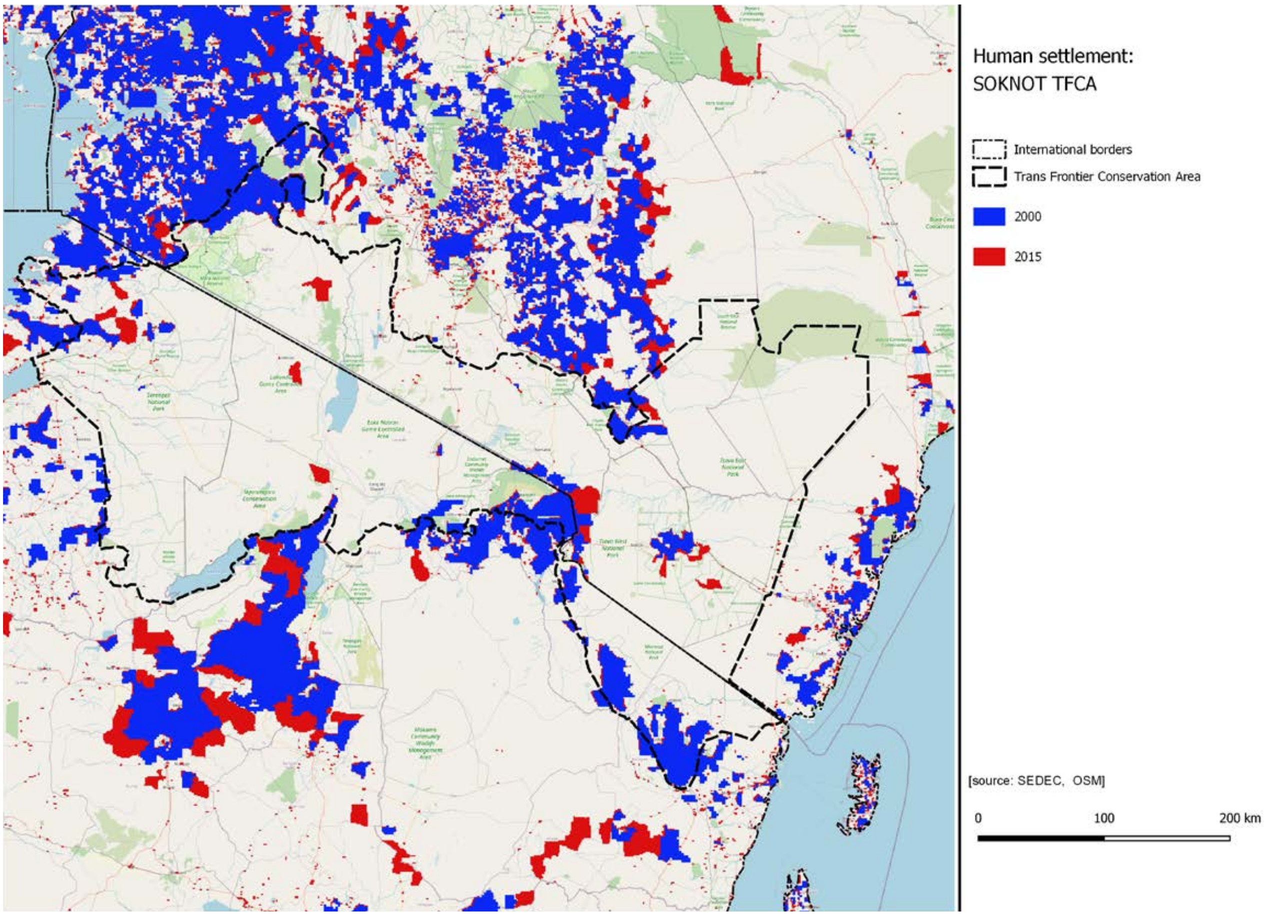
The GHSL multitemporal collections are derived from spatial analysis that relies on a combination of fine-scale satellite image data, census data, and crowd sourced or volunteered geographic information sources. In the figure above, all categories of human settlement change are included (apart from Class 10 (water) and Class 11 (very low density in rural areas). Hence 'urban', in this context, covers all classes of settlement, including areas of Low Density Rural, but excluding Very Low Density Rural settlement:

I. Class 30: Urban Centre grid cell.
II. Class 23: Dense Urban Cluster grid cell.
III. Class 22: Semi-dense Urban Cluster grid cell.
IV. Class 21: Suburban or peri-urban grid cell.
V. Class 13: Rural cluster grid cell.
VI. Class 12: Low Density Rural grid cell
VII. Class 11: Very low-density rural grid cell
VIII. Class 10: Water grid cell.

Figure 9 shows the location of human settlements up to 2000 (blue) and new settlement that emerged between 2000 and 2015[35] (red). This indicates that there has been a dramatic increase in human settlements during that 15-year period, and this is likely to have continued during the period since 2015. Focusing on relatively recent human settlement expansion, showing "hotspot" areas of recent growth, can be used to identify where landscapes may be subject to settlement expansion in the future. These include areas in East Africa (Kenya, Tanzania, and Ethiopia), West Africa (Nigeria and coastal West Africa), Malawi and Madagascar. However, a map for the whole of the continent is of limited use when trying to identify risks to specific conservation areas.

Using the same data to focus on specific sensitive landscapes can reveal potential threats to these areas from human settlements and associated food system activities. Figure 10 shows the significant areas of human settlement expansion within and around the Southern Kenya Northern Tanzania (SOKNOT) transboundary conservation area (TFCA) – see Box 3. More recent settlements are visible for example, at Mugumu in Western Tanzania towards the shore of Lake Victoria. This is confirmed by reference to the most recent Google Earth imagery. However, human settlement expansion is significantly more pronounced outside SOKNOT, possibly reflecting the high levels of protection across this landscape. Some of the settlements may be related to the emergence of a tourism industry around Mount Kilimanjaro and hence may not pose a direct threat to the protected areas. However, there will inevitably be additional pressures on the environment from urban sprawl and pollution from economic activities and transport.

Figure 10. *Human settlement expansion in SOKNOT (Southern Kenya Northern Tanzania), 2000 to 2015*



Source: Joint Research Centre - JRC - European Commission, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2021. Global Human Settlement Layer: Population and Built-Up Estimates, and Degree of Urbanization Settlement Model Grid. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/h4154f0w. Accessed 10/10/23.

35 This is the latest date for which spatial data is available in the public domain.

BOX 3. SOUTHERN KENYA NORTHERN TANZANIA (SOKNOT) TFCA

The SOKNOT transboundary conservation area (TFCA) covers an area of 134,000 km². It includes the following three ecosystems: Mara-Serengeti; Amboseli-West Kilimanjaro and Tsavo-Mkomazi and the areas that connect them. The landscape is famous for its variety of internationally renowned and iconic conservation areas. These include three UNESCO World Heritage Sites (Ngorongoro, Serengeti, Kilimanjaro), a Ramsar Site (Lake Natron), a UNESCO Biosphere Reserve (Amboseli), four important bird habitats (Lake Natron, Loita, Amboseli, West Kilimanjaro) as well as 39 community conservancies, three Wildlife Management Areas, and the 'seventh wonder of the world' (Mara-Serengeti). These reflect its extraordinary biodiversity and tourism value. The landscape is home to millions of wild animals including threatened and endangered species such as elephant, black rhino, lion, cheetah, hirola and African wild dog. The annual wildlife migrations between Masai Mara and Serengeti are among the largest worldwide and a main tourist attraction.

Source: https://www.wwf.or.tz/our_work/our_priority_landscapes/southern_kenya_northern_tanzania_landscape/, accessed 11 October 2023

CROPLAND EXPANSION

Population increase contributes to increasing food demand, which can be met from domestic production or imports. Domestic production can be increased through agricultural intensification, cropland expansion or both. Hence cropland expansion is (part of) a food system response to increasing food demand. As crops are also exported, cropland expansion can also be the result of increasing agricultural exports – but as outlined in section 3.2.1, the proportion of cropland expansion for the production of export crops is relatively small. Figure 11 adds cropland expansion[36] to Figure 9, thus showing the spatial distribution of these interrelated, but not normally overlapping drivers.

© WWF / Simon Rawles

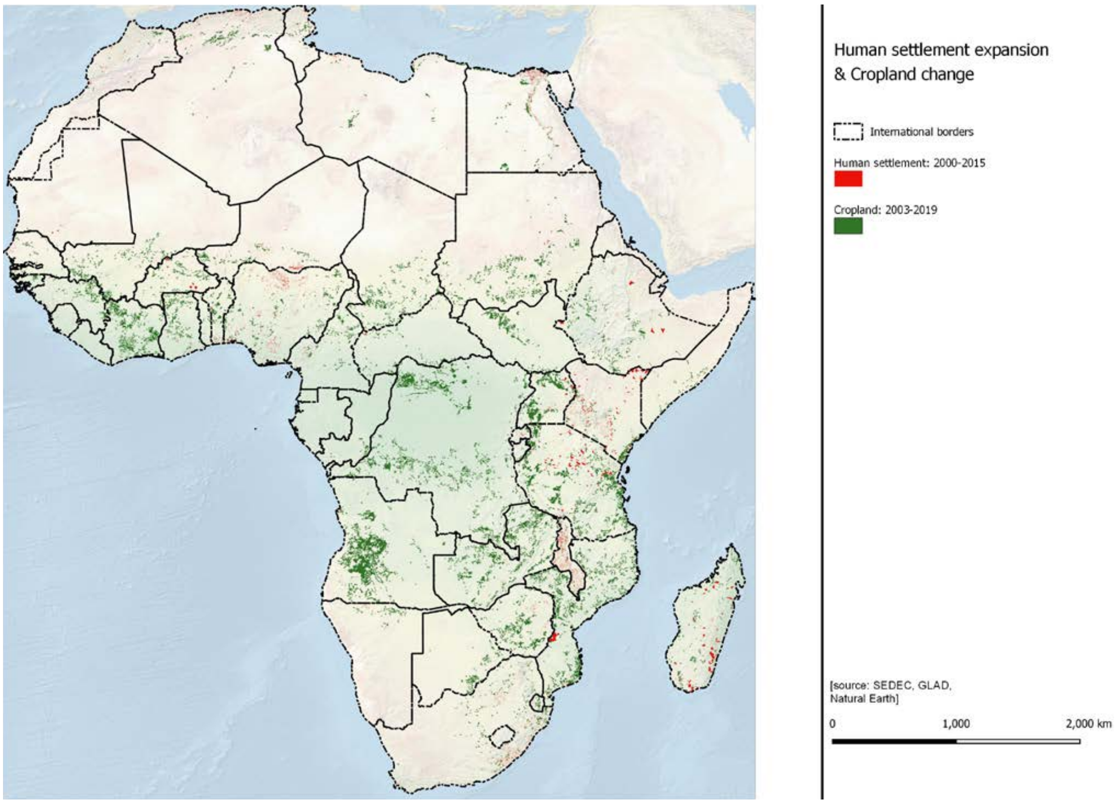
Figure 11 shows that there has been significant recent cropland expansion in most parts of SSA, with a concentration in West Africa, Angola, DRC, Mozambique, the Great Lakes region, coastal Kenya, South Sudan, and Zambia. Cropland expansion has a significantly larger spatial footprint than the increase in human settlements.

Areas of cropland expansion are not expected to overlap with areas of urban growth, as the two land uses are mutually exclusive. However, Figure 11 shows that they can happen in relative proximity, with urban growth frequently associated with cropland expansion within the same country. This may be as a result of high population density being associated with high levels of urban growth and high food demand, driving agricultural expansion.

Exceptions include the Southern parts of Sudan and Chad, and parts of Angola (where cropland expansion has not been accompanied by urbanization), and along the south-eastern coastal belt South Africa (where cropland expansion has been low despite a growing urban population). The extent to which population increase is accompanied by cropland expansion also depends on (a) the potential for further agricultural expansion (in particular, suitability for crop production), and (b) the productivity of existing and newly developed cropland, with higher yields enabling feeding more people on less land. This might explain relatively low increases in cropland expansion in Ethiopia, despite high population densities, with crop yields there having increased significantly during the past two decades.

36 The map does not include tree plantations such as oil palm, nor does it include temporary farmland (from shifting cultivation). Hence it does not include agricultural expansion for export crops such as cocoa, oil palm, cashew etc., nor does it include all land under shifting cultivation. This means that this data, which is derived from the analysis of satellite images, underrepresents cropland expansion overall. Other datasets are available but either only cover specific countries or are mapped at a coarser spatial resolution and for a shorter period (for example the Copernicus Global Land Service (CGLS) https://land.copernicus.eu/global/products/lc).

Figure 11. *Human settlement expansion (2000 to 2015) and cropland expansion (2003 to 2019) in Africa*



Sources:

(i) Human settlement expansion: Joint Research Centre - JRC - European Commission, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2021. Global Human Settlement Layer: Population and Built-Up Estimates, and Degree of Urbanization Settlement Model Grid. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). [*https://doi.org/10.7927/h4154f0w*](https://doi.org/10.7927/h4154f0w)

(ii), Cropland extent: Pittman, K., Hansen, M.C., Becker-Reshef, I., Potapov, P.V. and Justice, C.O., 2010. Estimating global cropland extent with multi-year MODIS data. Remote Sensing, 2(7), pp.1844-1863. Joint Research Centre (JRC), European Commission, and Center for International Earth Science Information Network (CIESIN), Columbia University. 2021. (Accessed 10 October 2023.

(iii) Natural Earth (Made with Natural Earth. Free vector and raster map data @ naturalearthdata.com)

Notes:

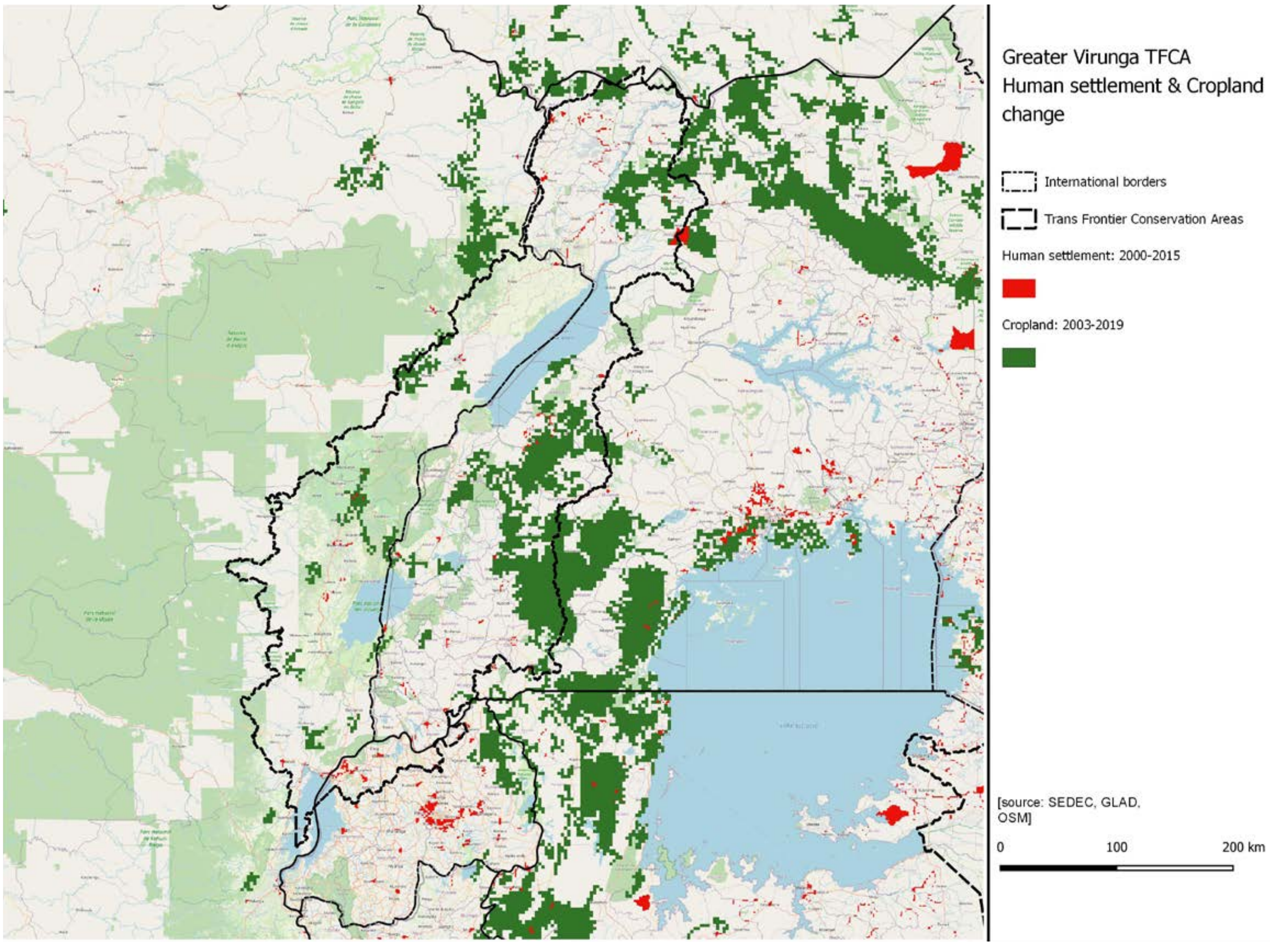
The data employs 250m MODIS (MODerate Resolution Imaging Spectroradiometer) satellite data to map global cropland extent. Overall results indicate that the MODIS layer best depicts regions of intensive broadleaf crop production (maize and soybean), with lower accuracy for areas of rice production. For regions of low agricultural intensification, such as parts of Africa, estimates of cropland extent are poorly characterized, regardless of crop type. The results reflect the value of MODIS as a generic global cropland indicator for intensive agriculture production regions, but with lower sensitivity in areas of low agricultural intensification. This means that in some areas on Figure 11, human settlement and cropland expansion overlap, probably resulting from a relatively low probability of classification accuracy for cropland, especially in areas of low agricultural intensity.

Data on cropland distribution was downloaded from the University of Maryland (GLAD) site (Potapov et al. 2022). Cropland is defined as land used for annual and perennial herbaceous crops for human consumption, forage (including hay), and biofuel. Perennial woody crops, permanent pastures, and shifting cultivation are excluded from the definition. The fallow length is limited to four years for the cropland class. The cropland mapping was done using the consistently processed Landsat satellite data archive from 2000 to 2019. The crop mapping was performed in four-year intervals (2000-2003, 2004-2007, 2008-2011, 2012-2015, and 2016-2019). There is one cropland layer per epoch (five layers total), with the file name referring to the last year of the interval (2003, 2007, 2011, 2015, and 2019). The map shows the second epoch (2015-2019).

When zooming in to the Greater Virunga Landscape (GVL - Box 4) in Figure 12, the threats to this unique landscape (Box 4) from agricultural expansion becomes clear, with significant cropland expansion in the northern and Eastern parts. However, there have been only limited increases in human settlements, possibly indicating expansion and agricultural intensification from existing centers of population as opposed to encroachment into new areas.

The map also shows that, outside GVL, there has been significant expansion of cropland along the shores of Lake Victoria, including very close to the urban centers of Kampala and Entebbe. This might indicate an expansion of peri-urban agriculture.

