TEEB for Agriculture and Food in Africa: assessing policy options to improve livelihoods

A report prepared for the TEEBAgriFood (The Economics of Ecosystems and Biodiversity for Agriculture and Food)
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Contents

List of Tables

List of Figures

Executive Summary and Recommendations

Agriculture remains the most significant sector in the African economy as it contributes around 15% to its total Gross Domestic Product on an average (GDP; OECD/FAO, 2016). It provides employment to around 60% of the workforce and is able to feed half of the population with the remaining half of the food demand met by imports. Growing demand for food due to the increasing population in sub-Saharan Africa (SSA) is one of the key challenges for agriculture. It is estimated that global population numbers will rise to about 9.7 billion by 2050 and about 1.3 billion will add to the existing African population. This will put enormous pressure on agriculture and food systems to respond in order to meet the food demand, reduce food imports and protect natural resources. At the same time, it provides an opportunity for African agriculture to respond more cohesively and improve value generated by this sector to society, the environment and the economy. This can help achieve self-sufficiency in food, increased employment to meet the needs of the growing workforce, and the protection of natural resources while contributing to the Sustainable Development Goals (SDGs). A comprehensive action plan with carefully developed policies is required to achieve these outcomes. It is recognised that the global agriculture and food systems cause damages to the environment and human health. However, these are not captured by the current economic system, leading to perverse and pervasive outcomes for society and the environment. Therefore, this report aims to consider all social and environmental externalities – both negative and positive, in sub-Saharan African agriculture and food systems. Its goal is to reflect these in the economic system by evaluating comprehensive costs and benefits through an innovative, universal, and inclusive framework, the 'TEEBAgriFood' framework. This assessment intends to stimulate appropriate policy responses for sustainable agriculture and food systems to be developed and ensure food and nutritional security as well as economic prosperity for all in Africa.

The report provides a regional analysis and narrative on the economics of the agriculture and food sector by focusing on Sub-Saharan Africa, highlighting the key positive and negative externalities it generates and the national and international policy context. These externalities are assessed with the TEEBAgriFood Evaluation Framework in three case studies: agroforestry (coffee/cocoa) in Ethiopia and Ghana, livestock in Tanzania, and rice in Senegal.

Cocoa (Ghana) and coffee (Ethiopia) in Agroforestry systems

This study quantifies the biophysical and social impacts and dependencies along the cocoa and coffee value chains in Ghana and Ethiopia, respectively (ICRAF, 2019). Its aim is to assess key negative and positive impacts to health, ecosystems and the economy of the processes associated with the value chains of the two commodity crops. This is achieved by applying the TEEB for agriculture and food (TEEBAgriFood) framework (TEEB, 2018). Following this framework, several invisible and visible benefits and costs within these value chains are identified, quantified, monetised and /or described. Most of these benefits and costs are represented in monetary values except for biodiversity, vegetative diversity and aquatic life diversity which were measured using diversity indices such as the Shannon-H index, the Simpsons index, the species richness index, or the Alpha index. Secondary data sourced from a variety of sources including peer reviewed journal articles and technical reports was used in the analysis.

Livestock systems in Tanzania

This study quantifies socio-economic and ecological externalities of value chain activities related to three livestock sectors in Tanzania using the TEEBAgriFood evaluation framework: the Pastoralist cattle system, the Backyard poultry system, and the Smallholder dairy system. The livestock described here has local value chains which are also examined in each case. Different actors exist in the pastoralists' cattle value chain in the Arusha region. The major actors in the chain are producers (farmers), middlemen, traders, abattoirs, butchers, supermarkets, hotels and individual consumers (final consumers). However, middlemen dominate the market and are reported to be the major means of market information. Backyard poultry production in Tanzania is a traditional sector at the smallholder level and has an important position in the rural household economy, supplying high quality meat and eggs, as well as increasing income for rural farmers. Most of the milk produced originates from the traditional small holder dairy system, comprised of over 90% of the cattle population, and is consumed at household level. Only about 3% of the milk is filtered through to the formal market.

Rice in Senegal

The rice sector in Senegal is facing the strong imperative of increasing the domestic production and processing of rice. Several substantial donors have suggested that investment should be made in the rice sector. However, there are a number of alternative pathways leading towards that goal. For example, increasing rice production through conventional high-input methods could ramp up yields, but there are rising costs related to increased fertilizer, pesticide and water use. Large-scale rice value chain projects may propose equally large rice mills, but the opportunity to process rice in smaller units may enable greater use of rice by-products such as livestock feed and promote greater equity through community ownership. Different pathways have different implications for employment in the agriculture and food sector. By using a holistic framework to review the possible pathways, many diverse aspects can be brought into focus at the same time, looking at impacts on not just economic or produced capital but also social, human and natural capital. The application of the TEEBAgriFood framework and system modelling has shown that alternative systems based on FAO's principles of agroecology can guide the further development of rice policies in Senegal and provide insights into policy opportunities and recommendations for capturing externalities into decision-making for better livelihood outcomes.

Three case studies clearly examine the key aspects of the value chains of coffee, cocoa, livestock, and rice. This analysis also recommends alternative systems and scenarios for policy makers to consider in their respective countries. For example, shaded coffee and cocoa systems promote several public benefits and can be incentivised through markets and by government-provided subsidies. Livestock systems in Tanzania provide food for millions of rural dwellers and need further support through training and quality inputs in order to realise their full potential. Rice in Senegal can be produced by using the principles of agroecology, thereby saving inputs cost. These savings can then be provided directly to farmers and the

R&D sector to support these multi-dimensional farming systems. Such approaches can lead to the development of self-sufficient systems in these countries. Further analysis is required at the continental scale, including key cereal crops that are essential for food security in SSA, in order to generate evidence to shift agriculture and food policies towards long term sustainability, the achievement of the SDGs and well-being for all.

Recommendations

Based on the analysis presented in earlier sections, some recommendations are suggested below.

- Subsidies for inputs can be carefully investigated to target desired outcomes for society rather than the narrow focus of per hectare productivity.
- FDI can be further channelled to invest in infrastructure required to support the agriculture sector such as roads, ports, storage, transport, finance, processing, and regulated markets.
- Extension services can be further improved by including training about the multidimensional aspects of farming and the move away from per ha productivity.
- There is a need to improve HDI by investing in education, children and women's health, and environmental sustainability for society to be healthy, better educated and capable of making informed decisions about food.
- The R&D sector needs investment and reforms. The current global agriculture system is geared towards a single, narrow focus that has to change. This research should trickle down to the African continent and SSA regions to transform agriculture and food systems.
- Agriculture is vital for 9 out of 17 SDGs and is a prominent sector in Africa's Agenda 2063. It therefore needs further attention from policy makers in terms of investment and national and regional policies.
- There is a need to:
  - Identify change agents to bring this transformation.
  - Increase production in a more sustainable manner while absorbing a growing labour force.
  - Promote diversification based on high quality processed products.
  - Promote efficient and more equitable value chains.
  - Make farms and agricultural systems more resilient.
  - Develop regional markets and control international integration.
  - Design and implement structural policies and instruments.
  - Reform development aid aimed at facilitating the structural reform process.
  - Clearly articulate the objective and a shared vision.

1. Introduction

Agriculture remains the most significant sector in the African economy as it contributes about 15% to its total Gross Domestic Product on average (GDP; OECD/FAO, 2016). It provides employment to about 60% of the workforce and feeds half of the population, the remaining half of the food demand is met by food imports. Growing demand for food due to the increase in population in sub-Saharan Africa (SSA) is one of the key challenges for agriculture. It is estimated that global population numbers will rise to about 9.7 billion by 2050, with a 1.3 billion increase to the existing African population. This will put enormous pressure on agriculture and food systems to respond in order to meet the food demand, reduce food imports and protect natural resources. At the same time, it provides an opportunity for African agriculture to respond more cohesively and improve value generated by this sector to society, the environment and the economy. This can help achieve self-sufficiency in food, increased employment to meet the needs of the growing workforce, the protection of natural resources and contribution towards the Sustainable Development Goals (SDGs). A comprehensive action plan with carefully developed policies is required to achieve these outcomes. It is recognised that the global agriculture and food systems cause damages to environment and human health. These are not captured by the current economic system, leading to perverse and pervasive outcomes for society and the environment. Therefore, this report aims to consider all social and environmental externalities – both negative and positive, in sub-Saharan African agriculture and food systems. It aims to reflect these in an economic system by evaluating comprehensive costs and benefits through an innovative, universal, and inclusive framework, the 'TEEBAgriFood' framework. This assessment intends to stimulate appropriate policy responses for sustainable agriculture and food systems to be developed and ensure food and nutritional security as well as economic prosperity for all in Africa.

Present and future self-sufficiency to meet the food demand is at the top of the African continent's agenda. So far, agricultural production has increased through the expansion of cultivated areas, whereas the productivity (yield) is stagnant or declining in many cases. Moreover, agricultural expansion causes biodiversity loss, the use of agrochemicals leads to eutrophication, the exposure to chemicals has several impacts on human health, and high energy use results in greenhouse gas emissions. Land degradation is common on the African continent, monocultures of rice and maize have led to dietary shifts causing negative health impacts as traditional and diverse diets have been replaced. These unintended consequences of agriculture and food systems need to be examined in order to minimise the damage to human and environmental health while improving productivity.

In addition to the challenges of achieving the SDGs, the African Union in 2013 developed its own agenda, widely knowns as Agenda 2063, mapping out an ambitious plan for overall progress in the African continent. The agriculture and food sector is one of the most prominent sectors that can help achieve these goals. The economic contribution of agriculture to the economy is increasing in Africa. The total GDP in Sub-Saharan Africa is USD 1.67 trillion, where agriculture, fishing, and forestry contribute USD 301 billion annually. By 2063, Africa's population will grow from 1.3 billion today to 3 billion. With this high population growth, food security remains a challenge for Africa. Although it has improved over time, the malnutrition rate in children reaches 15%. There is a significant increase in calories per capita, from 2000 in 1963 to over 2600 today, expected to reach 3000 by 2063. The promotion of calorie-based agriculture in SSA has dominated to ensure food security. However, such agriculture often overlooks nutritional heath. There are several other factors that limit the realisation of agriculture's full potential in the African context. Climate change is one such factor, making severe droughts and water stress become major local issues. This could lead to groundwater and surface water shortages. IPCC scenarios indicate yield losses of 27-32% in major cereal crops. Moreover, a quarter of greenhouse gas emissions are related to agricultural and land use activities. These are likely to increase as agriculture intensifies in pursuit of producing more food. Interlinkages between agriculture and natural resources as well as agriculture's impact on human and environmental health needs to be understood for appropriate policy responses to be developed for the transformation of agriculture systems. Without a clear understanding of its impacts, future agricultural development is likely to follow same the path that it has been treading on in the past without much success. The analysis of such a complex system with multiple dimensions, including natural, social, and human health aspects is required to develop clear pathways for the progress of sustainable agriculture and society.

Africa has shown tremendous progress in shaping its agricultural policy to meet the growing food demand and protect its natural resources. One such programme is the Comprehensive Africa Agriculture Development Programme (CAADP), agreed by the African Union (AU) in Maputo, Mozambique, in 2003. CAADP provides a broad framework for the transformation of agriculture to generate wealth, achieve food security and nutrition, and attain economic growth and prosperity for all. It has clear targets to achieve 6% annual growth in agricultural GDP, and an allocation of at least 10% of public expenditures to the agricultural sector. This is an integral part of the New Partnership for Africa's Development (NEPAD).

"*Agriculture is everyone's business: national independence depends on its development because it enables us to escape the scourge of food insecurity that undermines our sovereignty and fosters sedition; it is a driver of growth whose leverage is now acknowledged by economists and politicians; it is the sector offering the greatest potential for poverty and inequality reduction, as it provides sources of productivity from which the most disadvantaged people working in the sector should benefit.*" (Ibrahim Assane Mayaki, NEPAD Agency).

Broader policy frameworks need to develop mechanisms to minimise negative impacts on society and the environment and ensure that the transformation of agriculture is achieved. This can be achieved by, (i) a comprehensive assessment of all costs and benefits of agriculture and food systems and their inclusion in national accounts, and (ii) a new theory of change that can facilitate appropriate policy responses. The lack of appropriate tools to measure and reveal such externalities is the main shortcoming of current policies around the globe. This gap has been addressed by the development of TEEBAgriFood Evaluation Framework.

1.1. Aim and objectives

This report aims to use the TEEBAgriFood Evaluation Framework to evaluate agriculture and food systems in general and particularly in SSA so that a complete analysis can inform better agriculture and food policies for the region.

The specific objectives of the report are,

- To provide a regional analysis and narrative on the economics of the agriculture and food sector by focusing on Sub-Saharan Africa, highlight key positive and negative externalities it generates, and the national and international policy context.
- To review the economic interdependencies between human (economic and social) systems, agriculture and food systems, and biodiversity and ecosystems in three case studies – rice in Senegal, agroforestry (coffee/cocoa) in Ethiopia and Ghana, and livestock in Tanzania using the TEEBAgriFood Evaluation Framework.
- To provide insights into policy opportunities and recommendations to capture externalities in decision-making for better livelihood outcomes.

The report is organised as below.

Section 2 provides background information on the economy, the environment and society in general for SSA. Section 3 provides a systems approach to assess agriculture systems. Section 4 elaborates on the key economic and agriculture polices. Section 5 assesses three case studies that used the TEEBAgriFood framework. It also analyses various farming systems and policies discussed in the three case studies. Section 6 provides a theory of change for the transformation of the agriculture sector in SSA. Section 7 concludes the report.

2. Overview of Sub-Saharan Africa

Sub-Saharan Africa is a part of the African continent located south of the Sahara, comprising 46 of Africa's 54 countries with diverse climatic zones (Figure 1).

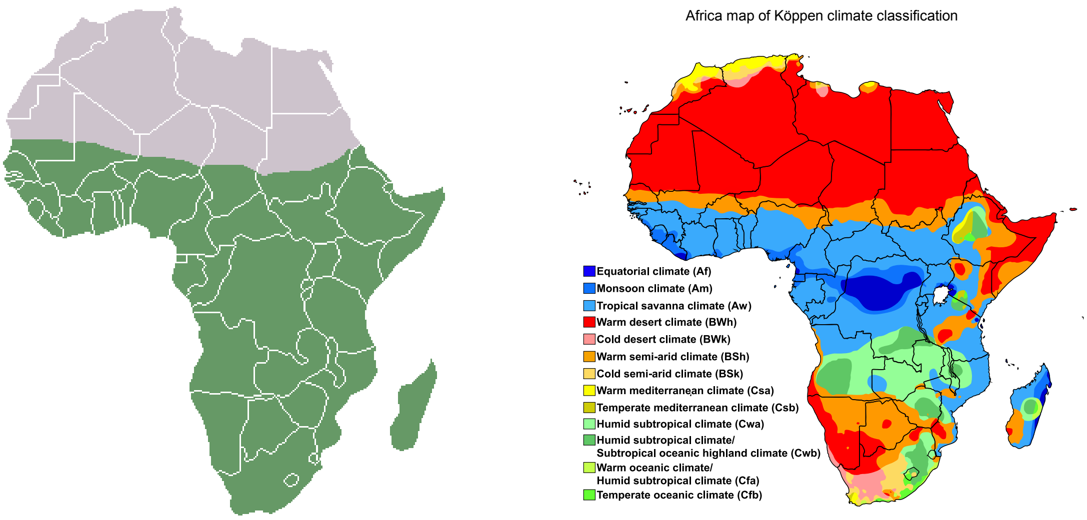

Figure 1 a) Sub-Saharan African countries, Source: Geiger, 1954. b) Climatic zones in the African continent. Source: UNDP, 2018.

2.1. Economy

The Gross Domestic Product (GDP) in the 46 SSA countries has increased significantly since 2000 (Figure 2, Table 1). After a slight decline from 2014, it is again showing growing trends. Value added by the agriculture, forestry and fishing sectors in four key regions of SSA are provided in Figure 3. These macroeconomic trends are the outcomes of progressive policies and investment in infrastructure. However, sustained economic growth has not led to high job growth rates. This lack of job growth has impacted poverty reduction efforts and increased inequality, with the Gini coefficient rising from 0.52 in 1993 to 0.56 in 2008 (African Development Bank, 2018). The income inequality in Africa is shown in Figure 4 below.

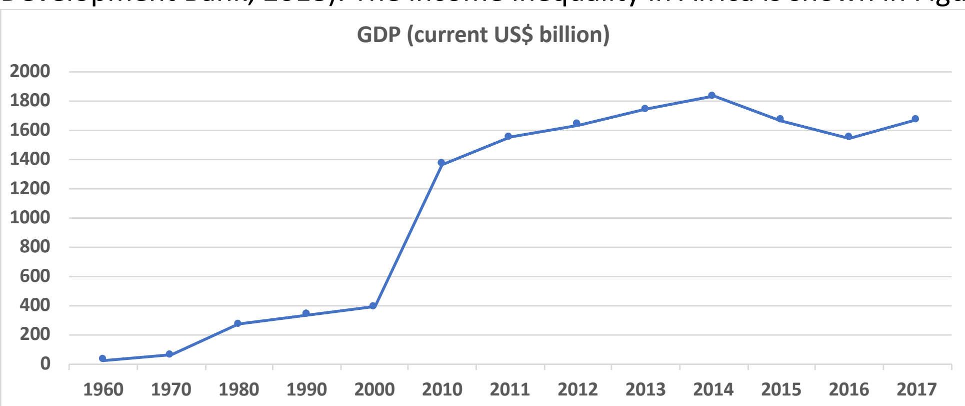

Figure 2 GDP in SSA USD from 1960 to 2017. Source: Drawn by the author, data from the World Bank, 2016.

Table 1 GDP in 46 countries (PPP international $, 2017). Source: World Bank, 2016.

Country Name	GDP, PPP (2017, current international $)	Country Name	GDP, PPP (2017, current international $)
Angola	197.88	Mali	41.04
Burundi	7.97	Mozambique	37.01
Benin	25.39	Mauritania	17.46
Burkina Faso	35.74	Mauritius	28.21
Botswana	38.93	Malawi	22.39
Central African Republic	3.38	Namibia	26.47
Cote d'Ivoire	95.63	Niger	21.83
Cameroon	89.35	Nigeria	1121.40
Congo, Dem. Rep.	72.17	Rwanda	24.89
Congo, Rep.	28.63	Sudan	198.76
Comoros	2.23	Senegal	54.69
Cabo Verde	3.77	Sierra Leone	11.54
Ethiopia	199.34	South Sudan	20.71
Gabon	36.60	São Tomé and Príncipe	0.68
Ghana	129.53	Eswatini	11.81
Guinea	28.52	Seychelles	2.80
Gambia, The	3.56	Chad	28.92
Guinea-Bissau	3.16	Togo	12.94
Equatorial Guinea	30.92	Tanzania	163.89
Kenya	163.29	Uganda	79.91
Liberia	6.07	South Africa	765.54
Lesotho	6.53	Zambia	68.79
Madagascar	39.76	Zimbabwe	40.14

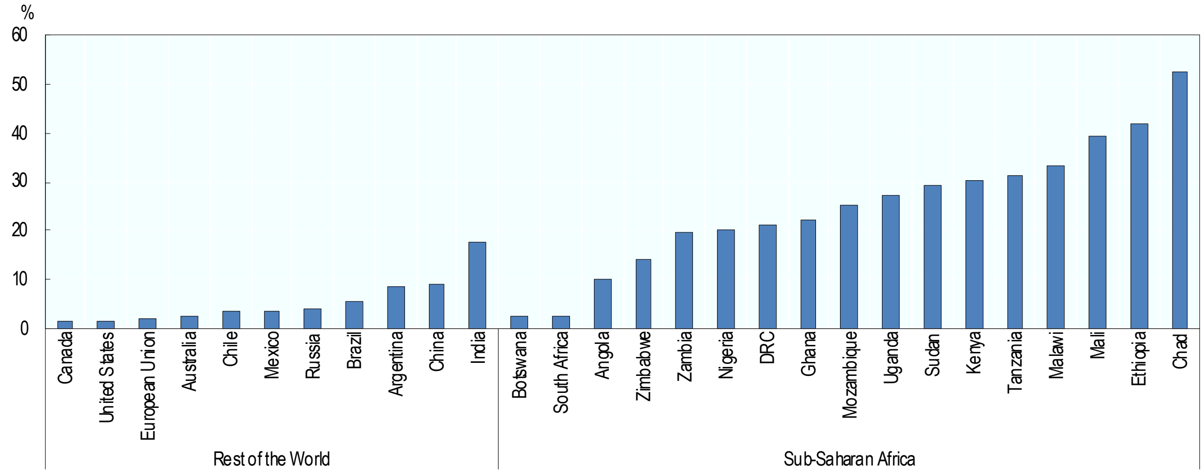

Figure 3 Agriculture as a share of total GDP in 2014GDP in SSA USD from 1960 to 2017. Source: World Bank, 2016.

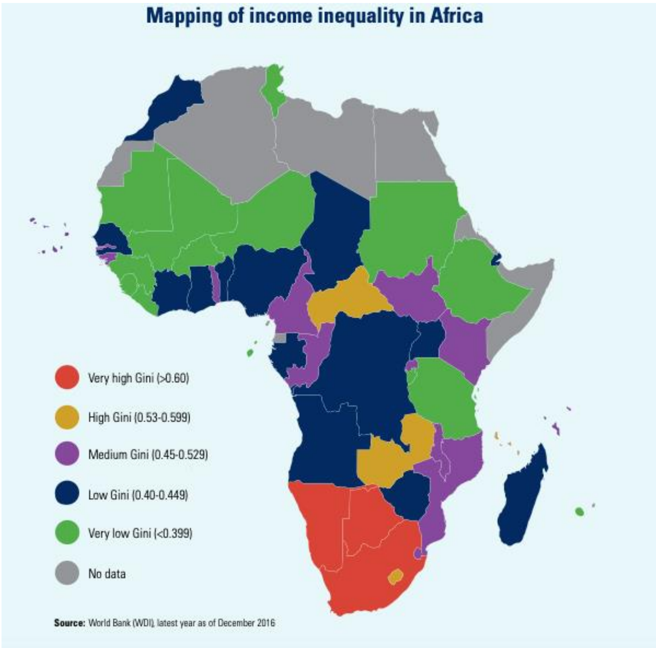

Figure 4 Map of African countries showing income inequality. Source: World Bank, 2016.

Agriculture is one of the key economic sectors, contributing about 15% to the GDP from the total arable land of 192 million hectares. It employs 60% of the total work force (Figure 5). Agriculture, however, only gets a small percentage of foreign direct investment as compared to other sectors. Out of total USD 30 billion in FDI, the agriculture sector only received USD 0.46 billion in 2010 (Figure 6).

Figure 5 Sectoral employment shares in Africa and other world regions. Source: AfDB Statistics.

