FUTURE PERSPECTIVES ON LAND FOR EASTERN AFRICA

Pilot study focusing on Ethiopia and Kenya

United Nations Development Programme (UNDP)
PBL Netherlands Environmental Assessment Agency
Joint Research Centre of the European Commission (JRC)
Wageningen University and Research (WUR)

Authors:

Ezra Berkhout[1,4], Elie Kodsi[2], Maurits van den Berg[6], Willem-Jan van Zeist[1,4], Richard Mwandendu[5], Stefan van der Esch[4], Felix Rembold[6], Michele Meroni[6], Michael Cherlet[6]

Contributors:

Andrzej Tabeau[1], Johan Meijer[4], Michel Bakkenes[4], Ben ten Brink [4], Anne Juepner [2], Hugh Eva[6], Christelle Vancutsem[6], Alessandro Dosio[6], Ruben Van De Kerchove[3], Federico Gianoli[6]

Acknowledgements:

We thank Ebby Chagala, Francis Inganga, Habtemariam Kassa, Stephen Kiama, Charles Lange, Silas Mulehi, Gumma Murali, Jamleck Ndambiri, Lucy Nganga, Andrew Sila, Charles Situma, Tamitrat Teshome, Paul Tuwei, Josephine Wanjiku and Kebede Yimam for their contributions and suggestions through the series of workshops and/or the review.

We thank Sasha Alexander, Barbera Bendandi, Bram Bregman, Emanuele Ferrari, Sergio Gomez y Paloma, Phemo Kgomotso, Norah Ngeny, Mwangi Njuru, Andrea Toreti, Nigussie Tefera Uregia, Michiel van Dijk and Olav-Jan van Gerwen for reviewing this manuscript

1 Wageningen Economic Research, Wageningen University and Research, Wageningen, The Netherlands.
2 United Nations Development Programme, Global Policy Centre on Resilient Ecosystems and Desertification, Nairobi, Kenya.
3 Flemish Institute for Technological Research (VITO), Mol, Belgium.
4 PBL Netherlands Environmental Assessment Agency, The Hague, The Netherlands.
5 Independent consultant, Kenya.
6 Joint Research Centre of the European Commission (JRC), Ispra, Italy.

European Commission | PBL Netherlands Environmental Assessment Agency | WAGENINGEN UNIVERSITY & RESEARCH

Table of Contents

Table of Figures

Table of Tables

List of abbreviations

AI-CD	African Initiative to Combat Desertification
ASALs	Arid and semi-arid lands
Bn	Billion
CIFOR	Center for International Forestry Research
COP	Conference of the Parties
CORDEX	Coordinated Regional-climate Downscaling Experiment
EC/JRC	European Commission/Joint Research Centre
FAO	Food and Agriculture Organization of the United Nations
FAPAR	fraction of Absorbed Photosynthetically Active Radiation
GCIs	Global change issues
GDP	Gross domestic product
GLO1	Global Land Outlook, 1st edition
Gt	Gigatons
ha	Hectare
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IGBP	International Geosphere-Biosphere Programme
IMF	International Monetary Fund
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPC	Integrated Food Security Phase Classification
IPCC	Intergovernmental Panel on Climate Change
Kcal	Kilocalorie
KNBS	Kenya National Bureau of Statistics
LDN	Land Degradation Neutrality
m	Meters
MSA	Mean Species Abundance
NCPD	National Council for Population and Development
NDVI	Normalized Difference Vegetation Index
NEPAD/ CAADP	New Partnership for Africa's Development/ Comprehensive Africa Agriculture Development Programme
NPP	National Population Policy
OWG	Online Working Group
PBL	Netherlands Environmental Assessment Agency
RCP	Representative Concentration Pathway
RUSLE	Revised Universal Soil Loss Equation
SDGs	Sustainable Development Goals
SPEI	Standardised Precipitation and Evaporation Index
SSPs	Shared Socioeconomic Pathways
TMF	Tropical Moist Forest
UNCCD	United Nations Convention to Combat Desertification
UNCTAD	United Nations Conference on Trade and Development
UNDP/ GC-RED	Global Policy Centre on Resilient Ecosystems and Desertification of the United Nations Development Programme
UNFPA	United Nations Population Fund
WAD	World Atlas of Desertification
WUR	Wageningen University and Research

EXECUTIVE SUMMARY

The first edition of the *Global Land Outlook* (GLO1) was published by the United Nations Convention to Combat Desertification (UNCCD) in September 2017. GLO1 explored the current pressures on land, the extent and impacts of land degradation, and how these might change up to 2050. It documented how changes in factors, such as population and consumption growth, agricultural productivity and land use change, interconnect. The report called for closer inspection of such changes to enable policymakers to design policies that not only address today's policy challenges, but also weather upcoming ones.

This report, and the project activities that contributed to it, is a first step in this direction. This pilot study zoomed in on the multiple land-use-related challenges faced by Ethiopia and Kenya, which have expressed interest in joining this study. This included sharing and discussing data on economic and population growth (Section 2), land use and land cover changes, land degradation and drought (Section 3), changes in crop and livestock productivity and production (Section 4), and food availability and agricultural trade (Section 5). Scenarios on land use change and degradation that were developed for GLO1, based on internationally developed reference scenarios (Shared Socio-economic Pathways (SSPs)), were adapted to include more detail for Ethiopia and Kenya. These projections were complemented with analysis of current trends and both were compared with policy plans and ambitions as developed in both countries. Data were presented and discussed in a series of online meetings in which government representatives and stakeholders from both countries participated.

A number of factors could not be taken on board in this pilot study. First, even while the COVID-19 crisis shifted most of the activities in this pilot study online, the actual impact of COVID-19 is not included in the scenario projections as they were developed at an earlier time. However, the impact of COVID-19 on food security and economic development in both countries is pronounced, at least in the short and medium term, as discussed in Section 2.1. Climate change impacts on agricultural production, the precise effects of which are highly uncertain for East Africa, has not been dealt with explicitly in the projections, but key insights are discussed in Section 2.2. Moreover, the quantitative analysis presented here is largely based on harmonized data sets at global level. Discrepancies or errors that are of little relevance at the global level tend to become more evident when zooming in at regional or national level. Some examples are given in the report. Still, five firm conclusions can be drawn from the analysis in this report.

The active engagement of scientists and government officials from both Ethiopia and Kenya strengthened ownership of this pilot study. They confirmed the pilot's usefulness while identifying options where this study may already inform ongoing processes of policy development in both countries. Scenarios allow stakeholders to identify key future challenges that warrant action today and build understanding of the impact of current policies on future outcomes.