Figure 12. *Human settlement expansion (2000 to 2015) and cropland expansion (2003 to 2019) in the Greater Virunga Landscape*



Sources:

(i) Urban expansion: Joint Research Centre - JRC - European Commission, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2021. Global Human Settlement Layer: Population and Built-Up Estimates, and Degree of Urbanization Settlement Model Grid. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). *https://doi.org/10.7927/h4154f0w*

(ii) Cropland extent: Pittman, K., Hansen, M.C., Becker-Reshef, I., Potapov, P.V. and Justice, C.O., 2010. Estimating global cropland extent with multi-year MODIS data. Remote Sensing, 2(7), pp.1844-1863. Joint Research Centre (JRC), European Commission, and Center for International Earth Science Information Network (CIESIN), Columbia University. 2021. (Accessed 10 October 2023),

(iii) Natural Earth (Made with Natural Earth. Free vector and raster map data @ naturalearthdata.com)

BOX 4. GREATER VIRUNGA LANDSCAPE (GVL)

This rich landscape in Central Africa is home to the world's last two remaining populations of mountain gorillas. This is one of the most biologically diverse parts of the planet. Its combination of ancient tropical forests, ice capped mountains, active volcanoes, savannah, swamps, and wetlands is home to elephants, hippos, unique birds, and rare plants. But Virunga-Bwindi's most famous residents are its critically endangered mountain gorillas. Found at the point where East Africa meets Central Africa, the Greater Virunga Landscape is a spectacular mosaic of wildly diverse landscapes from steamy papyrus swamps to permanent glaciers and from savannahs and forests to active volcanoes. The Virunga-Bwindi landscape is spread across the borders of three countries in central Africa: Democratic Republic of the Congo (DRC), Uganda and Rwanda.

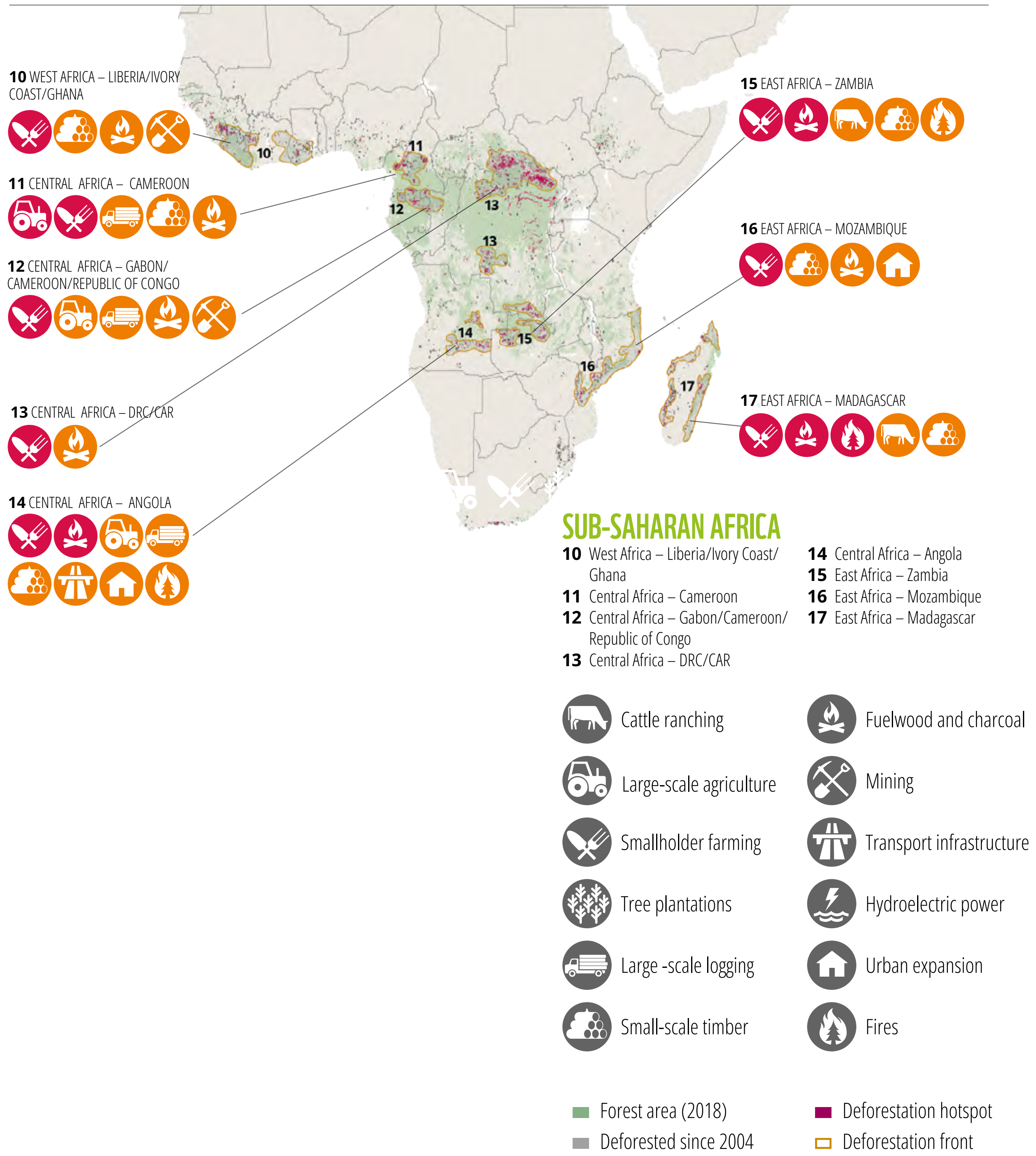
Running down the borders of three countries, the Virunga Bwindi landscapes range from dense, lush forests to dry savannahs, volcanic lava plains and snow-capped mountains. Virunga-Bwindi is the only place in the world where one can find the critically endangered mountain gorilla – divided into groups almost equally between the Virunga mountains and Bwindi Impenetrable National Park.

Source: https://africa.panda.org/our_work/priority_landscapes/

DEFORESTATION

Another lens to consider when looking at agri-food system impacts is deforestation, which is both a food system response (related to cropland expansion) and impact. Considering eight "deforestation fronts" in SSA (Figure 13), smallholder farming was the leading cause of deforestation in seven, with large-scale agriculture being the leading cause in only one (Central Africa). So, whilst there are many drivers of forest loss, in particular logging for timber and charcoal production – and these may well be the main drivers in specific locations – smallholder agriculture is responsible for forest loss in much of the continent (see also section 3.2.1).

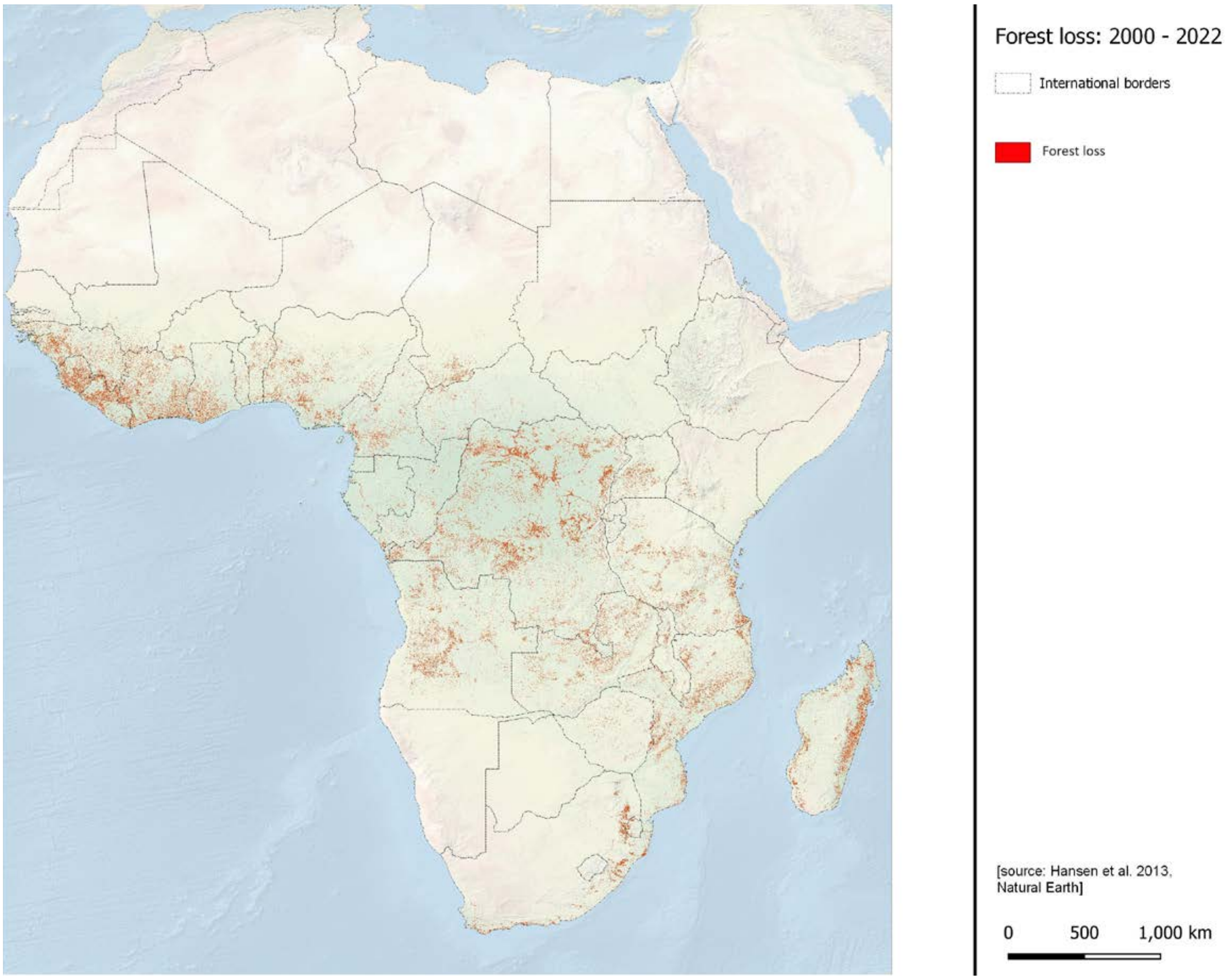
Figure 13. Main drivers of deforestation along 8 deforestation fronts in Sub-Saharan Africa



Source: Pacheco et al. 2021

The spatial distribution of forest loss (between 2000 and 2022) is shown in Figure 14, with a concentration in West Africa, the Congo basin and in Madagascar.

Figure 14. *Forest loss in Africa, 2000 to 2022*

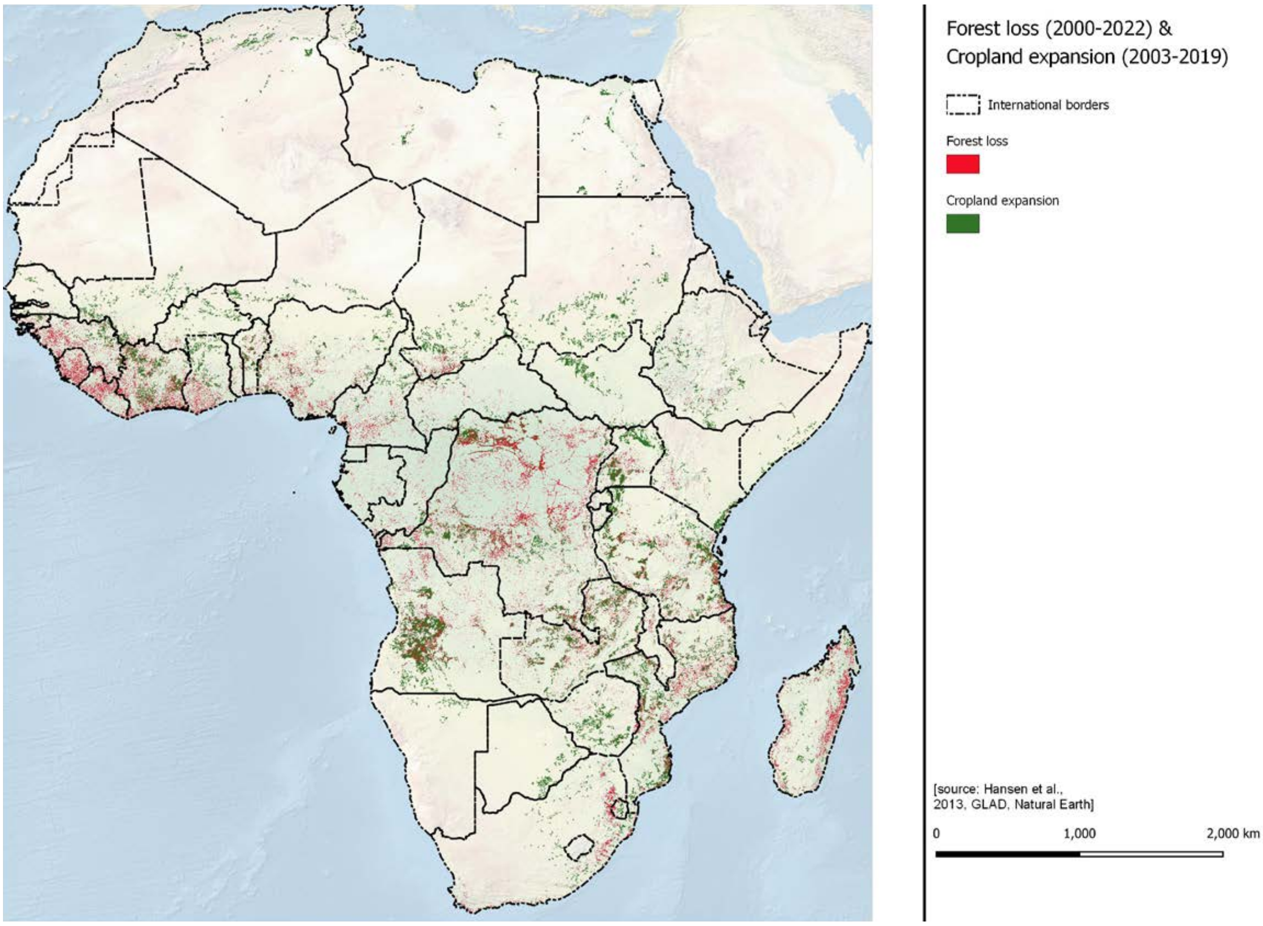


Source: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850-53

Note:

- The Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland, in partnership with Global Forest Watch (GFW), provides annually updated global-scale forest loss data, derived using Landsat time-series imagery.
- The data used here are forest loss during the period 2000-2022, defined as a stand-replacement disturbance, or a change from a forest to non-forest state. Encoded as either 0 (no loss) or else a value in the range 1-20, representing loss detected primarily in the years 2001-2022, respectively. In this case all years of change (1 – 20) are displayed cumulatively. Forest loss is defined as a stand-replacement disturbance or the complete removal of tree cover canopy at the Landsat pixel scale.

Figure 15. *Cropland expansion (2003 to 2019) and forest loss (2000 to 2022) in Africa*



Sources:

(i) Forest loss: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850-53;

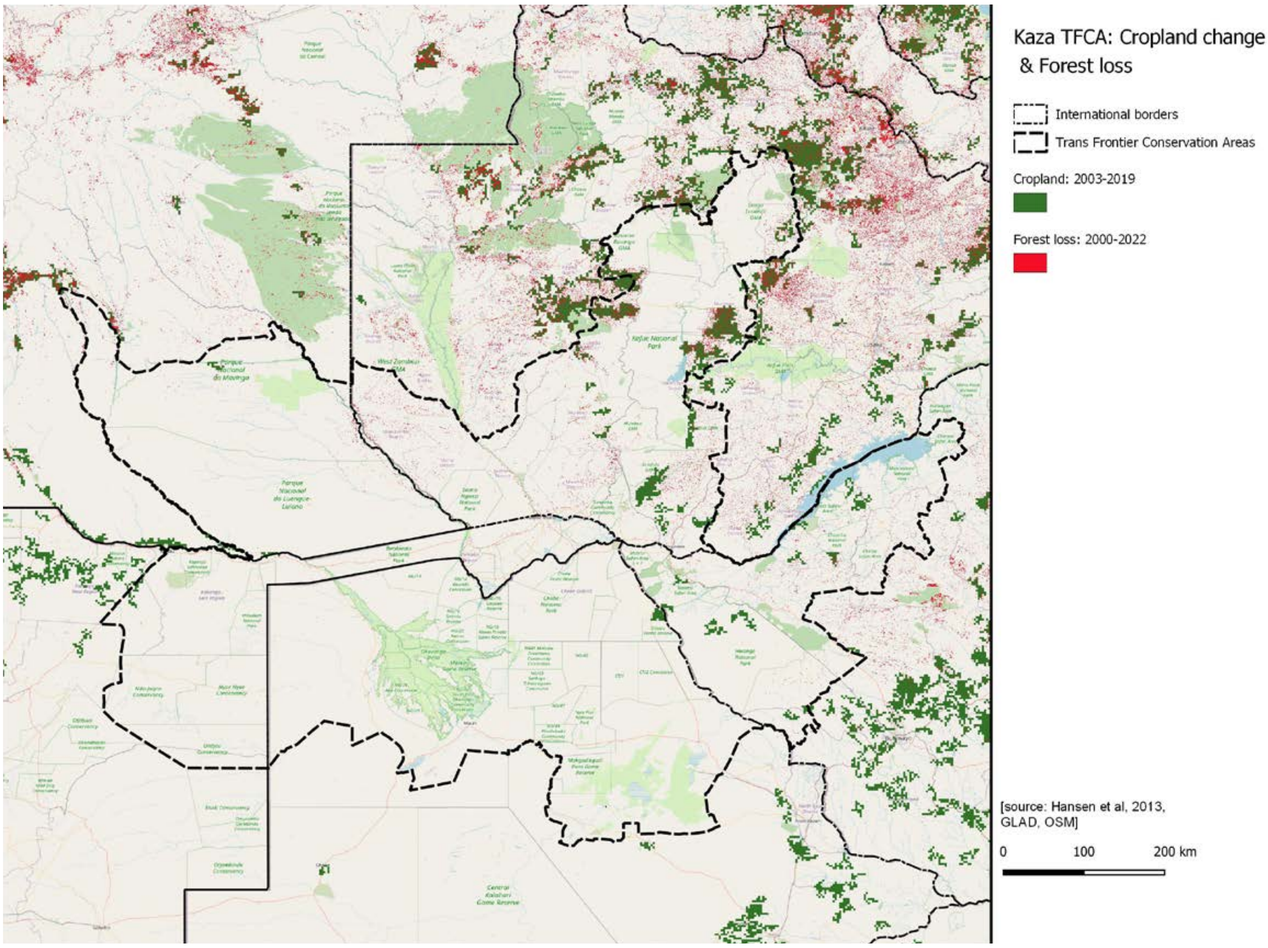
(ii), Crop expansion: Pittman, K., Hansen, M.C., Becker-Reshef, I., Potapov, P.V. and Justice, C.O., 2010. Estimating global cropland extent with multi-year MODIS data. Remote Sensing, 2(7), pp.1844-1863. Joint Research Centre (JRC), European Commission, and Center for International Earth Science Information Network (CIESIN), Columbia University. 2021. (Accessed 10 October 2023].

Figure 15 shows both forest loss and cropland expansion, with significant overlaps (shown in blue) in particular in the northern part of DRC and in western Angola (indicating that forest loss here is mostly driven by cropland expansion).

However, forest loss also occurred outside areas mapped as cropland expansion, e.g., in Eastern Madagascar. Whilst this will partly be explained by the different time periods of available data and misclassification of satellite imagery, it also indicates that in these areas, forest loss may be the result of factors other than cropland expansion, such as logging, charcoal production, commercial (non-food) tree crops, forest fires etc.

Some of the areas with high levels of cropland expansion are concentrated in the savannah zones of Africa, which are not classified as forests in the data used for this report. These include Angola, the Guinea savannah zone of West Africa, and areas in Southern Africa (Zimbabwe, Zambia and Mozambique). Hence the loss of tree cover in these areas, largely as a result of cropland expansion, is underrepresented in this map.