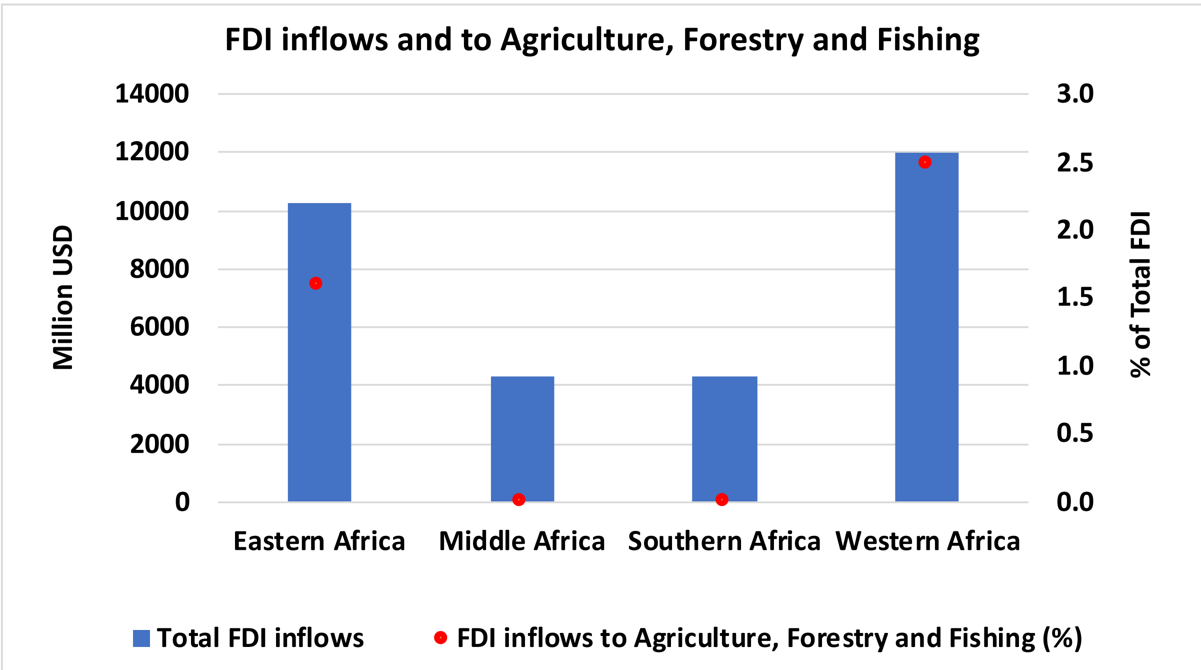

Figure 6 FDI inflows in SSA and to agriculture, forestry and fishing sector . Source: Drawn by the author, data from the World Development Indicators, World Bank, 2019, https://datatopics.worldbank.org/world-development-indicators/.

2.2. Community

The community in sub-Saharan Africa is diverse, with several different beliefs and traditions. The society is communal in nature, as there is more emphasis on common resources than individual needs. For economic development processes and synergies among nearby states, various regional countries have formed four communities (Figure 7): The East African Community (EAC), the Economic Community of West African States (ECOWAS), the Southern African Development Community (SADC) and the Economic Community of Central African States (ECCAS).

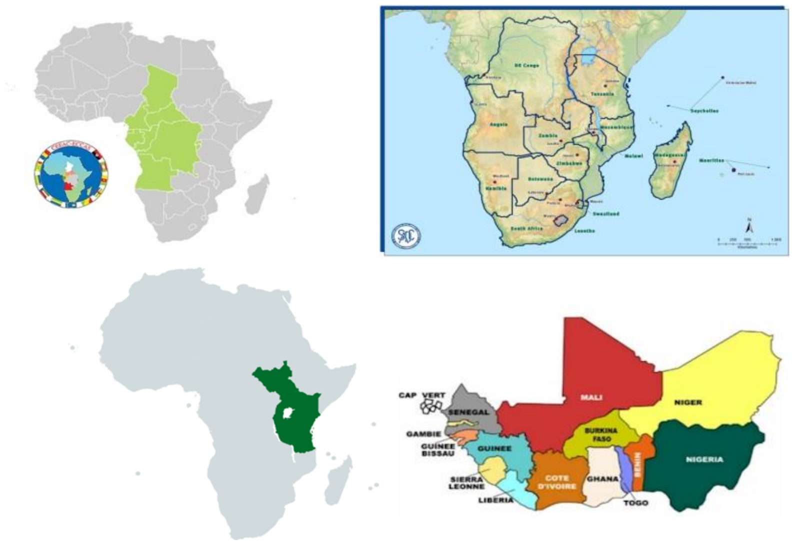

Figure 7 Geographic representation of four economic communities in SSA . Source: Drawn by the author, maps from the East African Community (EAC, https://www.eac.int/overview-of-eac), The Economic Community of West African States (ECOWAS, http://www.ecowas.int/)

2.2.1. The East African Community (EAC)

The East African Community (EAC, https://www.eac.int/overview-of-eac) is a regional intergovernmental organisation comprised of six Partner States: the Republics of Burundi, Kenya, Rwanda, South Sudan, and Uganda, and the United Republic of Tanzania, with its headquarters in Arusha, Tanzania. The EAC has a combined population of about 172 million citizens and a combined Gross Domestic Product of USD 172 billion (https://www.eac.int/overview-of-eac).

The EAC is one of the fastest growing regional economic blocs in the world, that engages at all political, economic and social levels within this region. It established a Common Market in 2010 and implemented the East African Monetary Union Protocol to facilitate economic progress.

2.2.2. The Economic Community of West African States (ECOWAS)

The Economic Community of West African States (ECOWAS, http://www.ecowas.int/) is a 15-member regional group with a mandate of promoting economic integration in all fields of activity in the constituting countries. Member countries of ECOWAS are Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone, Senegal, and Togo.

The Vision of ECOWAS is the creation of a borderless region where the population has access to its abundant resources through the creation of opportunities under a sustainable environment. ECOWAS has created an integrated region where the population enjoys free movement, has access to efficient education and health systems and engages in economic and commercial activities while living in dignity in an atmosphere of peace and security.

2.2.3. Southern African Development Community (SADC)

The Southern African Development Community (SADC, https://www.sadc.int/) is an inter-governmental organisation of 15 member states. Its aim is to promote sustainable and equitable economic growth and socio-economic development.

The objective of the SADC is to achieve its Common Agenda that explains the key strategies and policies of the institution. The SADC Common Agenda includes the promotion of sustainable and equitable economic growth, of socio-economic development for poverty eradication, of common political values, systems, and other shared values, and of the consolidation and maintenance of democracy, peace and security in the region.

2.2.4. The Economic Community of Central African States (ECCAS)

The Economic Community of Central African States (http://www.ceeac-eccas.org/index.php/fr/) includes 11 member countries: Angola, Burundi, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Rwanda and São Tomé and Príncipe. The ECCAS is designated in the African Economic Community as one of the eight pillars of the African Union.

The ECCAS aims to promote and strengthen a harmonious cooperation in order to realize a balanced and self-sustained economic development, particularly in the fields of industry, transport, communications, energy, agriculture, natural resources, trade, customs, monetary and financial matters, human resources, tourism, education, culture, science, technology, and the movement of persons. It seeks to achieve collective self-reliance, raising the standards of living, maintaining economic stability, and fostering peaceful relations between the member States while contributing to the development of the African continent.

2.3. Human development

The Human population in Africa is growing, currently reaching a total number at 1.29 billion with 40% of the urban population and about 60% living in rural areas (Figure 8). The population of sub-Saharan Africa is about 1 billion with a growth rate of 2.3%. The UN predicts the population number to reach between 1.5 and 2 billion by 2050.

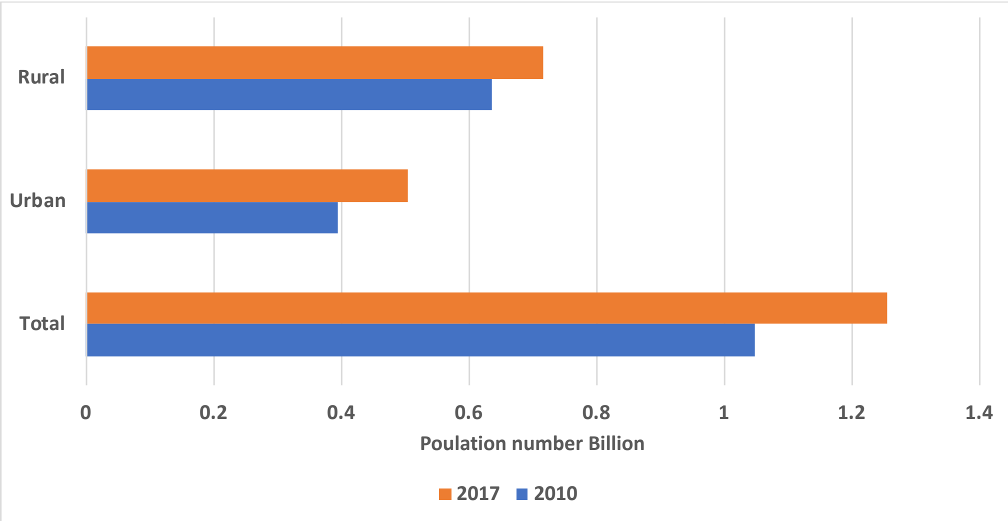

Figure 8 Total population in Africa . Source: Drawn by the author, data from the UNDESA, Population Division – World Population Prospects, the 2017.

On the Human Development Index (UNDP, 2018), SSA scores 0.537 in 2017, which has increased from 0.398 in 1990 (Figure 9). The Gender inequality index is the highest in SSA (Figure 10). The percentage of the working-age population that engages actively in the labour market, either by working or looking for work in SSA is 69.5%, where employment in agriculture is 57.2%. The overall life satisfaction in SSA scores a 4.4 out of 10, including Education quality (57%), Health care quality (47%), Standard of living (46%), Feeling safe (female 49%, male 60%), freedom of choice (73%), Confidence in judicial system (55%), Actions to preserve the environment (55%), and Trust in the national government (62%). The current health expenditure is 5.3% of the GDP in SSA. Malnutrition is prevalent with 36.4% of children under the age of 5 considered malnourished. Life expectancy at birth is 53.7 years. Adult literacy is about 60%, with public expenditure at 4.9% of GDP.

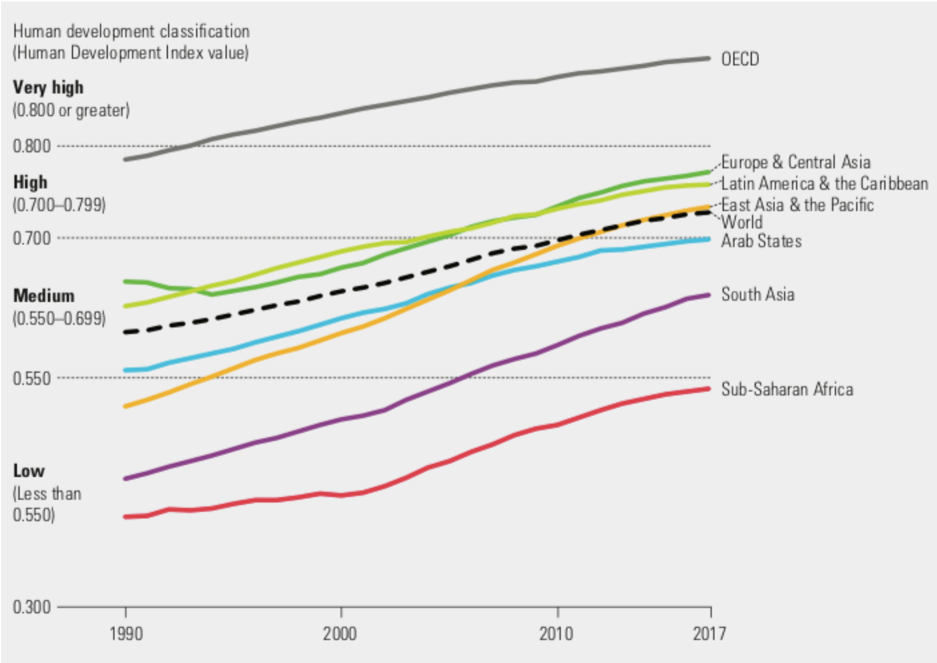

Figure 9 Human Development Index values, by country grouping, 1990–2017. Source: Human Development Report Office, UNDP, 2018.

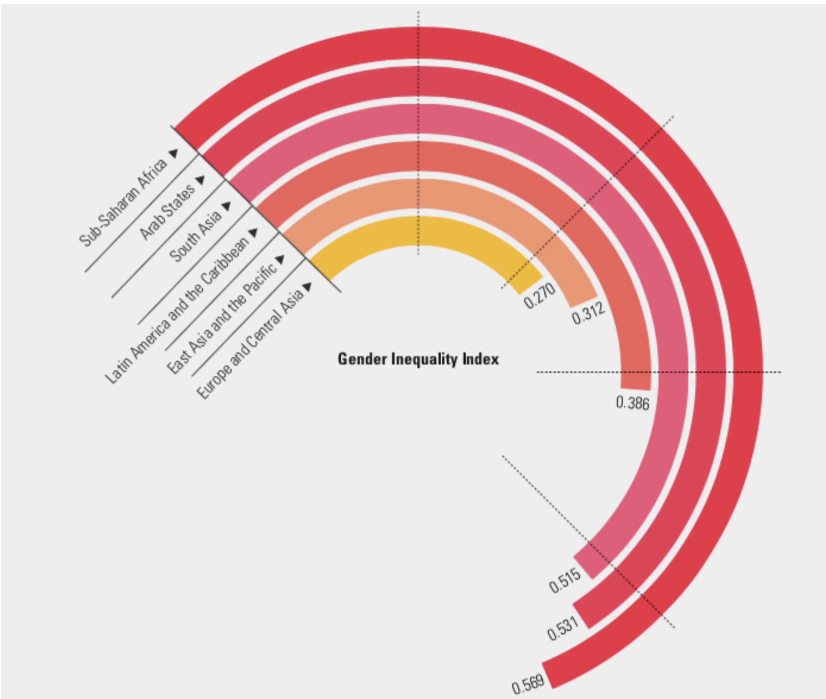

Figure 10 Gender Inequality Index, by developing region, 2017. Source: Human Development Report Office, UNDP, 2018.

2.4. Natural resources

Africa is rich in resources, especially natural resources such as rich and fertile tracts of land, forests, water resources, biodiversity and marine resources. SSA is abundant in natural resources with forests covering 28.2% of the total land. However, this has decreased since 1990 by 11.7%. Per capita CO_2 emissions are 0.9 tonnes per year. Renewable energy constitutes 70% of the total energy used (UNDP, 2018). One third of the mineral resources that can promote economic development are in Africa. However, development and growth activities often result in environmental degradation. In addition, climate change is likely to put further pressure on economic activities and agriculture, in particular due to the variability in temperature (Figure 10) and precipitation (Figure 12) in the region.

According to projections made by NEPAD (2013), climate change will have significant impacts in Africa, with an increase in temperature between 1.5 and 3 degrees by 2063 (Figure 11) and a decrease in regional precipitation of 6% by 2063 (Southern Africa) to an increase of 5% (Eastern Africa) (Figure 11). In many other areas, water stress is likely to impact development, while air and water quality will deteriorate in urban areas.

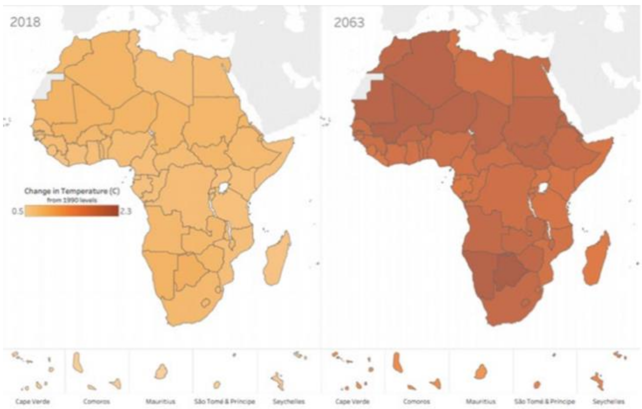

Figure 11 Temperature increases in Africa are projected between 1.5 and 3 degrees by 2063. Source: NEPAD, 2013.

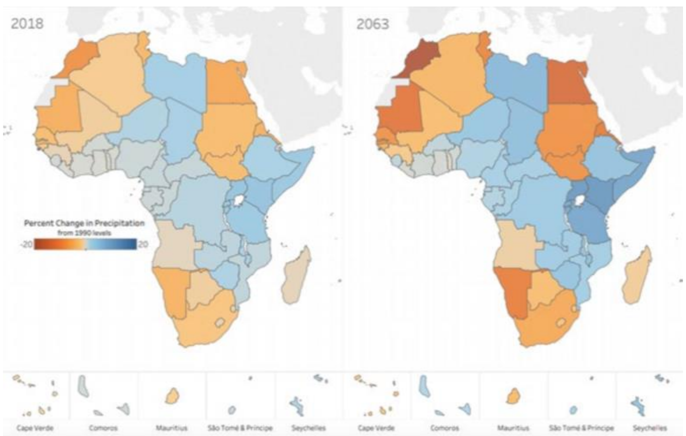

Figure 12 Regional precipitation changes in Africa range from a decrease of 6% by 2063 (Southern Africa) to an increase of 5% (Eastern Africa.) Source: NEPAD, 2013.

Despite the fact that Africa only contributes around 3.5% to global carbon emissions, the effects of climate change will be far more severe for Africa than other global regions. The Current Path projects that the temperatures in Africa will rise by 2°C by 2063 (Figure 13). This is consistent across African regions. Northern, Southern, and Western Africa are projected to experience less rainfall. Many crops grown on the continent are already close to their thermal limits, which will further strain their production. Africa is also projected to lose, on average, 4.1% of its cropland by 2039 and 18.4% by 2100.

Africa is expected to experience the largest negative impact on agricultural yields compared to other global regions (Moyer et al., 2018). By 2063, the Current Path suggests that African yields will decrease by 5% compared with 1990 levels (Figure 14, using the same technology and agricultural inputs). This is supported by a meta-analysis that projects that average crop yields in the continent will decrease by 8% by the 2050s.

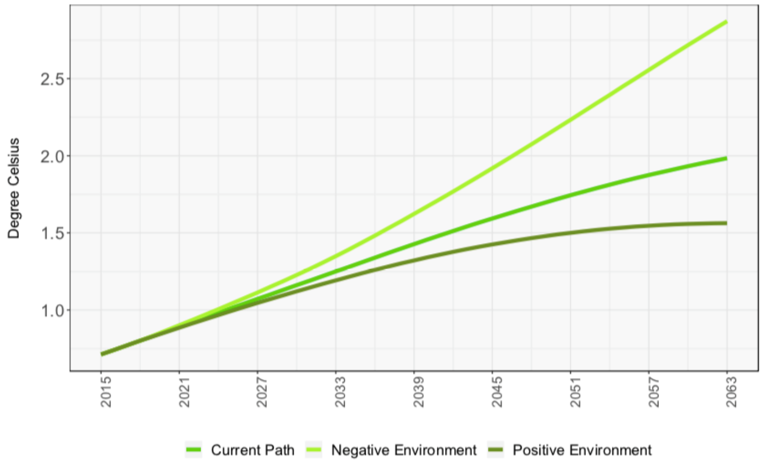

Figure 13 Temperature change across Current Path, Negative Environment, and Positive Environment scenarios, 2015-2063. Source: Moyer et al., 2018.

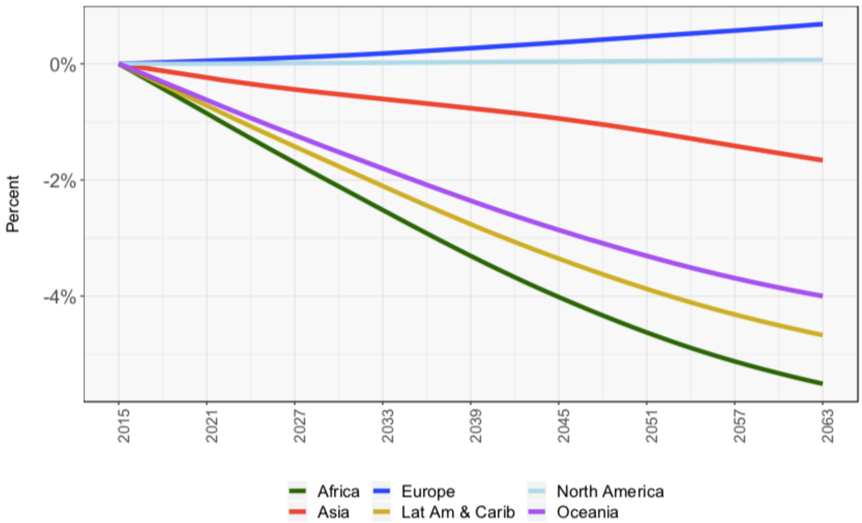

Figure 14 Impact of climate change on agricultural yield change by region, 2015-2063. Source: Moyer et al., 2018.

In the African region, there is considerable uncertainty and variability in precipitation projections. Extreme weather events, which may include prolonged droughts as well as floods, will likely increase in frequency and intensity. Africa's proportion of arid and semi-arid areas is projected to grow between 5% and 8% by 2080. By 2100, climate change could lead to losses of $19 to $48 billion. In addition to impacting agriculture, climate change is likely to affect other sectors such as health, with increased incidences of malaria. It may also cause conflicts over scarce food and water resources and depressing economic growth, trigger migration and sea level increase that will displace coastal dwellings, reduce tourism and biodiversity, and render many informal settlements vulnerable to flooding, which can further lead to health problems as water and sanitation services are affected.

2.5. Food security

Food security in Africa has improved considerably over time with calories per capita increasing from 2,000 in 1963 to over 2,600 today. They are expected to reach 2,780 by 2038 and nearly 3,000 by 2063. While calories are available, the number of malnourished children is high, at about 15% (UNDP, 2018). Malnourishment leads to stunted growth rates, which is defined as the percentage of the population with permanent reductions in physical and mental abilities as a result of childhood under-nutrition. 21% of the population is affected by stunting in Africa.

Despite an increase in area under agriculture and total production of food crops, food security remains a challenge, with agriculture yields remaining low. Africa imports between 5% and 10% of its total food and will have to rely on global food markets for over 30% of food imports by 2038 if its agriculture and food systems fail to respond to the growing demand.

The challenge for food security is partially due to poor growth in agricultural technology. Figure 15 shows the current path for the evolution of agricultural yields and two alternative scenarios. The high-growth scenario assumes an increase in the diffusion of agricultural technology.