The data put forward in this pilot study could play an important role in devising ways to mitigate trade-offs or as the basis for difficult choices. For example, the maps presented in this study point to areas most at risk of land use conversion, and could inform policymakers in revising forest and nature conservation strategies and/or targeting compensation policies in such areas. A platform in which key stakeholders discuss and share data, and possibly develop additional scenarios, would be a fruitful starting point for identifying where trade-offs arise and how these can be mitigated. Key insights from such a platform have then potential to inform multiple layers or spheres of government policy.

Many recent trends are in line with the more pessimistic forward-looking scenario (SSP3), with high population growth and low growth of agricultural productivity rates. This is despite clear national policy aspirations that are often aligned with the more optimistic scenario SSP1, or the middle-of-the road scenario SSP2. An outcome closer to the SSP3 scenario implies a much greater claim on land by agriculture. The conversion of forests, natural savannas and, in some instances, rangeland is already apparent in current trends. And in each of the scenario projections, further conversion is anticipated. However, SSP1 documents a scenario with much smaller expansion of agriculture, but nonetheless a robust increase in agricultural production. Food availability per capita in both countries is highest in this scenario. The strong productivity increases in agriculture also imply more pressure on the condition of land and soils, requiring attention to sustainable management to prevent further degradation and limit vulnerability to drought.

The land-related challenges facing Ethiopia and Kenya are well recognized in the policy responses developed. Policies aim to address pressures such as population growth and land degradation, and interventions have been developed to raise agricultural productivity and prevent forest loss. Ethiopia, for instance, is one of the few countries in Africa to surpass the New Partnership for Africa's Development/Comprehensive African Agriculture Development Programme (NEPAD/CAADP) target of spending 10 per cent of its annual budget on agriculture. In Kenya, achieving 100 per cent food security is one the "Big Four" priorities adopted by the government in 2017–2022. Yet, the gap between stated aspirations and actual trends is substantial.

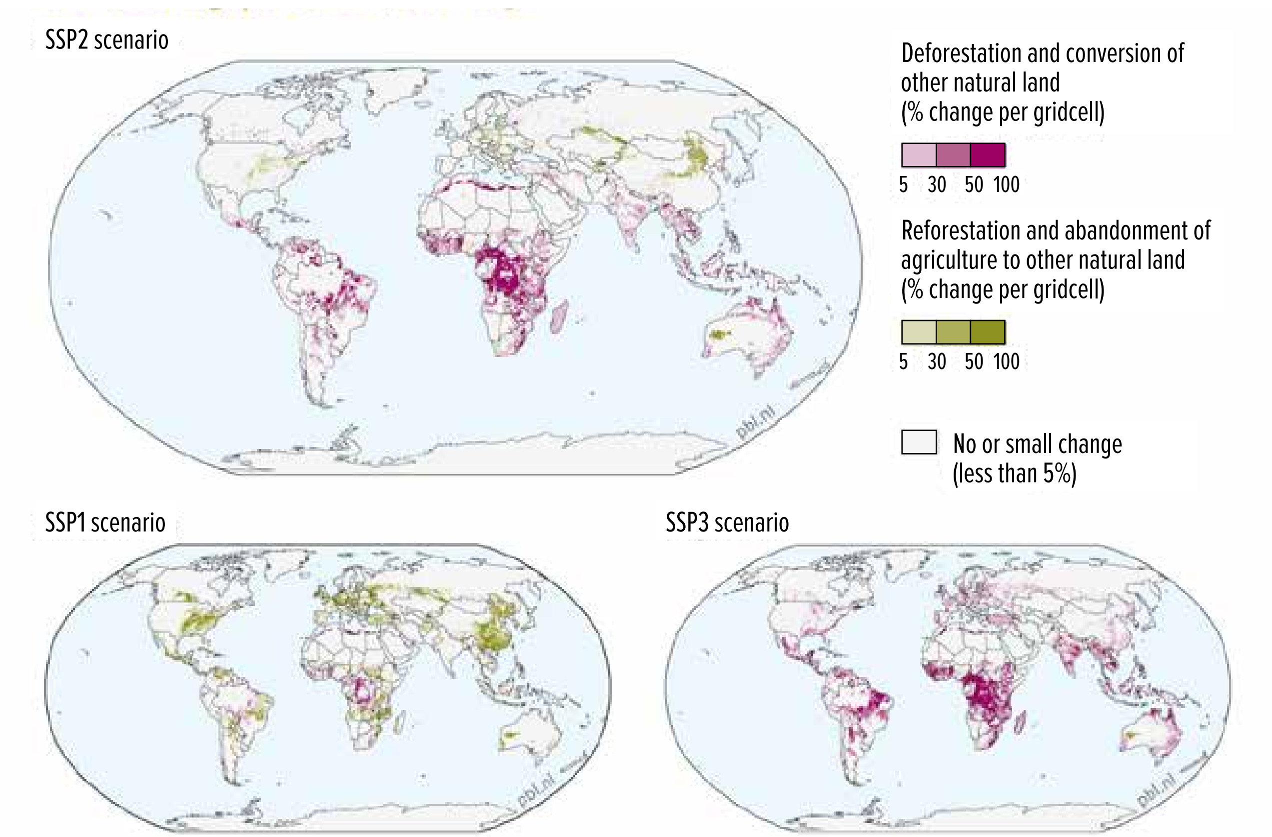
The gap revealed between policy ambitions and actual trends means that goals are in place but implementation is key. Here, the clear trade-offs presented in the trends and scenarios imply this will not be an easy process. Even in the optimistic scenario (SSP1), some conversion of natural areas to agriculture occurs to meet future demand for food although this is at odds with policy objectives in both countries. For instance, Kenyan policies aim for a 10 per cent increase in forest cover by 2030. Goals for increasing forest cover indicate less space for accommodating food production by a burgeoning rural population. Mitigating such a trade-off points to the need to consider how to compensate groups in society that may lose out and mount a public response, coordinated over different layers of government

There are several promising avenues to expand on this pilot. There may be scope to deepen the scenario development in this exercise in a participative and interactive manner. Current scenarios were based on internationally developed reference scenarios (SSPs) but could be modified to account for country-specific challenges, policy options or debates. Possibly building on the above, there are options to expand coverage to themes that were not or only partially addressed in the current pilot. These may include biophysical topics such as climate change and interannual weather variations, water resources or biodiversity, but could also address current socioeconomic themes in greater detail, for instance, food security or the long-term impact of COVID-19. In addition, a follow-up to this project may expand to other countries cooperating within the African Initiative to Combat Desertification (AI-CD). Based on country demand and available resources, an expansion to other countries in East or West Africa could be envisioned.