Figure 16. *Cropland expansion (2003 to 2019) and forest loss (2000 to 2022) in the Kavango- Zambezi (KAZA) Transfrontier Conservation Area*



Sources: Same as Figure 15

Notes: Cropland expansion is derived from medium-resolution satellite imagery with a spatial resolution (pixel size) of 250m from the MODIS (MODerate Resolution Imaging Spectroradiometer) sensor. By contrast, forest loss is based on much finer resolution Landsat data, hence the difference in the apparent pixel size.

Zooming into the Kavango- Zambezi TFCA (Figure 16 and Box 5), cropland expansion and forest loss are concentrated in the northern part of Kaza, threatening this unique landscape. Cropland expansion is also happening in the SW and SE of Kaza, but because of the definition of forest in the data used, any removal of woodlands and shrubs in these drier areas would not show up as forest loss (similar to the West African savannah – see Figure 15)

BOX 5. KAVANGO- ZAMBEZI (KAZA) TRANSFRONTIER CONSERVATION AREA

The Kavango- Zambezi Transfrontier Conservation Area (KAZA TFCA, or KAZA for short) is a large-scale, land-based conservation project covering contiguous parts of Angola, Botswana, Namibia, Zambia, and Zimbabwe. KAZA is the world's largest TFCA, roughly the size of France or the size of Zimbabwe and Malawi combined. Vibrant, diverse communities of around 2.7 million people reside within its boundaries, mostly concentrated along the Okavango and Zambezi Rivers. KAZA's biodiversity and freshwater supply live in delicate balance.

Maintaining this balance is critical for transboundary ecological connectivity, the flow of benefits to communities, and the protection of viable wildlife populations, including 225,000 elephants – the largest elephant population in the world and around half of Africa's total, 15% of the world's wild cheetahs, 15% of Africa's lions, and 25% of Africa's wild dogs. Wildlife in the KAZA region face threats from the intertwined issues of increasing poaching, habitat loss, fragmentation and degradation, human-wildlife conflict, insufficient incentives for communities to protect wildlife, increasing impacts of climate change, increasing human congregation in areas of high conservation value, and human infrastructure development along rivers and corridors.

Source: https://www.wwfnamibia.org/programmes/wwf_in_kaza/

4.3. IMPACTS ON KEY BIODIVERSITY AREAS

In this section, the focus is on overlaps of recent human settlement expansion, cropland expansion, and deforestation, with important ecosystems on the continent. Key Biodiversity Areas (KBAs) were used to indicate biodiversity concentration. KBAs are considered the most important places in the world for species and their habitats.[37]

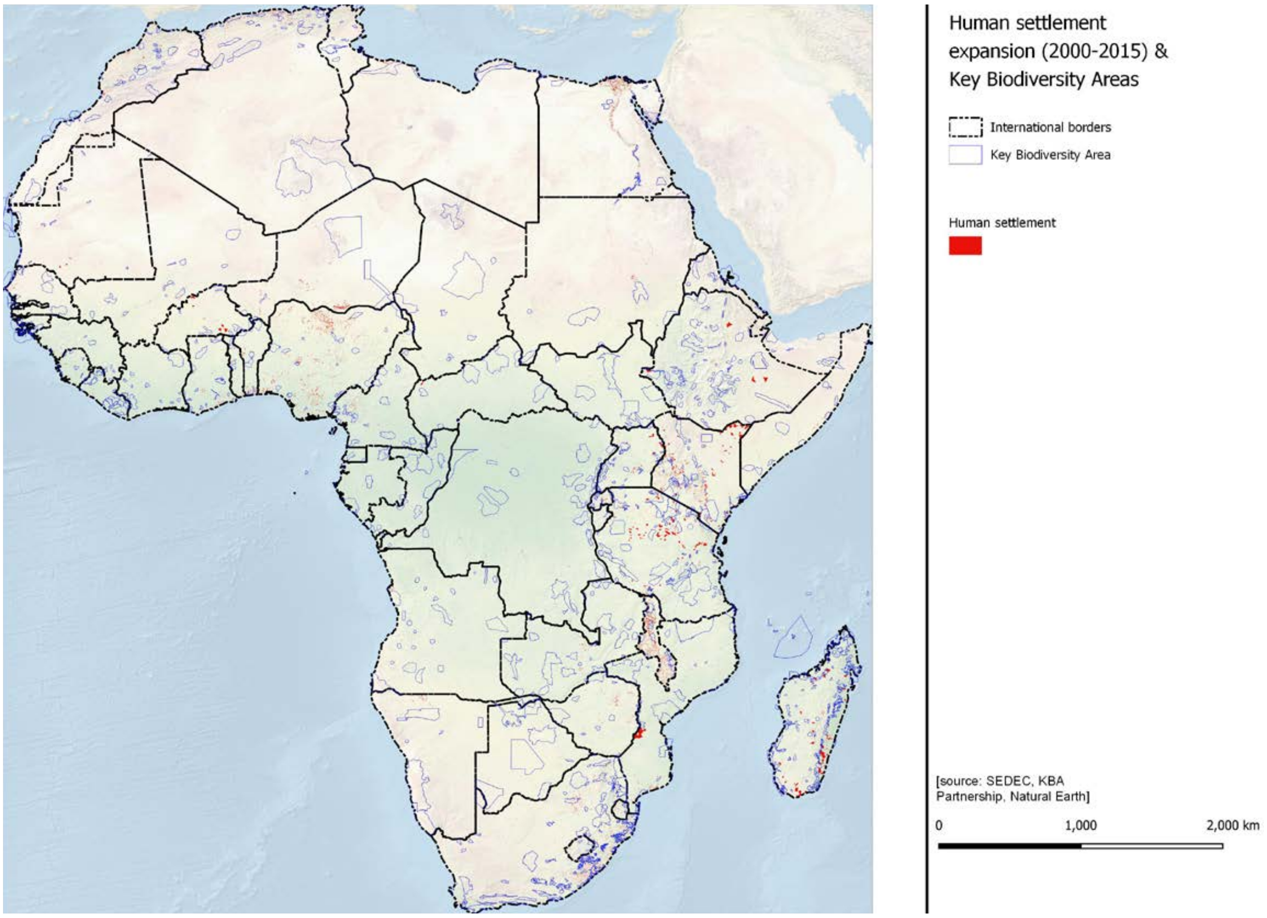
Overlaying the spatial pattern of food system driver proxies (human settlement and cropland expansion) with boundaries of KBAs provides an indication of the extent to which these areas have been particularly affected by land use change in the recent past and may still be under threatened in the future. Figure 17 shows the pattern for the African continent overall, with relatively limited urban expansion overall, and none that appears to affect KBAs.

However, at this scale, it is difficult to identify the specific KBAs that may potentially be under threat from human settlement expansion. Figure 18 therefore zooms in to Malawi, a country with a high population density and high rate of urbanization. It shows that the expansion of human settlements has almost exclusively happened outside KBAs, partly because KBAs overlap to some extent with protected areas, where settlement development is prohibited.

Settlement expansion is possibly easier to contain than cropland expansion, with a higher level of scrutiny and higher proximity to law enforcement agents in urban areas.

37 A Global Standard for the Identification of Key Biodiversity Areas established a science-based process for KBA identification, founded on a standard methodology. It builds on four decades of experience in identifying important sites for different subsets of biodiversity, including Important Bird and Biodiversity Areas, Alliance for Zero Extinction sites, Important Plant Areas, Prime Butterfly Areas, and key biodiversity areas for freshwater and marine species. The KBA Standard harmonizes these existing approaches and provides a common currency for the identification and safeguard of sites important for threatened biodiversity, geographically restricted biodiversity, ecological integrity and ecosystem intactness, biological processes, and irreplaceability in terrestrial, inland water, and marine environments.
Sites qualify as global KBAs if they meet one or more of 11 criteria, clustered into five higher level categories: threatened biodiversity, geographically restricted biodiversity, ecological integrity, biological processes, and irreplaceability. See https://www.keybiodiversityareas.org/working-with-kbas/proposing-updating/criteria for a detailed list of KBA criteria. The KBA criteria can be applied to species and ecosystems in terrestrial, inland water, and marine environments, and may be applied across all taxonomic groups (other than micro-organisms).

Figure 17. *Human settlement expansion (2003 to 2019) and Key Biodiversity Areas (KBAs) in Africa*

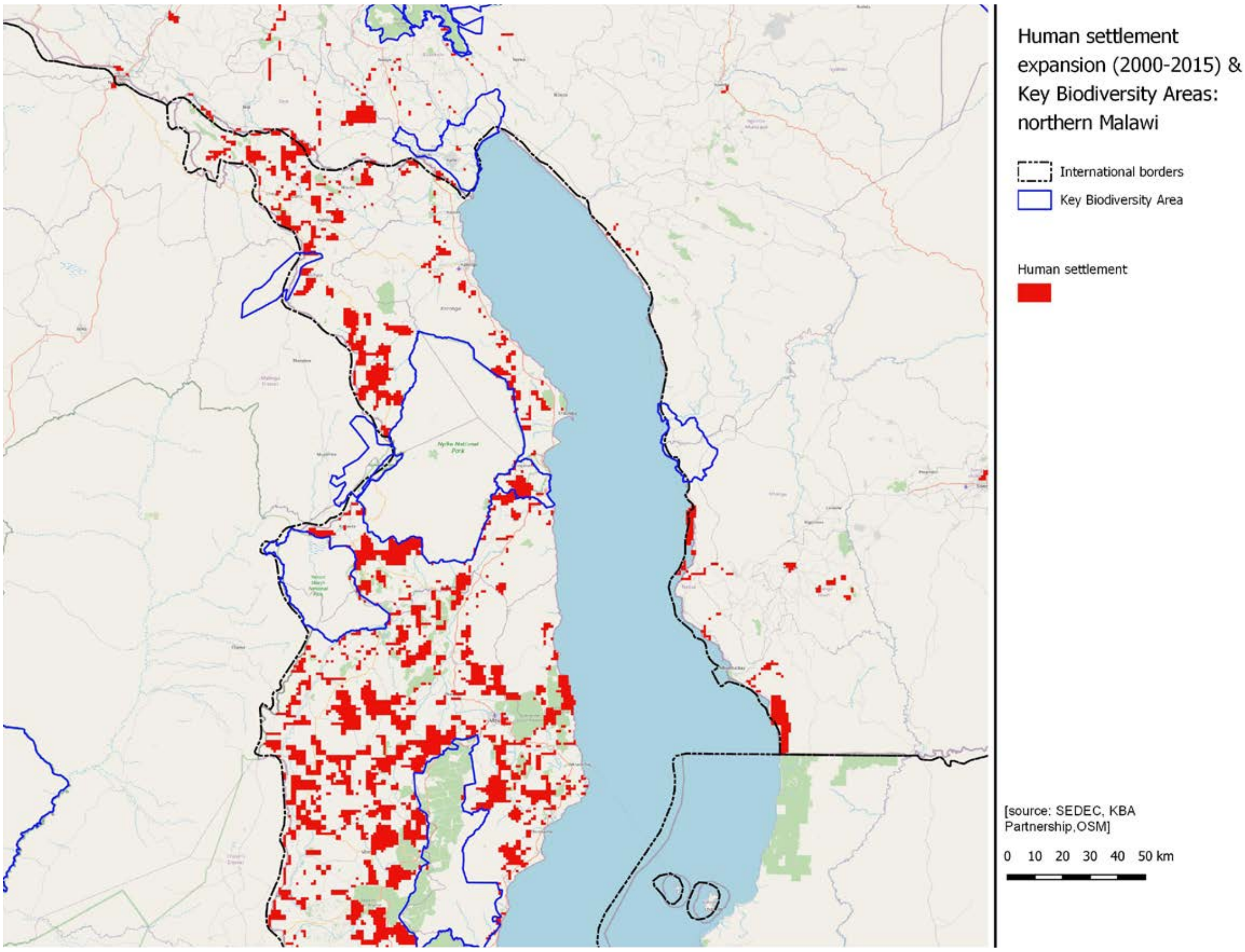


Sources:

(i) Urban expansion; Joint Research Centre - JRC - European Commission, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2021. Global Human Settlement Layer: Population and Built-Up Estimates, and Degree of Urbanization Settlement Model Grid. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). [https://doi.org/10.7927/h4154f0w;](https://doi.org/10.7927/h4154f0w)

(ii) Key Biodiversity Areas; BirdLife International ([year e.g. 2017]). The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Rewild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and WWF. Available at www.keybiodiversityareas.org. [Accessed 10 October 2023].

Figure 18. *Human settlement expansion (2003 to 2019) and Key Biodiversity Areas (KBAs) in Northern Malawi*

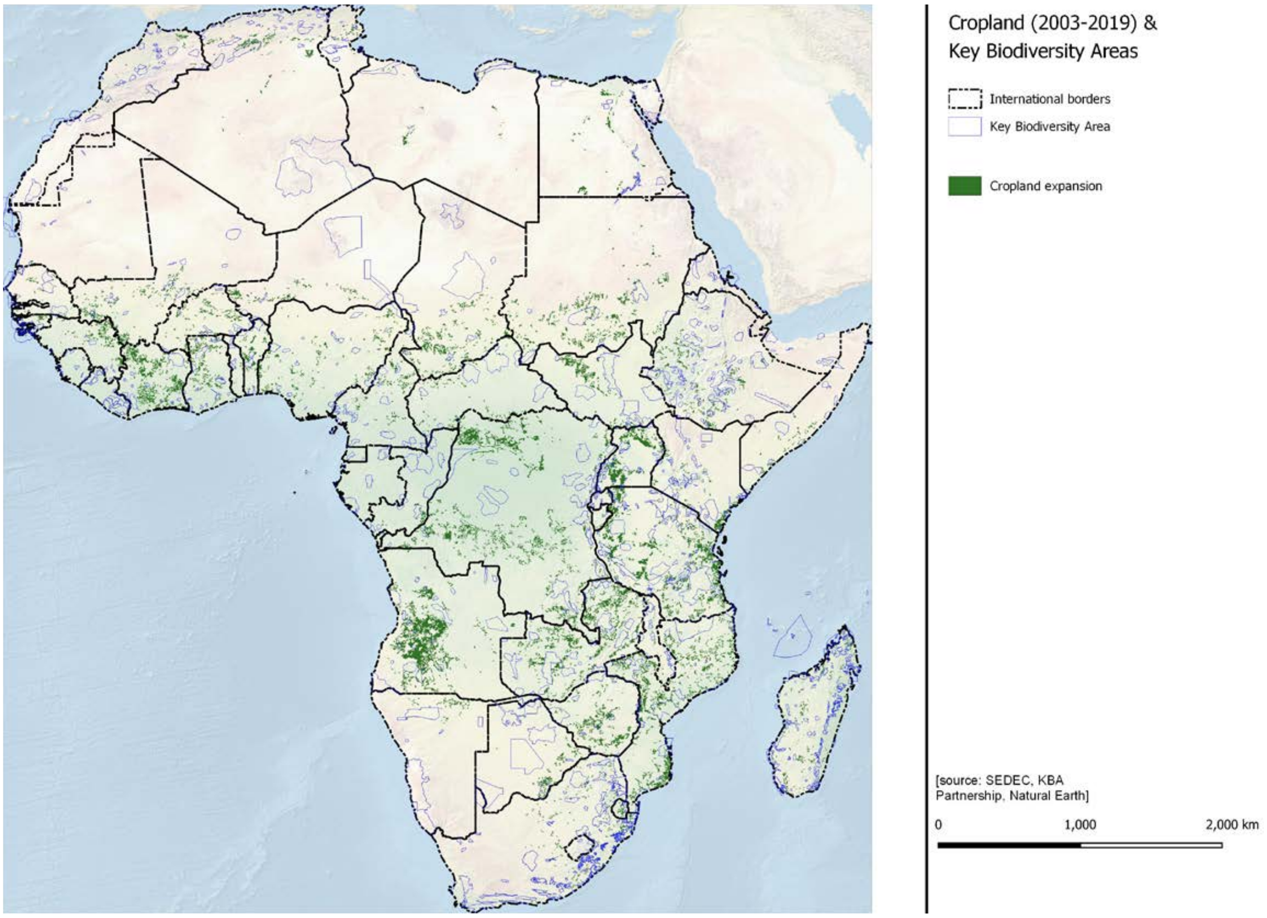


Source:

(i) Urban expansion. Joint Research Centre - JRC - European Commission, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2021. Global Human Settlement Layer: Population and Built-Up Estimates, and Degree of Urbanization Settlement Model Grid. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/h4154f0w. Accessed 10 October 2023]

(ii) Key Biodiversity Areas. BirdLife International ([year e.g. 2017]). The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Rewild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and WWF. Available at www.keybiodiversityareas.org. [Accessed 10 October 2023].

Figure 19. Cropland expansion (2003 to 2019) and Key Biodiversity Areas in Africa



Sources of data:

(i), Crop expansion; Pittman, K., Hansen, M.C., Becker-Reshef, I., Potapov, P.V. and Justice, C.O., 2010. Estimating global cropland extent with multi-year MODIS data. Remote Sensing, 2(7), pp.1844-1863. Joint Research Centre (JRC), European Commission, and Center for International Earth Science Information Network (CIESIN), Columbia University. 2021

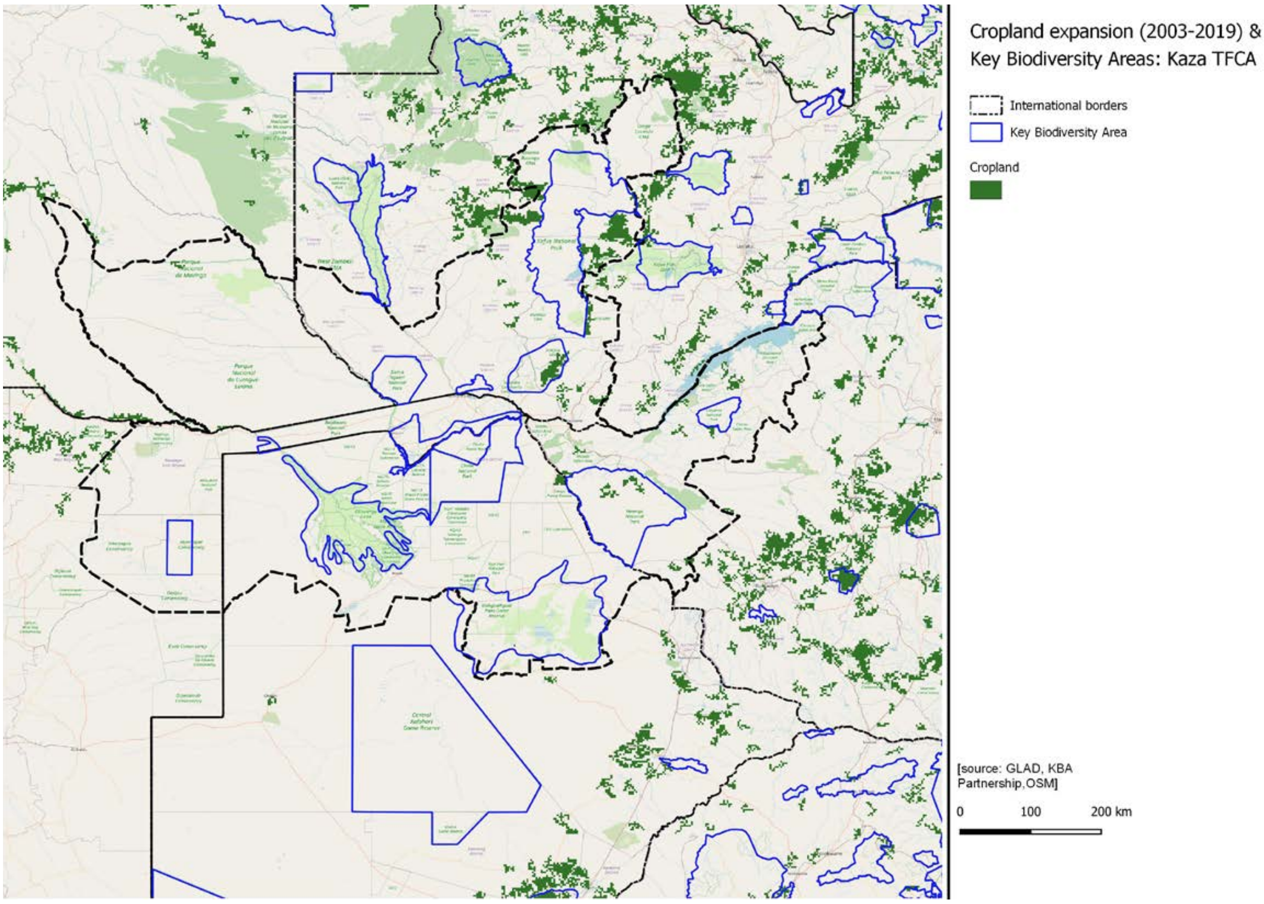
(ii) Key Biodiversity Areas; BirdLife International, The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Rewild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and WWF. Available at www.keybiodiversityareas.org. [Accessed 10 October 2023].