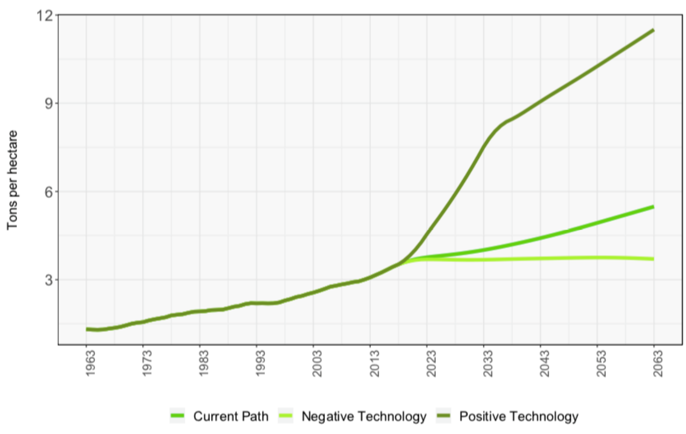

Figure 15 Average agricultural yields in Africa, history and forecast across three scenarios (negative technology, current path, positive technology). Source: Moyer et al., 2018.

Fertiliser use in Africa as compared to world use is extremely low (Table 2, Figure 16). The fertiliser input growth in agricultural yields can be improved through a combination of technology adoption, ICT-based agricultural information sharing, drip irrigation, integrated soil fertility management (ISFM) with a sustainable application of fertilizer, etc.

Table 2 Arable land, total nitrogen use and per hectare N application . Source: Drawn by the author, data from FAOSTAT, 2019.

	Arable land (million ha)	Nutrient nitrogen N (million tonnes)	Nutrient N tonnes/ha
World	1423.79	110.18	0.077
Africa	234.95	3.83	0.016
Eastern Africa	66.40	0.86	0.013
Middle Africa	25.90	0.07	0.003
Northern Africa	42.77	1.95	0.046
Southern Africa	14.09	0.44	0.031
Western Africa	85.79	0.51	0.006

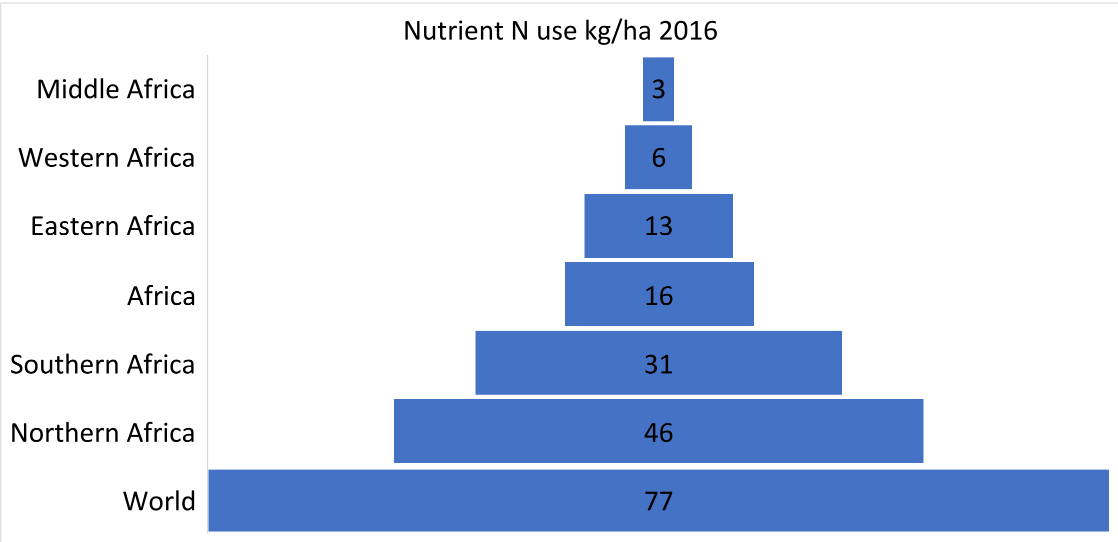

Figure 16 Nitrogen use per hectare in World and Africa. Source: Drawn by the author, data from FAOSTAT, 2019.

3. Systems approach in agriculture and food systems

In this study, a systems approach is applied to investigate the multi-dimensional and complex nature of agriculture and food systems.

3.1. Why a systems approach?

Global agriculture and food systems are complex and non-linear in nature. These systems are described as ‘eco-agri-food’ systems by the TEEBAgriFood framework (Figure 17). It is “a descriptive term for the vast and interacting complex of ecosystems, agricultural lands, pastures, inland fisheries, labor, infrastructure, technology, policies, culture, traditions, and institutions (including markets) that are variously involved in growing, processing, distributing and consuming food” (TEEB, 2018).

These eco-agri-food systems are underpinned by ecological systems, supported by physical systems, and managed by people (social systems). Their interactions with rest of the economy are conducted through economic systems. Therefore, such complex systems cannot be studied by following ecological or economic science only. Their study requires an integrated transdisciplinary approach that includes multiple disciplines such as agronomy, biology, agroecology, economics, social science, political science, and so on. Hence, systems thinking is required to understand these eco-agri-food systems. Systems thinking, which focuses on the identification of interrelationships between components, is urgently needed to help us find areas where synergies are possible and where interventions will have the most impact, while identifying where trade-offs must be recognized and negotiated.

We apply this approach to agriculture and food systems in SSA to understand various drivers of agricultural production and development and identify policy options to enhance sustainable development in the region.

The ambition of the TEEBAgriFood evaluation in three case studies is to improve the conditions for integrated decision-making for a more sustainable eco-agri-food system. This can only be convincingly done by taking a systems approach to understand how the eco-agri-food system functions within natural and social systems, while simultaneously considering cultural narratives and the need for transformational change. To achieve this, the contributions of natural and social capital to the eco-agri-food system need to be made visible. This implies not only focusing on production processes, but also on multiple interactions, feedback loops, and pathways by which the environment and agriculture contribute to human health and well-being.

While systems science has existed for more than six decades, to meaningfully embrace the systems approach requires fundamental changes in the way we view and analyse problems and design solutions, as well as the type of institutions we create and use to do this. The TEEBAgriFood study offers a tool, in the form of an Evaluation Framework, to help us advance towards this type of change.

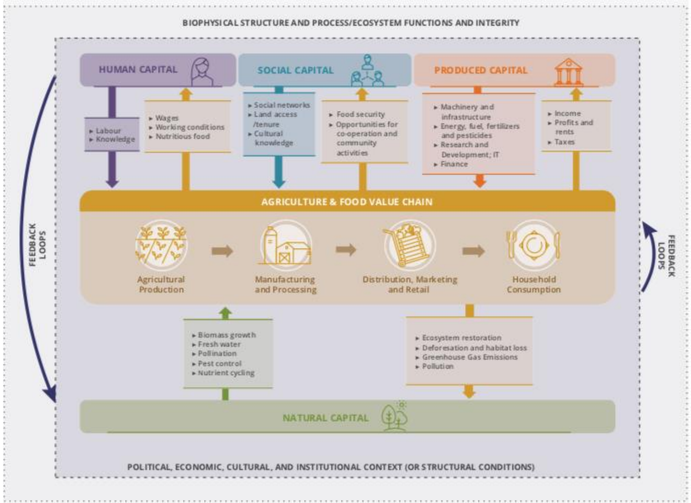

Figure 17 Modified high-level 'systems' diagram of an archetypal eco-agri-food system. Source: adapted from TEEBAgriFood, 2018.

3.2. Diversity of farming systems in SSA

Sub-Saharan Africa is a vast continent, with highly diverse farming systems and a general preference for crop types based on local cultures and traditions. This agricultural diversity is reflected in the unique regional, national, and local production and consumption patterns. North Africans consume a diet based on wheat, Central Africans and those living in the Gulf of Guinea consume more roots, tubers, and plantains, and those in Southern Africa prefer maize. This diversity also exists within countries like Ethiopia or Nigeria. In addition, the dynamic nature and diversity of agriculture in Africa is reflected in the various different structures, organisation methods and farming systems.

Africa is dominated by small-scale family agriculture with farms dependent mainly on family farm labour. Statistics on family agriculture are difficult to acquire, but the fact that the vast majority of small farms are family-run gives an idea of the importance of this phenomenon. With few exceptions, land resources are distributed in a relatively equitable manner.

Drivers of agricultural growth

As is demonstrated from its high share in GDP (Figure 3), the prospects of the agricultural sector heavily influences economic development in most countries in Sub-Saharan Africa.

From 1990 to 2013, the total value of agricultural production, measured in constant US dollars, increased by 130% (Figure 18). The crop sector dominates total agricultural production value, accounting on average for almost 85% of total production value over the 24-year period. This share differs across regions, ranging from 53% in Southern Africa, to more than 90% in Western Africa.

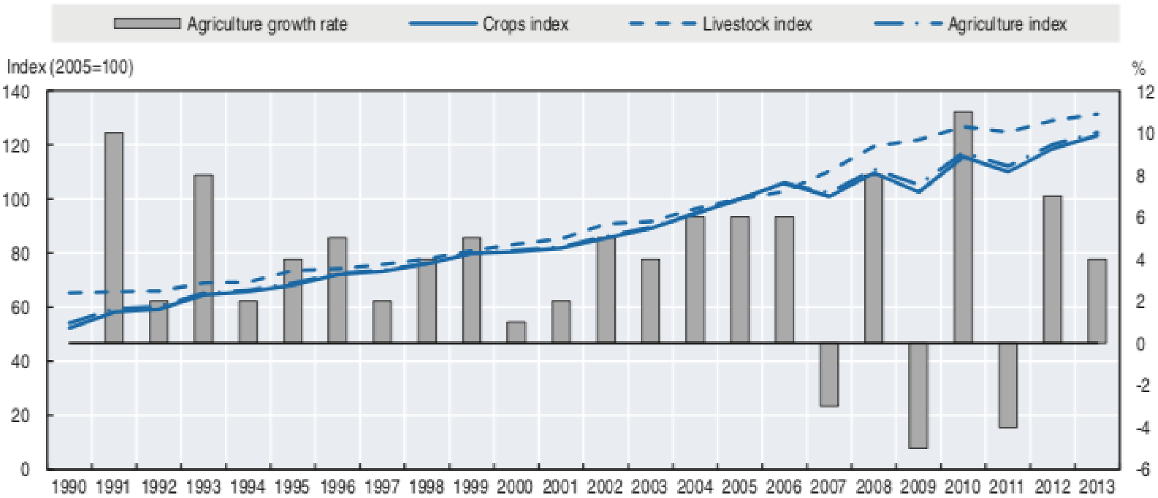

Figure 18 Gross agricultural production value in Sub-Saharan Africa measured in constant 2004-06 US Dollars . Source: OECD, 2016.

Agricultural growth has been underpinned by area expansion

The African model of agricultural growth differs significantly from that of Asia or South America. In Asia, growth was driven largely by intensification, whereas in South America, it was the result of significant improvement in labour productivity arising from mechanisation. By contrast, strong growth in SSA agricultural output has accrued predominantly from area expansion and intensification of cropping systems, as opposed to large-scale improvement in productivity (NEPAD, 2014; Brink and Eva, 2009).

Agriculture's contribution to employment

The agricultural sector plays a pivotal role in employment in SSA, employing more than half of the total workforce. While its importance for the rural population is well documented, recent surveys suggest that agriculture is also the primary source of livelihood for 10% to 25% of urban households. National census data indicates that the number of people employed primarily in agriculture has increased over time (Yeboah and Jayne, 2015).

Emergence of a West African food economy

West Africa's cities are now home to 133 million people, 25 times more than in 1950 (OECD, 2016). Between 2000 and 2010 alone, the urban population grew by over 48 million people. Consequently, the size of the food economy is growing spectacularly. Bolstered by urbanisation and income growth, household food consumption patterns are changing, and the food economy is developing (Figure 19).

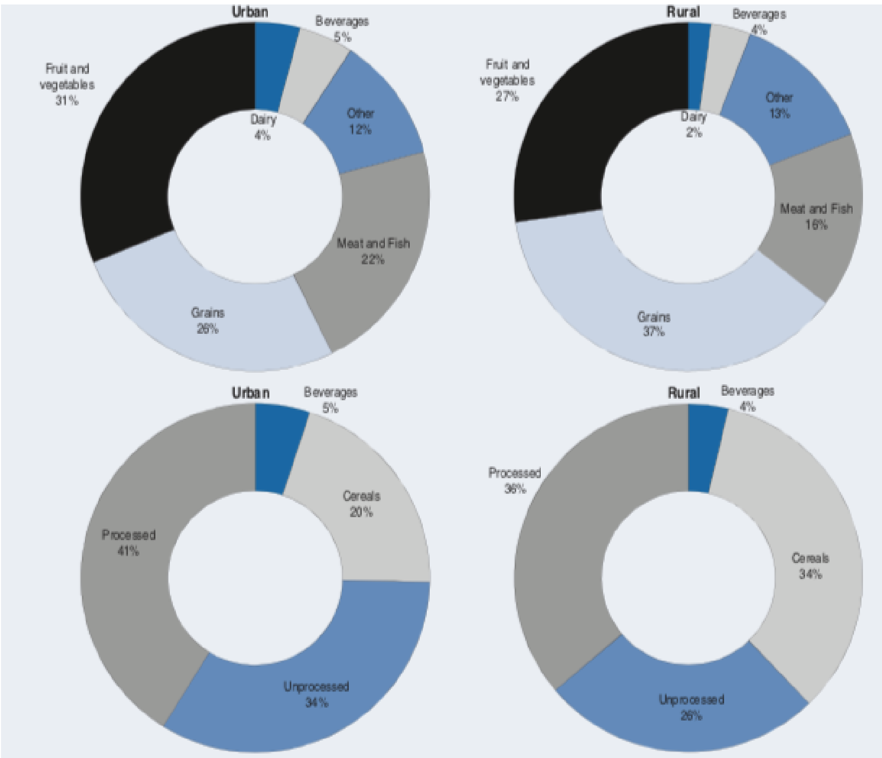

Figure 19 West African food basket by food groups and area in 2010 . Source: OECD-FAO Agricultural Outlook 2016-2025, OECD, 2016.

3.3 Key crops in Sub-Saharan Africa

Cereals

Cereals remain the primary source of energy for more than 962 million people across SSA and are therefore critical to food security. However, the composition of human cereal consumption differs from the global norm in that maize is an important staple. Maize continues to dominate the cereal market, accounting for almost 40% of total cereal consumption by 2025, followed by other coarse grains (27%), rice (18%) and wheat (15%) (Figure 20, OECD, 2016). In line with unique historic preferences, consumption growth also differs by region: while maize accounts for the largest share of additional cereal demand in Southern, Eastern and Central Africa, demand growth for rice exceeds any other cereal in West Africa.

Cereal production is projected to expand by 3.2% p.a. by 2025, rising by more than 41 Mt relative to the 2013-15 base period (OECD, 2016). Coarse grains account for the bulk of the expansion. Combined with maize, they contribute more than 80% of additional cereal production.

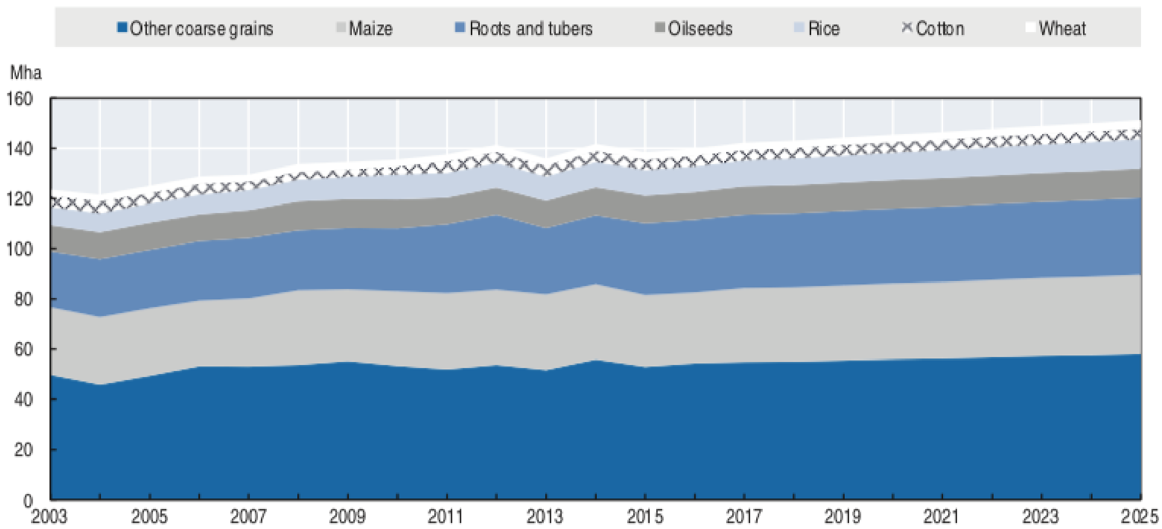

Figure 20 Crop area in Sub-Saharan Africa. Source: OECD, 2016.

Roots and tubers

As an affordable and nutritionally rich staple, roots and tubers are an important constituent of SSA diets, particularly in Central and Western Africa, where their per capita consumption exceeds any cereal product (Figure 21). Even when population growth is accounted for, the total demand in SSA as a whole in exponentially growing, approaching 100 Mt (55 kg per capita) by 2025. Of the additional 18 Mt to be consumed by 2025, almost 9 Mt are attributed to Western Africa, reflecting an average annual growth rate of 2.6%, compared to 2.4% and 2.8% in Central and Eastern Africa respectively (OECD, 2016).

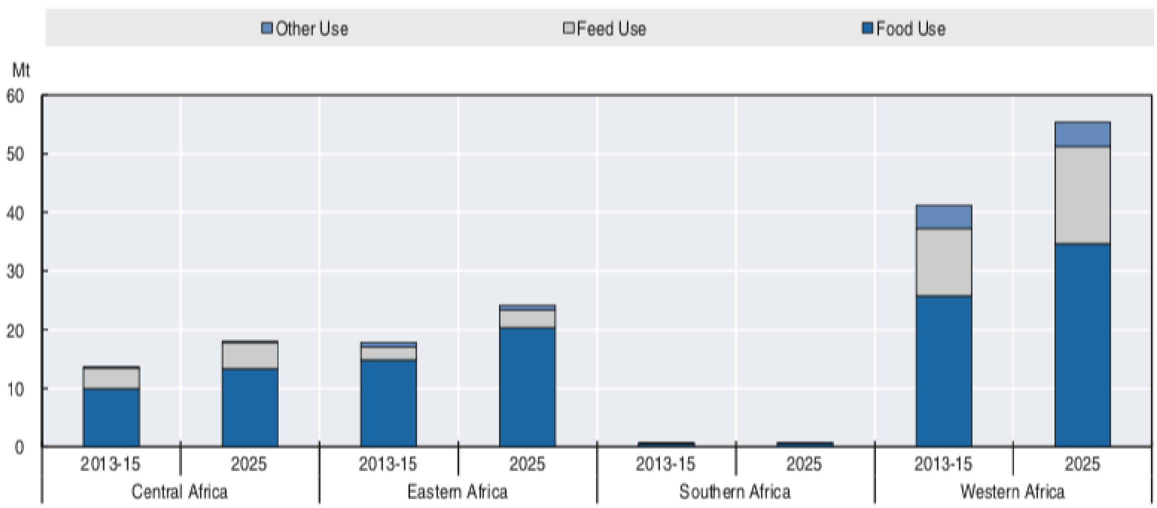

Figure 21 Roots and tubers consumption in Sub-Saharan Africa. Source: OECD/FAO, 2016.

Oilseeds and oilseed products

In line with global trends, oilseed production in SSA has expanded rapidly over the past decade, but has been concentrated in a few countries. Soybean production has soared by just over 1 Mt, yet almost 90% of the additional area is in South Africa, implying a total expansion of just over 0.1 Mt across the rest of SSA. Similarly, almost 75% of other oilseed production growth are attributed to Nigeria, South Africa and Senegal. Oilseed production across SSA is projected to expand by an annual average of 2.3% p.a., to exceed 11 Mt by 2025, only 2% of the global production (OECD, 2016.

Pulses

Pulses offer tremendous potential to alleviate malnutrition in SSA and its contribution to total protein intake is higher than in any other region in the world. Per capita consumption remains well above the global average of 6.9 kg per capita in Central (10 kg), Eastern (22 kg) and Western Africa (17 kg). The growth in per capita consumption of 2.5% p.a. (2.6 kg) over the past decade is to be sustained to 2025 and growth exceeds 2.5 kg per capita in all regions except Southern Africa, where consumption is already low in the base period (OECD, 2016).

Cotton

Cotton has emerged as an important cash crop in SSA, despite its small share in global production of 5.5%. Produced mainly for the export market, it has provided smallholder producers with a means to overcome input accessibility constraints through contract farming, playing a critical role in poverty alleviation in rural areas.

Sugar

Sugar generally represents a success story within SSA agriculture. At an aggregate level, SSA is a net importer, yet several countries in Eastern and Southern Africa rank among the lower cost producers in the world and consistently export . Least Developed Countries in SSA have benefited from quotas providing preferential access to a lucrative sugar market in the European Union, supporting production growth over the past decade. Swaziland, Mauritius, Mozambique, Zambia, Malawi and Zimbabwe have all successfully exported to the European Union.

Meat and eggs

Per capita meat consumption in SSA, at only 11 kg p.a. (Figure 22), represents less than a third of the global average. Yet, significant regional differences are evident both in levels and composition. Meat consumption in Southern Africa is four times higher than any other region and, while this is heavily influenced by South Africa, consumption in countries such as Namibia and Botswana are also well above the SSA average. However, accounting for population results in higher total meat consumption in Eastern and Western Africa, which together account for 54% of SSA meat consumption (OECD, 2016+.

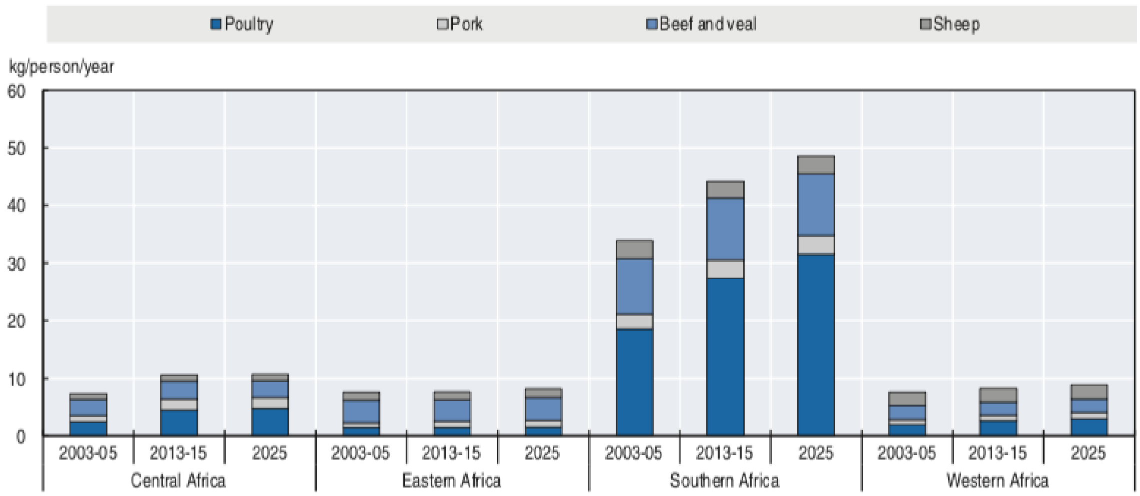

Figure 22 Meat consumption in Sub-Saharan Africa. Source: OECD/FAO, 2016.