1 INTRODUCTION

The first edition of the *Global Land Outlook* (GLO1) was published by the United Nations Convention to Combat Desertification (UNCCD) in September 2017. GLO1 explored the current pressures on land, the extent and impacts of land degradation, and how these might change up to 2050. In several regions of the world, land degradation and competition for land result in acute challenges for policymakers, including the urgent need to improve agricultural production and safeguard important biodiversity sites, and in trade-offs and conflicts between alternative uses of land. GLO1 highlighted these pressures and challenges in work by the Joint Research Centre of the European Commission (EC/JRC), based on the *World Atlas of Desertification*, and in forward-looking projections based on three scenarios developed by the Netherlands Environmental Assessment Agency (PBL) (Figure 1-1).

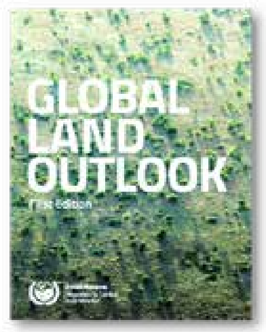
FIGURE 1-1: Projected land use change under the three scenarios developed for GLO1 (SSP1/Sustainability; SSP2/Middle of the Road; SSP3/Fragmentation).
Source: van der Esch, ten Brink et al., 2017.)



Source: PBL/IMAGE

These analyses clearly showed the need to take interactions between human development and land use into account if countries are to develop policies that are not only able to respond to today's problems but also answer tomorrow's challenges. They confirmed the importance of developing a better understanding of soil, land, water, climate, agriculture and food developments in regions that are expected to see large changes in these domains over the coming decades. Africa as a whole is expected to see major shifts in land use, agricultural productivity, and rural-to-urban migration over the coming decades. National governments have a key role to play in channelling these developments, accelerating them where important and responding with legislation and regulation where necessary, especially to mitigate conflicts between conservation, climate change and food production goals.

1.1. Background



The independent evaluation of GLO1 called for "more emphasis on areas which face a 'perfect storm' of factors including land degradation, for testing the global scenarios within specific regions, and providing more detail at the regional or even country level" (UNCCD, 2017b). The pilot study described in this report was designed in response to this recommendation with the objective of testing the GLO1 scenarios within Eastern Africa to assess the order of magnitude of potential future changes to land use and their impacts on societies, and to connect to national policymakers.

A pre-proposal highlighting the objectives, approach and intended results of the pilot study was prepared by the Global Policy Centre on Resilient Ecosystems and Desertification of the United Nations Development Programme (UNDP/GC-RED), PBL and EC/JRC. The note was submitted to the Third Regional Forum of the African Initiative for Combating Desertification (AI-CD), hosted by the Government of Kenya in Nairobi in May 2019. The AI-CD welcomed the study and recommended to start with a pilot study focusing on Kenya and Ethiopia. Based on the results achieved and the resources available, the initiative could be extended at a later stage to other countries in the region.

In partnership with the Governments of Kenya and Ethiopia, UNDP/GC-RED, PBL and EC/JRC hosted a side event during the fourteenth session of the Conference of the Parties to the UNCCD (COP14) in New Delhi in September 2019. The event brought all the stakeholders in this initiative together to agree on the next steps, including the methodology and relevant data sources available for conducting the pilot study.

Following COP14, a project proposal was developed in November 2019 to present the data available for the pilot study, covering current and recent trends in land use, land cover and agricultural production (JRC), as well as forward-looking scenarios at the East African country level (PBL and Wageningen Economic Research). Together these data sets describe an up-to-date reference on current and future land use and quality in the region, as well as projected changes in closely related socioeconomic indicators regarding agricultural production, food supply and security.

This report is the outcome of the pilot study conducted in 2020. Its findings, conclusions and recommendations will be shared with policymakers and stakeholders in Kenya and Ethiopia as well as with other AI-CD countries in the region.

1.2. Objectives

The objectives of this study are to:

- Build capacity on the use of scenario studies and their application to national-level strategic policymaking in Kenya and Ethiopia on sustainable land use and management;
- Inform policymakers and stakeholders in Kenya and Ethiopia on recent trends (past 10–15 years) and potential future changes up to 2050 in land use and their impacts on agriculture, food supply and security; and
- Identify key challenges for both countries resulting from these trends, given current policies and policy objectives.

Based on these objectives, the results of the study can be used to inform the national dialogue at government level on policy priorities and interventions on land use and management, with a quantitative analysis of recent trends, a scenario exploration of projected changes, and national-level data, estimates and perceptions.

1.3. Methodology

The study builds on the work of EC/JRC on recent trends in land use and condition for the *Global Land Outlook* and the *World Atlas on Desertification*. EC/JRC is responsible for the global land component of the Land Service of Copernicus, the European flagship programme on Earth observation. In addition, the study leverages EC/JRC's work on monitoring food security in East Africa, including its contributions to the Integrated Food Security Phase Classification (IPC) and to the multi-agency Global Report on Food Crises. EC/JRC's contribution regarding recent trends and the current state of affairs serves as a baseline and/or contextual background for the scenario modeling.

For projections on future changes to land up to 2050, the study uses the PBL computer model framework IMAGE. This model framework was developed to assess the global impact of socioeconomic drivers on a range of environmental indicators, including land change. The IMAGE model is coupled with an economic model (MAGNET) developed by Wageningen Economic Research, part of Wageningen University and Research (WUR). This general equilibrium model simulates global agricultural supply and demand. For this study, the model was disaggregated to account for country-specific production and intracountry trade in Sub-Saharan Africa in greater detail, including the focus countries of this pilot (Tabeau, Van Zeist et al., 2019; van Zeist, Tabeau et al., in prep). Finally, projected changes in land use were allocated using the GLOBIO model developed by PBL. Further details of these models are provided in Annex A.

Initially, the methodology of the study was based on the organization of two technical workshops, the first in Nairobi and the second in Addis Ababa. However, these workshops were cancelled due to the COVID-19 pandemic and replaced by an online working group (OWG). A workplan was developed for the OWG comprising five virtual sessions, or discussion blocks, held between June 2020 and April 2021 as follows:

- **Session 1 – Launch of OWG** (19 June 2020): Introduction of the members of the OWG; overview of the background, objectives, methodology and intended results of the study; and presentation on scenario analysis and its use for informing policymaking.
- **Session 2 – Land Use Changes** (3 July 2020): Discussion of the information available to

conduct the study, including data on recent trends and the current state of affairs provided by EC/JRC; forward-looking scenario studies developed by PBL; and locally available information (reports, publications, statistics, etc.) available in Kenya and Ethiopia.

- **Session 3 – Socioeconomic Impacts** (7 August 2020): Review of the first draft of the core section of the study on "Land Use Changes" and discussion of the impacts of these changes on agriculture, food supply and security.
- **Session 4 – Policy Implications** (25 September 2020): Discussion of the policy implications and key messages of the study to better inform policies on land use and management in both countries.
- **Session 5 – Final Report** (April 2021): Presentation of the final report and discussion of the next steps to share its conclusions and recommendations with policymakers and stakeholders in Kenya, Ethiopia and the region.