Figure 19 shows that KBAs have been more affected by cropland expansion in the past than by human settlement expansion. As is to be expected, this applies in particular to those KBAs located in zones that are suitable for crop production – with no or hardly any cropland expansion into KBAs located in the Sahara or the deserts of Southern Africa.

To gain an understanding of the specific dynamics and risks in a particular context or location, it is again necessary to zoom in to country- or landscape level, where agroecological, socio-economic and policy contexts interact to produce a particular pattern.

Such case studies have been undertaken for different parts of the African continent (e.g., Balima et al. for West Africa or Belay et al. 2022 for parts of the Afromontane area of Ethiopia). The percent of KBAs affected by cropland expansion by country is shown in Annex 1, with significant differences between countries and regions. Figure 20 shows considerable cropland expansion in the KAZA TFCA, especially along the margins in the Northwestern Province of Zambia. Isolated KBAs are affected by this expansion – in particular the game management area south of Kafue National Park in Zambia. Cropland expansion also affects the connectivity of KBAs.

Figure 20. *Cropland expansion (2003 to 2019) and Key Biodiversity Areas within the KAZA TFCA*

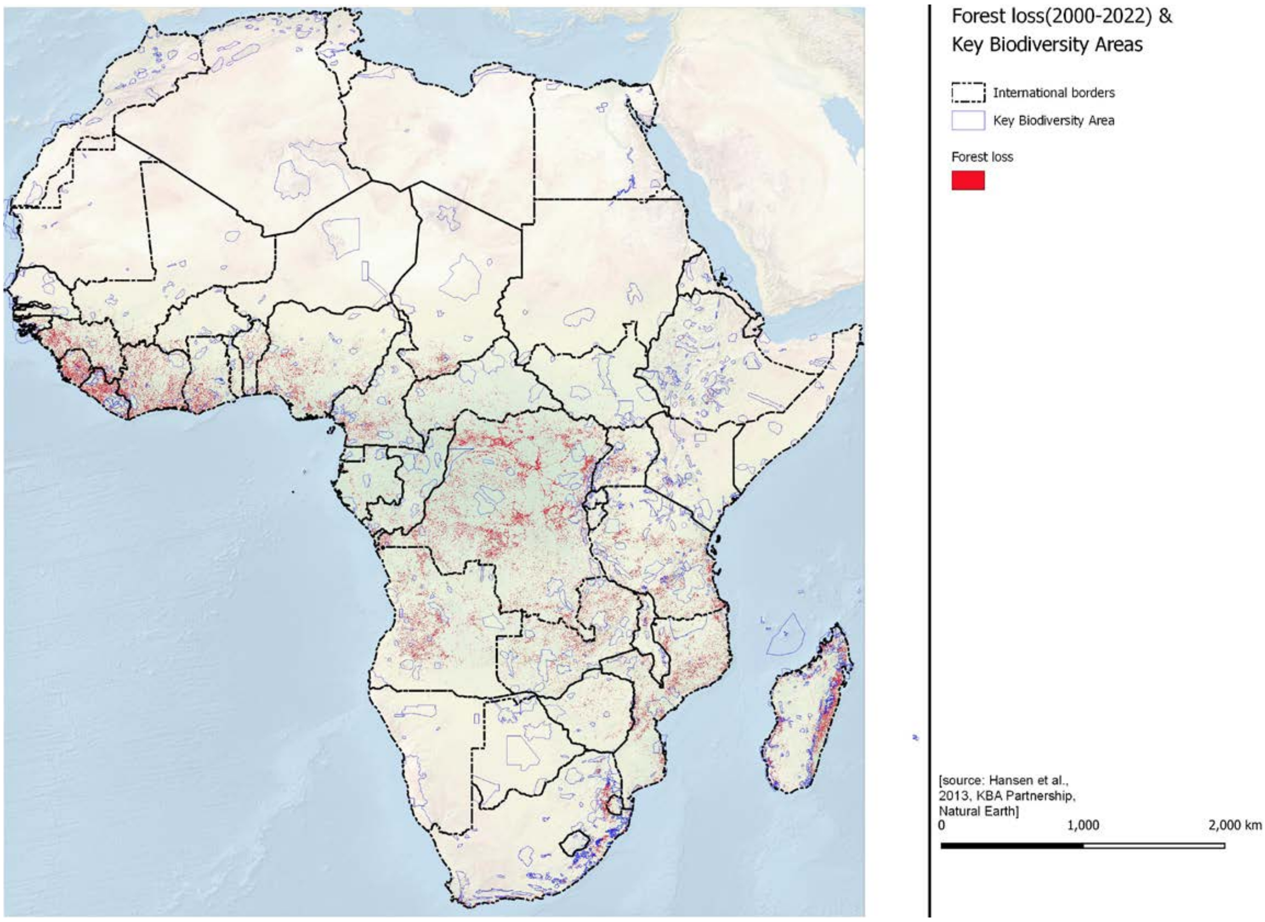


Source:

(i) Crop expansion; Pittman, K., Hansen, M.C., Becker-Reshef, I., Potapov, P.V. and Justice, C.O., 2010. Estimating global cropland extent with multi-year MODIS data. Remote Sensing, 2(7), pp.1844-1863. Joint Research Centre (JRC), European Commission, and Center for International Earth Science Information Network (CIESIN), Columbia University. 2021

(ii), Key Biodiversity Areas; BirdLife International, The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Rewild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and WWF. Available at www.keybiodiversityareas.org. [Accessed 10 October 2023].

Figure 21. *Forest loss (2000 to 2022) and Key Biodiversity Areas in Africa*



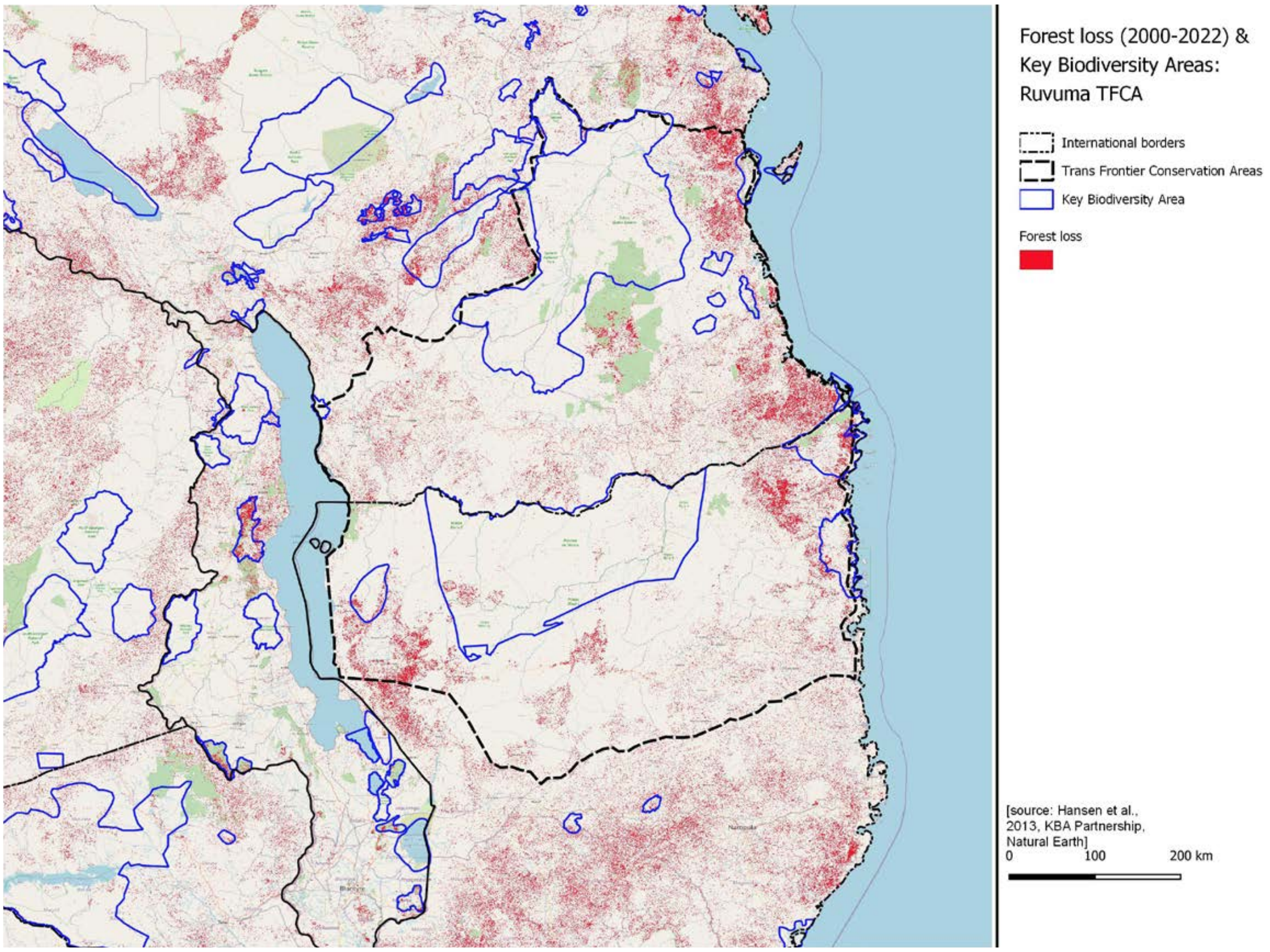
Sources of data:

(i) Forest loss: Hansen. M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850-53

(ii) Key Biodiversity Areas: BirdLife International, The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Rewild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and WWF. Available at www.keybiodiversityareas.org. [Accessed 10 October 2023].

To conclude this chapter on the spatial distribution of food system impacts, Figure 21 shows where forest loss (largely associated with smallholder farming) happened within KBAs in Africa. Focusing on the Ruvuma TFCA (Figure 22), it becomes clear that extensive areas of forest loss have occurred here, especially in the coastal region of Mozambique, with many of the smaller KBAs affected. Whilst agricultural expansion will have played a role, forest loss is also driven by charcoal production, supplying households in the expansion coastal towns.

Figure 22. *Forest loss (2000 to 2022) and Key Biodiversity Areas within the Ruvuma landscape*



Sources of data:

(i) Forest loss: Hansen. M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850-53

(ii) Key Biodiversity Areas; BirdLife International, The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Rewild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and WWF. Available at www.keybiodiversityareas.org. [Accessed 10 October 2023].

BOX 6. RUVUMA TRANSBOUNDARY LANDSCAPE

Within the Landscape there are over 2,000 species of plants, over 430 species of birds, and 60 species of mammals. Key species include African elephant, black rhino, African wild dog, lion, leopard and cheetah among others. Notably the elephant population in Ruvuma is the single largest population in East Africa and was once the second largest on the African continent. Thus, the landscape is important for Tanzania and Mozambique's tourism industry that is dependent on charismatic wildlife such as elephant, rhino and lion.

The landscape is also home to a population of over 8 million people, the majority of whom depend heavily on its natural resources. While the landscape already makes a sizeable contribution to the economy in Tanzania and Mozambique, through tourism, there is potential to improve that for the benefit of people and nature.

Source: https://www.wwf.or.tz/our_work/our_priority_landscapes/ruvuma_transboundary_landscape/

© Greg Armfield / WWF-UK

4. MOVING AWAY FROM "BUSINESS AS USUAL": EMERGING DECISION SPACES

1. DECISION SPACES FOR INFLUENCING THE FUTURE OF FOOD SYSTEMS DEVELOPMENT IN AFRICA

Sections 3 provides a bleak picture for Africa's ecosystems, with the impacts of food systems transformations likely to continue threating biodiversity and natural capital across the continent – if developments continue along a "business as usual" (BAU) trajectory. Such a trajectory shows high increases in food demand that are met partly via domestic food production and partly by agricultural imports. As agricultural productivity would increase only slowly in this scenario, increasing domestic production would necessitate the expansion of cropland. For countries relying heavily on exports of agricultural commodities, such as Cote d'Ivoire (cocoa) or Zimbabwe (tobacco), a BAU trajectory would mean increases in the production of agricultural commodities that are sold on the world market with minimum amounts of processing / value addition (Johnson et al. 2022). Without clear land use planning, pockets of agroecological and regenerative agriculture would be spread almost randomly between areas with extensive, traditional farming systems, and areas with high use of external inputs and mechanization. This would have significant negative impacts on ecosystems, contributing to decline in Africa's natural capital.

But these developments are not inevitable. There are political and investment choices that can be made now to steer away from this scenario, and to arrive at alternative, more desirable futures. These futures would need to optimize benefits for people and planet, providing for immediate human needs (food and income), whilst protecting the natural resources base on which human life depends. Transforming Africa's food system in such a direction would require actions on different fronts. Benton et al. (2021), who analyzed global food system impacts on biodiversity, identified three main levers for food system transformation:

1. **Dietary change.**[38] Benton et al. argue that, firstly, global dietary patterns need to converge around diets based more on plants, owing to the disproportionate impact of animal farming on biodiversity, land use and the environment. Such a shift would also benefit the dietary health of populations around the world and help reduce the risk of pandemics. At the same time, global food waste (which is at least partly associated with diets), and losses must be reduced significantly. Together, these measures would reduce pressure on resources including land, through reducing food demand.

2. **Setting aside land for biodiversity.** Secondly, more land needs to be protected and set aside for nature. The protection of land from conversion or exploitation is the most effective way of preserving biodiversity, so we need to avoid converting land for the opportunity to increase biodiversity. Restoring native ecosystems on spared agricultural land offers the opportunity to increase biodiversity.

3. **Adapting the way we farm the land.** Thirdly, we need to farm in a more nature-friendly, biodiversity-supporting way, limiting the use of harmful inputs and replacing monoculture with polyculture farming practices.

These levers apply to food systems globally and would need to be adapted to the specific context and needs of African countries, where a large proportion of the population is currently not enjoying an appropriate diet and living standard, nor access to the resources, knowledge and incentives needed to bring about the required changes to their farming practices.

Another attempt to identify levers and potential solutions, with a focus on land use competition, was made in the recent report from the World Resources Institute on the Global Land Squeeze (Searchinger et al. 2023). It proposes four areas of action: Produce, Protect, Reduce and Restore (Box 7). There is some overlap with Benton's levers: "Produce" includes the way we farm, "Protect" is about setting aside land for biodiversity, "Reduce" is about dietary change and tackling waste and losses to reduce demand.

These actions can be translated into nationally appropriate policy and investment choices, and the potential future impacts of these choices on agrifood systems can be explored using scenario development. Scenarios can be used to model potential future land use patterns, and decision makers can explore these patterns to identify appropriate actions (including the management of trade-offs between competing land use objectives).

38 See also WWF (2020) on the merits of plant-based diets.

BOX 7. POTENTIAL SOLUTIONS FOR THE GLOBAL COMPETITION FOR LAND

Produce: means to produce more land-based goods and services on the same land, including boosting agricultural productivity, increasing urban density, and producing more products per hectare affected while at the same time reducing GHG emissions and other environmental impacts.

Protect: means using these land-use efficiency gains to protect remaining forests and other native habitats.

Reduce: means reducing the demand for land and land-based products, such as reducing food loss and waste, shifting to plant-rich diets, and recycling paper.

Restore: means both improving damaged forests and habitats so that they provide the maximum benefits for climate and biodiversity and reforesting those agricultural lands that provide little food and have little improvement potential but that could be restored to healthy forests or other habitats. Over time, if agricultural land demand can be reduced even as the global population grows, larger restoration efforts become appropriate.

Source: Searching et al. 2023

Last, but not least, the WWF study "Solving the great food puzzle" (WWF 2022) identified 20 levers for food systems transformation at national level, which can together bring about significant changes in three key action areas that overlap again with those above: production, food loss and waste and diets.

Scenario development can be used to explore the effect of (individual or combinations of) such levers on potential plausible futures. However, the likely effectiveness of each lever will vary between countries and regions.

Table 4 includes the authors' (subjective) assessment of the relevance of the lever for the African continent (shading indicates particularly relevant levers).

Table 4. *Levers for food systems transformation*

NATURAL RESOURCES MANAGEMENT	**Optimize land-use**	Use all agricultural lands to their maximum potential including optimizing crop yields through better food production practices that more efficiently use water and fertilizers, preserve ecosystem functions, and contribute to resilient landscapes (supported by land use planning)
	Restore biodiversity	Develop and implement food production practices that restores biodiversity in active agricultural land and restores less productive areas to natural habitat for biodiversity conservation.
	Increase carbon storage	Develop and implement food production practices that increase carbon stores in soils and in above ground biomass.
	Increase diversity	Support the production and consumption of nutritious indigenous crops through agrobiodiverse cropping systems.

GOVERNANCE AND INSTITUTIONS	**Support smallholder farmers**	Redesign agricultural development and extension programs to provide financial assistance, infrastructure, and education to support farmers to grow and market nutritious and indigenous crops and access markets.
	Improve land tenure rights	Improve land tenure rights and develop actions that encourage collective ownership and indigenous land rights
	Strengthen national level commitments	Coordinate and strengthen national-level commitments on shifting to healthy diets, reducing food loss and waste, and scaling nature-positive food production.
	Raise ambition of National Dietary Guidelines	Develop National Dietary Guidelines that emphasize both human health and environmental sustainability and encourage a diverse consumption of foods including indigenous crops.
EDUCATION AND KNOWLEDGE	**Strengthen research and development**	Increase research and development opportunities in domestic universities and with food producers, into food production methods that support production of healthy foods using nature-positive food production practices.
	Improve data collection and measurement	Improve data collection and measurement of progress on national level commitments towards meeting health and environmental goals that are aligned with international health, climate, and biodiversity targets.
	Increase public awareness	Launch engaging and compelling mass media and behavior change communication campaigns about healthy eating and reducing food loss and waste.
	Promote traditional foods	Promote traditional food cultures associated with good nutrition by supporting and protecting traditional foods, providing information about traditional dishes and public awareness campaigns
TECHNOLOGY	**Adopt high-tech methods**	Adopt high-tech food production methods such as the sustainable use of non-conventional water sources and controlled environments for food production
	Develop infrastructure	Develop innovative infrastructure and post-harvest storage technologies, packaging and processing techniques for nutritious foods to reduce loss and waste of nutritious foods
	Develop alternative proteins	Develop and promote alternative proteins such as plant-based meat alternatives and algal species high in nutritional value
TRADE	**Support healthy food imports**	Design trade policies to prioritize the supply of nutritious foods over foods manufactured high in fats, sugars and salt
	Develop nature-positive supply chains	Develop trade policies that support nature-positive food production, such as trade agreements and traceability tools, and changes in markets
FINANCE	**Redirect subsidies to improve production**	Redirect agri-food subsidies from staple crops and harmful production practices to increasing nature-positive production of nutritious foods
	Finance school food and public procurement programs	Finance school food and public procurement programs that promote and enable supply and consumption of healthy and sustainable foods
	Provide financial incentives and taxes to improve consumption	Provide financial support that increases the availability, affordability and appeal of nutritious foods, and implement taxes that decrease the affordability of foods high in fats, sugars and salt

Source of levers: WWF 2022

Note: Shading indicates the authors' assessment of levers that are most relevant in Africa

It becomes clear that there are many interventions that national governments and other stakeholders can implement to bring about a food system transformation that reduces environmental impacts, whilst providing the food and income that their citizens depend on.