Fish

Fish and fishery products play an important role in food security in SSA, representing a valuable source of nutrients for healthy and diversified diets. Average per capita fish consumption in SSA is among the lowest in the world (8-9 kg vs. 19-20 kg of the world level), but the contribution of fish to animal protein intake is higher than the world average (over 20% compared to 17% at world level), and this share exceeds 50% in countries such as the Gambia, Ghana, Senegal and Sierra Leone. Projections predict a 36% increase of food fish supply by 2025, compared to the average 2013-15 level, but accounting for significant population growth, the per capita increase is a mere 3%. Domestic supply is insufficient to meet demand and imports are expected to constitute an important share of the food fish supply, increasing by 32% in 2025 compared to the 2013-15 level (OECD, 2016).

Dairy

Milk production's enormous potential in economic development and food security in rural areas makes dairy an important subsector in SSA (Figure 23). Particularly in Southern and Eastern Africa, the commercialisation of the sector has illustrated dairy's potential to provide a regular income source that reduces poverty and improves living standards. Eastern Africa currently constitutes more than half of total milk production in SSA, and the vibrant smallholder farming sector has made a considerable contribution to milk production growth of 37% over the past decade. Sustained production growth is projected for the Outlook, rising by an annual average of 2.7% in Eastern Africa and 2.5% in SSA. Kenya's dairy sector represents a particularly well-developed value chain in the region, with a range of small, medium, and large-scale producers, and accounts for almost 15% of the additional milk production. Support services in the sector are more developed than in other parts of SSA, and underpin the success of the sector (OECD, 2016).

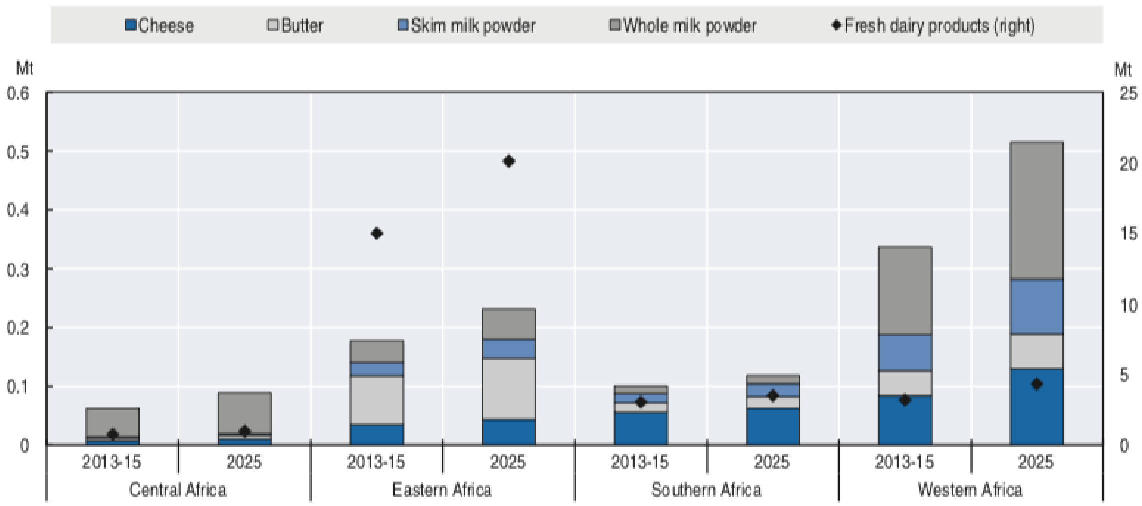

Figure 23 Dairy product consumption in Sub-Saharan Africa. Source: OECD/FAO, 2016.

Fruit and beverage crops

A number of developing countries in SSA rely heavily on the export of primary commodities, such as tropical beverage crops, fruits, and raw materials for the bulk of their export revenues. Such exports constitute an important source of revenue for smallholder producers and provide rural households with employment opportunities at the farm level and throughout the value chain. At the macro-economic level, the production and export of tropical beverage crops, fruits, and raw materials support government fiscal resources through tax revenues and contribute to foreign currency reserves that facilitate the imports of food and other goods and services. Beyond these benefits, their consumption has important nutritional benefits that support food security, and sales proceeds enable access to essential staples as well as other goods and services (OECD, 2016).

4. Overview of institutions and development policies

This section summarises the programme of the leading institution of the African Union, as well as some of the key economic and agricultural policies and programmes that are driving agriculture development in Africa.

4.1. African Union Development Agency (AUDA-New Partnership for Africa's Development (AUDA-NEPAD)

The New Partnership for Africa's Development (NEPAD) is the African Union's (AU) project with an overall vision for Africa's development (NEPAD, 2003). Recently, the AU has decided to transform the NEPAD Planning and Coordination Agency into the African Union Development Agency (AUDA) as the technical body of the AU. AUDA-NEPAD aims to (i) promote regional integration towards the accelerated realisation of Agenda 2063; (ii) strengthen the capacity of African Union Member States and regional bodies; (iii) serve as the continent's technical interface with all of Africa's development stakeholders and development partners. Overall, it aims to achieve the SDGs by 2030 and continue to make progress by following the Africa agenda 2063 (NEPAD, 2003).

The NEPAD's goal for the agriculture sector is to eliminate hunger, reduce poverty and food insecurity, expand exports, and increase economic growth for sustainable development, coupled with the preservation of the natural resource base (Table 3).

Table 3 Creating a positive environment for agricultural development: possible NEPAD principles. Source: NEPAD, 2003.

1	Establish and maintain a sound macroeconomic policy framework.
2	Ensure efficient physical infrastructure through regulatory reforms.
3	Encourage and promote the growth, diversification and deepening of the financial sector.
4	Remove obstacles to cross-border trade and investment.
5	Undertake measures to enhance the entrepreneurial, managerial and technical capacities of the private sector.
6	Strengthen national and sub-regional mechanisms for investment and trade.
7	Strengthen chambers of commerce, trade and professional associations and regional networks.
8	Organise dialogue between government and the private sector.
9	Strengthen and encourage the growth of micro, small, and medium-scale industries.
10	Provide assistance to improve the technical and managerial capabilities of business enterprises.

4.2. Comprehensive Africa Agriculture Development Programme (CAADP)

Motivated by the need for a vibrant and sustainable agricultural sector, a number of policy initiatives have been integral to the sector's development over the past decade. CAADP was prioritised within the 2003 Maputo Declaration on Agriculture and Food Security through commitments to allocate at least 10% of the national budgetary expenditure towards its implementation, with the aim of achieving a 6% annual growth of the agricultural sector (NEPAD, 2003). However, less than 20% of the countries involved have achieved their commitment on agricultural spending. More recently, these commitments were reaffirmed in the Malabo declaration on accelerated agricultural growth, which pledged to end hunger in Africa by 2025 (African Union, 2014).

The Comprehensive Africa Agriculture Development Programme (CAADP) developed by the AU focuses on investment in four 'pillars' that accelerate Africa's agricultural development. These four pillars are, (i) extending the area under sustainable land management and reliable water control systems, (ii) improving rural infrastructure and trade-related capacities for market access, (iii) increasing food supply and reducing hunger, and (iv) Agricultural research, technology dissemination, and adoption.

Africa aims to achieve food security for its increasing population with growing demands for diverse types of healthy and nutritious food, protect natural resources, and improve human capital. Feeding 1.5 billion people by 2030 and 2 billion by 2050 is a daunting task. This can be achieved through comprehensive policy aims to integrate natural, social, and human capital for the development of the agriculture sector, as envisaged by the TEEBAgriFood framework (TEEB, 2018). To meet these goals, the following strategy can be followed as guided by NEPAD.

1. Increasing production more sustainably, while absorbing a growing labour force
2. Promoting diversification based on high quality processed products
3. Promoting efficient and more equitable value chain development
4. Making farms and agricultural systems more resilient to a changing environment
5. Developing regional markets and controlling international integration

For the last 15 years, the CAADP has been encouraging the placement of agriculture at the centre of the development agenda for African states and regional economic communities. However, agricultural institutions and public policy instruments have been considerably weakened by 20 years of simultaneous state and private sector disinvestment and reduced international assistance for the agricultural sector. Most agricultural producers do not have the institutional and financial environment that enable them to manage their farms and adapt to environmental and market changes. However, at the same time, new stakeholders have emerged and structured themselves. This is especially the case for the agricultural organisations that have become key players in formulating and implementing agricultural policies. The CAADP has now become a recognised 'brand' throughout Africa and the rest of the world.

Challenges faced by the CAADP

- The first challenge is to respond to hopes raised at the country and Regional Economic Communities (REC) level and thereby affirm the impact of the CAADP by ascertaining whether or not the process has really contributed to an increase in production and resource mobilisation.

- A second risk is that of increased bureaucracy within the CAADP. Some stakeholders consider that the CAADP does not speak enough to their problems. They view the CAADP as overly focused on method and process – which coincides with NEPAD's mandate – and lacking focus on farmers' priorities.
- The third risk stems from centrifugal tendencies of different origins: experts and institutions have a high capacity to invent new concepts that become the norm for action, yet whose lifespan is aligned with that of the emergence of a new paradigm.

4.3. Regional integration and policies

Africa is the least integrated continent in the world with only 10% of the external trade of its 54 countries being conducted within Africa (72% for the EU, 52% for Asia). Since the early 2000s, economic and trade globalisation has been accelerating regional integration processes. This renewed momentum affects all subregions in Africa, although it is clearly less visible in North Africa, where the level of intraregional trade is very low (2.7%). In East and Southern Africa, the three regional organisations – EAC, COMESA and SADC — have been committed since 2008 to creating a vast 'tripartite' free trade area comprised of 26 countries and accounting for half of Africa's GDP.

- Regional agricultural policies are becoming more widespread: The deepening of the regional integration process at the REC level, along with the NEPAD initiative, has led to regional agricultural policies being developed to complement national policies. The African Union has initiated a process that should ultimately lead to the creation of an African Economic Community.
- The rise of agriculture producer organisations: The smallholder farmer movement in Africa covers multiple forms of organisations that differ in the way they are structured, their missions, the nature of their members, their size, etc. They often have a pyramid structure, starting at the village level, which performs economic and social functions, and goes up to national federations and umbrella organisations.
- Networks in different subregions at the continental level: The rise of regional integration and sector-based policies served to speed up the structuring of producer organisations at the subregional level in the early 2000s. These regional networks met in 2010 to create the Pan African Farmers' Organization (PAFO). They have become active partners of Regional Economic Communities (RECs), the African Union, and NEPAD. However, these networks remain fragile due to their members' vulnerability, their difficulties in becoming more professional and, sometimes, their insufficiently representative nature.

4.4. Challenges for agriculture and food security

Agriculture faces four major strategic challenges in most of the countries of the African continent.

Economic challenges

More than half of all people living in Africa depend on agriculture for part or all of their livelihood. Based on this premise, fostering agricultural growth means working to boost income and to generally improve the living conditions of one in two Africans, the majority of whom are poor. Promoting agricultural growth also spurs economic development in upstream and downstream subsectors and, particularly, in those related to the storage, marketing, and processing of agricultural products and the distribution of food. There is also considerable job creation potential. Finally, developing the agricultural sector meets macroeconomic challenges. Despite its significant potential, Africa is a net importer of agricultural products today.

Human challenges: reducing food and nutritional insecurity

Although agricultural development alone is incapable of eliminating hunger and malnutrition, it is an obligatory, essential and priority element of this process. First, higher agricultural productivity and more efficient markets for agricultural products reduce food prices, thereby enabling access to food for the poorest rural and urban dwellers. Improving diets depends on an increase in income among the poor and a diversification of local production: in particular, the development of livestock rearing and market gardening subsectors; but also, at times, the development of enriched or fortified products (infant cereals, for example).

Environmental challenges: the sustainable management of natural resources

Agriculture uses but also manages land, water, and energy resources. Agricultural development and the sustainable development of natural resources are inextricably linked.

Over the last 20 years, the development of Africa's agricultural sector has mobilised more and more cultivable land. At the same time, the sustainability of some agrarian systems has been threatened by several factors: the effects of climate change and population increase, the latter which puts pressure on land resources and compromises the capacity of traditional production systems to renew soil fertility. The challenge for the coming years is to accelerate growth in production while controlling its impact on the environment and natural resources such as land, water, and energy, which are the foundations for the development potential of future generations. Addressing these issues requires a systemic and lasting boost in the productivity of natural factors, but also in the formulation and implementation of rules to protect the long-term interests of people living in these areas. Finally, protecting forestry and fishery resources is a major challenge for Africa and the rest of the world in terms of biodiversity conservation. With regard to forests, the challenge also lies in carbon capture and, consequently, its impact on climate change. African forests are a global public good and their protection requires agricultural development models that prioritise increasing land productivity rather than expanding the amount of land under cultivation.

Political challenges: affirming sovereignty, and contributing to stability, security and Africa's international standing

The development of Africa's agricultural sector is linked to crucial political challenges. The 2007-2008 food riots were a harsh reminder that within the context of more rapid information distribution, securing a supply of food is not only critical from a human development perspective, but it is in fact becoming a prerequisite for the continent's political stability. Supplying urban populations with food was perceived in the past as the most sensitive issue, but greater market penetration in rural areas and an increase in access to information and education will only heighten political sensitivity regarding food and agricultural issues.

Properly managing access to natural resources and their use is a key issue for peace, security and effective land management. An increase in the number of clashes between farmers and conflicts caused by the expropriation of populations after land has been purchased or as a result of colonial heritage carry the risk of destabilisation and even of crises between neighbouring countries. The extreme inequality of access to land and capital pave the way for sedition movements and social uprisings.

In a context of structural tensions in global food markets, Africa, with its considerable and underexploited agricultural potential, has a strong case to put forward on the international geopolitical stage. Yielding a profit from this dormant political asset would require sustainable productivity growth in order to enhance the value of Africa's agricultural export potential and, above all, control of the production and marketing of agricultural products by African farmers and entrepreneurs. This raises questions concerning the position that the continent will take in international trade negotiations to become a key player in defining fairer rules for the game.

5. Application of the TEEBAgriFood framework

The TEEBAgriFood Evaluation Framework establishes "what should be evaluated" and represents the next generation of assessment tools for eco-agri-food systems (Figure 24). It supports the assessment of different eco-agri-food systems, covering their human, social, economic, and environmental dimensions, from production to consumption. The common, production-only, focus of assessment, using metrics of yield per hectare, ignores the significant range of social and environmental impacts that must be included for a complete evaluation. The Framework applies a multiple-capitals based approach, and supports the use of monetary and non-monetary approaches to impact assessment, including value-addition. As a comprehensive and universal framework, it highlights all relevant dimensions, and drives policymakers, researchers, and businesses to broaden their information set for decision-making.

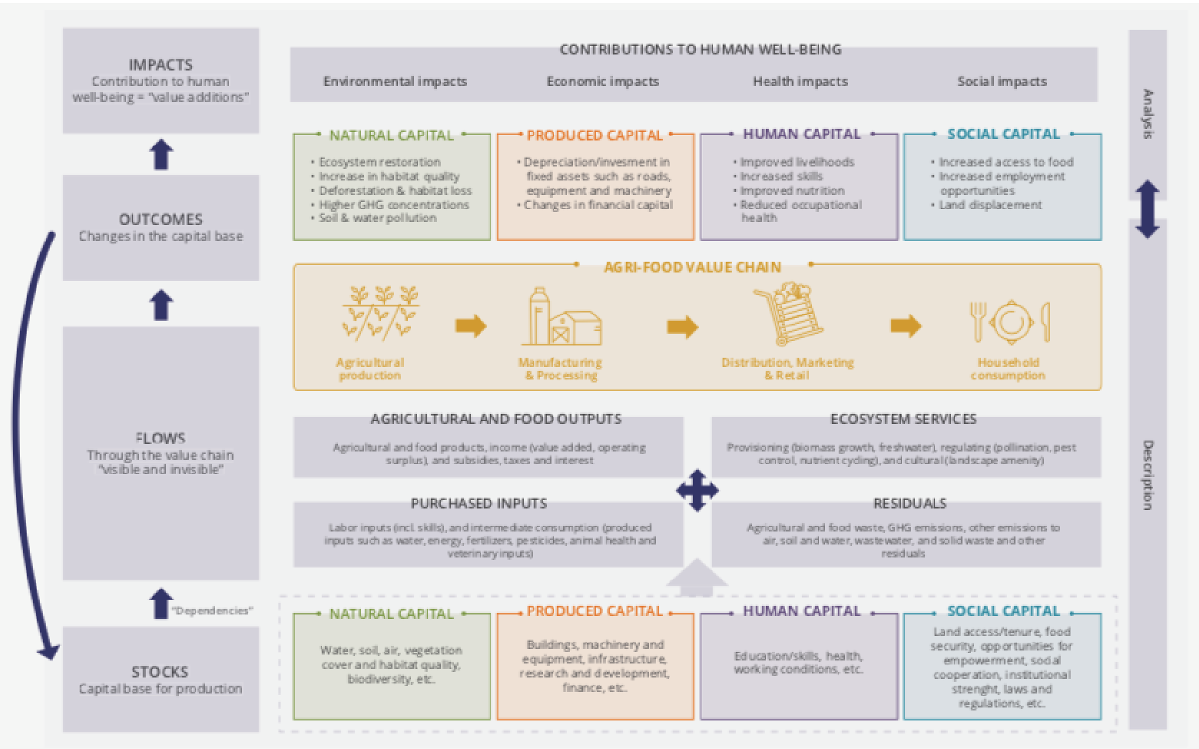

Figure 24 Elements of the TEEBAgriFood framework. Source: TEEB, 2018.

This framework is applied in three case study countries in order to examine all interdependencies and interlinkages between natural, social, and human capital, along with produced capital. Three case studies are designed to reveal the complex nature of eco-agri-food systems that operate in Africa. Although these are not representative of all types of agriculture, they provide a model and analysis to examine different types of externalities. This assessment is intended to inform policy decisions to improve agriculture and food systems and also human and environmental health.

The three case studies examine: agroforestry systems in Ethiopia (coffee) and Ghana (cocoa), traditional livestock systems in Tanzania and rice production in Senegal. In this section, we analyse these three case studies. They are structured as below for consistency, as suggested by the TEEBAgriFood framework:

- Summary
- Purpose of evaluation
- Entry point and spatial scale
- Scope of the value chain
- Focus on specific stocks, flows, outcomes and impacts
- Evaluation technique
- Collect data and undertake evaluation
- Report and communicate findings

5.1. Agroforestry systems in Ghana (Cocoa) and Ethiopia (Coffee)

Summary

This study quantifies the biophysical and social impacts and dependencies along the cocoa and coffee value chains in Ghana and Ethiopia, respectively (Wainaina et al., 2019). Its aim is to assess key negative and positive impacts to health, ecosystems and the economy of the processes associated with the value chains of the two commodity crops. This is achieved by applying the TEEB for agriculture and food (TEEBAgriFood) framework (TEEB, 2018). Following this framework, several invisible and visible benefits and costs within these value chains are identified, quantified, monetised and /or described. Most of these benefits and costs are in monetary values except for biological, vegetative, and aquatic life diversity, which are measured using diversity indices such as the Shannon-H index, the Simpsons index, the species richness index, or the Alpha index. Secondary data collected from various sources such as peer reviewed journal articles and technical reports is used in the analysis.

Purpose of evaluation

The purpose of this evaluation is to carry out a full scale analysis of all interdependencies and impacts throughout the value chain of coffee in Ethiopia and cocoa in Ghana. Each of these two commodities is produced in agroforestry farming systems. Therefore, the analysis includes a comparison of two types of systems for each of the commodities. The aim is to identify better farming systems that can generate sustained value for these sectors of society while helping protect natural resources.

Entry point and spatial scale

The entry point for this case study is farming systems, as these cash crops are produced in both countries.

Scope of the value chain

<u>The cocoa value chain</u> in Ghana has four stages, starting at the cultivation of the cocoa beans and ending at the consumption of the final chocolate product. The first stage is the production

of the cocoa beans which takes place in Ghana, where the cocoa trees grow. Second, the processing of cocoa beans and manufacturing generally takes place in other countries, mostly in Europe. The manufacturing phase is where the cocoa is prepared for confectionary consumption. The third stage is the marketing and distribution of the cocoa products, in which transport is a key process. Finally, the fourth stage involves consumption, which mainly occurs outside Ghana.

The coffee value chain consists of four stages. Coffee production in Ethiopia is constituted of forest coffee (10%), semi-forest coffee (30%), garden coffee (50 %), and plantation coffee (10%) (Amamo, 2014). The coffee sector in Ethiopia is largely a smallholder sector with 95% of the production realized on small family farms with an average farm size of less than 2 ha, and the remainder on large plantations (Mitiku et al., 2017; Hirons et al., 2018). The manufacturing and processing stage includes two processes for coffee in Ethiopia: wet (fermented and washed) and dry (natural) processing. Marketing and distribution have two streams in Ethiopia: the Ethiopian Commodity Exchange (ECX) and the co-operative structure; which are co-ordinated and regulated by the state through the Ministry of Trade and Co-operative Promotion Agency respectively (Hirons et al., 2018). Approximately 40 to 50% of the coffee produced in Ethiopia is consumed domestically, while the rest is exported (Mitiku et al., 2017; Hirons et al., 2018). Of the exports, a greater proportion (about 51%) is exported to Europe, 14% to North America, 12% to Saudi Arabia, 9% to Japan, 4% to Sudan, and the remaining 9% is exported to the other countries (Minten et al., 2014).

The four steps are included in the case study details described below.

5.1.1. Cocoa agroforestry in Ghana

Cocoa serves as the major source of revenue for the provision of socioeconomic infrastructure in Ghana. In terms of employment, the industry employs about 60% of the national agricultural labour force and contributes about 70–100% to the annual household income (Ntiamoah and Afrane, 2008). Cocoa farming occupies 1.5 million hectares in Ghana, second only to Côte d'Ivoire in the world (Läderach et al., 2013). Even though cocoa farming is one of the country's dominant land-use activities, it is characterized by relatively small landholdings that range from 0.4 to 4 hectares (Asare, 2015). Cocoa has played a key role in the conservation of forests and their biodiversity in Ghana, both negatively and positively. On one hand, cocoa has been an important factor in forest conversion for agriculture (Asare, 2006). The rapid expansion of extensive cocoa production systems in the last two decades has been found to be a major cause for deforestation and forest degradation in West Africa (Obiri et al., 2007; Gockowski and Sonwa, 2011). On the other hand, shaded cocoa provides a valuable secondary habitat for forest fauna and flora in agricultural landscapes (Schroth and Ruf, 2004). It is estimated that 50% of the cocoa farming area in Ghana is under mild shade, while about 10% is managed in full sun. Overall, the last decades have seen a decrease in the use of shade in cocoa farming in West Africa (Ruf, 2011; Läderach et al., 2013).