Thirty-two professionals from Kenya, Ethiopia, EC/JRC, PBL, UNDP, the World Agroforestry Centre (ICRAF), the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and the Center for International Forestry Research (CIFOR) contributed to the deliberations of the OWG.

This pilot study did not develop new scenarios using nationally available data. Rather, it aimed to raise awareness of and familiarity with the potential to use scenario analysis for informing policymaking. As such, it introduces the data sets available at EC/JRC on recent trends and the current situation, as well as the scenario studies prepared by PBL and Wageningen Economic Research. This information was complemented with information on land-use policy objectives and strategies obtained from national reports and studies.

Scenario analyses serve to explore what the future may look like under a set of coherent assumptions on key factors driving change. The insights gained by such analyses can help answer numerous policy questions that relate to changes in land use and condition and associated societal impact. Examples of such questions include:

- What are the impacts of increasing food demand, land degradation and climate change on the condition and availability of land in the region?
- To what degree will countries be self-sufficient in food production and, if so, what are the implications for land use and land cover change, such as forest areas? Or, how large are necessary increases in agricultural and livestock productivity?
- In which locations are trade-offs between nature conservation (through protected areas) and agricultural production most likely to occur?
- How will different assumptions about population growth, global trade integration, climate change and land degradation affect the answers to the questions above?

Scenario analyses allow policymakers to anticipate the changes and challenges, for instance, by prioritizing policies towards themes and areas where they are most needed, with due attention to potential trade-offs.

Data from three distinct scenarios are presented. These scenarios are the so-called Shared Socioeconomic Pathways (SSP), and referred to by the abbreviations SSP1 ("Sustainability"), SSP2 ("Middle-of-the-road") and SSP3 ("Fragmentation"). These SSPs have been developed by a group of international organizations that often use scenario studies (Popp, Calvin et al. 2017; Riahi, van Vuuren et al. 2017; Doelman, Stehfest et al. 2018). Further details of the assumptions underlying each of the scenarios can be found in Annex A. Climate change impacts were not taken into account for the scenarios for this pilot study. It is worth pointing out that many of these assumptions are directly based on trends documented by key international organizations, such as the Food and Agriculture Organization of the United Nations (FAO).

The scenarios in this pilot phase will reveal the general direction of the anticipated changes and provide an order of magnitude for these changes. The study is based on authoritative data sets and scenarios, rooted in internationally agreed reference scenarios, that can already be used to inform policymaking.

Depending on the evaluation of this pilot phase, the initiative could be scaled up in Kenya and Ethiopia (for instance, by analysing the effect of policy changes or land restoration initiatives in a new scenario) and extended to other countries in, or beyond, the region (for instance, in West Africa, where AI-CD is equally active). As trends in the wider subregion, beyond the pilot phase countries, will affect land use in Ethiopia and Kenya, and vice versa, such an exercise could add significant value. Additional efforts are needed to mobilize the necessary financial resources for scaling up this initiative into a full-fledged programme on the ground, integrating capacity building and technical and policy support.

1.4. Organization of this report

This report begins by presenting data on key underlying drivers of land use change – population growth and economic development – as well as a short reflection on the impact of COVID-19 (Section 2). Thereafter, data on land use change and degradation are discussed in Section 3, illustrating further linkages between the Sustainable Development Goals (SDGs) on arresting land degradation (SDG 15.3) and deforestation (SDG 15.2) as well as agricultural expansion. Subsequently, agricultural productivity and changes thereof (SDG 2.3 and 2.4) are discussed in Section 4. Broader societal impacts related to food security (SDG 2.1), self-sufficiency and trade (SDG 17.10 –17.12) are presented in Section 5.

Each section starts with a reflection on current and recent backward-looking trends. These data are generally supplied by the EC/JRC, based on various data sources as discussed in the text. Secondly, each section presents forward-looking data from the scenarios computed by PBL and Wageningen Economic Research. Finally, each section closes with a reflection on relevant policies in both countries.

This report provides detail on the evolution of key indicators in the sphere of land and agriculture in Kenya and Ethiopia, in the recent past as well as outlooks through 2050. This also includes insights into the scale on which agriculture and rangelands infringe on remaining natural areas. Closer inspection of changes in biodiversity, the impact of climate change and water availability are relevant. In addition, wider socioeconomic and institutional factors affecting land use change, such as tenure systems and changes therein, are not addressed in this pilot. This also applies to trends related to land use and agriculture in countries neighbouring Kenya and Ethiopia, all of which constitute elements that may be included in a follow-up study.

2

THE CONTEXT: SHORT-TERM SHOCKS AND LONG-TERM TRENDS

Various drivers (short-term shocks and long-term trends) shape land use, land condition and agricultural production; these are discussed below. Demographic changes and economic growth (Section 2.3) are explicitly accounted for in the forward-looking projections presented in this report. The effects of climate change on agriculture are not included and time to adjust the scenarios to the regional situation was limited. The impacts of short-term shocks, such as COVID-19, drought and locust invasions, are also not included. A brief discussion of the potential effects of COVID-19 and climate change are discussed in Sections 2.1 and 2.2, respectively, but a more detailed analysis of the long-term impact of these factors remains.

2.1. COVID-19 pushes back development goals

As the scenario projections presented in this report were developed before the emergence of the COVID-19 crisis, they do not convey any information on the long-term impact of the pandemic. Similarly, the data presented on recent trends do not yet reflect the very recent impact of COVID-19.

Nonetheless, studies have emerged highlighting the major short-term impacts of COVID-19 on the economies and food sectors in both countries, notably quick scans on Ethiopia (Wageningen University and Research, 2020) and Kenya (Wageningen University and Research and SNV Netherlands Development Organization, 2020; Odhiambo, Lewis et al., 2021). Drawing from these studies, several trends become apparent. Mobility restrictions have had a major impact on income and food security, at least in the short run and particularly for young people and low-income groups. These groups are mostly employed in the informal sector, as casual agricultural workers, or with small and medium-sized enterprises (SMEs) involved in food processing. In Kenya, for instance, 80 per cent of the jobs are found in the informal sector. Employment in urban areas decreased sharply, while mobility restrictions also impacted distribution of agricultural input as well as movement of agricultural labourers. In Ethiopia, 38 per cent of casual labourers lost their job in the first months of 2020.

At the same time, stockpiling of staple food items led to temporary increases in food prices, again impacting low-income groups the most. As a result, the poverty rate in 2020 is expected to rise by 13 percentage point in Kenya and an additional 3–3.5 million people will become food insecure in the near future. In Ethiopia, the poverty rate increased by 9 per cent in the first half of 2020, with an additional 10 million people living below the poverty line. Severe acute malnutrition in Ethiopia will rise by 10–15 per cent.