Challenges will include a lack of resources for the necessary investments, as well as the lobbying power of those who benefit from the status quo. Opportunities lie in an increasingly aware civil society and general public, who want to see changes that will safeguard the future of future generations.

2. SCENARIO DEVELOPMENT AS A TOOL TO EXPLORE DECISION SPACES

Scenario development is useful to tool to explore the potential future impacts of drivers resulting from choices made by governments, investors and other development actors now. These include policy and investment decisions and the instruments for implementing these. Several recent reports have outlined the scope of choices or levers with regards to food systems development. The specific combination of levers for a country or region depends of course on the specific context – hence an analysis of food system challenges and opportunities from an economic, social and environmental perspective must always come first.

There have been several attempts in the past to map out the decision spaces for agri-food systems by considering opposite constellations of the main uncertain drivers. These drivers tend to be related to governance, institutions, and policies, which have important impacts for food system trajectories and can be modified in the short to medium term.

For example, a study on "The future of food security, environments and livelihoods in Western Africa" carried out by the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS) in 2016 worked with regional experts to develop regional socioeconomic scenarios for West Africa's development, agriculture, food security and climate impacts[39]. They used two key drivers to frame the resulting four scenarios in Figure 23:

- Policy driver: The extent to which short-term or long-term priorities will be the focus of governance, and
- Dominant force: The extent to which state actors or non-state actors will be the driving force in the region.

Figure 23. *Four socio-economic scenarios have been developed by stakeholders in West Africa, structured around two axes of uncertainty: a) will short-term priorities or long-term priorities be the focus of governance and b) will state actors or non-state actors be the driving force in the region?*

Source: Palazzo et al. 2016

Dominant Force	Policy driver: Short-term priorities	Policy driver: Long-term priorities
State actors	Governments facilitate short-term gain: cash, carbon and calories	A slow and painful transition to sustainable states
Non-state actors	Ungoverned, quick and chaotic development; dealing with crises at the expense of investment	A struggle between civil society and the private sector that is ultimately productive

39 Similar studies were carried out for other parts of Africa -see https://ccafs.cgiar.org/outcomes/national-climate-agriculture-and-socio-economic-development-policies-and-plans-formulated-use for details.

Such scenarios provide useful entry points to explore decision spaces that can lead to different outcomes from BAU. They can also inform quantitative modeling (using the IMPACT and GLOBIOM[40] models) to analyze interactions and tradeoffs between different outcomes.

Other examples of the use of scenarios for exploring the future of food systems development in Africa are shown in Table 5 below.

Table 5. *Scenarios for African food systems*

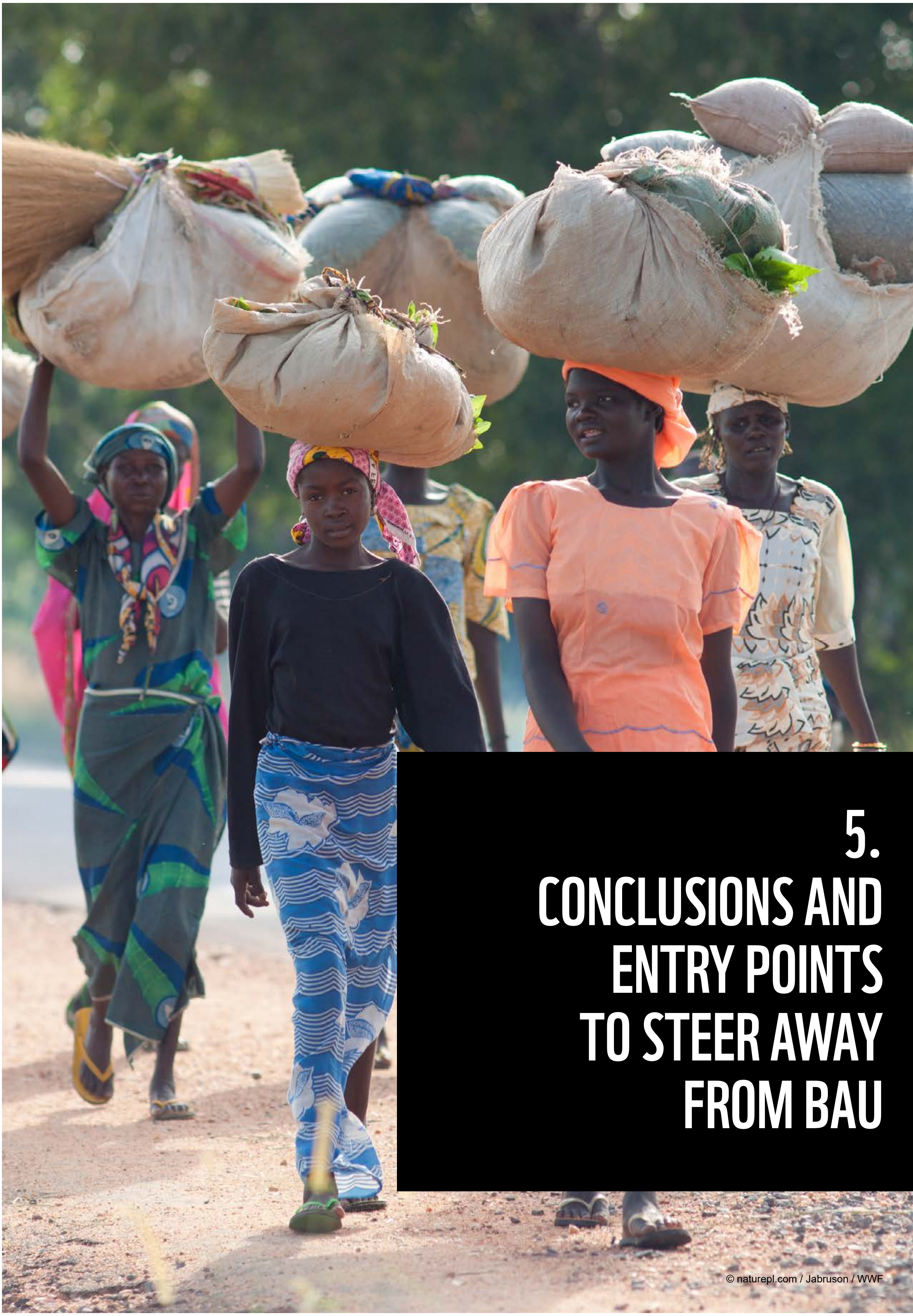
Key drivers / uncertainties	African Ecological Futures report (WWF 2015, annex 6)	The future of food security, environments and livelihoods in Western Africa (CCAFS 2016)	The future of food security, environments and livelihoods in Eastern Africa (CCAFS 2013)
Uncertainty 1	the locus of governance and decision-making around infrastructure and land development and natural resource use – centralized versus decentralized approach	Will short-term priorities or long-term priorities be the focus of governance?	Regional integration: Will the countries of Eastern Africa integrate politically and economically, or will a fragmented status quo be maintained?
Uncertainty 2	the focus of economic production and associated infrastructure and land development – whether production is export led (oriented towards global trade) or regionally-driven (oriented towards intra-African trade)	Will state actors or non-state actors be the driving force in the region?	Mode of governance: Will governance – the rules, regulations, institutions, and processes affecting the behavior of individuals and groups – be characterized by a reactive or proactive stance of governments, the private sector and civil society?
Resulting scenarios	• **Going global:** Where resource rich regions take a planned export-driven path to developing extractive and agricultural commodities, based on centralized decision making and connected economic infrastructure. • **Helping Hands:** Where resource rich areas are the focus of extractive economic activities driven by local actors developing local resources for export through decentralized decision making and supported by local (off-grid) infrastructure. • **All In Together:** Where densely populated areas with renewable resources develop local agricultural industries through participatory decision making and local co-operative schemes driven by local actors. • **Good Neighbors:** Where the future is characterized by a strong drive for African-based development to increase intra-regional trade. As countries begin to take a coherent domestic view with regards to their production and consumption, large regional infrastructure investments are needed.	• **Cash, carbon and calories:** Governments facilitate short term gain • **Self-determination:** A slow and painful transition to sustainable states • **Save Yourself:** Ungoverned, quick and chaotic development; dealing with crises at the expense of investment • **Civil Society to the Rescue?** A struggle between civil society and the private sector that is ultimately productive	• **Sleeping Lions** – a story of regional fragmentation and reactive governance • **Lone Leopards** – a story of continued fragmentation but proactive governance • **Herd of Zebra** – a story of strong regional integration but reactive governance • **Industrious Ants** – a story of strong regional integration and proactive governance

40 A global model to assess competition for land use between agriculture, bioenergy, and forestry. See https://iiasa.ac.at/models-tools-data/globiom (accessed 17 November 2023)

Developing scenarios with stakeholders can be an effective way of building on local expertise and illustrating important challenges and trade-offs. It is also a useful mechanism to bring together actors who do not normally collaborate, for example because of sectoral silos (food and agriculture vs environment).

For the purpose of accessing the decision space related to future agri-food systems, we propose to focus sch scenarios on key drivers of food system development that are highly uncertain, but likely to have strong impact on the spatial and qualitative impacts of food systems on the environment. These can be used to frame scenarios (plausible futures), based on the constellation of drivers. Each scenario in turn provides challenges and opportunities for food systems transformation.

Annex 3 of this reports provides some initial ideas on the angles that could be taken in developing a set of appropriate scenarios for exploring the potential future impacts of drivers resulting from choices made by governments, investors and other development actors when it comes to food systems development.



5. CONCLUSIONS AND ENTRY POINTS TO STEER AWAY FROM BAU

This report has outlined the significant, mostly negative environmental impacts of Africa's food systems, as well as some of the potential future risks to Africa's environmental future, if agrifood systems continued to develop along their current trajectory. This section concludes with the main challenges and opportunities to steer Africa's food systems from a BAU path and enhance Africa's ecological futures.

1. CONCLUSIONS

1.1. FOOD DEMAND AND CROPLAND EXPANSION

Domestic food demand is the main driver for cropland expansion in most of SSA. The main past and current environmental impacts from African agrifood systems have been deforestation and cropland expansion, driven by food crop production for the domestic market. Despite the overwhelming evidence, the relative importance of food crop production for the local market in cropland expansion continues to be underrepresented in much of the literature on food system transformation. This is a key challenge, as many actors operating in the agrifood system space see the expansion of export-oriented agriculture, mostly through commercial farms, as the main culprit for deforestation and cropland expansion and hence focus their advocacy messages on these. Whilst export-oriented agriculture is the main driver of cropland expansion and deforestation in parts of some countries (e.g., cocoa production in Ghana), it is not the main driver overall.

Most cropland expansion has so far been driven by smallholder farmers who primarily produce food crops for their own consumptions, and not by larger commercial farms. This is the situation at the continental level - in specific locations or countries, the situation may be different, with commercial farms being responsible for cropland expansion. Hence, initiatives to reduce cropland expansion need to address ways of improving the livelihoods, incomes and employment opportunities for smallholder farmers, to steer them away from environmentally destructive (and often not very lucrative) agricultural activities. This could include the introduction of more sustainable farming practices, but only if this is combined with ways of increasing the value of farm produce - considering the predominantly small (and continuously diminishing) size of these farms.

Cropland expansion is likely to continue. Considering demographic and dietary trends, and the associated increases in food demand in Africa and elsewhere, producing sufficient food will require further cropland expansion in most countries in Africa. Future expansion is likely to be concentrated in countries with high levels of population growth and poverty, combined with some availability of suitable land for farming and limited environmental governance. These include parts of DRC, Sudan, Sahelian countries and Angola. In addition, export-oriented agriculture is likely to continue to grow, often at the expense of natural habitats. Spatial analysis shows that recent cropland expansion has happened in landscapes with a high biodiversity value, such as Kaza and GVL. Encroachment of protected areas (and of key biodiversity areas that are not currently protected) is likely to continue in countries with poorly enforced environmental protection – in particular in areas with rapidly growing population and human settlements, and a lack of alternative livelihood opportunities. The demand for fuel (charcoal) and timber will continue to play an important role in deforestation – but these drivers often go hand-in-hand with cropland expansion.

National food self-sufficiency has ignored comparative advantages for food and nature. Staple food self-sufficiency at all costs is not always a good option from an environmental or an economic perspective – it can drain public and donor resources (e.g., production of irrigated rice under large dams in West Africa, Bazin et al. 2017), which could be used instead to develop agricultural value chains and invest in sustainable agriculture. Rwanda is an example of a country that strategically assessed its comparative advantage, opting to produce high-value crops and using its national parks to generate income from tourism, whilst importing its main food crop maize (Adolph et al. 2021). Better regulated intra-African trade could help assure countries that they can purchase staples without being fully exposed to world market fluctuations. However, recent research (Li et al. 2023) suggests that global rainfed breadbaskets are at risk of experiencing simultaneous crop failure, justifying a cautious approach to a dependency on grain imports. With public opinions of their governments often being closely connected to food prices, it is understandable that governments in Africa and elsewhere aim to stabilize staple food prices at a low level.

But a re-assessment of this strategy, which considers all options for revenue generation from natural resources, could result in more sustainable solutions.

Urban diets (and, increasingly, rural diets) in Africa are becoming unhealthier, following similar trends in Europe and the Americas, resulting in increases in diabetes and heart diseases (Chinwe et al. 2022). A double burden of malnutrition is affecting an increasing proportion of Africa's population, with negative impacts on human development, but also on the environment supporting it.

Food waste and losses indirectly contribute to cropland expansion. Postharvest losses remain significant in much of the African continent, despite some investments in storage facilities. Urbanization and the associated dietary shifts might contribute to increases in food waste during the distribution and consumption stages, with food travelling further (WWF 2021).

Land degradation also contributes to cropland expansion. Every hectare of land that is taken out of production due to e.g., desertification, soil erosion, acidification is lost for food production, but also lost, to some extent, for nature (unless carefully restored via e.g. natural or assisted regeneration).

1.2. AGRICULTURAL PRODUCTION PATHWAYS

Sustainable agriculture needs to deliver on productivity increase. Productivity on existing farmland needs to be increased sustainably to reduce the need for cropland expansion. Land sharing vs land sparing is an ongoing debate, but evidence (e.g., Perrings and Halkos 2015) suggests that, in the long term, agricultural intensification is causing overall less biodiversity loss by reducing future cropland expansion. For most of Africa, extensive farming systems are not an option, considering the trends in food demand. Agroecology, regenerative and climate-smart agriculture need to deliver on productivity and do that with decent returns to labor. There is huge scope to increase labor productivity through appropriate mechanization, reducing in particular the burden for women.

However, there are trade-offs between intensification and conservation objectives. Increasing productivity may involve increasing use of irrigation, inorganic fertilizer, and agrochemicals. Wetlands and water bodies need to be protected from excessive water withdrawal – but irrigation is a key objective of national agricultural policies of African nations. The environmental impacts of agricultural inputs can be locally significant, with limited effective regulation and enforcement in place. With agricultural and environmental departments often operating in isolation, trade-offs are not recognized and hence not managed. In addition, smallholder farmers' access to any agricultural and rural advisory services is poor in most parts of the continent, let alone services that support sustainable farming methods.

Knowledge intensive strategies such as agroecological and regenerative practices are less lucrative to promote for private service providers than agro-inputs and have hence been limited to relatively small areas with specific project support.

The proportion of medium- to larger farms is likely to continue to grow and export-oriented production will probably increase. (Jayne et al. 2016). This may well pose new threats because these farms will potentially have a more significant environmental footprint (e.g., less diversity of crops, higher use of agrochemicals). But size could also be an advantage, as such farms would be able to invest in environmentally more benign farming systems (e.g., agroforestry, soil and water conservation, etc.) and may be more influenced by consumer choices and preferences for sustainably produced food. However, expansion of export crop production may not necessarily provide significant employment and income for local people, whose decisions often drive land use changes.

Poverty is driving unsustainable agricultural practices and cropland expansion. The use of unsustainable farming methods is both an effect and cause of poverty. For example, during the COVID-19 pandemic, many urban youths returned to their villages and started farming, as they lost their urban livelihoods - but without secure land rights (in particular for women) and resources to invest in sustainable production systems, many of these new farmers may have resorted to farming methods that mine soils and negatively affect downstream farmland and ecosystems.

1.3. VALUE CHAIN DEVELOPMENT

The environmental impact of value chain development can be locally significant. Food processing is likely to expand significantly in Africa, as urban populations and demand for processed food increase. Whilst this provides opportunities for much-needed income generation and diversification, negative environmental impacts can occur where there is a lack of regulation and its application. Agrifood business could be informal or formal, with the informal sector already a key player in providing food for the poor. There is scope for supporting the informal sector in meeting minimum environmental standards, thereby reducing risks for the environment, but also for poor consumers.

There is also a **risk that value chain investments near KBA / biodiversity hotspots / protected areas may attract more people to these areas,** increasing the pressure overall (Adolph et al. 2022). There is currently limited awareness about these risks among environmental and development NGOs and major development investors. This risk is not always picked up by conventional environmental and social impact assessments (Adolph 2022) and hence well-meaning initiatives to add value to agricultural production in fragile environments, intended to reduce the need to expand farm size, could have the opposite effect.

1.4. POLICIES AND GOVERNANCE

Policy incoherences at all levels contribute to competition for land and a lack of strategic interventions for land use. A key challenge is that organizations and initiatives focusing on food and agriculture on the one hand, and on environmental conservation on the other, tend to operate in isolation, often resulting in disconnected or even conflicting objectives and actions.

This applies to donor organizations, government ministries and NGOs alike. Policy disconnects (Jeary et al. 2022) between agricultural and environmental policies are rife, resulting in conflicting objectives with regards to land use. There are also disconnects and trade-offs between wider economic objectives and sustainability considerations. This is not unique to Africa, with many Western economies experiencing similar challenges (Heyen et al. 2020).

2. RECOMMENDATIONS

The recommendations presented here are necessarily broad, addressing sustainable food systems development for a whole continent with vastly different socioeconomic and natural resources. They are meant as a starting point for more nuanced discussions at country-level.

2.1. DEVELOP AND IMPLEMENT COHERENT POLICIES THAT ACKNOWLEDGE AND MANAGE TRADE-OFFS AND BRIDGE THE GAP BETWEEN SECTORAL SILOS.

The transition towards sustainable and fair food systems requires coherent policies and political will to implement them. Inevitably, there will be trade-offs between growth, sustainability and equity objectives, and between short term needs and long-term considerations. Negotiating priorities across sectors and line ministries at national level requires better mechanisms and spaces where these sectoral actors can meet, understand each other's perspectives, pressures and priorities, and move towards a better understanding of the linkages between food systems and ecosystems.

At the national level, this also requires considering both food self-sufficiency objectives and the comparative advantages for food and nature. Meeting future food demand will need to be met from a combination of intensified domestic production, reduced food losses and waste, and regional and global trade. The "right" mix of each depends on several factors that are country-specific and could be explored through scenario development and other tools.