Representing a global value chain, cocoa has become the country's most important agricultural export commodity and a vital contributor to Ghana's development (Kolavalli and

Vigneri, 2011). The livelihoods of 30% of the population depend upon the cocoa sector (Gockowski et al., 2011).

Evaluation
The TEEBAgriFood framework is applied to assess produced, natural, social and human capital in the cocoa agroforestry systems. For benefits and costs incurred at the production stage of the value chain, shaded cocoa systems and full sun/unshaded or high-tech cocoa systems are considered. For the subsequent stages of the value chain (i.e. manufacturing, processing, transport, consumption) these systems are not differentiated.

Stocks
This section summarises the stocks and any changes in these stocks resulting from the different activities along the cocoa agroforestry value chain in Ghana.

Natural capital
These refer to the stocks of natural capital within the system. Most of the natural stocks discussed are in the production stage. For cocoa farming systems, carbon stocks, soil nutrient stocks and biodiversity are examined.

Carbon stocks (Above ground, below ground, soil carbon stocks)
Agroforestry systems have received increased attention as potentially cost-effective options for climate change mitigation due to their importance in carbon storage and sequestration, while also maintaining livelihoods. For shaded cocoa, the above ground carbon stock reported by various studies ranges from 15.8 Mg C ha-1 to 25.8 Mg C ha-1. For unshaded cocoa the range is between 17.8 to 39.2 Mg C ha-1. The reported soil carbon stock levels are however higher; ranging between 34.8 to 83.7 Mg C ha-1 for shaded cocoa systems and from 33.3 to 99.8 Mg C ha-1 for unshaded cocoa. On average, the level of above carbon stocks is slightly higher for the unshaded cocoa system (25 Mg C ha-1) valued at approximately USD 519-3,276 per ha compared to the shaded systems (22 Mg C ha-1) valued at USD 601-3,791 per ha.

Soil nutrient stocks and soil fertility
Generally, soil nutrient levels are higher within the shaded cocoa systems compared to the unshaded system. For example, Blaser et al. (2017) compared soil nutrient levels (C, P, K and N) between shaded cocoa and unshaded cocoa in topsoils in Ghana. The soils from shaded cocoa areas had on average significantly more C (by 20%) and more N (by 16%) compared to unshaded cocoa soils. However, there were no significant differences in total P and extractable K between soils in shaded cocoa systems and unshaded systems. A similar comparison by Asase et al. (2008) shows higher % soil N in moderately shaded cocoa systems (0.24%) compared to high tech cocoa systems (0.19%). Further still Asase et al. (2008) report substantially more available soil P stock in shaded cocoa systems (15.5 ug/g) compared to high tech systems (9.9 ug/g).

Biodiversity
Agroforestry has been shown to improve biodiversity conservation. According to Jose (2012), agroforestry plays five major roles in conserving biodiversity: (1) agroforestry provides habitat

for species that can tolerate a certain level of disturbance; (2) agroforestry helps preserve the germplasm of sensitive species; (3) agroforestry helps reduce the rates of conversion of natural habitats by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; (4) agroforestry provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (5) agroforestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitats.

Produced capital

Profit margins between shaded cocoa and full-sun cocoa as well as other profitability measures in Ghana sourced from (Gockowski and Sonwa, 2011; Namirembe et al., 2015) are provided. In terms of financial benefits, the full-sun cocoa systems were more profitable (almost twice as profitable) than the shaded cocoa systems for all the policy regimes considered-no tax or subsidy regimes, with tax and with subsidy regimes. However, in recognition of the environmental benefits of shaded cocoa there are efforts to pay these farmers certification premiums to make it as profitable as the full-sun cocoa.

Human capital

Human health effects from pesticide use and exposure to waste processing

The pathways through which pesticides applied to cocoa farms may affect human health include: 1) pesticide residues contaminating drinking water sources 2) traces of pesticides left in cocoa beans and 3) physical contact with pesticides during the process of pesticide application. The cocoa bean has a high content of butter or fat which can absorb the active ingredients found in insecticides (Afrane and Ntiamoah, 2011). Thus Okoffo, Fosu-Mensah and Gordon (2016) assessed the levels of pesticide residues in fermented dried cocoa beans to find out whether the pesticides residue levels in Ghana's cocoa beans are a public health concern. They found that the levels of organochlorine pesticide residues in the fermented dried cocoa beans analysed compared favourably to the European Union (EU) commission regulations on pesticide residues, showed no health risks to consumers, and no threat to cocoa exports to Europe.

Similarly, several studies have assessed the levels of pesticide residues in soils and drinking water sources from cocoa farms in Ghana (e.g. Fosu-Mensah et al., 2016a; Fosu-Mensah et al., 2016b; Okoffo, 2015; Okoffo, Mensah and Fosu-Mensah, 2016) to determine whether they are a health hazard. For these studies, although most of the pesticide residues recorded in water were below the World Health Organization Maximum Residue levels (WHO MRLs) for drinking water, some pesticides exceeded the WHO MRLs at certain sampled sites. This therefore suggests that pesticide residue concentrations in some of the wells from which samples were obtained for this study may pose a health hazard to farmer households and their entire community who utilize water from these same sources.

However, most of the direct health effects of pesticides were linked to the cocoa farmers' process of pesticide application without protective gear. For example, a study by Okoffo,

(2015) assessed the health impacts among cocoa farmers in Ghana. They reported that almost all the farmers interviewed experienced health related issues during and after the application of pesticides. The majority of the farmers reported cases of watery eyes (83%), headaches (74%), dizziness (55%), chest pains (42%), coughing (32%) and skin irritation (30%) during and after applying pesticides in cocoa farms. Other less common health impacts that were reported include nausea, body weakness, burning or itchy eyes and excessive sweating.

Social capital

Under social capital, child labour laws and gender issues around cocoa production in Ghana are captured.

Child labour and forced labour within cocoa production in Ghana

In Ghana, about one in every six children aged 7-14 were working in 2005/06 (Krauss, 2013). Children aged 5-12 years mainly engage in weeding, gathering and carrying pods to pod-breaking points, carrying water for on-farm spraying, and carting fermented cocoa beans to drying points. Older children (15-17 years) are involved in additional tasks of harvesting pods, pod breaking and mistletoe cutting. The common assumption in the literature is that child labour in developing countries is driven by income poverty. According to Krauss (2013) household decisions for or against child labour are rarely the consequence of one single factor (for example, monetary poverty) or event (for example, an income shock).

Children face several physical risks when working in cash crops. Work overload, children's use of machetes, their role in transporting cocoa pods and other crops, and their participation in spraying pesticides and other agro-chemicals are frequently discussed health hazards. Children working in cocoa consistently complain about pain in the neck, back, shoulders and arms (Mull and Kirkhorn, 2005; Thorsen, 2012). Children are also more susceptible to pesticide poisoning than adults due to a larger relative surface area, hence experiencing more severe toxic impacts (Mull and Kirkhorn, 2005).

Gender issues in cocoa production

Cocoa is produced largely in traditionally structured societies, where women experience great difficulty to obtain legal land titles; even when their husband dies, and they run the farm themselves. Without land titles, they are often excluded from saving and credit systems as well as access to training and certification schemes (Cocoa Barometer, 2015). They are also often underrepresented in farmers' organisations, public meetings and leadership roles in communities even though women increasingly running the cocoa farms. According to Cocoa Barometer (2018), in West Africa women run approximately a quarter of the cocoa plantations. Although there are differences between men and women's tasks, women are engaged in most of the cocoa production steps, from preparing seedlings to selling beans.

In addition, women employed in the cocoa farms generally earn lower wages and the best paying jobs are reserved for men; this is justified by saying that women are physically weaker, and the more physically demanding jobs are better paid (UTZ Certified, 2009). Jobs for hired female labour often revolve around the sorting and sifting of the beans on drying tables. Similarly, women hardly participate in cooperatives. Constraining factors for participation include a lack of awareness of the benefits of cooperative membership, lack of time and lack of invitations to meetings. This has a negative effect on access to better markets for women cocoa farmers (UTZ Certified, 2009).

However, according to UTZ certified (2009) some cocoa certification programs have included a requirement for gender inclusiveness aimed at addressing these differences between men and women in cocoa production and marketing. The most common certification program that address gender inclusiveness is the UTZ certification. Among the standards required for this certification are equal wage rates for both genders, health and safety regulations for pregnant and breast-feeding women, maternity leave, childcare and representation of women in unions and cooperatives.

Flows

Agricultural and food outputs

A comparison is made with outputs from full-sun cocoa systems and high-tech systems (cocoa grown under highly intensive systems with high use of external inputs). The quantities are derived from various studies within Ghana and are valued at the current producer price in Ghana. Cocoa yield was largely obtained from long-term yield regression analyses for shaded and full-sun cocoa systems (Gockowski et al., 2011; Gockowski et al., 2013; Asase et al., 2014) and field estimates (e.g. Wade et al., 2010). The cocoa yields were lowest in shaded cocoa (approximately 366 kgs per Ha) compared to full-sun cocoa (451 kgs per Ha) and high-tech cocoa (1041 kgs per Ha). These yield levels compare favourably with the yield reported in FAO (2016) of 510 kg per ha and that reported elsewhere. For example, (Foundjem-tita et al., 2016) reported a yield of 540 kgs per ha; Asare (2016) reported a yield of 450-539 kgs per ha. The cocoa was valued at USD 4.85 per kg which is the PPP equivalent of the 2017 cocoa price issued in Ghana by COCOBOD (Ghana cedi 7.42).

However, for the shaded cocoa systems, in addition to cocoa, there are additional products including; plantain, timber, fruits and other food products. Since cocoa agroforestry is often combined with timber production, it was assumed that moderate shade agroforestry contains in addition to cocoa, 30 fruit trees and approximately 10 timber trees per hectare (Namirembe et al., 2015). This gives an average timber yield of 0.65 m3/ha based on data from (Obiri et al., 2007; Gockowski et al., 2011; Gockowski et al., 2013; Asare et al., 2014). We also included the value of plantain within the shaded cocoa systems valued at US$ 3,130 per ha as well as other food products valued at US$ 2,822 per ha (Gockowski et al., 2013; Namirembe et al., 2015). Cumulatively, the total value of all the products was highest for the cocoa agroforestry systems (USD 8,139 per Ha). The total product value is almost equal for high tech cocoa system (USD 5,049 per Ha) and full-sun cocoa system (approximately USD 5,319 per Ha).

Purchased inputs

The inputs are estimated from studies across Ghana and then valued at the current market price (Figure 25, Wainaina, et al., 2019). For all the three cocoa production systems, labour cost constitutes the greatest component of input cost; it was estimated at 1,494 USD per Ha for shaded cocoa, 1,565 USD per Ha for full-sun cocoa and about 2,359 USD per Ha for high tech cocoa. The use of fertilizer and agrochemicals is substantially low for agroforestry cocoa and is estimated at 18 USD and 21 USD per ha respectively. As expected, it is highest for high tech cocoa systems, estimated at 551 USD per ha and 165 USD per Ha, respectively. Cumulatively, the total costs are highest for the high-tech cocoa system (approximately USD 3,427 per ha), followed by the full-sun cocoa system (USD 1,996 per ha) and are lowest for the shaded cocoa systems (USD 1,885 per ha).

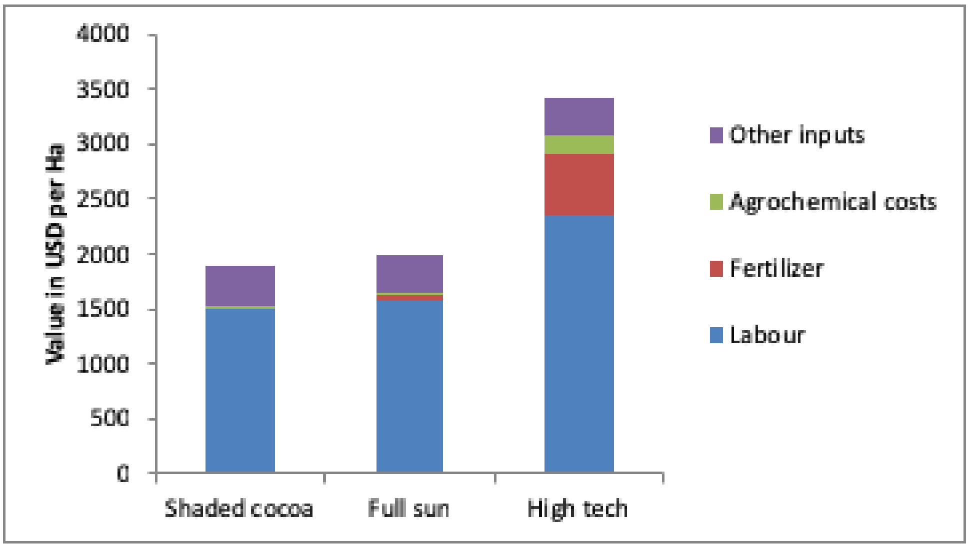

Figure 25 Comparison of input costs in the cocoa production by cocoa system. Source: Wainaina, et al., 2019.

Energy costs in the processing and manufacturing of cocoa beans

The energy quantities were adapted from a study that conducted a life cycle analysis of cocoa in Ghana (Ntiamoah and Afrane, 2008). The total energy cost incurred in processing one tonne of cocoa beans is estimated at approximately USD 89. This comprises electricity costs (USD 9.3), diesel costs (USD 67.2) and petrol costs (USD 12.3).

Water footprint in chocolate and other cocoa products

The water footprint is an indicator of direct and indirect appropriation of freshwater resources. The water footprint estimates were sourced from two studies: one estimated the water footprint of chocolate manufactured in the UK, one of the major markets of cocoa sourced from Ghana (Konstantas et al., 2018), and the other estimated the global water footprint of different food items including chocolate (Mekonnen and Hoekstra, 2011). The blue water footprint indicated by Konstantas et al. (2018) is composed of water used in raw materials production, manufacturing and packaging. The blue water footprint level is estimated at 458 litres per kg of chocolate, averaged for three types of chocolates consumed in the UK. Of the three, packaging is the main hotspot (55%–73%), followed by the raw materials production (16%–30%) and manufacturing (7%–13%).

To value the water footprint, the price of irrigation water use in Ghana is used as a proxy. The value estimated by Aidam (2015) at approximately US$ 0.41 per m3 is used. Applying the real

2017 price after adjusting for inflation (US$ 0.54 per m3), we estimate the water footprint cost for 1kg of chocolate at US$7.3 per kg of chocolate.

Transport cost within the Ghana cocoa value chain

To compute the transportation cost within Ghana, a rate of US$ 0.25 per km per tonne is used (Teravaninthorn and Raballand, 2009). The shipping cost from Ghana to Europe is fixed at an average price of US$ 45 per tonne.

Ecosystem services

Biological pest control

The value of biological pest control in the cocoa agroforestry systems in Ghana is estimated. Biological pest control is expected to be higher in the shaded systems compared to the unshaded systems. The value of the biological pest control is equated to the value of avoided loss attributable to biological pest control. The economic value was generated by the percentage of avoided loss (31%) of the estimated total value of cocoa in the shaded systems (USD 2,565 per ha). The value is estimated at USD 795 per Ha.

Pollination

The value of bees or the total economic value of pollinating services delivered to coffee by bees in each of the coffee fields was calculated by multiplying their coffee yields by local market prices of coffee beans (US$/kg) and by the pollination dependency factor (Munyuli and Mushambanyi, 2014). The pollinator dependency factor is an indicator of the pollination contribution to the production value per hectare and is influenced by the variation in richness and abundance of pollinators in the coffee fields.

Residuals

Carbon emissions during cocoa production per tonne of cocoa

Tropical forest conversion to agricultural land uses accounts for a share of greenhouse gas emissions due to land use change in West Africa. Gockowski and Sonwa (2011) compared greenhouse gas emissions for different cocoa production systems in West Africa. The net carbon emission for shaded and full-sun cocoa was calculated as the difference in the time-averaged carbon stock of the original closed canopy tall forest and that of the cocoa land use system. Shade trees were defined as any tree with more than 50% of its canopy above the cocoa canopy and full-sun cocoa was defined as cocoa grown in any farm with fewer than 13 shade trees per ha.

Greenhouse gas emissions along the value chain

The manufacturing stage emits the highest amount of GHGs averaging at 0.67 kg CO_2 equivalent per kg of chocolate, followed by packaging (0.34 kg CO_2 equivalent per kg of chocolate) and transportation (0.31 kg CO_2 equivalent per kg of chocolate). The total GHG emissions for the entire value chain are valued at US $ 23-143 per kg of chocolate produced. The bulk of the GHG emissions in the chocolate/cocoa value chain is at the production stage (Ntiamoah and Afrane, 2008; Konstantas et al., 2018).

Water and soil emissions from pesticides used in the production of cocoa

Several studies have assessed the level of pesticide residues in soils and drinking water sources from cocoa farms in Ghana (Fosu-Mensah et al., 2016a; Fosu-Mensah et al., 2016b; Okoffo, 2015; Okoffo, Mensah and Fosu-Mensah, 2016).

TEEBAgriFood framework mapping

All the stocks and flows are then mapped using the TEEBAgriFood framework in the cocoa agroforestry systems (Table 4).

Table 4 Table showing the mapping of the various elements for the cocoa agroforestry systems.

Value chain	Agricultural production	Manufacturing, processing, distribution and retail	Consumption
Outcomes (change in capital)			
Natural capital			
Produced capital			
Human capital			
Social capital			
Flows			
Outputs			
Agricultural and food production			
Income / operating surplus			
Purchased inputs to production			
Labour			
Intermediate inputs (fuel, fertilizer, etc)			
Ecosystem services			
Provisioning			
Regulating			
Cultural			
Residual flows			
Food waste			
Pollution and emissions (excess N & P, GHG emissions, etc.)			

Legend	
	Descriptive information available
	Quantitative information available
	Monetised information available
	Not included in study

5.1.2. Coffee agroforestry in Ethiopia

Coffee accounts for 60% of Ethiopia's exports and the government estimates that about 15 million households depend either directly or indirectly on coffee for their livelihood. The coffee sector in Ethiopia is largely a smallholder sector with 95% of production occurring on small family farms with an average farm size of less than 2 ha, and the remainder on large plantations (Mitiku et al., 2017; Hirons et al., 2018). Coffee production in Ethiopia is constituted of forest coffee (10%), semi-forest coffee (30%), garden coffee (50%) and plantation coffees (10%) (Amamo, 2014).

Evaluation

The TEEBAgriFood framework is applied to assess produced, natural, social and human capital in the cocoa agroforestry systems. For benefits and costs incurred at the production stage of the value chain, semi forest and garden coffee are considered. For the subsequent stages of the value chain (i.e. manufacturing, processing, transport, consumption) these systems are not differentiated.

Stocks

Natural capital

Above and below ground carbon stocks, soil nutrient levels within coffee agroforestry systems, vegetative industries, water pollution from coffee processing industries and loss of aquatic organisms due to water pollution from processing industries are assessed.

Carbon stocks

Information regarding the levels of carbon stocks is sourced from different studies in Ethiopia (Negash et al., 2013; Tadesse et al., 2014; Negash and Kanninen, 2015; Negash and Starr, 2015; Vanderhaegen et al., 2015a; De Beenhouwer et al., 2016; Denu et al., 2016). Carbon quantities are valued using the market price of carbon and the social price of capital. On average, the above carbon stock levels were higher in semi forest coffee systems estimated at 208 C Mg per ha valued at US$ 4,964-31,314 while that of the garden coffee systems was estimated at 158.8 C Mg per ha valued at US$ 3,788-23,892. On the other hand, the below carbon levels were lower in semi-forest coffee system estimated at 95 C Mg per ha valued at US$ 2,254-14,219 while in the garden coffee system 123 C Mg per ha valued at US$ 2,940-18,545.

Water pollution from processing waste into water bodies

Coffee processing plants are among the major agro-based industries responsible for water pollution in Ethiopia. The most commonly used processing method in Ethiopia is wet processing, and it is expanding in the country (Minuta and Jini, 2017). Wet processed coffee is considered superior in quality than dry processed coffee. In Ethiopia, there are more than 400 wet coffee processing installations, all of which are located at the vicinity of rivers (Woldesenbet, Woldeyes and Chandravanshi, 2014; Olani, 2018). This is because a lot of water is needed to wash the beans, remove the pulp and the mucilage. Water bodies are also used for the direct disposal of the wastewater released from the wet coffee processing plants. All in all, wet coffee processing industries in Ethiopia do not re-use the water which is used for de-pulping and fermentation. Thus, all the generated wastewater is directly released to downstream water bodies, and sometimes in disposal pits (Olani, 2018). On average, coffee processing results in effluent wastewater to an extent of about 3,000 litres per tonne of coffee processed (Murthy et al., 2004). In addition, coffee by-products of wet processing constitute around 40% of the wet weight of the fresh fruit (Woldesenbet, Woldeyes and Chandravanshi, 2016).

The rise in the number of wet coffee refineries has thus resulted in the enormous disposal of waste effluents which are unwisely discharged into nearby natural waterways that flow into rivers and/or infiltrate ground water, becoming a main threat to surface and ground water quality (Woldesenbet, Woldeyes and Chandravanshi, 2014; Tekle, 2015; Ejeta and Haddis, 2016). Wastewater directly discharged into nearby water bodies also causes many severe health problems including spinning sensations, eye, ear and skin irritation, stomach pain, nausea and breathing problems among the residents of nearby areas (Woldesenbet, Woldeyes and Chandravanshi, 2014).

To value the cost of water pollution from wet coffee processing in Ethiopia, the cost of treating the wastewater is used as a proxy. The cost is comprised of the construction cost of a bioreactor (2,356 USD) and the total annual operating cost (2,998 USD). Thus, the total annual cost of treating wastewater from coffee processing industries which we used as the proxy for water pollution was estimated at 5,354 USD (assuming 8 tonnes of coffee are processed daily). We adjusted the cost values for inflation using the CPI to reflect the real value as of 2017.

Vegetative diversity

Vanderhaegen et al. (2015) compared vegetative diversity in forest systems, semi-forest coffee systems and garden systems in Ethiopia. As indicated by all the biodiversity indices (Shannon H, observed species richness and the Simpsons diversity index), the vegetative diversity was the richest in forest systems followed by semi-forest (agroforestry) coffee systems and was the poorest in garden coffee. Vegetation diversity (Shannon's H Index) is nearly half in semi-forest coffee (1.28) and nearly one third (0.78) in garden coffee compared to forest and forest coffee (2.06) systems (Vanderhaegan et al. 2015). Similarly, according to Tadesse et al. (2014) the total number of species found in semi-forest coffee systems represent 50% of those found in forests, while garden and plantation coffee systems in Ethiopia only contain 21% of the species found in forests. This highlights the ecological role of agroforestry systems in maintaining vegetative diversity.