In both countries, production and exports of key agricultural commodities have slowed down. Regional trade was impacted due to temporary border closures, affecting both formal and informal cross-border trade. In Ethiopia, exports of coffee and sesame were expected to stall. In Kenya, exports of tea, coffee and horticulture were reported to be down by 40 per cent, due to reduced international demand and lack of transport capacity. Not only will this impact workers in these sectors, it also reduces foreign currency reserves, thereby putting a strain on government spending in the short to medium term.

The health crisis and the emerging impacts described above have inspired government responses. Indeed, notwithstanding the deep impacts in the first half of 2020, Kenya's economy showed signs of recovery after the second quarter, aided by government responses (cutting tax rates, easing of monetary policy). In addition, the agricultural sector benefited from above average rainfall and horticultural and tea exports picked up (IMF, 2020). COVID-19-related border closures in East Africa and the resulting traffic jams and impact on regional trade have pressed the case for further East African trade integration (UNCTAD, 2020a).

While the short-term impacts of COVID-19 on food production and food security have become increasingly clear, the medium and long-term implications remain poorly understood. It remains to be seen when mobility restrictions in these countries will (or can) be fully eased. Whether agricultural production and associated employment will then pick up quickly is unknown. The latter is also conditional on investment by Foreign Direct Investment (FDI) and the respective governments in public support for the agricultural, livestock and forestry sectors. FDI declined by 28 per cent in Sub-Saharan Africa, less steeply than in developed countries (49%) (UNCTAD, 2020b). But, reductions in national income and exports have led to an increase in debt-to-GDP (gross domestic product) ratios in Kenya and Ethiopia (Fitch Ratings, 2020; IMF, 2020), casting doubt on enhanced public support after the pandemic.

This analysis makes clear that COVID-19 has set both countries off track for reaching their development goals. The long-term implications remain uncertain. A recent scenario-based study (Verhagen, Bohl et al., 2021) suggests that by 2050 in the best case GDP growth will be 6.9 per cent (Ethiopia) and 0.9 per cent (Kenya) lower than a no-COVID-scenario. In the worst case, GDP could be 17.4 per cent and 14.3 per cent lower for Ethiopia and Kenya, respectively. As a consequence, the assumptions and starting points underlying the scenario projections are relatively optimistic. The actual levels of GDP and food security are lower than starting levels assumed in the scenario projections, while constrained public finances in both countries may lower growth in agricultural and livestock productivity.

2.2. The uncertain impact of climate change

Research on climate change in Africa has been fairly extensive, thanks to large initiatives, in particular the authoritative Coordinated Regional-climate Downscaling Experiment (CORDEX[1]), a global partnership with a strong dedicated group focusing on Africa (CORDEX-Africa). Key aims of CORDEX are to produce and foster the analysis of coordinated sets of regional downscaled climate projections under strict quality criteria. Several studies based on CORDEX-Africa data have a specific focus on Eastern Africa or countries within the region. Given the uncertainties in climate simulations and the internal variability of the climate system, these studies typically consider an ensemble of projections using

1 https://cordex.org/


Photo: UNDP Kenya

several models. Most of the runs are available for the high-emission scenarios (RCP 8.5)[2], which thus provide a better representation of the range of possible climate outcomes than ensembles for low-emission scenarios, such as RCP2.6. Because of this advantage, many studies use the ensemble results at the timing of 1.5 and/or 2 degrees of global warming (compared to pre-industrial levels) calculated in high-emission scenarios as a proxy for low-emission scenarios, in line with the Paris agreement. For projections until 2050, differences between emission scenarios are relatively small compared to differences among ensemble members (Nikulin, Lennard et al., 2018), because of the similar emission trajectories in all scenarios until the 2030s.

Results show a coherent and robust (i.e. strong agreement among ensemble members) warming across Eastern Africa, which tends to warm faster than the global mean, likely leading to an increase in the length and frequency of heat waves over the region (Russo, Marchese et al., 2016; Dosio, 2017).

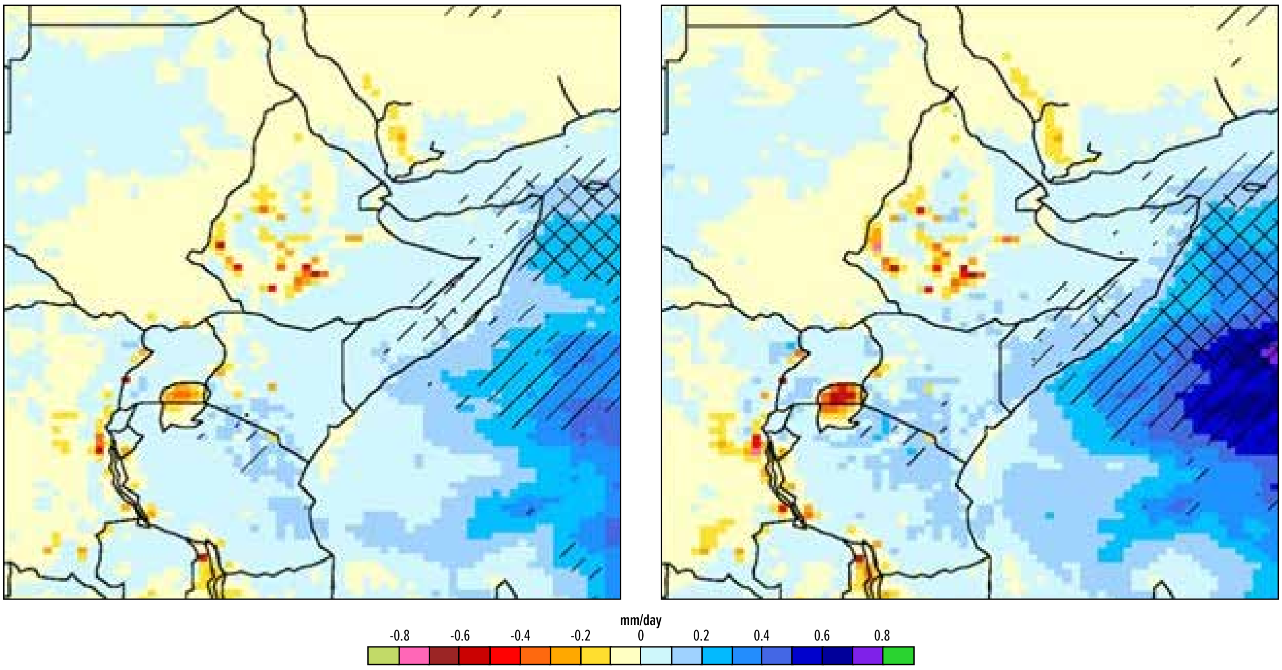
Future trends in precipitation projections are more variable. The majority of projections show a positive change in most of the Horn of Africa (Osima, Indasi et al., 2018; Figure 2-1), with the strongest increase along the Indian Ocean, and which becomes more robust towards the end of the century (Dosio, Jones et al., 2019). Further inland — e.g. western Kenya and in the Ethiopian highlands — the change becomes very uncertain and tends to become negative in some regions. The increase in precipitation is mainly expressed as heavier showers, with little or no change to the number of rainy days and the duration of dry spells. There is even an increase in the duration of dry spells in some regions, such as in southwestern Kenya and the Ethiopian highlands, particularly in the June-August period. For these reasons, and considering the effects of increased evapotranspiration due to the higher temperatures, little or no benefit can be expected for agricultural production in the region, and adaptations will be needed (e.g. water harvesting, flood control) to more erratic rainfall regimes. Moreover, associated with the expected erratic rainfall and heavier showers, soil erosion is also expected to increase (Borrelli, Robinson et al., 2020).