© Jonathan Caramanus / Green Renaissance / WWF-UK

Participatory land and water use planning, within a national or even regional framework for such planning, could be used to identify biodiversity hotspots and prioritize areas for agricultural intensification and conservation. This could also address the challenges of urban expansion as an important driver of land use change, which is pushing agriculture into more remote areas.[41]

2.2. INVEST IN INCREASING AGRICULTURAL PRODUCTIVITY IN A SUSTAINABLE WAY

The development, piloting and scaling out of context-appropriate sustainable and productive agriculture requires agricultural innovation systems that bring together local knowledge, technical and institutional innovations from different sources, and resources to pilot and adapt practices. Whilst research implemented by agricultural research organizations has produced valuable insights and technologies, the adaptation of these findings to local contexts and the scaling out beyond a few pilot sites have been slow and inadequate.

Support to de-centralized innovation processes could be funded in part by a repurposing of government spending on input subsidies (such as inorganic fertilizers). Examples for innovation platforms for agricultural development include the Prolinnova country platforms (PROmoting Local INNOVAtion in ecological agriculture and NRM)[42], the CGIAR-led Sub-Saharan Africa Challenge Program (SSA CP – Lynam et al. 2010) and the Research-into-use Programme (RIUP – Frost 2013).

2.3. SUPPORT POOR FARMERS IN A TRANSITION TO SUSTAINABLE AGRICULTURAL OR NON-AGRICULTURAL LIVELIHOODS

Unsustainable farming practices by smallholder farmers in SSA are largely the result of insufficient access to resources, including land, capital (in the form of agricultural loans), inputs and knowledge. For some farmers, local innovation and adaptation (as described under B. above), combined with enabling conditions to access resources, could sustainably transform their farming practices. For others, in particular for the growing number of (often landless) youths, increasing employment and income generating opportunities is essential to reduce unsustainable cropland expansion in remote areas close to KBAs and protected areas. The "stick" option alone (fines for trespassing into protected areas) has had limited effects in preventing cropland expansion.

2.4. INVEST IN ENVIRONMENTALLY AND SOCIALLY RESPONSIBLE VALUE CHAIN DEVELOPMENT

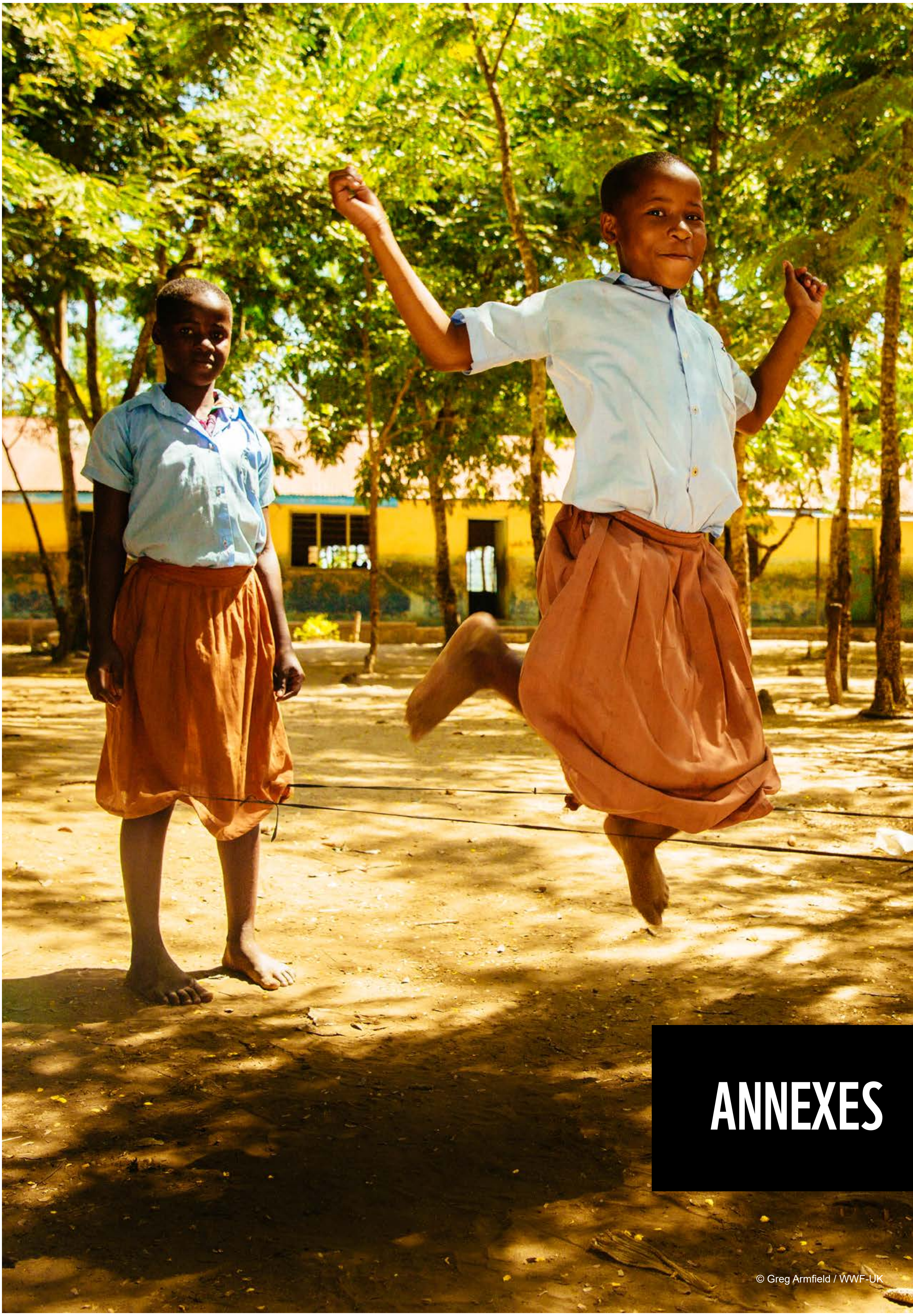
Adding value to agricultural production to boost incomes and reduce pressures on land needs to be a priority across SSA. There is an urgent need to improve the value addition of the agri-food system to reduce its land use footprint (produce less and better and gain more income from it). However, regulating the sector to manage environmental impacts needs to be done in a way that does not sideline informal businesses, which are key for employment and food provision of the poor.

2.5. INCREASE AWARENESS OF HEALTHY SUSTAINABLE DIETS

Shifting the food demand from the growing middle class away from unhealthy processed foods and animal-based foods, whilst ensuring that access and affordability of nutritious food is ensured for poorer households, could reduce the pressures on Africa's ecosystems, whilst contributing to a healthier population. This would require governments and development agencies to start influencing dietary habits now, before the patterns observed in the Americas and Europe repeat themselves, with the associated burden on health services.

41 See e.g. https://earthobservatory.nasa.gov/images/149624/crop-expansion-accelerates-in-africa.

42 https://prolinnova.net/category/country-platforms/



© Greg Armfield / WWF-UK

ANNEXES

ANNEX 1. PERCENT OF KBA SUBJECT TO CROPLAND EXPANSION BY COUNTRY

Country	Percent of KBA subject to crop expansion	KBA as percent of country area
Algeria	0.76	9.33
Angola	0.17	6.32
Benin	0.56	12.89
Botswana	0.09	24.19
Burkina Faso	1.99	4.75
Burundi	14.05	3.84
Cameroon	1.71	8.73
Chad	0.07	9.90
Congo	1.70	19.63
Cote d’Ivoire	0.42	7.28
Democratic Republic Congo	0.19	6.99
Djibouti	0.00	5.06
Egypt	1.72	3.80
Equatorial. Guinea	0.00	15.02
Eritrea	0.00	25.59
Eswatini	2.33	19.12
Ethiopia	0.05	12.81
Gabon	0.00	10.75
Gambia	0.00	27.85
Ghana	1.00	7.89
Guinea	4.04	2.76
Guinea-Bissau	0.00	82.31
Kenya	0.64	12.45
Lesotho	0.00	8.52

Country	Percent of KBA subject to crop expansion	KBA as percent of country area
Liberia	0.00	29.29
Libya	0.26	2.60
Madagascar	0.17	21.44
Malawi	0.46	15.01
Mali	0.73	1.95
Mauritania	0.70	2.23
Morocco	0.08	14.14
Mozambique	0.07	17.90
Namibia	0.00	12.81
Niger	0.07	9.13
Nigeria	1.14	3.99
Senegal	0.52	20.45
Sierra Leone	0.00	6.96
Somalia	0.86	9.99
South Africa	0.08	17.02
Sudan	0.30	2.68
Tanzania	0.06	19.48
Togo	3.84	8.37
Tunisia	0.55	8.91
Uganda	3.29	9.65
Zambia	0.38	13.82
Zimbabwe	0.27	8.29

Source: Calculated from data in Figure 19.

ANNEX 2. ESTIMATES OF POTENTIALLY AVAILABLE CROPLAND (1000S OF HECTARES)

Country	Excluding forest land			Including forest land			Forested % of PAC		
	Suitable	Profitable		Suitable	Profitable		Suitable	Profitable	
		Medium mgt	High mgt		Medium mgt	High mgt		Medium mgt	High mgt
Angola	18,700	1,644	8,472	32,600	3,617	17,400	43%	55%	51%
Cameroon	5,488	5,267	8,357	17,300	21,400	26,600	68%	75%	69%
CAR	8,520	10,300	18,200	13,900	20,000	33,600	39%	49%	46%
Chad	12,600	561	6,919	15,600	561	8,279	19%	0%	16%
Congo-Brazz.	3,292	6,788	7,166	16,900	21,600	25,300	81%	69%	72%
DRC	33,300	23,800	31,400	130,000	111,000	132,000	74%	79%	76%
Ethiopia	4,716	3	1,114	5,817	8	1,492	19%	56%	25%
Ghana	3,555	558	1,903	4,530	814	2,473	22%	31%	23%
Guinea	3,749	1,685	8,245	5,201	3,070	11,700	28%	45%	30%
Ivory Coast	3,415	2,221	5,096	5,557	4,251	8,790	39%	48%	42%
Kenya	4,458	301	998	5,175	334	1,144	14%	10%	13%
Madagascar	16,300	13,100	19,100	18,300	15,600	22,500	11%	16%	15%
Mozambique	21,400	4,258	10,500	33,300	7,399	17,200	36%	42%	39%
South Africa	4,577	95	1,992	5,116	137	2,424	11%	30%	18%
Sudan	41,900	2,306	9,874	50,000	3,305	13,400	16%	30%	26%
Tanzania	16,100	1,598	4,937	22,900	2,559	7,381	30%	38%	33%
Zambia	25,500	0	3,349	42,100	0	5,056	39%	0	34%
Zimbabwe	5,736	97	4,643	7,032	157	5,861	18%	38%	21%
East/ Central	125,658	46,310	81,710	261,306	160,232	224,045	52%	71%	64%
Southern	93,975	19,205	48,137	140,574	26,931	70,586	33%	29%	32%
West	27,719	14,581	37,207	53,978	55,237	89,304	49%	74%	58%
SSA	247,352	80,096	167,054	455,859	242,400	383,935	46%	67%	56%

Source: Chamberlin et al. (2014)

Notes: The first column shows the PAC (potentially available cropland) estimates resulting from applying the suitability criteria; the subsequent columns show the profitability criterion under the assumption of medium-input levels (characteristic of semi-commercialized smallholders) and high-input levels (characteristic of larger commercial farms), respectively.

ANNEX 3. FOOD ACQUISITION AND PRODUCTION OPTIONS: AN EXAMPLE OF FOOD SYSTEM SCENARIOS

The two drivers selected for this example of potential scenarios are the nature of staple food acquisition (whether staple foods are primarily produced domestically or primarily imported) and the nature of food production systems (whether via agroecological or via high external input reliant methods). Countries have some level of control over both of these drivers but need to manage the resulting trade-offs. A recent analysis of policy coherence in three African countries (Ethiopia, Ghana and Zambia) showed that agricultural policies aim for self-sufficiency in staple foods (via agricultural intensification, including expansion of irrigation), whilst environmental and climate change policies of the same countries commit to protecting existing natural habitats from agricultural expansion, whilst also reducing emissions and pollution from agricultural intensification (Jeary et al. 2022). Hence, scenario development can also be used to highlight disconnects between different food system related sectors and their policies.

The second driver on production pathways explores effectively the land sharing vs land sparing options, assuming that a high external input system could achieve high levels of productivity in the long term (with associated environmental costs and benefits).

- **Food acquisition:** Whether African governments aim to achieve food self-sufficiency in staple foods at all costs, or whether they (continue) to rely on food trade / imports (both within Africa and globally). This decision / policy choice is critical, as it is one of the main determinants of the land use footprint of the food system. There is considerable variation and uncertainty associated with this driver, as it has a strong political dimension. Whilst most African countries are WTO members and have e.g. committed to abolishing export subsidies, a recent study on policy coherence with regards to food and environment in Africa found that some African countries have nevertheless committed to staple food self-sufficiency to reduce their exposure to food price spikes.
- **Food production pathways:** Whether African governments pursue a strategy of regenerative / agroecological agriculture that is knowledge and labor intensive, but provides higher levels of other ecosystem services, or whether they rely primarily on high external input production systems with use of inorganic inputs, mechanization etc. This uncertainty is one of the "elephants in the room", with some actors (notably AGRA and the AU) promote a modernization of the agricultural sectors via a high external input pathway, whilst others (notable the Global Alliance for the Future of Food and many international NGOs) advocate an agroecological and regenerative approach to agriculture. African governments are exposed to lobbying from both sides, and different countries have opted for different approaches – which may change in the future.

Based on these key uncertainties, the resulting scenarios are shown in Figure 24. For each of these scenarios, a narrative can be formulated to establish potential or likely food systems impacts on ecological futures.

The scenario example presented here focuses on two key decisions: the source of staple foods and the associated production system. There are many other choices with regards to agrifood systems that could lead to a deviation from the BAU situation. The available levers depend on the context, including a country's or region's resources (natural, physical, socio-economic, financial) and their integration into regional and global networks of commodity trade, investments, migration, etc. The next section presents an overview of levers available for food system transformation.

Figure 24. *Examples of agri-food system scenarios*

Staple food acquisition via...	Food production pathways via ...high external input dependency and irrigation	Food production pathways via ...regenerative / agroecological production
...domestic production / food self sufficiency	**A.** Domestic food demand is met through domestic production, using a high productivity model of production, which enables some extent of land sparing. Negative environmental impacts emerge from the intensive use of synthetic inputs, but important ecosystems are still under threat, as domestic production is not sufficient to meet demand.	**B.** Domestic staple food demand is met through domestic production but using largely regenerative / agroecological methods with a reduced level of productivity but enhanced environmental benefits. Most land suitable for agriculture is used for farming, but natural habitats have almost disappeared.
...regional and global trade	**C.** Domestic staple food demand is met through a combination of traded food / food imports (where this is economically viable) and intensive, high-external input-reliant domestic production. Whilst there are some negative impacts from intensive use of synthetic inputs, it is possible to protect important ecosystems from agricultural expansion because food demand is partly met via imports.	**D.** Domestic staple food demand is met through a combination of traded food / food imports (where this is economically viable) and regenerative / agroecological production. This enables setting aside some land for protection from agricultural activities, whilst also increasing ecosystem services from farm land.

SCENARIO A

Meeting domestic food demand (staples - cereals and root / tubers) by 2063 through domestic production would require significant increases in crop production in most African countries. Using a high productivity model of production, with a closure of the yield gap of 80%, some countries would be able to spare land for biodiversity and other ecosystem services (or export food). However, other countries would need to convert all land suitable for agriculture into farmland to meet their domestic demand in cereals, whilst several would not be able to meet that demand even if all land was converted. Van Ittersum et al. (2016) calculated that, out of 10 countries analyzed (Burkina Faso, Ghana, Mali, Niger, Nigeria, Ethiopia, Kenya, Tanzania, Uganda and Zambia), six (Ghana, Niger, Nigeria, Kenya, Tanzania and Uganda) would not be able to produce sufficient cereals even if the yield gap (between possible yields and actual yields in 2010) was closed by 80% and most or all of the available cereal area was cultivated.

The remaining 4 countries would be able to meet national self-sufficiency with cereals and produce enough for export.

With the anticipated increases in regional trade resulting from AfCFTA, it may be possible that Africa could be cereal self-sufficient as a region overall under this scenario, with surplus production from 'land rich' countries being sold to deficit countries. This analysis is based on the IMPACT model data from IFPRI and has not been updated to reflect actual production and yield trends in Africa or expanded to include more African countries.

However, a range of other factors would also influence outcomes. Countries with cereal deficit may not be able to afford imports from other African countries, if their price is higher than world market price. Already now, West Africa imports significant quantities of rice, whilst rice produced domestically (under large scale irrigation) is more expensive than imports.

In environmental terms, the main impacts of this scenario could be:

- Some extent of land use change: Both agricultural expansion into hitherto not cultivated land and potentially some rehabilitation of farmland / return to natural habitat (Van Ittersum et al. calculated that an 80% yield gap closure could lead to farmland reduction in 3 out of the 10 countries: Burkina Faso, Mali, Ethiopia – these are countries with relatively low levels of productivity (so high levels of gain from yield gap closure).
- Increases in irrigation to achieve high levels of productivity, reducing river flow and affecting wetlands.
- Risk of pollution of waterways from agrochemicals.
- Risk of agrobiodiversity loss due to high use of potentially harmful external inputs and a trend towards more efficient monoculture systems.
- Risk of land degradation as a result of unsustainable agricultural practices, e.g. overuse of inorganic fertilizer, lack of the use soil and water conservation and organic matter.

SCENARIO B

If African countries aimed to become food self-sufficient via a low-external input pathway, relying on agroecological and regenerate agriculture, they may only be able to close the yield gap to 50% or less. Again, looking at the analysis of van Ittersum et al. (the only of its kind available at the moment), a 50% yield gap closure would not be enough to enable any of the 10 countries in the analysis to become cereal self-sufficient – and the cereal land required would exceed the amount of suitable land available in three countries (Niger, Nigeria and Uganda). Hence, acquiring some grain through regional or global trade would be inevitable.

The environmental impacts of a less intensive, but still self-sufficiency-focused pathway could be:

- Extensive land use changes, resulting in the conversion of natural habitats into farmland to a high extent.
- Depending on the farming systems adopted, the resulting cropland could be managed in a sustainable way, with limited or no land degradation or pollution from agrochemicals.
- his scenario would be a typical 'land sharing' one, whereby farming systems replace natural landscape, but in a relatively 'benign' way. However, the impacts of habitat loss and deforestation on biodiversity would still be significant.

SCENARIO C

If domestic food demand was met through a combination of traded food / food imports and intensive, high-external input reliant domestic production, the pressure on land would be reduced, and domestic production could focus on high value produce such as tea, coffee, vegetables etc. Some countries, notably Rwanda, have already adopted such an approach, enabling them to keep a relatively large proportion of land under effective conservation (over 9%, despite high population densities) and forest cover (about 20%). The environmental impacts could mean:

- Limited agricultural sprawl and potentially even reduction in area under cultivation, if the regional and global market can supply staples at a competitive price and if the high-value agricultural commodities produced in-country, together with other economic activities, provide sufficient revenue / foreign exchange for importation of food.
- Similar to scenario A, the environmental impact of the existing agricultural production would depend on the production system and could entail land degradation and pollution, if intensive farming methods were not practiced sustainably.
- If there were food price spikes regionally or globally, as a result of conflicts, pandemics or other disruptions, a reliance on food imports could result in rapid, uncontrolled spread of farming, as households come under pressure and have to rely on their own production for food. This strategy was visible during the COVID-19 pandemic, when lockdowns resulted in increased unemployment and a return of migrants to rural areas (where the only livelihood opportunity was farming), combined with an increase in world market prices of food, making imports more expensive.