Produced capital

Profits in the coffee production stage

A recent study by Mitiku, Nyssen and Maertens (2018) conducted a household survey among farmers producing coffee in shaded and unshaded systems. They reported higher economic returns and profits from semi-forest coffee plots than from garden coffee plots which were largely attributed to the better prices received due to the certification. This implies that the certification of semi-forest coffee might create the right incentives for farmers to practice land-sharing between less intensive coffee production and semi-natural forest conservation. Namirembe et al. (2015) also estimated the gross margins of semi-forest coffee systems and garden coffee in Ethiopia using the benefit transfer method to acquire the data. They however reported higher gross margins in garden coffee compared to semi-forest coffee.

Certification premium paid to coffee farmers for maintaining shade trees

In Ethiopia, coffee certifications emerged in the early 2000s to certify democratically organized smallholder producer cooperatives, mostly through cooperative unions. Fairtrade and Organic certification schemes started in Southwestern Ethiopia in 2005, whereas Rainforest Alliance started their schemes in 2007 (Akoyi and Mitiku, 2018). Rainforest Alliance certification programs seek to link environmental and economic goals by providing a premium coffee price to producers who maintain shade trees and thereby contribute to the protection of forest cover and biodiversity (Takahashi and Todo, 2017). Although not all coffee producers within semi-forest systems are certified, certified semi-forest coffee usually attracts better market prices (certification price premium) (Mitiku, Nyssen and Maertens, 2018). The certification premium in Ethiopia (estimated in 2007) was approximately 15-20% of the regular coffee price (Takahashi and Todo, 2017). Similarly, a household survey conducted in south-western Ethiopia by (Mitiku, Nyssen and Maertens, 2018) showed that the coffee price of certified semi-forest coffee (18.3 ETB per kg) was significantly higher than that of uncertified garden coffee (14.92 ETB per kg). This translates to an estimated certification premium of approximately 22.7% of the regular coffee price. The value of the certification premium in US$ per ha was computed as the value of the percentage premium for semi-forest coffee per ha (estimated at US$ 155.9 per ha).

Profits earned along the coffee value chain in Ethiopia

Following a study by Shumeta et al. (2012), exporters take the largest profit margin (51%) in the coffee value chain while producers and local assemblers take the smallest profit margin (14%). Wholesalers in the town centres take up about 21% of the profit margin.

Human capital

Ailments due to processing waste discharged in water bodies

Processing waste from effluent discharged by wet processing coffee plants is one of the causes of negative health effects among the people who reside within the vicinity of these plants (Haddis and Devi, 2008). The World Health Organization (WHO) standard for effluent discharged on land for irrigation and into receiving water has a limit value of (300 mg/l) chemical oxygen demand (COD) and (100 mg/l) biological oxygen demand (BOD) (Haddis and Devi, 2008; Tekle et al., 2015). The levels of BOD and COD in the water bodies near the processing industries are way higher compared to the WHO recommended levels, which are most likely causing negative effects among the population there. Wastewater directly discharged to the nearby water bodies from wet processing industries causes many severe health problems including; spinning sensations, eye, ear, and skin irritation, stomach pain, nausea and breathing problems among the residents of nearby areas (Haddis and Devi, 2008; Woldesenbet, Woldeyes and Chandravanshi, 2014). A study by Haddis and Devi (2008) on people residing in the vicinity of a wet coffee processing plant in Jimma zone in Ethiopia found that they were using stream water which was contaminated. The majority of the population within the vicinity of the river (at least 89%) reported to be suffering from at least one health problem. People within the vicinity of a coffee processing plant reported having some health problems; about 89% reported having spinning sensations, 85% experienced skin irritation, 75% had breathing problems and 42% had stomach problems. Other less reported ailments include eye irritation (32%) and nausea (25%).

Traditional knowledge and role of coffee in social gatherings at household level

Ethiopians are heavy coffee drinkers, ranked as one of the largest coffee consumer groups in Sub Saharan Africa. Nearly half of Ethiopia's coffee produce is locally consumed. Coffee in Ethiopia has both a social and cultural value. It is mainly consumed during social events such as family gatherings, spiritual celebrations, and at times of mourning (Amamo, 2014).

Flows

Agricultural and food outputs

Garden coffee systems have intensive management: coffee plants are mostly regenerated from selected wild seedlings or nursery-raised cultivars. The original forest species are mostly limited to shade trees, grown in addition to a variety of other crops, such as fruit trees, tubers, spices and false banana (Enset ventricosum) (Wiersum et al., 2008 Abebe et al., 2013).

The yield values are sourced from various studies conducted in Ethiopia by using either; household and plot surveys (e.g., Mitiku, Nyssen and Maertens, 2018) or benefit transfers (e.g. Reichhuber and Requate, 2012). The coffee yields are lower in the agroforestry systems compared to garden coffee. For example, a recent study by Mitiku, Nyssen and Maertens, (2018) using household and plot-survey data from Southwest Ethiopia finds that intensified garden coffee plots bring higher yields (858 kg per ha) than less intensified semi-forest coffee plots (531 kgs per ha). Similarly, a comparison by Wiersum et al. in 2008 showed that coffee yields were higher for garden coffee (450kg per ha) compared to semi-forest coffee (150 kg per ha). On average from the various sources, coffee yield are higher for garden coffee (approximately 542 kgs per ha) compared to semi-forest coffee (377 kgs per ha). We valued the coffee at USD 1.97 per kg of coffee. This was sourced from Namirembe et al. (2015) and adjusted for inflation to reflect the price as of 2017 using consumer price indices drawn from the World Bank data. The total value of coffee was estimated at 743 US$ per ha for semi-forest coffee and 1,068 US$ per ha for garden coffee.

In addition to coffee, semi-forest coffee systems in Ethiopia provide other outputs including; timber valued at US$ 313 per ha, honey valued at US$ 54 per ha, wood fuel valued at US$ 209 per ha and other non-timber products valued at USD $4 per ha. Similarly, other products reported in garden coffee systems include; building materials (US$ 381), honey (US$ 51), wood fuel (US$ 13) and medicinal products (US$ 0.06 per ha). Cumulatively, the total product value was higher for garden coffee compared to semi-forest coffee estimated at US$ 1,513 per ha and US$ 1,322 per ha, respectively.

Purchased inputs

Inputs in the production of coffee

In Ethiopia, the use of inputs such as chemical fertilizers and pesticides in coffee production is very low, even in garden coffee systems. Hence, the process of coffee intensification is less associated with capital intensification and different from the situation where shade coffee is converted into monoculture coffee plantations with high external input use, as observed in other countries (Mitiku, Nyssen and Maertens, 2018). Hence for most of the studies on coffee production in Ethiopia, the often-reported input cost is the labour cost. The capital cost reported by Mitiku, Nyssen and Maertens (2018) includes costs such as plot audits for certified coffee plots, seedlings costs and transaction costs such as transportation costs.

Inputs in processing of coffee

Water use during coffee processing

The coffee processing industries uses large quantity of water (an average of 147m3/day) for pulping, fermentation and washing of the coffee cherry with no recirculation (Tekle et al., 2015). For wet processed coffee (the most popular type in Ethiopia), about 5-15 litres of water are required to recover 1 kg of clean green coffee beans (the actual volume of water used depends on the pulping process, fermentation intensity and coffee bean transportation volume) (Haadis and Rani, 2008; Woldesenbet, Woldeyes and Chandravanshi, 2014; Woldesenbet et al., 2015). Similarly, Olani (2018) indicates that about 10-20 litres of water are required to process 1kg of coffee beans in Ethiopia. About 15 litres of water on average are needed to process 1kg of coffee beans valued at US $29.25 per tonne of coffee beans processed.

Water use in the coffee value chain (Total water footprint of coffee)

The total water footprint for roasted coffee (18,925 litres per kg) is higher than green coffee (15, 897 litres per kg) (Mekonnen and Hoekstra, 2011). Similarly, the total water footprint for roasted coffee as reported by Chapagain and Hoekstra (2007) is higher than that of green coffee. To value the water footprint levels, the price of irrigation water is used in Ethiopia as a proxy. The study reports pricing levels of 0.00015US$ per m3 as of 2014, we adjusted for inflation to reflect the real price in 2017 estimated at 0.0002US$ per m3.

Other direct costs incurred from farm gate to export market

Cost incurred by coffee traders from farm gate to wholesalers/ECX Addis Ababa

After production, farmers sell their coffee to traders who eventually sell it to wholesalers or take it to the ECX. The costs are estimated for one tonne of coffee from the Jimma region of Ethiopia to wholesalers / the regional ECX in Jimma town. Processing and handling costs constitutes the largest share of costs (37%), followed by the traders' margins (24%). The major component of processing and handling cost is the impurity loss during cleaning which accounts for approximately 26%. Transport costs in this case only accounts for about 4%. Other administrative costs include; bank and commission (11%), tax and admin costs (13%) and other licensing and operating expenses (11%).

Cost incurred from the ECX centre to the border (Djibouti)

Since Ethiopia is landlocked, its coffee is exported through the Djibouti border in Somali. The estimates are based on the costs incurred in moving coffee from Ethiopia's capital, Addis-Ababa to Djibouti border in Somali. The largest share of these costs is the processing and handling costs (47%), followed by the wholesalers' margin (20%) and transport costs (16%). Again, the largest component of the processing and handling costs is the impurity losses (about 31%). Other cost components include; bank charges (10%), ECX costs (2%), port costs (3%) and other costs (2%).

Ecosystem services

Soil erosion control and nutrient cycling

The values for soil erosion control, soil formation and nutrient cycling were adapted from Temesgen et al. (2018) which provides values for ecosystem services in coffee agroforestry systems in Goedeo region in Ethiopia. The values were reported in 2007 US $ value, using Ethiopia's CPI reported by World Bank (2018) we adjusted them to 2017 US$ equivalents.

Pollination services

To impute the economic value of pollination services across the various coffee systems, we infer the values estimated in similar coffee systems in Uganda. The value of bees or the total economic value of pollinating services delivered to coffee by bees in each of the coffee fields was calculated by multiplying their coffee yields by local market prices of coffee beans (US$/kg) and by the pollination dependency factor (Munyuli and Mushambanyi, 2014). The pollinator dependency factor is an indicator of the pollination contribution to production value per hectare and is influenced by the variation in richness and abundance of pollinators in the coffee fields. The value was highest for garden coffee (USD 940 per ha) compared to the semi-forest coffee (USD 670 per ha) and highly shaded coffee systems (USD 422 per ha). Similarly, adapting from Temesgen et al. (2018) the value for pollination services in agroforestry systems in Goedeo region of Ethiopia were estimated at 79 USD per ha.

Water regulating services

Trees regulate the amount of water available in the soil by controlling soil–plant–atmosphere water relations. Soil water content is often higher on farms with rather than without trees due to increased infiltration rate, reduced soil evaporation and reduced transpiration (Kuyah et al., 2016). We adopt values from Temesgen et al. (2018) indicating the value of water regulation and water treatment in agroforestry systems in Ethiopia. The values were estimated at approximately USD 10 per ha and USD 83 per ha for water regulation and water treatment respectively.

Biological pest control and coffee berry disease reduction

Shaded coffee has been shown to significantly reduce the incidences of coffee berry disease; the losses as a result of coffee berry disease are significantly higher under full-sun coffee compared to shaded coffee (Bedimo et al., 2008). The 20% yield difference can be interpreted as the value of avoided loss owing to shaded coffee systems. Using the 20% proportion of avoided loss, we compute the value of biological disease control in shaded coffee system (20% of the total coffee yield value in shaded coffee, USD 743 per ha). This was estimated to be approximately USD 150.8 per ha. The value adopted from Temesgen et al. (2018) for biological pest control in agroforestry coffee in Ethiopia is however lower (USD 27 per ha).

In another study in Costa Rica, Karp et al. (2013) estimated the avoided yield loss due to pests in shaded coffee systems to be approximately 50%. However, this proportion is the loss preventable by biological agents (birds and bats) and may not be fully attributable to agroforestry.

Residuals

Greenhouse gases emissions along the coffee supply chain

Emissions at processing stage

The quantities of emissions are adapted from a study conducted in neighbouring Kenya intended to assess greenhouse gases along the coffee value chain. Total amount of GHGs emitted at the processing stage (wet processing) is estimated at 2.51 KgCO2e/kg coffee beans (Maina et al., 2015). The GHG emissions are estimated at 16, 315-102,910 US $ per tonne of coffee beans. Of the total GHG emissions, the highest proportion (98%) is due to generation of wastewater from pulping, fermentation and washing of coffee cherry. The rest arises from transport (1.4%) and energy use (0.7%) during processing.

Emissions during domestic and international coffee transport

The total domestic transport emissions are estimated at 97.5 kgCO2e per tonne of green coffee beans based on an estimated distance of 650 km, while the international transport emissions are estimated at 110.7 kgCO2e per tonne based on a distance 12,200 km. The emission rate per km is however lower for international transport (by flight at 0.00907 kgCO2e per tonne per km) compared to the domestic transport rate (by lorry at 0.15 kgCO2e per tonne per km). The total value of GHG emissions for both domestic and international transport is estimated at 1,353-8,536 US $ per tonne of coffee beans.

Greenhouse gas emissions after coffee export (Europe as destination)

Most of Ethiopian coffee (>50%) is exported to Europe (Minten et al., 2014). The carbon footprint related to the processes in Europe is 3.05 kg CO2e per kg of green coffee. Much of the emissions are released during the roasting (6%), packaging (4%), distribution (5%), and grinding and purchasing (9%) processes; the emissions are the greatest at the consumption stage (71%), and during the end phase (disposal) (5%). The consumption stage is the most intensive source of emissions and has a big impact on the overall carbon footprint. Emissions at this stage come from the high demand of energy required for the preparation of coffee with an automatic coffee machine (Killian et al., 2013). The total post-export coffee emissions are estimated at 19,825-125,150 USD per tonne of coffee.

TEEBAgriFood framework mapping

All the stocks and flows are then mapped using the TEEBAgriFood framework in the coffee agroforestry systems in Ethiopia (Table 5).

Table 5 Table showing the mapping of the various elements for the coffee agroforestry systems.

Value chain	Agricultural production	Manufacturing, processing, distribution and retail	Consumption
Outcomes (change in capital)			
Natural capital			
Produced capital			
Human capital			
Social capital			
Flows			
Outputs			
Agricultural and food production			
Income / operating surplus			
Purchased inputs to production			
Labour			
Intermediate inputs (fuel, fertilizer, etc)			
Ecosystem services			
Provisioning			
Regulating			
Cultural			
Residual flows			
Food waste			
Pollution and emissions (excess N & P, GHG emissions, etc.)			

Legend	
	Descriptive information available
	Quantitative information available
	Monetised information available
	Not included in study

5.2. Traditional livestock systems in Tanzania

Summary

The objective of this study is to evaluate the socio-economic and ecological outcomes of value chain activities related to three livestock sectors in Tanzania using the TEEBAgriFood evaluation framework. The aim is to improve decision-making in livestock production policies and to enhance its viability, not just economically but also socially and environmentally. The three different livestock production systems studied, are:

- The pastoralist cattle system (Maasai);
- The backyard poultry system; and
- The smallholder dairy system.

Purpose of evaluation

The purpose of the evaluation is to examine the traditional livestock systems in Tanzania to improve policy options for better livelihood opportunities.

Entry point and spatial scale
The entry point for this case study is farming systems.

Scope of the value chain
The livestock described here have local value chains which are also examined in each case. Different actors exist in the pastoralists' cattle value chain in Arusha region. The major actors in the chain are producers (farmers), middlemen, traders, abattoirs, butchers, supermarkets, hotels and individual consumers (final consumers). However, middlemen dominate the market and are reported to be the major means of market information.

Backyard poultry production in Tanzania is a traditional sector at the smallholder level, and has an important position in the rural household economy, supplying high quality meat and eggs and increasing income for rural farmers.

The bulk of produced milk originates from the traditional smallholder dairy system representing over 90% of the cattle population, and is consumed at the household level, with only about 3% of the milk filtering through to the formal market.

The next four steps are included in the case study details described below.

5.2.1. The pastoralist cattle system
Livestock production in Tanzania falls under three sub-systems: commercial ranching, pastoralism and agro-pastoralism. Commercial ranching constitutes around 2% of all livestock activities in Tanzania. The remaining proportion is occupied by either pastoralism or agro-pastoralism. Pastoralism is practiced in areas characterized by poor soils and insufficient rainfall. These areas are normally unfit for crop cultivation. Therefore, livestock are mainly kept for subsistence, storage of wealth and cash earnings. The most popular livestock are cattle, goat, sheep and poultry. The United Nations Industrial Development Organization (UNIDO) defines 'pastoralism' as a traditional cattle production system, which relies entirely on natural pasture for animal rearing (UNIDO, 2012).

Produced capital
The income of the reference pastoralist herd, which has counts 300 cattle heads and 110 between sheep and goats, is relatively high. Such a herd will however be owned by 3-9 households. On top of the income earned through sales, a substantial share of income is earned in kind, as food for the household. When relating the total pastoralist income (in-kind and financial) to the best estimate of labour input of the pastoralist system, a pastoralist income per FTE is over two times higher than the rural agricultural minimum wage. This estimate points to a relatively high income, compared to informal agricultural labourers in the region that very often earn much less than a formal minimum wage, but it is subject to high uncertainty. The picture of pastoralist income excludes two elements: such a pastoralist

group of households has about $66,000 in savings as herd value, and a pastoralist livestock system has positive externalities in landscape management.

When reviewing an alternative system with higher inputs, economic results show that an increase in year-round feed availability and basic veterinary measures can increase financial income, primarily due to an increased offtake rate due to the lower mortality of animals, allowing pastoralist households to sell more cattle while their herd remains the same size.

Natural capital

Through their customary way of managing the land, pastoralists create around $4.90 in ecosystem services per kilogram of pastoralist beef, sum of carbon storage, land degradation and contribution to tourism, using the medium estimate of carbon storage. The largest share of this positive impact ($4.00) is the preservation of carbon stocks, the rest in land degradation prevention ($0.52) and contribution to tourism ($0.35) (Figure 26). For reference, one kg of meat costs $2.93 to a Tanzanian consumer in the region. In other words, crop farming and paddock grazing reduce carbon storage, degrade land, and damage tourism relative to pastoralism. The carbon storage positive externality amounts to 70% to 260% of the consumer price of pastoralist meat. The loss of soil carbon stocks is a side effect of conversion to settled farming as well as land degradation. Upper and lower bound estimates are provided as carbon storage loss is subject to a high degree of uncertainty. The review shows that carbon storage remains a very important externality although uncertainty is high, and the former estimate was on the high end.

The value of land degradation prevention is a positive externality of pastoralist meat, amounting to 18% of the consumer price. Finally, the contribution of pastoralism to tourism value of national parks is quantified to be 12% of the consumer price of pastoralist beef. In interpreting these results, it is important to keep in mind that they are region-specific and emerge from the comparison with the most likely alternative for the region, namely sedentary farming. This means that caution should be used when comparing these results with the natural capital externalities of other livestock systems used elsewhere.

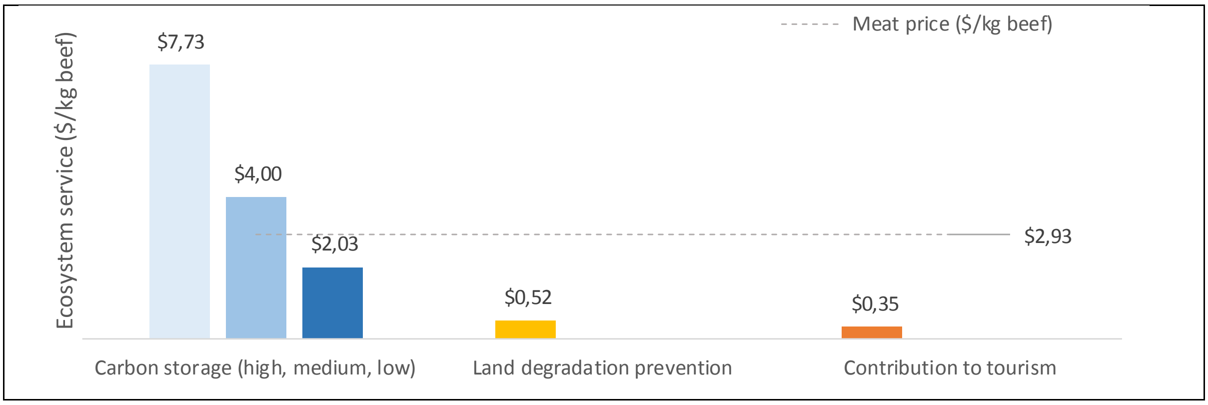

Figure 26 Positive externalities (ecosystem services) of pastoralism compared to the price of meat ($/kg beef). Source: Baltussen et al., 2019.

Human capital assessment

Education and skills

The delivery of quality agricultural extension services in Tanzania has been a centre of attention for a long time, given the fact that the majority of Tanzanians (more than two thirds) live in rural areas and depend on small-scale agriculture. In 2015, Tanzania had 7,974 extension staff, which was just over half the national requirement of 15,082 for placement in every village and ward (URT, 2016. While insufficient human resources hinder the efficient delivery of extension services (MAFS, 2013), it is argued that even the services offered by existing staff fall short in diagnosing smallholder dairy farmers' problems and transferring practical knowledge due to the low capacity of extension officers and/or their limited understanding of the smallholder dairy farming environment. Consequently, extension services have not led to significant increases in production among smallholder dairy farmers (CUTS International, 2011).

All improved livestock farming systems require improved knowledge and skills on modern livestock farming practices that contribute to improved agricultural output, e.g. improved knowledge on the correct application of inputs. Access to education remains low, but an improved pastoralist system could increase income and make education more affordable.

Human health

Animal diseases can also impact human health via zoonoses. There is a potential risk in cases of avian flu outbreaks due to backyard chickens living around or in people's houses, or the use of antibiotics in animal production systems. The use of medicines for animals can also influence human health, and should only be used to cure animals and not for prevention. This to prevent that viruses or bacteria become resistant to certain medicines, which could also contribute to antibiotic resistance among humans.

Working conditions

The labour used in smallholder dairy farming is basically derived from family members, but is sometimes hired (IFAD, 2016). Working conditions in general are not affected by the improved scenarios, no matter how many additional theoretical jobs are generated for the smallholder dairy system. However, the presented improvements require an increase in labour that can be either performed by the household or by hired workers. Also, opportunities are created further downstream in the value chain considering the increased supply of meat that is processed for human consumption.