Considering the joint effect of these elements, it is likely that the current scenarios described in this pilot study, not yet accounting for climate change, are likely to overstate actual changes in agricultural productivity, food security or trade. Moreover, general equilibrium models as used in this study are less suitable for modelling shocks, such as droughts, and changes in the frequency thereof. It is also for this reason that this pilot study chooses to complement explorative data from the scenarios with data on recent and current trends.

2 Representative Concentration Pathway (RCP) of greenhouse gases, which covers a wide range of plausible emission scenarios. Originally, a set of four RCPs was produced that led to radiative forcing levels of 8.5, 6, 4.5 and 2.6 W/m2 (watts per metre squared) by the end of the 21st century.

FIGURE 2-1: Annual changes in rainfall relative to 1971–2000 reference period, under 1.5 (left) and 2.0(right) °C global warming (compared to pre-industrial levels) based on the ensemble mean of 25 CORDEX RCP8.5 simulations. Areas where the projected change is most robust are hatched: Positively sloped for areas where at least 80% of the simulations agree on the sign of the change, plus negatively sloped for areas where the signal- to-noise ratio is equal or more than 1.0.

Source: Osima, Indasi et al., 2018.



2.3. Increasing population and economic growth

Two key underlying drivers of changes in land and agriculture are population growth and GDP development. Changes in both the number of people and their spending power have large implications for the demand for food, as well as the type of food, and consequently for the intensity of agricultural and livestock production and the land area required for it.

TABLE 2-1: Evolution of population and GDP in Ethiopia and Kenya, 1980–2050

Country	Variable	1980	2015	2050 SSP1	2050 SSP2	2050 SSP3
Ethiopia	POP	38	98	153 (56%)	170 (73%)	195 (98%)
Ethiopia	GDP	7	45	601 (1,223%)	378 (732%)	236 (419%)
Ethiopia	GDP / cap	198	462	3,929 (750%)	2,226 (381%)	1,210 (162%)
Kenya	POP	16	46	74 (59%)	80 (72%)	95 (105%)
Kenya	GDP	14	44	414 (843%)	279 (535%)	195 (344%)
Kenya	GDP / cap	872	946	5,597 (492%)	3,485 (269%)	2,054 (117%)

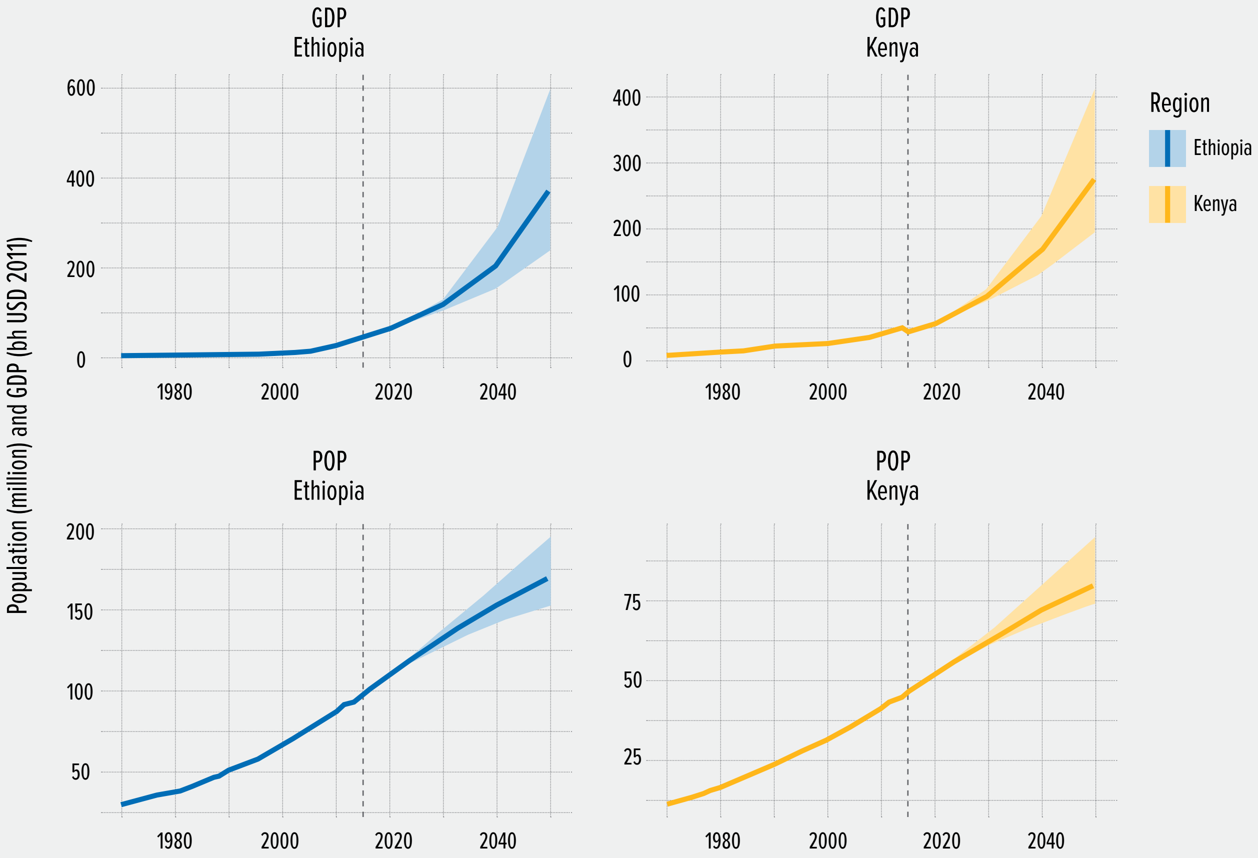
Population (million), GDP (bn $US 2011), and GDP/cap ($US 2011/p). The last three columns show percentage change from 2015 in brackets. Sources: Historical data (up to 2015) are from (World Bank, 2021); the projections are based on trends from the SSP database (https://tntcat.iiasa.ac.at/SspDb) (Doelman, Stehfest et al., 2018; van Zeist, Tabeau et al., in prep).