SCENARIO D

If food was imported, as well as produced at country level in an agroecological or regenerative manner, the benefits of a limited agricultural sprawl could potentially combine with a reduced negative impact of the existing farming systems. In particular, countries with fragile ecosystems that provide economic benefits through tourism or via production of high value, low volume commodities (aromatics, forest coffee etc.) could achieve high levels of ecosystem protection, whilst still assuring food availability. However, this scenario would require countries to have a well-developed non-farm rural economy that produces the revenue required for food importation, and the employment opportunities for rural people to prevent them from converting land into farmland.

ANNEX 4. USING SPATIAL ANALYSIS TO ENGAGE LOCAL STAKEHOLDERS: A CASE STUDY FROM ZAMBIA

CONTEXT AND OBJECTIVES

Land use change is the biggest threat to African ecosystems - degrading, reducing or fragmenting ecosystems. This applies also to Zambia – home to some of Africa's most diverse and abundant wildlife, an important source of income for rural households due to wildlife tourism (Richardson et al. 2012). But cropland in Zambia is expanding quickly, mostly at the expense of forests and woodlands. According to Global Forest Watch,[43] Zambia lost 2.25Mha of tree cover between 2001 and 2022, equivalent to a 9.4% decrease in tree cover since 2000, causing 831Mt of CO_2 emissions. The main driver of tree cover loss has been small scale farming and shifting cultivation, accounting for 92 to 98%[44] during that period.

Reasons for smallholder farmers' cropland expansion in Zambia include population increase, the shortage of non-farm employment and income generating opportunities (especially for youths with no capital to invest and limited education), land degradation (because of unsustainable farming practices) and climate change impacts that reduce crop yields, and market demand for crops both within and outside the country. These factors are influenced by policies, institutions, and markets, which determine prices of produce and inputs, and access to technology.

Table 6. *Cereal demand increase by 2050 and recent developments in cereal production and cropland area in Zambia*

Indicator	Value
Population 2050 (and as proportion of 2010 population)	43 million (325%)
Cereal demand 2050 as % of that in 2010	519 %
Cereal area as proportion of total current cropland	35%
Actual maize yields (2003–2012) used for yield gap analysis	2.3 tons harvested per ha
Annual maize yield increase (1991–2014)	55 kg per ha per year
Cropland area 2010	3.5 Mha
Increase in cropland area (2004–2013)	0.8 Mha

Source: Van Ittersum et al. 2016

Cropland expansion is bound to continue, as demand for staples (in particular maize) is projected to increase until at least 2050 and yields on existing cropland have increased at a slower rate than demand (Table 6). But even if yields continued to increase at such a slow rate, Zambia would be able to be self-sufficient in cereals because of the availability of land outside protected areas that is suitable for cereal production and that is currently not cultivated. Data from Global Forest Watch shows that most tree cover loss (which is associated with cropland expansion) is occurring outside protected areas (Figure 25) – which includes some areas with high ecosystem value. In these areas, local chiefs oversee land use decisions and the formulation and enforcement of local by-laws related to land use.

It is therefore essential to engage with these traditional leaders, in addition to government officials, to bring about awareness of the scale and potential impacts of land use changes and explore ways of mitigating the trade-offs between agricultural land use and habitat protection.

THE APPROACH

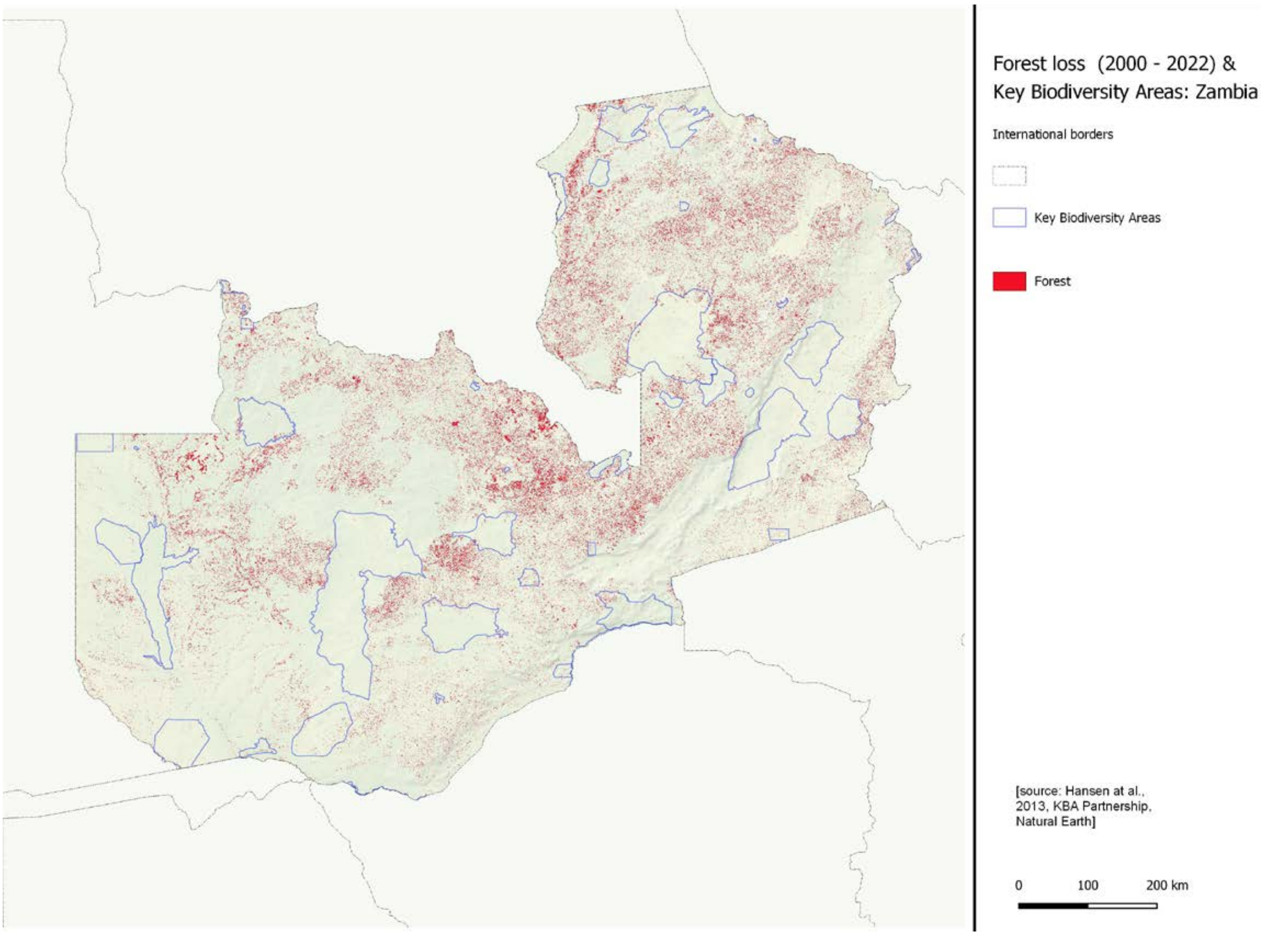
The transdisciplinary research project Sentinel (Social and Environmental Trade-Offs in African Agriculture), led by IIED, worked with Copperbelt University in Zambia from 2017 to 2023 to explore land use trade-offs between food production and conservation. The main steps in the research process included:

43 https://www.globalforestwatch.org/dashboards/country/ZMB

44 Calculated from global forest watch data, ibid.

- A context analysis of agriculture and land use in Zambia (document review, Mweshi et al. 2022);
- Participatory scenario development to engage national level stakeholders in a forward-looking exercise that recognizes long-term threads and opportunities (Kwenye et al. 2022);
- Selection of field research sites where agricultural expansion is ongoing;
- Quantitative and qualitative research on the drivers and impacts of agricultural expansion in these sites and future land use scenarios;
- An analysis of agricultural and environmental policies in Zambia (Jeary et al. 2022);
- Use of serious gaming to understand farmers' decisions regarding agricultural expansion and intensification (Adolph et al. 2022);
- Stakeholder workshops at site level to discuss and agree four future land use scenarios with local stakeholders in the two sites and initiate reflections on land use planning.

Figure 25. *Forest loss in Zambia between 2000 and 2022 and key biodiversity areas*



Source: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850-53

In order to develop future (2050) land use maps for two research sites, the (qualitative) land use scenarios (storylines) were translated into a quantitative table of land 'demand', based on an assessment of the area of land required to satisfy the conditions of each of the four scenarios for each land cover category in 2050 (Figure 35). This was informed by the "serious gaming" exercise that provided information about farmers' cropland demands.

TerrSet Land Change Modeler (LCM) software was used to project future land cover change to 2050. The technique relies on 'explaining' past change in land cover mapped from two sets of classified satellite images with reference to a set of statistically significant physical (soils, topography) and socioeconomic (population, proximity to roads/settlements) variables. These significant variables were subsequently used to project the distribution of land cover to 2050 based on the land demand for each land cover category for each of the four scenarios.

The resulting land use maps were presented to local stakeholders (traditional leaders, officials from the ministries of agriculture and the environment, farmer organizations and development agencies) to discuss implications for land use planning.

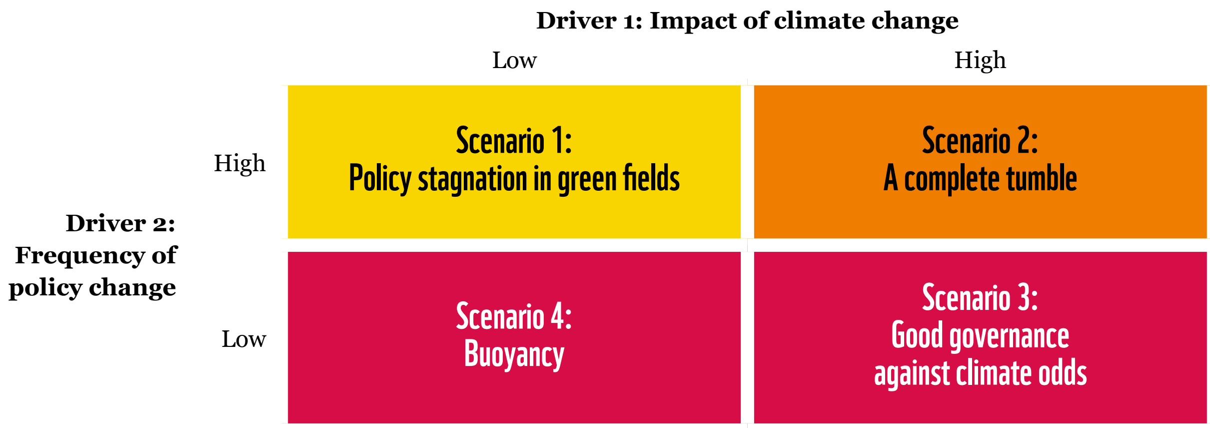
RESULTS

The participatory scenario process produced four scenarios (Figure 35). Informed by the assumptions derived from the serious gaming exercise, the scenario descriptions are as follows:

1. Policy stagnation in green fields: High frequency of policy change and low impact of climate change. Policies are not evidence based but rather are driven by the short-term political aspirations of politicians. High crop prices and maintenance of good soil fertility result in good profits and spare cash to expand, leading to a significant loss of closed/open woodland and other native vegetation, including grass/shrub.
2. A complete tumble: Frequent policy change and high climate change impacts. The short-term planning horizon arising from frequent policy changes is causing constant turmoil for everyone and every sector in Zambia. High crop prices and declining soil fertility result in strong motive to intensify, using extra cash from crop sales to purchase inputs.
3. Good governance against climate odds: A more stable policy environment arising from high quality of governance with policies that are grounded in scientific evidence and implemented accordingly. However, climate change adaptive capacity is inadequate, leading to high impacts of climate change. Low crop prices combined with declining soil fertility result in rapid expansion into areas of closed open forest and other native vegetation.
4. Buoyancy: A stable policy environment with evidence-based policies that take a long-term perspective, and low levels of climate change impact due to high ability to adapt, where agricultural investments lead to increased economic and social prosperity, and clear recognition and management of trade-offs. Maintenance of soil fertility but low crop prices provide the motivation to diversify, planting different crops to minimize the risk of poor harvests resulting from poor fertility.

In addition, BAU assumes a simple linear extrapolation of past trends in land cover change (2000–2021) derived from the most recent good quality land cover data available from satellite imagery. It assumes that the factors affecting land cover change remain stable and, strictly, is not a scenario.

Figure 26. *Four scenarios of the future of agricultural development in Zambia*



Source: Kwenye et al. 2022

Table 7 shows the changes in land cover between 2000 and 2021 for one of the sites (Chitokoloki, North-Western province), and how the trajectories of projected change to 2050 for the four land cover types vary between scenarios. Thus, for Scenario 1 it is projected that the area of Closed woodland will decline significantly (High >40 percent), compared with Scenario 4 where Closed woodland is projected to decline significantly.

Table 7. *Land cover demand (low, medium, high) under the four scenarios and Business-as-Usual for Chitokoloti, North-Western province*

	Land cover		% change 2021–2050				
	2000	**2021**	**B-a-U**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Cropland	6.65	12.2					
Closed woodland	32.83	19.4					
Open woodland	12.53	20.0					
Other (riparian, grass/shrub)	47.98	49.8					

Notes: The colors are designed to show positive (green shades) and negative (red shades) as low, medium and high change between the 2021 baseline and 2050.

Source: Griffiths et al. 2022

Positive	**Negative**
Low 1-20	Low 1-20
Medium 20-40	Medium 20-40
High >40	High >40

When the results were presented to and discussed with traditional chiefs and local leaders at the research sites in 2022, there were two main outcomes:

1. Raising awareness about the impact of agricultural expansion on the environment. The initiative provided a platform for farmers to engage with key stakeholders in the agriculture, land and environment sectors. Stakeholders indicated that it increased their awareness and that this is likely to influence future decisions on cropland expansion into the forest and alternative options such as regenerative agriculture, to address declining soil fertility (a major driver of cropland expansion).

2. Support for integrated land use planning. Local authorities (councils) face a challenge in the context of unregulated cropland expansion into forests and other ecologically sensitive areas. There is currently a disconnect between traditional authorities and local government entities in their understanding of “regulated development”, which affects agriculture, the environment and livelihoods. Stakeholders requested that development actors could facilitate bringing together traditional leaders (who own more than 50% of the land) and councils to develop integrated land use plans in order to stem cropland expansion and thus conserve natural habitats. They suggested that there should be parcels of land set aside for agriculture, grazing, environmental protection and settlements, rather than the current situation, where development is uncoordinated at regional and village levels.

MAIN LESSONS AND RELEVANCE FOR WWF

The exercise demonstrated how national level scenarios can be ‘downscaled’ to the local level to raise awareness about potential future land use changes amongst those stakeholders with some influence on farmers’ decisions. Whilst engaging with continental and national stakeholders can bring about subtle changes in perceptions and priorities, it usually takes a long time for these to translate into specific policy changes, and for these policies to be implemented at scale. Working directly with local stakeholders can contribute to changes on the ground, if e.g., local chiefs enact new by-laws on cropland expansion.

REFERENCES

ACORD (2016) Chinese, Brazilian and Indian Investments in African Agriculture: Impacts, Opportunities and Concerns. London: ACORD

Adjei-Nsiah S, Opoku A, Frimpong KA and Isaac D (2022) Editorial: Soil Fertility Management for Sustainable Food Production in sub-Saharan Africa. *Frontiers in Sustainable Food Systems* Vol 6

Adolph B, Allen M, Beyuo E, Banuoku D, Barrett S, Bourgou T, Bwanausi N, Dakyaga F, Derbile EK, Gubbels P, Hié B, Kachamba C, Naazie GK, Niber EB, Nyirengo I, Tampulu SF and Zongo AF (2021) Supporting smallholders' decision making: managing trade-offs and synergies for sustainable agricultural intensification, *International Journal of Agricultural Sustainability,* 19:5-6, 456-473

Adolph B, Barrett, S, Guarín A, Nicolini G, Assefa F, Tizazu B, Fikreyesus D, Nebsu B, Mungoo J, Kimani A, Naramabuye F, Sirikare S and Natukunda S (2021). Agri-food systems that work for people and planet: challenges and opportunities from Ethiopia, Kenya, Rwanda and Uganda. London: IIED

Adolph B (2022) Can Agricultural Intensification Stop Cropland Expansion in sub-Saharan Africa? Strengthening Capacity in Agriculture, Livelihoods, and Environment (SCALE) Associate Award. Washington: Mercy Corps

Adolph B, Jellason NP, Kwenye JM, Davies J, Dray AG, Waeber PO, Jeary K and Franks P (2023) Exploring Farmers' Decisions on Agricultural Intensification and Cropland Expansion in Ethiopia, Ghana, and Zambia through Serious Gaming. Land 2023, 12, 556.

Adolph B, Franks P, Kwenye JM (2022) More agricultural intensification, more deforestation? Recognising the risk of profitability-driven expansion of cropland in Zambia. London: IIED

African Union (2021) Africa common position on food systems - Regional Submission to the UN Food Systems Summit. Addis Ababa: African Unionuu

African Union Commission (2022) 3rd CAADP Biennial Review Report 2015-2021. Addis Ababa: African Union

Aleman JC, Blarquez O and Staver CA (2016), Land-use change outweighs projected effects of changing rainfall on tree cover in sub-Saharan Africa. Global Change Biology, 22: 3013-3025.

Altchenko Y and Villholth KG (2015) Mapping irrigation potential from renewable groundwater in Africa – a quantitative hydrological approach. Hydrology and Earth System Sciences, 19, 1055–1067, 2015.

AUC/OECD (2022), Africa's Development Dynamics 2022: Regional Value Chains for a Sustainable Recovery, AUC, Addis Ababa / OECD Publishing, Paris

Audsley E, Brander M, Chatterton J, Murphy-Bokern D, Webster C, and Williams A (2009). How low can we go? An assessment of greenhouse gas emissions from the UK food system and the scope to reduce them by 2050. FCRN-WWF-UK.

African Union (2023) Dakar Declaration on Food Sovereignty and Resilience (Dakar 2). Dakar, Senegal, January 27, 2023

AGRA (2022) Africa Agriculture Status Report. Accelerating African Food Systems Transformation (Issue 10). Nairobi, Kenya: Alliance for a Green Revolution in Africa (AGRA).

Ambikapathi R, Schneider KR, Davis B et al. (2022) Global food systems transitions have enabled affordable diets but had less favourable outcomes for nutrition, environmental health, inclusion and equity. Nat Food 3, 764–779 (2022).

Balima LH, Nacoulma BMI, Bayen P, N'Guessan Kouamé F, Thiombiano A (2020) Agricultural land use reduces plant biodiversity and carbon storage in tropical West African savanna ecosystems: Implications for sustainability. Global Ecology and Conservation, Volume 21

Bazin F, Hathie I, Skinner J and Koundouno J (2017) Irrigation, food security and poverty – Lessons from three large dams in West Africa. London: IIED and Ouagougou: IUCN

Belay T, Melese T and Senamaw A (2022) Impacts of land use and land cover change on ecosystem service values in the Afroalpine area of Guna Mountain, Northwest Ethiopia, Heliyon, Volume 8, Issue 12.

Beltran-Peña A, Rosa L and D'Odorico P (2020) Global food self-sufficiency in the 21st century under sustainable intensification of agriculture. Environmental Research Letters, Volume 15, Number 9.