Social capital assessment

The pastoralist cattle system: in the improved scenario the communal consumption of beef is assumed to stay stable, which means that relative to the baseline, a larger share of the herd is sold on the market. The supply of beef from the pastoralist system will increase and contribute to food security.

A higher production in rural areas also has the advantage of creating a decrease in the risk of a shortage of livestock products or a sharp increase in the prices of livestock products if supply is lower because of natural conditions.

Opportunities for empowerment

The Maasai have strong, culturally prescribed norms for the division of responsibilities and labour between age groups and sexes. Adult married men are primarily managers and supervisors in the livestock keeping businesses. They are responsible for gathering all the necessary information on range conditions, water availability and marketing. They also make decisions on residence location, herd movement, herd splitting, the daily orbit of grazing and the person to carry out the herding. In the evening, men inspect animals as they return home to make sure none are lost, determine whether they have grazed enough, and whether any are about to give birth or are sick. Men are also responsible for veterinary drugs and perform castrations and other minor veterinary procedures. They also decide when and which animals should be slaughtered, sold or buffered. However, they may wish to consult other household members in order to do so. It is important to note that in pastoralist communities, participation in political affairs is often at the discretion of the men (Kipuri and Ridgewell, 2008).

Women in pastoralist communities are responsible for all major domestic household decisions, including those relating to the care of children, collection of water and fuelwood, food preparation and house-building and/or maintenance (Kipuri and Ridgewell, 2008). In addition, women also take part in some livestock management activities including the care of very young stock which usually spend the day around the boma; and inspection of their sub-household's animals, to make sure all have returned from grazing and are in good health. Any problem is reported to the household head. Likewise, milking is carried out by women, and they have the right to the milk of their animals (Kipuri and Ridgewell, 2008).

Recent levels of demand amongst pastoralist communities have been reported to be increasing (Bishop, 2007). However, Carr-Hills's study of six East African countries found the rates of primary school enrolment for children in pastoralist communities to be significantly below the national average in each country (Carr-Hill et al. 2005). Much of the literature on education for pastoralists has concentrated on the reasons for their low levels of participation and attainment in education. Many of the explanations suggested in literature focus on the practical challenges of providing education to pastoralist populations. Pastoralist areas generally have low population densities resulting in long distances to schools and varying degrees of mobility amongst pastoralists, making it difficult for children to attend static schools. It has also been argued that pastoralist dependence on child labour is not compatible with schooling. It has been noted by several authors that pastoralism in East Africa requires a much heavier commitment of child labour than cultivation (Bishop, 2007). Another explanation which has been put forward is that pastoralists are often amongst the poorest groups in the countries they inhabit, and consequently parents do not have access to cash to pay for schooling costs such as uniforms and contributions to schools.

On the other hand, children carry most of the routine work of the Maasai household. They take care of almost all of the herding and much of the work around the boma. Children become involved from the age of 3 or 4 years old, helping with tasks such as carrying children and lambs into or out of the house and watching animals around the boma. This fulfils three functions: it helps protect the animals from predators, it trains the children as future herders and it keeps the children occupied so their mothers can do other jobs. At 6 or 7 years old a child becomes a full-time herder, beginning with goats and sheep. At 8 or 9 years old children start herding calves. By the age of 11, children, particularly boys, begin to herd older cattle, initially as apprentices to an older herder. Girls tend to deal with goats, sheep and calf herding and less on cattle than boys. If girls herd calves, goats, or sheep, they usually return to the boma in time to help with young-stock management, preparations for milking and domestic tasks.

TEEBAgriFood framework mapping

All the stocks and flows are then mapped using the TEEBAgriFood framework in the pastoralist systems in Tanzania (Table 6).

Table 6 Table showing the mapping of the various elements for the pastoralist systems in Tanzania.

Value chain	Agricultural production	Manufacturing, processing, distribution and retail	Consumption
Outcomes (change in capital)			
Natural capital			
Produced capital			
Human capital			
Social capital			
Flows			
Outputs			
Agricultural and food production			
Income / operating surplus			
Purchased inputs to production			
Labour			
Intermediate inputs (fuel, fertilizer, etc)			
Ecosystem services			
Provisioning			
Regulating			
Cultural			
Residual flows			
Food waste			
Pollution and emissions (excess N & P, GHG emissions, etc.)			

Legend	
	Descriptive information available
	Quantitative information available
	Monetised information available
	Not included in study

5.2.2. The backyard poultry system

Backyard poultry production in Tanzania is a traditional sector at the smallholder level, and has an important position in the rural household economy, supplying high quality meat and eggs and increasing income for rural farmers (URT, 2016). The local chicken ecotypes are well adapted to local circumstances and resistant to diseases. They are kept under free range and find their own feed. Often the birds get leftovers or food not suitable for human consumption. Housing is often limited to night shelters, and medical care is very limited. This low-input system for poultry also has a relatively low production level in terms of egg and meat production, with high death rates. The flock size per household generally varies from 10 to 30 (URT, 2012; Boki, 2000), and occasionally up to 150 chickens (Kisungwe, 2012). In the backyard these chickens are generally kept in small scale traditional system by the rural poor and managed by women and children. They play a vital role in households by providing an important source of high-quality nutrition, an income, as well as quick cash to pay for medicine, food, transportation or school fees, and manure. They supply over 70% of the poultry meat and eggs consumed in rural areas as well as about 20% in urban areas (URT, 2010). Its demand in urban centres is high as most people in Tanzania prefer the taste of local chicken over the taste of exotic breeds that are perceived as rather tasteless due to their rearing method; local chickens are also considered free of antibiotics, hormones and other harmful chemicals (Mlozi et al., 2003).

Produced capital

The socio-economic importance of backyard poultry is not in the absolute income generated, but rather in the ability for women to generate cash revenues and nutrition at very low input costs. In the alternative scenario, the in-kind income increases slightly when adding feed quality and fencing measures.

Backyard poultry contributes equally to nutrition and cash inflow of rural households. A large share of the total offtake of chicken (about 30%) kept by a household is used for own consumption rather than sold. For a reference household owning 29 chickens, the value of consumed poultry meat and eggs, in-kind income, amounts to $56, more than half of the income of $87 in sales (Figure 27).

When a chicken is sold, there is a large profit, as there are virtually no input costs. The $56 of in-kind income include $9 value of consumed eggs. The majority of eggs are however being hatched rather than consumed.

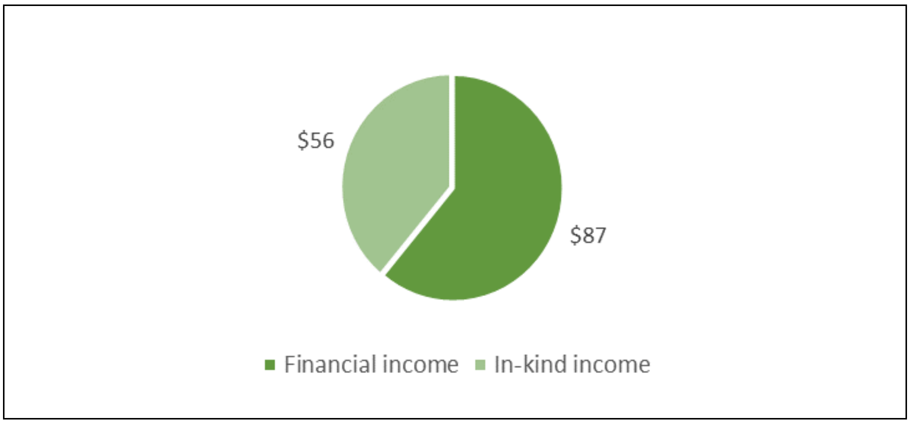

Figure 27 Annual in-kind and financial income from backyard poultry for a household ($/household/year). Source: Baltussen et al., 2019.

Natural capital

The results of the environmental assessment are shown in Figure 28. In graph A of this figure, the effects of the lower mortalities are shown: less replacement hens and roosters are needed, so that the number of females and males available for slaughter increases slightly. The amount of feed (in kg dry mass) required by animals in the different groups is roughly the same, because the different rations in the baseline and the improvement scenario have similar energy contents. Reduced mortality, increased egg productivity, in addition to better quality feed contribute to the improvement of production efficiency and result in reduced emissions intensity both for egg and meat. The land occupation (graph C) increases because the protein crops introduced in the ration have a higher land occupation than the swill. The impact per kg of meat goes down by about 10% (graph D). The egg productivity goes up more strongly, resulting in a stronger reduction of the impact per egg (not shown in graph). The major contribution to the emissions intensity is the N_2O from soils and manure, followed by CO_2 from energy use and enteric CH_4 emissions (graph E).

The herd dynamics in a flock of 29 animals are variable. People may need to barter or trade chickens in order to balance their flock and match it with the feed availability, but this is not likely to happen. The actions chicken smallholders will take should be determined given their incentive structures in the context of the policy measures.

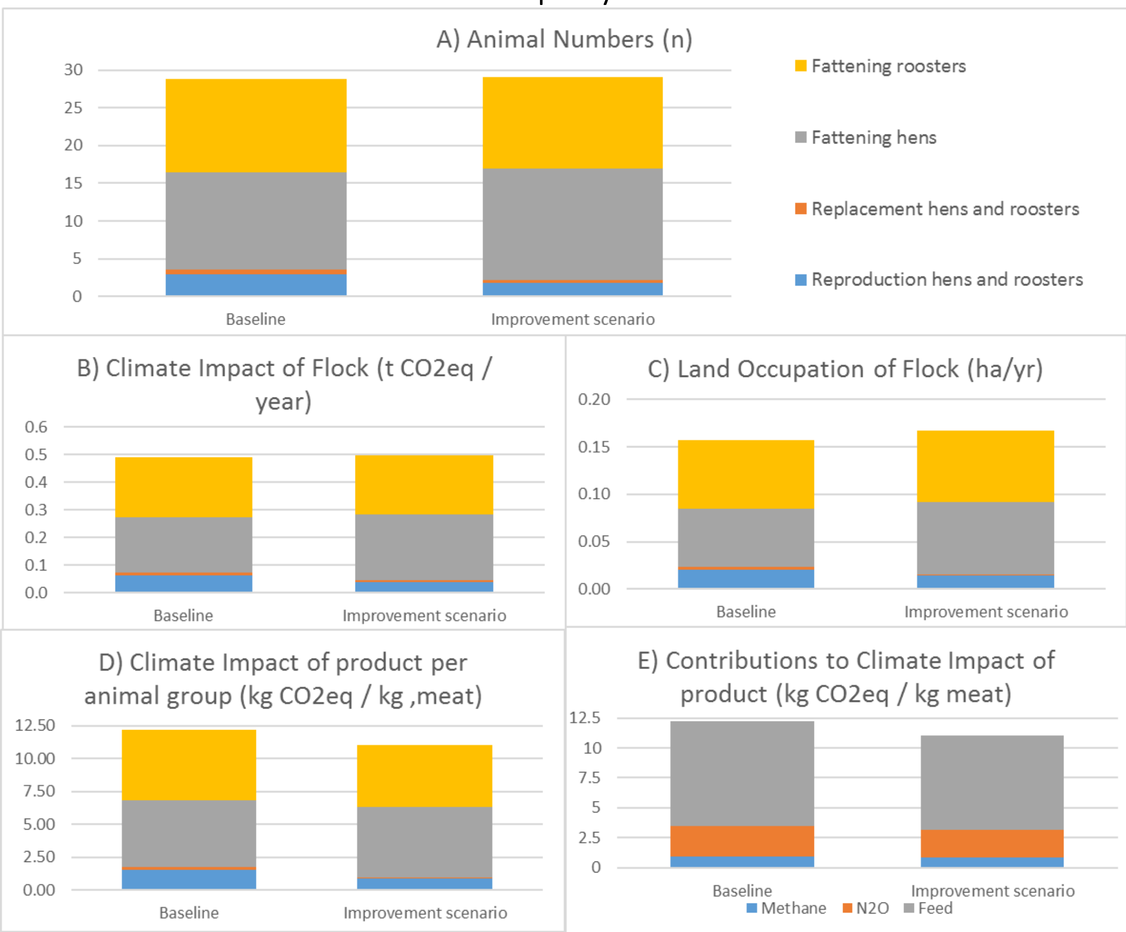

Figure 28 Natural capital assessment results for backyard poultry: A) Animal numbers for each groups; B) Climate change Impact of Entire Flock; C) Land Occupation of Entire Flock; D) Climate Impact per unit of product, specified per animal group; E) Contributions.

Other environmental issues may occur to a highly variable extent. If chicken manure is concentrated in housing and not used for fertilization, some freshwater eutrophication due to P emissions and groundwater and seawater eutrophication due to N emissions might arise, but this is unlikely. Use of irrigation water, particulate matter formation due to NOx emissions and carbon emissions from land use change may all be caused by the production of more compound feed. This is not deemed realistic; the feed cultivation will intensify to cause environmental impact only if the feeding of backyard chickens changes more radically than in the current improvement scenario and across a very high share of the households.

Social and Human capital assessment

Poultry is largely owned by the women, and are not considered livestock by the men in Tanzania. The savings value in chicken kept by the reference household is around $100. As discussed elsewhere in this report, chickens are an important form of savings for low-income households and are especially relevant for women, who generally take care of the animals, in a context where women are often excluded from participating in other economic activities. As such, the poultry sector provides serious opportunity for the empowerment of women. At the individual level, when a woman starts to generate her own income, she improves her status and decision-making power in relation to household matters such as the children's upbringing and general expenditure. Moreover, she feels more confident and independent as she gains control over resources and no longer needs to consult her husband about the smallest economic matters. However, gender based constraints remain present (Gueye, 2003) and there is a serious risk that this activity might be taken over by the men. For the implementation of an improved scenario, the social context should be considered by setting women-owned groups or cooperatives or other support functions in order to empower gender-based poultry management.

TEEBAgriFood framework mapping

All the stocks and flows are then mapped using the TEEBAgriFood framework in the poultry system in Tanzania (Table 7).

Table 7 Table showing the mapping of the various elements for the poultry system in Tanzania.

Value chain	Agricultural production	Manufacturing, processing, distribution and retail	Consumption
Outcomes (change in capital)			
Natural capital			
Produced capital			
Human capital			
Social capital			
Flows			
Outputs			
Agricultural and food production			
Income / operating surplus			
Purchased inputs to production			
Labour			
Intermediate inputs (fuel, fertilizer, etc)			
Ecosystem services			
Provisioning			
Regulating			
Cultural			
Residual flows			
Food waste			
Pollution and emissions (excess N & P, GHG emissions, etc.)			

Legend	
	Descriptive information available
	Quantitative information available
	Monetised information available
	Not included in study

5.2.3. The smallholder dairy system

The dairy sub-sector represents about one-third of the 4.6% livestock industry's contribution to the Gross Domestic Product (GDP) (Njombe et al., 2011; URT, 2013). Despite the potential benefits of the dairy sub-sector, commercial dairy activities in the country are at an infancy stage. The bulk of milk produced originates from the traditional cattle that form over 90% of the cattle population and is consumed at household level, with only about 3% of the milk filtering through to the formal market (Urassa and Martin, 2013). Despite this, the dairy sub-sector contributes to the employment of over 2 million households working at different stages in the value chain: production, processing, marketing and consumer stages (Urassa and

Martin, 2013). The dairy sub-sector has greater potential for improving people's livelihoods through improved nutrition arising from milk consumption, increased employment and incomes raised from sales of milk and milk products, both in rural and urban areas. Nevertheless, its potential has not been fully unlocked.

The dairy sub-sector is usually divided into two main categories: the traditional sector with local breeds and the modern sector with grade cattle (cross-breeds and pure-breeds). Sometimes milk produced on medium to large scale farms with grade cattle (crossbreeds and pure-breeds) are counted as a separate third category. The traditional system is the largest category and is based on local zebu cattle where milk is one of main the products besides meat, savings, draft, etc. The milk produced under this system is mainly used for home consumption, and only excess can be marketed (Nell et al., 2014). Traditional systems include pastoralism, agro-pastoralism and smallholder mixed farmers (sedentary). Milk is an important product for home consumption and seasonal surpluses are available for marketing, provided there are customers (Nell et al., 2014). With this system, owners of the crop land can benefit from cattle manure which has the potential to improve soil fertility. Likewise, milk produced by agro-pastoralists is used for home consumption, and any seasonal surpluses may be marketed if there is an opportunity to sell. Smallholder mixed farming, also known as sedentary farming, is a production system mainly in the sub-humid areas of Tanzania (Nell et al., 2014). Under this system cattle are mainly kept for manure to improve soil fertility. Cattle density under this system is generally low. Milk production per unit area is low and consequently milk offtake per unit is also low, with a high collection cost.

Dairy systems based on grade dairy cattle are the second category of milk production in Tanzania. The cattle kept under this system are mainly crossbreds of exotic dairy breeds with either Tanzanian Shorthorn Zebu or Boran.

Produced capital

In the traditional value chain, the income of a dairy farmer is about 80% of the sales price of a kg of milk. At the farm level, the share of income that is in-kind is relatively low compared to the financial income, and the largest share of production is sold rather than consumed. The annual net income of smallholder dairy farmers, including the value of milk consumed at home, is $705. A limitation of the above is the exclusion of crop cultivation and other livestock (sheep, goats or chicken) in the economic analysis. Additionally, the potential meat produced from dairy cows and bulls sold for slaughtering, as well as sheep, goats and chicken has not been taken into account. Especially in the baseline scenario, this is expected to potentially add substantially to the basic income level of the household. For future research it is recommended to include crops and meat for a richer economic perspective. The alternative scenario included is much more profitable then the baseline, due to a radical increase in milk production per lactating cow.

Natural capital

The results of the natural capital assessment of smallholder dairy systems are shown in Figure 29. In graph A of this figure, the reduced bull to cow ratio (i.e. increased use of artificial insemination) and the lower mortalities are shown: in order to maintain five lactating adult females, the other animal numbers can go down. The amount of feed (in kg of dry matter) required by animals in the different groups is lowered by about 10%, because they can take more energy from fresh grass than from crop residues. Lactating cows will increase their feed intake in order to produce ten times more milk. The combined effect of herd composition and feed intakes on the climate impact (graph C) is a reduction of a third, with notable shifts of the impact contributions from different animal groups. Land occupation (graph D) goes down more strongly than the climate impact, because more feed can be taken from fresh cut grass than from grazed grassland and land providing crop residues. The strong increase in milk productivity reduces the impact per kg of milk very strongly (graph E). The meat impact is also strongly reduced, because the meat production increases and a larger share of the impact is allocated to the milk instead of the meat. The major contribution to this impact comes from methane (CH_4), mainly from enteric fermentation but also from manure (graph F).

Furthermore, it is likely the yield of grass is lower than the default values in GLEAM (Global Livestock Environmental Assessment), so that land occupation is significantly higher and stocking density is lower. It is likely that more grazing land will be required if numerous smallholders in the same area switch to this system. Since roadside grazing only would not provide sufficient grazing area, how this area will be made available is an important question. Some smallholders might stop cattle farming if they can get the services and manure provided by the cattle from their surroundings, but all changes depend on the incentive structures that vary across Tanzanian communities.

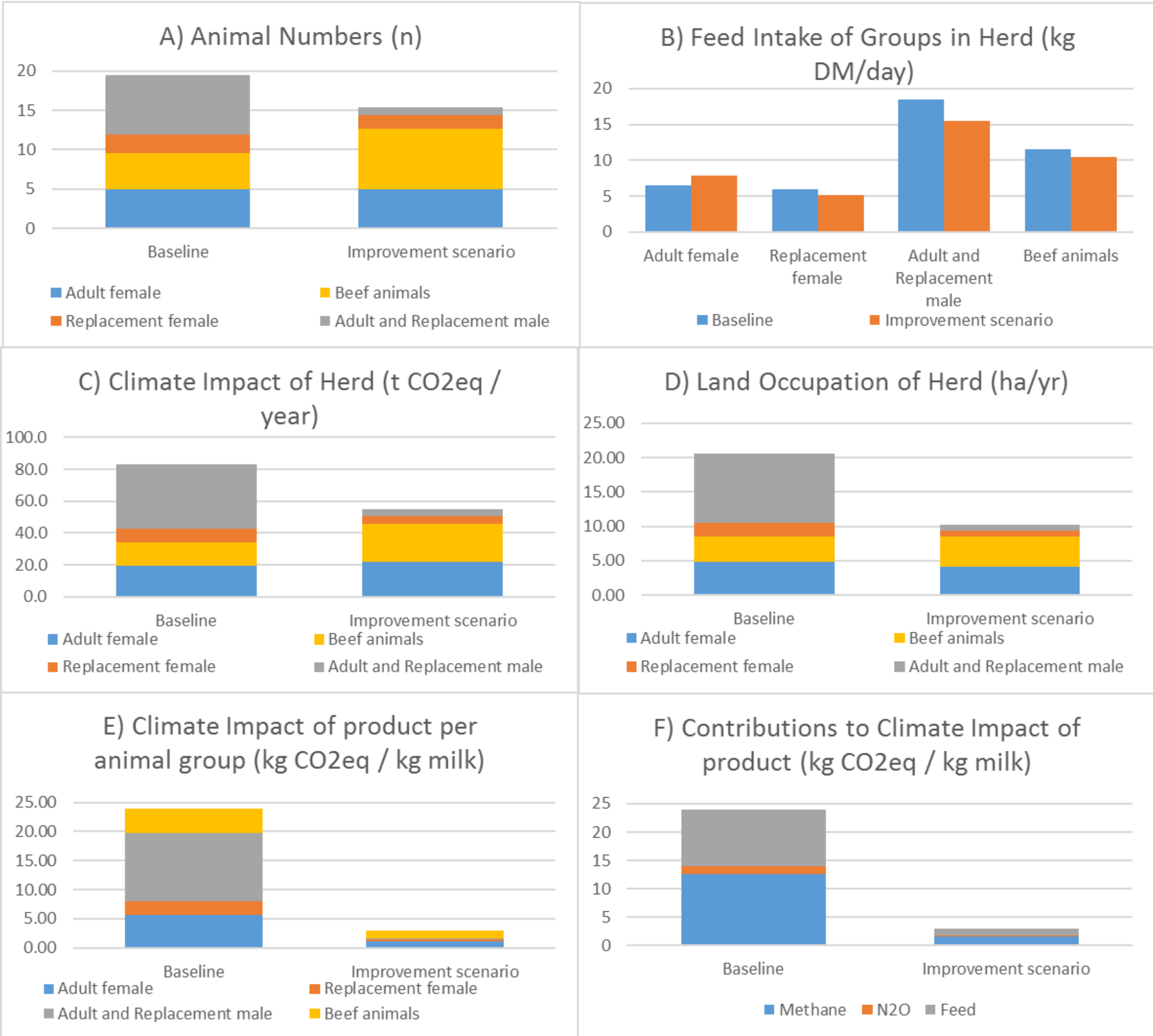

Figure 29 Natural capital assessment results for dairy smallholders: A) Animal numbers for each groups; B) Feed intake for each group, per animal; C) Climate change Impact of Entire Herd; D) Land Occupation of Entire Herd; E) Climate Impact per unit of products.