Table 2-1 and Figure 2-2 provide detail on the changes in GDP and population from 1980 and 2015, as well as projected changes in each scenario in 2050. Considering population growth, the SSP2 scenario forecasts an increase for both Kenya and Ethiopia of at least 50 per cent in 2050, to 170 million inhabitants in Ethiopia and 80 million in Kenya. There is a considerable range across the three scenarios. Under the sustainability scenario (SSP1), growth in population is limited to 153 million inhabitants by 2050 in Ethiopia and 74 million in Kenya. Conversely, in the fragmentation scenario (SSP3), the anticipated population by 2050 amounts to 195 million Ethiopians and 95 million Kenyans.

Considering growth in GDP, the middle-of-the-road scenario (SSP2) assumes an increase from around $US45 billion in both countries today, to nearly $US378 billion and $US279 billion for Ethiopia and Kenya, respectively. These increases are notably lower in the SSP3 scenario, and higher in the SSP1 scenario. Part of the projected difference in GDP between the countries in 2050 is due to the difference in population.

FIGURE 2-2: Population and GDP projections for Kenya and Ethiopia for SSP scenarios, 1980–2050. The solid lines represent SSP2. In the case of GDP SSP1 defines the upper boundaries and SSP3 the lower boundaries of the shaded region. The reverse holds for the case of population growth.

Source: IMAGE/MAGNET computations. See also Table 2-1.



Combined, these figures reveal a distinctly different evolution of GDP per capita over time. Smaller growth in population, coupled with stronger economic growth (SSP1), leads to stronger growth in GDP per capita. In the fragmentation scenario (SSP3), there is only a moderate increase in GDP per capita, as much of the economic growth is offset by a stronger population expansion.

When designing policies in the realm of land use and food security, these underlying changes in population, GDP or GDP per capita are a given. Overall, policies in these domains will only have minor impacts on population growth and GDP, which are mostly determined by economic and societal developments outside of rural sectors. But, the impacts of these underlying drivers on land use and food security are profound, as the following sections highlight in closer detail.

2.4. Reflection on relevant policies

2.4.1. Ethiopia

The National Population Policy (NPP) was adopted in 1993 (Government of Ethiopia, 1993) to address the country's high maternal and child mortality, high fertility and rapid population growth. An assessment of the implementation of the NPP revealed that despite considerable progress in the areas of reproductive health service delivery, population data collection and research, education and communication, the population growth rate remained high at 2.6 per cent per year in 1994–2007 (Hailemariam, Alayu et al., 2011). Weak coordination and institutional arrangements, limited monitoring and evaluation, and the lack of a comprehensive population programme are some of the problems that have hindered implementation of the policy.

The World Population Dashboard shows that the population growth rate for 2015–2020 is estimated at 2.6 per cent (United Nations Population Fund (UNFPA), 2020). The UN projects that by 2050 the country's population will grow to over 205 million people, from around 115 million today (United Nations, 2019), an indication that population growth evolves according to the SSP3 scenario. This development trajectory will exert significant pressure on agricultural land and food security, increase the extent of land under cereals and challenge forest conservation. In essence, all aspects of agricultural production will be affected.

The implementation of population policy directives could be strengthened to slow down population growth and bring it in line with SSP2 projections, at least in the short to medium term, while striving to achieve a more sustainable pathway as in the SSP1 scenario.

Ethiopia's economy experienced strong, broad-based growth averaging 9.4 per cent per year between 2010/11 and 2019/20 (World Bank, 2021). Industry, mainly construction and services, accounted for most of the growth. Agriculture made a lower contribution to growth in 2019 compared to the previous year. This impressive growth led to positive trends in poverty reduction in both urban and rural areas. The share of the population living below the national poverty line decreased from 30 per cent in 2011 to 24 per cent in 2016. The government is currently finalizing its new 10-year Perspective Development Plan for the period 2020/21 to 2029/30. The plan aims to sustain the remarkable economic growth achieved under the Growth and Transformation Plans in 2010–2020, while putting more emphasis on the private sector.

However, Ethiopia remains a low-income country with a per capita GDP of $US856 in 2019 (World Bank, 2021). Continued population growth in line with SSP3 will lead to a modest increase in GDP per capita, reaching $US1,210 by 2050 compared to $US2,252 and $US3,929 in the case of SSP2 and SSP1, respectively. Bridging the gap between actual levels of and stated ambitions for population growth and economic development will enable Ethiopia to evolve along the SSP2-SSP1 development pathway, thus meeting its policy ambition to become a middle-income country.

2.4.2. Kenya

The Government of Kenya, in Sessional Paper No.3 of 2012 (Ministry of State for Planning, 2012),, has advocated for population control through a decreased fertility rate, with several government programmes on birth control and child welfare. According to Kenya National Bureau of Statistics (KNBS) projections, Kenya's population will reach 57 million in 2025 and increase to 64 million by 2030 (KNBS, 2012). The population growth rate has kept to 2.9 per cent in recent years, well above the national target of 2.4 per cent, leading to a projected population of around 100 million in 2050 (National Council for Population and Development (NCPD), 2013).

The projections of the Government of Kenya are in line with the SSP3 population estimates, which result in increased pressures on land resources. As such, there is a need to review implementation of government population policies to reduce the annual growth rate and meet the agreed national target of 2.4 per cent. This will help align population growth with the projections of SSP2, which forecast the population to reach 80 million in 2050 versus 95 million in SSP3.

Vision 2030 aims for the transformation of Kenya's economy into an upper-middle-income economy by 2030 (Government of Kenya, 2008). Central to this transformation is achieving an ambitious target of 10 per cent annual GDP growth by 2022, focusing on priority economic sectors including tourism, agriculture and livestock, manufacturing and financial services. The government forecasts the economy to reach $US125 billion by 2030. However, there are major obstacles to achieving this objective and it is unlikely that Kenya will join the ranks of upper-middle-income economies by 2030 (ISS, 2018). Bridging the gap between actual levels of and stated ambitions for population growth and economic development will enable Kenya to evolve within the SSP2-SSP1 development pathway.