Béné C, Prager SD, Achicanoy HAE, Alvarez Toro P, Lamotte L, Cedrez CB, Mapes BR (2019) Understanding food systems drivers: A critical review of the literature, Global Food Security, Volume 23, 2019, Pages 149-159, ISSN 2211-9124

Benton TG, Bieg C, Harwatt H, Pudasaini R and Wellesley L (2021) Food system impacts on biodiversity loss - Three levers for food system transformation in support of nature. London: Chatham House.

Benton TG and Harwatt H (2022) Sustainable agriculture and food systems - Comparing contrasting and contested versions. Research Paper, Environment and Society Programme. London: Chatham House.

BEUC (Bureau Européen des Unions de Consommateurs) (2020) One bite at a time: Consumers and the transition to sustainable food. Analysis of a survey of European consumers on attitudes towards sustainable food. Brussels: BEUC

Blench R (1999) Animal traction in Africa: analysing its environmental impact. In: Starkey P and Kaumbutho P (eds), Meeting the challenges of animal traction. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA), Harare, Zimbabwe. London: Intermediate Technology Publications.

Bouët A, Odjo SP and Zaki C, eds. (2022) Africa Agriculture Trade Monitor 2022. Kigali and Washington, DC: AKADEMIYA2063 and International Food Policy Research Institute.

Bwanausi Kabuye N and Adolph B (2020) Trade-offs in sustainable intensification: Malawi country report. London: IIED

Von Braun J, Afsana K, Fresco L, Hassan M and Torero M (2020) Food Systems – Definition, Concept and Application for the UN Food Systems Summit. A paper from the Scientific Group of the UN Food Systems Summit. March 5, 2021.

Buckley L, Ruijian C, Yanfei Y and Zidong Z (2017) Chinese agriculture in Africa: Perspectives of Chinese agronomists on agricultural aid. Discussion Paper, IIED, London.

CDP (2020) CDP Africa Report: Benchmarking progress towards climate safe cities, states and regions. London: CDP.

Chamberlin J, Jayne TS, Headey D (2014) Scarcity amidst abundance? Reassessing the potential for cropland expansion in Africa. Food Policy, Volume 48, Pages 51-65.

Chiaka JC and Zhen L (2021) Land Use, Environmental, and Food Consumption Patterns in Sub-Saharan Africa, 2000–2015: A Review. Sustainability 13, 8200.

Chung MG and Liu J (2022) International food trade benefits biodiversity and food security in low-income countries. Nat Food 3, 349–355 (2022).

Dakyaga F, Derbile E, Naazie G, Faamu Tampulu S, Faabelangne D, Beyuo E and Gubbels P (2020). Trade-offs in sustainable intensification: Ghana country report. London: IIED

Daum T and Birner R (2020) Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. Global Food Security, Volume 26

de Bruin S and Dengerink J (2020) The impact of urbanisation on food systems in West and East Africa: Opportunities to improve rural livelihoods. The Hague: PBL Netherlands Environmental Assessment Agency

Deininger K, Byerlee D, with Lindsay J, Norton A, Selod H, Stickler M (2011) Rising Global Interest in Farmland: Can it Yield Sustainable and Equitable Benefits? Washington DC: World Bank Publications

Djoumessi YF (2022) New trend of agricultural productivity growth in sub-Saharan Africa, Scientific African, Volume 18, e01410, https://doi.org/10.1016/j.sciaf.2022.e01410

ELD Initiative and UNEP (2015). The Economics of Land Degradation in Africa: Benefits of Action Outweigh the Costs. Bonn: ELD secretariat

Encyclopaedia Britannica (2022) Terrestrial hotspots of biodiversity. https://www.britannica.com/science/hot-spot-ecology

FAO (2010) “Climate-Smart” Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Rome: FAO

FAO (2018) The 10 elements of agroecology. Guiding the transition to sustainable food and agricultural systems. Rome: FAO

FAO (2022) Introducing the Agrifood Systems Technologies and Innovations Outlook. Rome: FAO.

FAO (2023) The State of Food and Agriculture 2023 – Revealing the true cost of food to transform agrifood systems. Rome: FAO

FAO, ECA and AUC (2021) Africa – Regional Overview of Food Security and Nutrition 2021: Statistics and trends. Accra, FAO.

FAO, IFAD, UNICEF, WFP and WHO (2022) The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable. Rome, FAO.

Florczyk AJ, Corbane C, Ehrlich D, Freire S, Kemper T, Maffenini L, Melchiorri M, Pesaresi M, Politis P, Schiavina M, Sabo F and Zanchetta L (2019) GHSL Data Package 2019, EUR 29788 EN. ISBN 978-92-76-13186-1, JRC 117104. Luxembourg: Publications Office of the European Union.

FOLU (2019) People, Health and Nature: A Sub-Saharan African Transformation Agenda. London: Food and Land Use Coalition.

Franks P, Hou Jones X, Fikreyesus D, Sintayehu M, Mamuye S, Danso EY, Meshack C, McNicol I, van Soesbergen A (2017) Reconciling forest conservation with food production in sub-Saharan Africa: case studies from Ethiopia, Ghana and Tanzania. London: IIED

Fritz S, Laso Bayas JC, See L, Schepaschenko D, Hofhansl F, Jung M, Dürauer M, Georgieva I, Danylo O, Lesiv M, McCallum I (2022) A Continental Assessment of the Drivers of Tropical Deforestation With a Focus on Protected Areas. Frontiers in Conservation Science, 3 (2022).

Frost, A (2013) Final Report, Research Into Use Programme, July 2006 – December 2012. Edinburgh: University of Edinburgh.

Future Agricultures (2010) Awakening Africa’s Sleeping Giant? The Potentials and the Pitfalls. Policy Brief. Brighton: Future Agricultures consortium

Global Center on Adaptation (2022). State and Trends in Adaptation Report 2022. Adaptation at the core of a prosperous Africa in an uncertain and warming world. Rotterdam and Abidjan: GCA

Gremmen B (2022). Regenerative agriculture as a biomimetic technology. Outlook on Agriculture, 51(1), 39–45.

Griffiths G, Manzoor SA, Adolph B, Davies J, Devenish A, Franks P, Jellason NP, Kwenye J, Robinson E and Zurek M (2022) Serious gaming to inform local scale scenarios of land cover change to 2050 in North-Western province, Zambia. London: IIED

Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman SV, Goetz SJ, Loveland TR, Kommareddy A, Egorov A, Chini L, Justice CO, and Townshend JRG (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (15 November): 850-53. Data available on-line HERE

Herrero M, Thornton PK, Mason-D'Croz D et al. (2020) Innovation can accelerate the transition towards a sustainable food system. Nature Food 1, 266–272

Heyen DA, Menzemer L, Wolff F, Beznea A and Williams R (2020) Just transition in the context of EU environmental policy and the European Green Deal. Issue Paper under Task 3 of the 'Service contract on future EU environment policy', Freiburg: Oeko-Institut

Hodson E, Niggli U, Kitajima K, Lal R and Sadoff C (2021) Boost nature-positive production. A paper on Action Track 3. A paper from the Scientific Group of the UN Food Systems Summit, July 18th 2021 Hou-Jones X, Mwitwa J and Franks P (2020) Food and forests: Understanding agriculture and conservation trade-offs in Zambia. London: IIED

International Food Policy Research Institute (IFPRI) (2022). Projections from IFPRI's IMPACT model: Climate change and food systems. In: 2022 Global Food Policy Report: Climate Change and Food Systems. Chapter 14, Pp. 146-161.

IPCC (2019) Summary for Policymakers. In: 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 [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

IRENA and FAO (2021) Renewable energy for agri-food systems – Towards the Sustainable Development Goals and the Paris agreement. Abu Dhabi and Rome.

Jayne TS, Meyer F, and Traub LN (2014) Africa's Evolving Food Systems: Drivers of change and the scope for influencing them. IIED Working Paper. London: IIED

Jayne TS, Chamberlin J, Traub L, Sitko N, Muyanga M, Yeboah FK, Anseeuw W, Chapoto A, Wineman A, Nkonde C and Kachule R (2016) Africa's changing farm size distribution patterns: the rise of medium-scale farms. Agricultural Economics, Volume47, IssueS1, Pages 197-214.

Jeary K, Adolph B and Franks P (2022) Coherence and disconnects in agricultural and conservation policies in sub-Saharan Africa. IIED Research report. London: IIED

Jeary K and Mwitwa J (2022) Policy disconnects: trade-offs and synergies between Zambia's objectives to increase agricultural production and conserve nature. London: IIED

Jellason NP, Robinson EJZ, Chapman ASA, Neina D, Devenish AJM, Po JYT, Adolph B (2021) A Systematic Review of Drivers and Constraints on Agricultural Expansion in Sub-Saharan Africa. Land. 2021; 10(3):332. https://doi.org/10.3390/land10030332

Johnson ME, Farris J, Morgan S, Bloem JR, Ajewole K and Beckman J (2022) Africa's Agricultural Trade: Recent Trends Leading up to the African Continental Free Trade Area, EIB-244, U.S. Department of Agriculture, Economic Research Service.

Joint Research Centre - JRC - European Commission, and Center for International Earth Science Information Network - CIESIN - Columbia University (2021) Global Human Settlement Layer: Population and Built-Up Estimates, and Degree of Urbanization Settlement Model Grid. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). Accessed 20 July 2023

Kaihura F and Stocking M (ed) (2003) Agricultural Biodiversity in Smallholder Farms of East Africa. Tokyo, New York, Paris: United Nations University press.

Kalischek N, Lang N, Renier C et al. (2023) Cocoa plantations are associated with deforestation in Côte d'Ivoire and Ghana. Nat Food 4, 384–393 (2023)

Kirui OK and von Braun J (2018) Mechanization in African agriculture: A continental overview on patterns and dynamics, ZEF Working Paper Series, No.169, University of Bonn, Center for Development Research (ZEF), Bonn

Kuhn A and Britz W (2021) Long-Term Scenarios for Sub-Saharan Africa's Agro-Food Markets with Varying Population, Income, and Crop Productivity Trends, Journal of Agricultural and Resource Economics, Volume 46, Issue 1, January 2021, Pages 20-36

Kwenye J, Mwitwa J, Zurek M, Adolph B, Devenish A, Franks P, Hebinck A (2022) Scenarios of agricultural development in Zambia - Produced during the Sentinel participatory scenario development workshop 2018. London: IIED

Lebreton L, van der Zwet J, Damsteeg JW, Slat B, Andrady A and Reisser J (2017) River plastic emissions to the world's oceans. Nature Communications 8, 15611

Lee M and Gambiza J (2022) The adoption of conservation agriculture by smallholder farmers in southern Africa: A scoping review of barriers and enablers, Journal of Rural Studies, Volume 92, pages 214-225.

Li H, Keune J, Smessaert F et al. (2023) Land–atmosphere feedbacks contribute to crop failure in global rainfed breadbaskets. npj Climate and Atmospheric Science 6, 51

Lynam JK, Harmsen K and Sachdeva P (2010) Report of the Second External Review of the Sub-Saharan Africa Challenge Program (SSA-CP). CGIAR Independent Science and Partnership Council,

Marshall Q, Fanzo J, Barrett CB, Jones AD, Herforth A, McLaren R (2021) Building a Global Food Systems Typology: A New Tool for Reducing Complexity in Food Systems Analysis. Frontiers in Sustainable Food Systems Vol 5.

Martin T (2018) High-value agricultural exports from Africa. OCP Policy Brief 18/03, Rabat: OCP Policy Centre.

Moyo B and Ravhuhali KE (2022) Abandoned Croplands: Drivers and Secondary Succession Trajectories under Livestock Grazing in Communal Areas of South Africa. Sustainability 14(10):6168

Mweshi M, Mwitwa J, Ng'andwe P, Phiri D, Kapembwa C, Devenish A, Hou-Jones X, Franks P and Adolph B (2022) Contextual analysis of agriculture in Zambia: A review of the agricultural sector in Zambia conducted in 2018-19 as a contextual analysis for the Sentinel project. London: IIED

Nkiaka E, Bryant RG, Okumah M and Gomo FF (2021) Water security in sub-Saharan Africa: Understanding the status of sustainable development goal 6. Wiley Interdisciplinary Reviews: Water, 8 (6). e1552. ISSN 2049-1948

Numbere A and Obanye C (2023) Environmental Impact of Bush Burning on the Physico-Chemistry of Mangrove Soil at Eagle Island, Niger Delta, Nigeria. American Journal of Plant Sciences, 14, 191-201.

Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, D'Amico JA, Itoua I, Strand HE, Morrison JC, Loucks CJ, Allnutt TF, Ricketts TH, Kura Y, Lamoreux JF, Wettengel WW, Hedao P, Kassem KR (2001) Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938.

Ordu AU (Ed.) (2023) Top priorities for the continent in 2023, Foresight Africa. Washington DC: The Brookings Institution.

Ordway EM, Asner GP and Lambin EF (2017) Deforestation risk due to commodity crop expansion in sub-Saharan Africa. Environmental Research Letters, Volume 12, Number 4

Pacheco P, Mo K, Dudley N, Shapiro A, Aguilar-Amuchastegui N, Ling PY, Anderson C and Marx A (2021) Deforestation fronts: Drivers and responses in a changing world. Gland, Switzerland: WWF

Palazzo A, Rutting L, Zougmoré R, Vervoort JM, Havlik P, Jalloh A, Aubee E, Helfgott AES, MasonD'Croz D, Islam S, Valin H, Ericksen PJ, Segda Z, Moussa AS, Bayala J, Kadi HA, Sibiry Traoré PC, Thornton PK (2016) The future of food security, environments and livelihoods in Western Africa: Four socio-economic scenarios. CCAFS Working Paper no. 130. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Perrings C and Halkos G (2015) Agriculture and the threat to biodiversity in sub-Saharan Africa. Environmental Research Letters Vol 10, No 9

Piñeiro V, Arias J, Dürr J et al. (2020) A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. Nature Sustainability 3, 809–820

Potapov P, Turubanova S, Hansen MC et al. (2022) Global maps of cropland extent and change show accelerated cropland expansion in the twenty-first century. Nat Food 3, 19–28 (2022).

Ramo R, Roteta E, Bistinas I and van der Werf GR (2021) African burned area and fire carbon emissions are strongly impacted by small fires undetected by coarse resolution satellite data. PNAS 118 (9) e2011160118

Regenerative agriculture initiative (2017) What is Regenerative Agriculture? Chico: Regenerative agriculture initiative.

Rhode C and Stitteneder T (2020) Creating Sustainable Cooperation Strategies with Africa: A Glance at Development Aid and FDI. CESifo Forum 2 / 2020 July Volume 21.

Richardson R, Fernandez A, Tschirley D and Tembo G (2012). Wildlife Conservation in Zambia: Impacts on Rural Household Welfare. World Development. 40. 1068-1081.

Rwamasirabo S (2021) African food systems. Kigali: PAFO (Pan-African Farmers Organization).

Scheren P, Tyrrell P, Brehony P, Allan JR, Thorn JPR, Chinho T, Katerere Y, Ushie V, Worden JS (2021) Defining Pathways towards African Ecological Futures. *Sustainability* 13(16):8894.

Searchinger T, Peng L, Zionts J and Waite R (2023) The Global Land Squeeze: Managing the Growing Competition for Land. Washington DC: WRI.

Silici L (2014) Agroecology - What it is and what it has to offer. London: IIED

Stephens PA (2015) Land sparing, land sharing, and the fate of Africa's lions. PNAS 112 (48) 14753-14754

Sumberg J. (2022) Future Agricultures: The promise and Pitfalls of a (Re)turn to Nature, Outlook on Agriculture, February 2022, DOI: 10.1177/00307270221078027

SWAC/OECD (2021) Food system transformations in the Sahel and West Africa: implications for people and policies, Maps & Facts, no. 4, April 2021.

Technoserve (2017). Food Processing in Sub-Saharan Africa. Solutions for African Food Enterprises. Final Report. Washington: Technoserve

TerrAfrica (2009) Policy and Financing for Sustainable Land Management in Sub-Saharan Africa. Lessons and Guidance for Action. Midrand: TerrAfrica / NEPAD Planning and Coordinating Agency.

Tostado L (ed) (2022) The pesticide Atlas 2022 – Kenya Edition. Nairobi, Berlin: Heinrich-Böll-Stiftung, Brussels: Friends of the Earth Europe, Berlin: Bund für Umwelt und Naturschutz, Brussels: PAN Europe

Ulimwengu JM, Constas MA, and Ubalijoro E (Eds.) (2021) Building Resilient African Food Systems After COVID-19. ReSAKSS 2021 Annual Trends and Outlook Report. Kigali and Washington, DC: AKADEMIYA2063 and International Food Policy Research Institute (IFPRI).

UNCTAD (2022) Rethinking the Foundations of Export Diversification in Africa: The catalytic role of business and financial services. Economic Development in Africa Report 2022. Geneva: UNCTAD

UNECA (2020) Economic Report on Africa 2020: Innovative Finance for Private Sector Development in Africa Development in Africa. Addis Ababa: UNECA

United Nations (2023) Growing Middle Class and Import Substitution. Connecting the Dots to Unlock Made in Africa. Policy Brief. Africa Dialogue Series. OSAA, AUPOM, AfCFTA, CFC, UNCTAD, ECA and UNIDO.

Uzokwe CE, Ebenso BE and Cade JE (2022) Dietary assessment of type-2 diabetes in Africa: A systematic scoping review. Diabetes Epidemiology and Management, Volume 6,100056.

van Dijk M, Morley T, Rau ML and Sagha Y (2021) A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. Nat Food 2, 494–501

van Ittersum MK, van Bussel LGJ, Wolf J, Grassini P, van Wart J, Guilpart N, Claessens L, de Groot H, Wiebe K, Mason-D'Croz D (2016) Can sub-Saharan Africa feed itself? Proceedings of the National Academy of Sciences 113 (52) 14964-14969

van Loon MP, Hijbee, R, ten Berge HFM, et al. (2019) Impacts of intensifying or expanding cereal cropping in sub-Saharan Africa on greenhouse gas emissions and food security. Glob Change Biol. 2019; 25: 3720– 3730.

Vervoort JM, Palazzo A, Mason-D'Croz D, Ericksen PJ, Thornton PK, Kristjanson P, Förch W, Herrero M, Havlik P, Jost C, Rowlands H (2013) The future of food security, environments and livelihoods in Eastern Africa: four socio-economic scenarios. CCAFS Working Paper no. 63. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.

Wezel A, Herren BG, Kerr RB, Barrios E, Gonçalves ALR and Sinclair F (2020) Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. Agron. Sustain. Dev. 40, 40 (2020).

WFP (2021) Food systems in Southern Africa. Drivers of change and opportunities for influence. Johannesburg: WFP Regional Bureau for Southern Africa and the Southern Africa Food Lab.

World Bank (2009) Awakening Africa's Sleeping Giant. Prospects for Commercial Agriculture in the Guinea Savannah Zone and Beyond. Directions in Development, Agriculture and Rural Development. Washington: The World Bank

Wineman A, Jayne TS and Stevens C (2022) The Relationship Between Medium-Scale Farms and Deforestation in Sub-Saharan Africa. Washington DC: USAID

World Meteorological Organization (WMO) (2022) State of the Climate in Africa 2021. Geneva: WMO.

WWF (WWF) - Regional Bureau for Africa, and African Development Bank (2015) African Ecological Futures 2015.

WWF (2020) Bending the Curve: The Restorative Power of Planet-Based Diets. Loken, B. et al., Gland, Switzerland: WWF

WWF-UK (2021) Driven to waste: The Global Impact of Food Loss and Waste on Farms. Woking: WWF.

WWF (2022). Solving the Great Food Puzzle: 20 levers to scale national action. Loken, B. et al., Gland, Switzerland: WWF

Working to sustain the natural world for the benefit of people and wildlife.

together possible™ panda.org

For contact details and further information, please visit our international website at www.panda.org