Biodiversity assessment

Mean Species Abundance (MSA) measured by ha per kg of protein for the 3 livestock systems is provided. MSA is a relative indicator between 0 and 1 that relates present population sizes of species in comparison to the population sizes of those species that would have occurred in unaltered reference situation, which is often indicated as pre-industrial. In basic terms, it is an indicator of the naturalness (e.g. the situation without human intervention) in a certain location.

For poultry the MSA per ha per kg is 0, for pastoralist it equals 0.04, and for dairy systems it is about 0.06. A value of 0.04 indicates that for the production of 1 kg of protein is the equivalent to the 100% loss of biodiversity in 0.04 ha.

In the improved scenarios there will be no impact for the MSA per ha per kg for the poultry and the beef systems. For both systems the land use will not change, and the intensity of land use remains the same. For the dairy system there will be an increase in the intensity and less land use change in the improved scenario compared to the present situation. It is unclear how this will influence the MSA per ha kg protein.

TEEBAgriFood framework mapping

All the stocks and flows are then mapped using the TEEBAgriFood framework in the smallholder dairy system in Tanzania (Table 8).

Table 8 Table showing elements of the TEEBAgriFood framework covered by the smallholder dairy system in Tanzania.

Value chain	Agricultural production	Manufacturing, processing, distribution and retail	Consumption
Outcomes (change in capital)			
Natural capital			
Produced capital			
Human capital			
Social capital			
Flows			
Outputs			
Agricultural and food production			
Income / operating surplus			
Purchased inputs to production			
Labour			
Intermediate inputs (fuel, fertilizer, etc)			
Ecosystem services			
Provisioning			
Regulating			
Cultural			
Residual flows			
Food waste			
Pollution and emissions (excess N & P, GHG emissions, etc.)			

Legend	
	Descriptive information available

	Quantitative information available
	Monetised information available
	Not included in study

5.3. Rice in Senegal

Summary

Rice is a critically important staple food crop in Senegal and is the most consumed cereal (Colen et al., 2013). In 2009, the average consumption of rice was 71.5 kilogram per person per year, which resulted in a total consumption of 984,000 tons of rice per year (Maclean et al., 2013). Senegal is one of the largest consumers of rice in West-Africa (Maclean et al., 2013). However, a considerable portion of rice comes from imports, estimated at around 80% in 2005, to provide the needed quantities for domestic consumption. This makes Senegal the second largest rice importer in Sub Saharan Africa (SSA) (Brüntrup et al., 2006), and also one of the largest net importers of food in the world (Stads and Sene, 2011).

Purpose of evaluation

The purpose of the evaluation is to assess the impact of the implementation of various agroecological interventions in Senegalese agriculture and more specifically their application in the rice sector.

Entry point and spatial scale

The production stages are the entry points for this evaluation in rice farming systems.

Scope of the value chain

This study is focused on rice production systems and examines a Business As Usual (BAU) scenario with current policies that are continued into the future, the Agroecology (AE) scenario as proposed by FAO, and includes the value chain from production to processing and consumption (Gemmill-Herren et al., 2019).

The next four steps are included in the case study details described below.

5.3.1. System dynamics model and preliminary scenario definition

The use of a system dynamics model aims to make visible the invisible negative and positive externalities of the conventional versus agroecological / sustainable rice intensification (SRI) production approach in Senegal. However, to maintain the internal logic of the scenarios, the scenarios assume the application of the two production approaches for other crops as well. Hence, we plan to analyse the following scenarios:

- The Conventional agriculture scenario / BAU (business-as-usual scenario) assumes no major changes in external conditions and a continuation of current government policies.
- The Agroecological / sustainable agriculture scenario assumes as much as possible the application of FAO principles on Agroecology in the agriculture of Senegal.

To assess the impact of changes in the production system, specifically the implementation of AE principles, we elaborate an AE scenario by grouping and identifying policy interventions for each AE principle and translating it into policy assumptions in the model. The table below presents the proposed interventions and policy assumptions for the ten agroecological principles and their evolution in the Agroecology (AE) scenario compared to the BAU (business-as-usual) scenario. The considerable research that has gone into calculating the relevant variable for each contrasted intervention are documented in the TEEB report by Gemmill-Herren et al., 2019.

Table 9 and Figure 30 presents the results for key indicators of the four types of capital in 2050 as change in the AE scenario compared to the BAU scenario, assuming the application of the AE principles to total crop production (third column), and respectively to rice production only (fifth column).

Example for interpretation: The simulation results indicate that in 2050, the cereal import dependency ratio is 21% lower in the AE scenario compared to the BAU scenario. Applying the share of rice to cereal production in tons, it is calculated that if only rice production is changed (implementing the AE principles only for rice) cereals import quantity reduces by 9% (compared to BAU scenario).

Table 9 Impact on key indicators in 2050 as change in the % in the Agroecological (AE) scenario compared to the Business as Usual (BAU) scenario. Source: Gemmill-Herren et al., 2019.

Type of Capital	Indicator	Total Change in Key Indicator in AE scenario compared to BAU scenario in 2050	Proportion of change attributable to rice sector	Change in Key Indicator due to changes in Rice Production
Natural Capital	Total water withdrawal per unit of GDP	-8%	0,141 [1]	-1%
	Forest land	25%	0,141 [1]	4%
	GEF benefits index for biodiversity	24%	0,141 [1]	3%
	PC pesticide dispersion in environment	-100%	0,660 [2]	-66%
Human Capital	Population (age 20-24) completed secondary school	11%	0,199 [3]	2%
	Under five mortality	-9%	0,199 [3]	-2%
	Total crops employment	10%	0,199 [3]	2%
	Unemployment rate	-12%	0,199 [3]	-2%
Produced Capital	Real pc GDP growth rate	98%	0,199 [3]	20%
	Interest on public debt as share of export	-78%	0,199 [3]	-15%
	Cereal import dependency ratio	-21%	0,422 [4]	-9%

	Total cereal production in tons	93%	0,422 [4]	39%
Social Capital	Prevalence of undernourishment	-40%	0,141 [1]	-6%
	Population below poverty line	-29%	0,199 [3]	-6%
	Conflict-related death rate	-25%	0,199 [3]	-5%
	Women in leadership position	14%	0,199 [3]	3%

[1] Rice production / total crops production (in tons in 2017 based on FAO data)
[2] Total pesticide use for rice / Total pesticide use in 2001 (Data for rice from Sow et al., and FAOSTAT: 186 / 282 = 66%.
[3] Production Value for rice / Production Value for total crops (Gross Production Value in constant 2004-2006 1000 I$ for 2016)
[4] Rice production / cereals production (fonio, maize, millet, rice, sorghum) (in tons in 2017 based on FAO data)

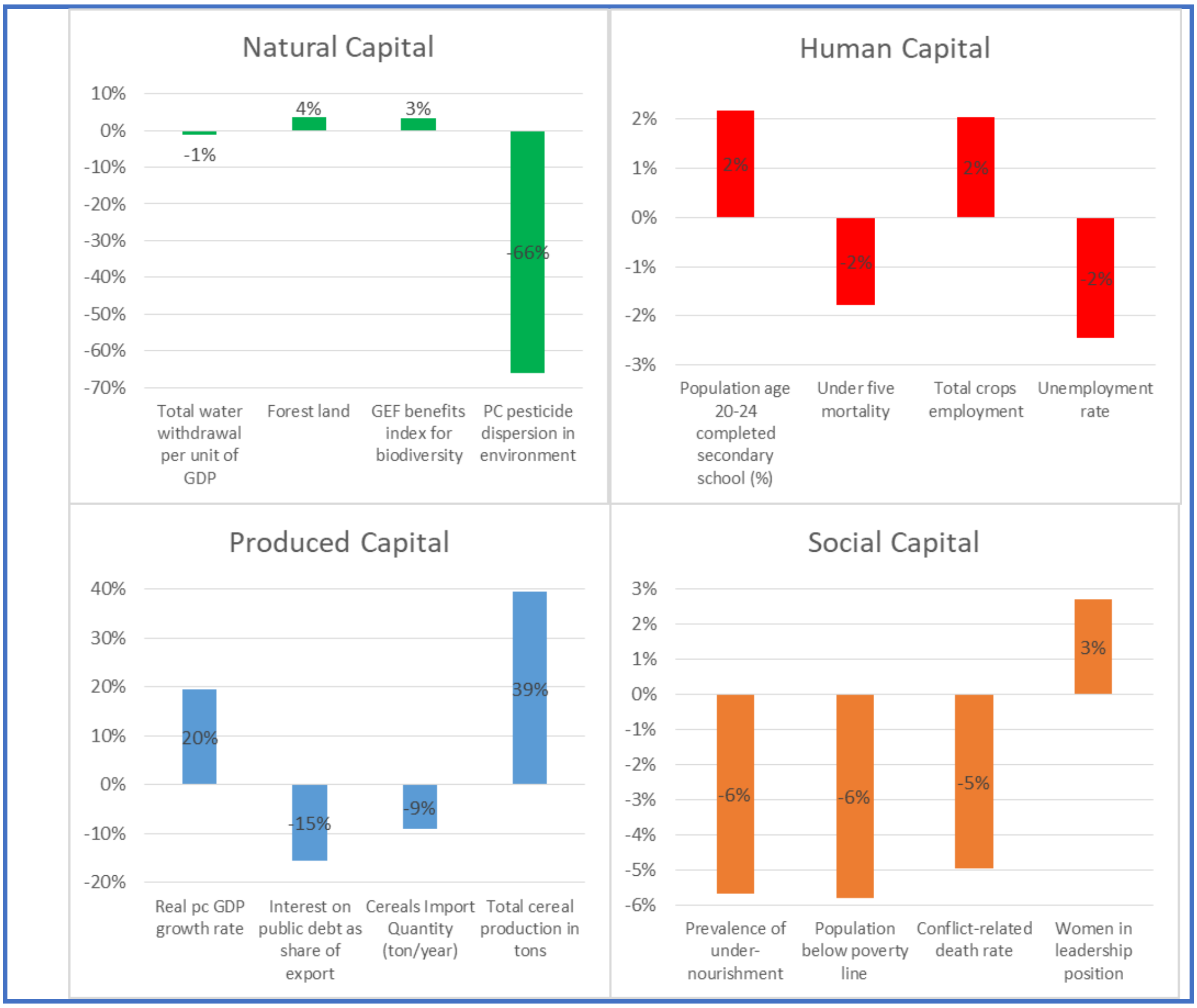

Figure 30 Impact of changes in rice production on key indicators in 2050 as change in the % in the Agroecological (AE) scenario compared to the Business as Usual (BAU) scenario. Source: Gemmill-Herren et al., 2019.

TEEBAgriFood framework mapping

All the stocks and flows are then mapped using the TEEBAgriFood framework in the ricedairy systems in Senegal (Table 10).

Table 10 Table showing the mapping of the various elements of rice systems in Senegal.

Value chain	Agricultural production	Manufacturing, processing, distribution and retail	Consumption
Outcomes (change in capital)			
Natural capital			
Produced capital			
Human capital			
Social capital			
Flows			
Outputs			
Agricultural and food production			
Income / operating surplus			
Purchased inputs to production			
Labour			
Intermediate inputs (fuel, fertilizer, etc)			
Ecosystem services			
Provisioning			
Regulating			
Cultural			
Residual flows			
Food waste			
Pollution and emissions (excess N & P, GHG emissions, etc.)			

Legend	
	Descriptive information available

	Quantitative information available
	Monetised information available
	Not included in study

6. Theory of change: From analysis to policy options

6.1. Outcome of applying the framework in three case studies

The application of the TEEBAgriFood framework in these three case studies has created a broader picture of these systems and included all aspects of the value chains. Below are some insights from a systems comparison in the three case studies. All three case studies indicate policy options that can be further explored to develop more sustainable agriculture and food systems in SSA.

Agroforestry systems

In terms of financial benefits, the full-sun cocoa systems are more profitable (almost twice as profitable) than the shaded cocoa systems. However, in recognition of the environmental benefits from shaded cocoa there are efforts to pay these farmers certification premium to make this system as profitable as the full-sun cocoa, approximately US$15 per tonne. There are arguments stating that the amount of certification premium paid to farmers is not enough to make the cocoa agroforestry systems as profitable as the full-sun cocoa systems, and that even with a premium of US$40 per ton, the profitability of Rainforest Alliance certified cocoa agroforestry systems is less than that of an intensive monoculture, owing to the higher productivity. Thus, there is a need to revisit the certification premium agenda and sensitize consumers on the environmental benefits of shade trees to increase their willingness to pay for these benefits.

There are massive imbalances in the global cocoa value chain. Cocoa and chocolate companies and retailers take up the bulk of the share-35% and 42%, respectively- while West African farmers (including Ghana) take up only 6.6%. Despite being the largest cocoa producers, Côte d'Ivoire and Ghana process only around 25% of their production, missing out on value that could be extracted from the chain. This highlights the need to promote cocoa value addition within Ghana and the other cocoa producing countries. The majority of the cocoa processing and manufacturing companies are based in the EU, especially in the Netherlands, Germany, UK and Switzerland, indicating the dominance of the EU in the chocolate value chain. Similarly, most of the retailers are in Europe.

There are serious health issues related to pesticide use in cocoa farms in Ghana and cocoa processing as well as from the wet coffee processing in Ethiopia. Treatment costs are used in the study as a proxy to estimate these negative health effects. However, this does not capture all the costs including labour days lost due to the illnesses, visitation costs by relatives, and so on. There is therefore a need for a more detailed study to capture all the health costs involved.

Traditional livestock systems

To increase food production and improve the income position of the value chain actors without harming the social system and the ecosystem, the development of improved livestock systems is required. Two key policy options are suggested:

- Policy to develop infrastructure to improve farmers' access to various inputs including feed, medicines and vaccines to increase productivity of the food supply chain; and
- Policy to offer knowledge by training livestock farmers through improved extension services to raise awareness on the importance of the utilization of improved inputs.

These suggested policy options are very much in line with current government strategies to stimulate investments in productivity enhancing inputs and include improved knowledge and extension services teaching the efficient use of inputs. It is important to create a mechanism to support these policies. The overuse of inputs should also be prevented by increasing the knowledge and skills of the farmers in order for them to be able to farm in a sustainable way. As such, a fair balance in input use is crucial to increase productivity without negatively impacting the ecosystem and human system.

Rice systems

There are strong imperatives facing the rice sector in Senegal; mainly increasing the domestic production and processing of rice. Several substantial donors have proposed that investment should be made in this sector. However, there are a number of alternative pathways leading towards that goal. For example, increasing rice production through conventional high-input methods could ramp up yields, but there are increased costs related to greater fertilizer, pesticide and water use. Large-scale rice value chain projects may propose equally large rice mills, but the opportunity to process rice in smaller units may enable greater use of rice by-products, such as for livestock feed, and promote greater equity through community ownership. Different pathways have different implications for employment in the agriculture and food sector. By using a holistic framework to review the possible pathways, many diverse aspects can be brought into focus at the same time, looking at impacts not just economic/produced capital but also social, human and natural capital. The application of the TEEBAgriFood framework and system modelling has shown that alternative systems based on FAO's principles of agroecology can guide the further development of rice policies in Senegal.

Some specific policy options suggested are to:

- Increase resource-use efficiency (e.g. replace inefficient with efficient irrigation equipment),
- Reduce mineral fertilizer and increase natural fertilizer use (e.g. soil fertility enhancement),
- Reduce pesticide use and increase integrated pest management (e.g. botanical extracts for pest management) (see also resilience),
- Implement agro-livestock integration,
- Diversify production and increase income,
- Implement and invest in climate change adaptation (e.g. local seed use, moisture management, research, restore habitats etc.),
- Enhance the provisioning of ecosystem services while ensuring the social foundation for inclusive and sustainable development by enabling the implementation of sustainable land management supporting specifically small-scale production, processing and storage in a holistic way,

- Reconnect producers and consumers by strengthening short food circuits and local markets, including small scale production and processing,
- Support farmers institutions and community-based cooperatives improving access to training, markets, inputs, capital, information, research, storage and processing options on a community level as well as the organization of marketing,
- Prevent the depletion of natural resources through land and natural resource governance,
- Develop and apply land management policies, particularly on the part of local government, that recognizes legal land ownership by women and youth and explicitly allocates land for agroecology, including registration of land designated for agroecology with market values, so that land holders have access to credit,
- Encourage the dissemination of technology without state involvement (e.g. farmer to farmer propagation, the dissemination of best practices, support the development and the official recognition of knowledge provided by the agroecological farms etc.),
- Increase the potential of territories to sustain their peoples by reconnecting food habits and culture as well as food production and food consumption (e.g. ensure that rice production matches the food preferences of consumer and promote the cultural value of rice in Senegal), job creation through knowledge and labour intensive agroecological production and the formalization of the sector (see culture and food traditions),
- Develop and support community seed banks at the local level, including research, inventories, and awareness raising and small-scale seed enterprises.

6.2. Food security in SSA

In order to achieve self-sufficiency and protect natural resources, other aspects of eco-agri-food systems are also vital in SSA. There is need to modify current agriculture and food policies to deliver nutritious food to growing population without impacting natural and social capital. The following actors displayed in table 11 can play a greater role in this transformation.

Table 11 Actors and typical levers and drivers of change for transformation of agriculture systems.

Actors	Lever/Driver of change
Farmers	Training, incentives
Workers	Training, skills, education
Extension officers	Knowledge, training
Scientists	Training
Market agents	Market based tools

Policy makers	Decision making tools
Consumers	Food choices
Civic society	Social equity
Governmental organisations	Welfare
Finance sector	Sustainable finance
Media	Awareness
Overseas development aid	Sustainability

6.2.1. The role of intra-regional trade

High domestic food price volatility poses a grave risk to the food security of poor households that spend a greater share of their income on food, and for households depending on agriculture for their livelihood. SSA is the most food insecure region in the world, where food price volatility can impact the food security of millions.

The role of intra-regional trade in reducing volatility and improving food security was recognised by the African Union (AU) in its Malabo Declaration on accelerated agricultural growth, which committed to boosting intra-African trade in agricultural commodities and services. Reductions of barriers to regional trade are an inexpensive means of reducing domestic prices and hold enormous potential to improve food security in the region. This positive contribution is already evident in regions where neighbouring countries are pooling production to stabilise markets through cross border trade (Mozambique-Malawi, Malawi-Zambia, Uganda-Kenya).

Feeding 1.5 billion people by 2030 and 2 billion by 2050 is the challenge that Africa intends to meet. Success requires a vision shared among the different stakeholders in agricultural development and food security. Growth in demand and its diversification offers a new opportunity for African agricultural producers and subsectors. This market potential is a veritable economic tool for transforming the agricultural sector. This transformation must assist in providing solutions to Africa's challenges: creating jobs, protecting natural resources, meeting the needs of consumers, etc.
However, to meet this challenge and to avoid the dependence on international markets for its food, Africa must heavily reinvest in agriculture. Economic and budget stability allows countries to put agriculture back in its rightful place within national budgets. Regional market integration and the control of the international integration of African economies are two other conditions for finding the way back to sovereignty.

6.2.2. Challenges and courses of action

Agriculture in Africa must accelerate growth by exploiting its potential to achieve food security, reducing its dependence on the international market and contributing to global economic growth and regional integration. It must do this by creating jobs for young people, integrating women and reducing social inequalities, while preserving natural resources and the environment.

Five priority intervention areas

To achieve the general objective of transforming agriculture, five intervention areas are outlined below.

1. Increasing agricultural production and productivity;
2. Improving the functioning of national and regional agricultural markets;
3. Fostering entrepreneurship and investment in agrifood value chains;
4. Fostering access to food and improved nutrition;
5. Improving the management of natural resources.

6.3. Recommendations

Based on the analysis presented in earlier sections, some recommendations are suggested as below.

- Subsidies for inputs can be carefully investigated to target desired outcomes for society rather than the narrow focus on per hectare productivity.
- FDI can be further channelized to invest in infrastructure that is required to support the agriculture sector – roads, ports, storage, transport, finance, processing, regulated markets.
- Extension services can be further improved through training on the multidimensional aspects of farming and the move away from the per ha productivity.
- There is need to improve HDI by investing in education, children and women’s health and environmental sustainability, to ensure that the society is healthy, better educated and capable of making informed decisions about its food choices.
- The R&D sector needs investment and reform as the current global agriculture system is geared towards a single narrow focus that has to change. This research should trickle down to the African continent and SSA region for the transformation of agriculture and food systems.
- Agriculture is vital for 9 out of 17 SDGs and is also a prominent sector in Africa agenda 2063, and therefore needs further attention from policy makers in terms of investment and national and regional policies.
- There is a need to:
- Identify change agents to bring this transformation;
- Produce more, in a more sustainable manner, while absorbing a growing labour force;
- Promote diversification based on high quality processed products;
- Promote efficient and more equitable value chains;
- Make farms and agricultural systems more resilient;
- Develop regional markets and controlling international integration;
- Design and implement structural policies and instruments;

- Reform development aid aimed at facilitating the structural reform process;
- Form a clearly articulated objective and a shared vision.

7. Conclusion

Agriculture is of great significance in SSA as it contributes a high share to the GDP in most countries. About 60% of the workforce is employed in agriculture, and a top priority for the development agenda. Despite the increase in the total value of agricultural produce, this region remains the most food insecure in the world. The Africa agenda 2063 advocates for accelerated agricultural growth to eradicate hunger in Africa by 2025. It aims to double agricultural productivity, reduce post-harvest losses and increase intra-regional trade levels. These efforts can also help improve social systems and provide gainful employment and ensure progress for all.

Such an ambitious agenda needs new tools and policies to guide this transformation in Africa, especially in SSA. The TEEBAgriFood framework applied in these three case studies demonstrate the usefulness of a multi-dimensional analysis that includes natural and produced capital on the one hand, and social and human capital on the other. Such an analysis can be used by policy makers to develop appropriate responses.

The three case studies clearly examined key aspects of the value chains of coffee, cocoa, livestock and rice. This analysis also recommended some alternative systems and scenarios for policy makers to consider in each respective country. For example, shaded coffee and cocoa systems promote several public benefits and can be incentivised through markets and the provision of subsidies by the government. Livestock systems in Tanzania provide food for millions of rural dwellers and need further support through training and quality inputs in order to realise their full potential. Rice in Senegal can be produced by using the principles of agroecology, thereby saving inputs cost. These savings can then be provided directly to farmers and R&D sector to support these multi-dimensional farming systems. Such approaches can lead to the development of self-sufficient systems in these countries.

Further analysis is required at a continent scale, including the study of key cereal crops that are essential for food security in SSA, in order to generate evidence for shifting agriculture and food policies towards long term sustainability, the achievement of the SDGs and well-being for all.

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