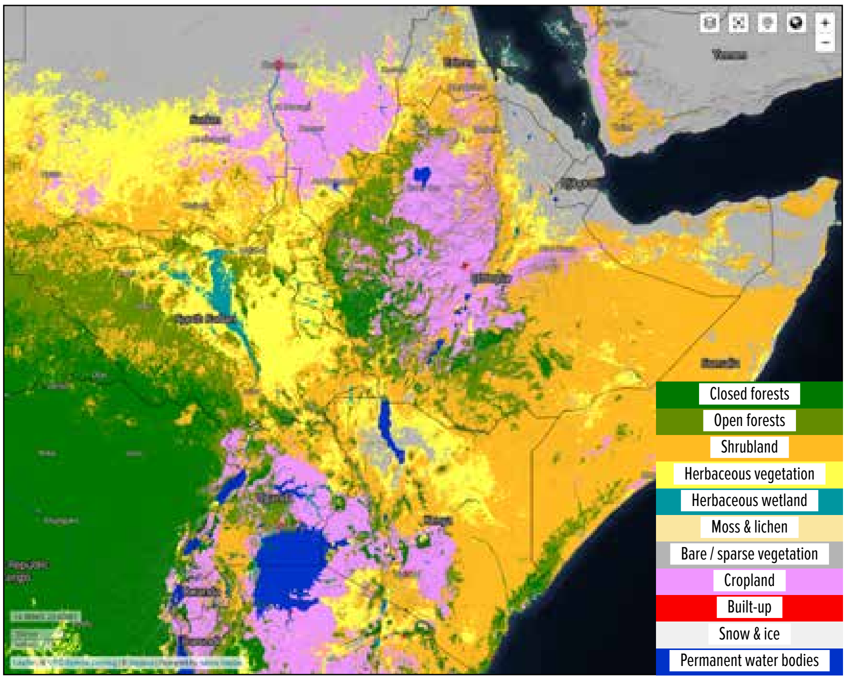

Photo: UNDP Ethiopia

3

EVOLUTION OF LAND USE AND LAND DEGRADATION

Against the backdrop of population dynamics and economic development described previously, this section explores changes in land use and land condition in the recent past as well as projected in the different scenarios. An overview of relevant data sources is given in Annex B.

FIGURE 3-1: Land cover in the Horn of Africa, 2019.
Source: Copernicus, 2020a.



A general overview of recent land use and cover in the Horn of Africa is shown in Figure 3-1. Croplands are mainly confined to the humid and sub-humid midland and highland regions, such as in eastern Ethiopia and southwestern Kenya. Rangelands predominate in the semi-arid regions, and pastoralism tends to become more nomadic toward the more arid regions, with herbaceous vegetation and sparse vegetation cover. However, most farms in the areas marked as cropland in Figure 3-1 are actually mixed crop-livestock systems (with livestock kept at (quasi-)zero-grazing basis, mainly fed on crop residues), which – thanks to the more favourable weather conditions – allow for a much higher livestock density (particularly of cattle) than the semi-arid rangelands (Gilbert, Nicolas et al., 2018; Robinson, Thornton et al., 2018).

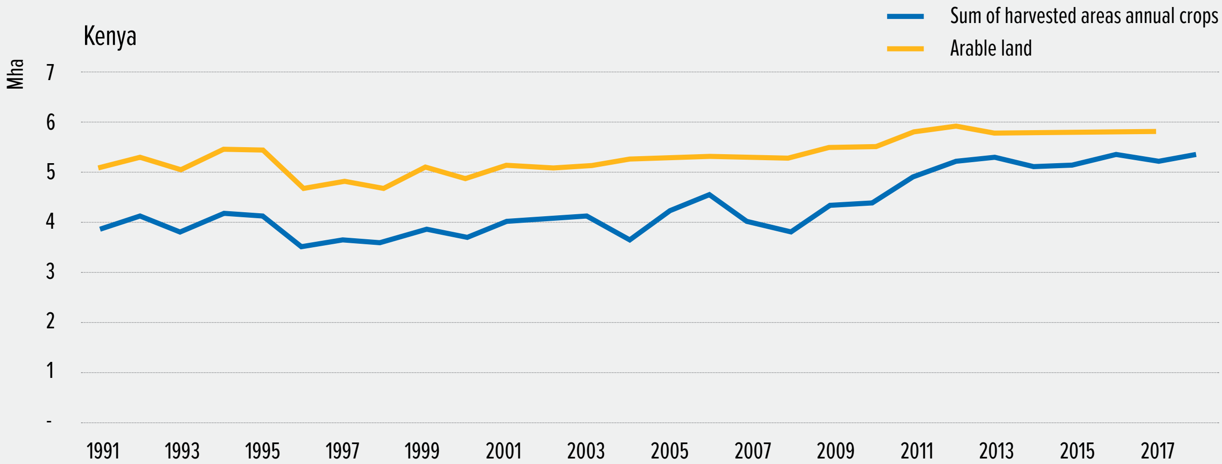
3.1. Land use changes (cropland, rangeland, forest/natural land)

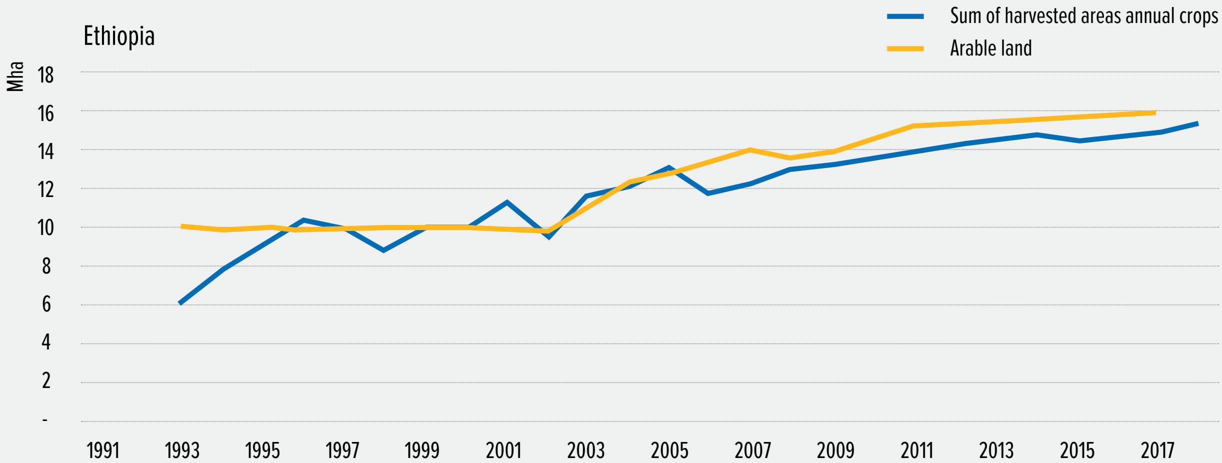
3.1.1. Recent trends

3.1.1.1. Cropland

Figure 3-2 shows the evolution of total area of arable land and harvested areas in Kenya and Ethiopia since the early 1990s, as based on FAOSTAT (FAO, 2020a).

FIGURE 3-2: Total area of arable land and harvested areas of annual crops in Kenya (1991–2018) and Ethiopia (1993–2018).
Source: Arable land, FAOSTAT (FAO, 2020); Harvested areas, own calculations based on FAOSTAT (FAO, 2020).

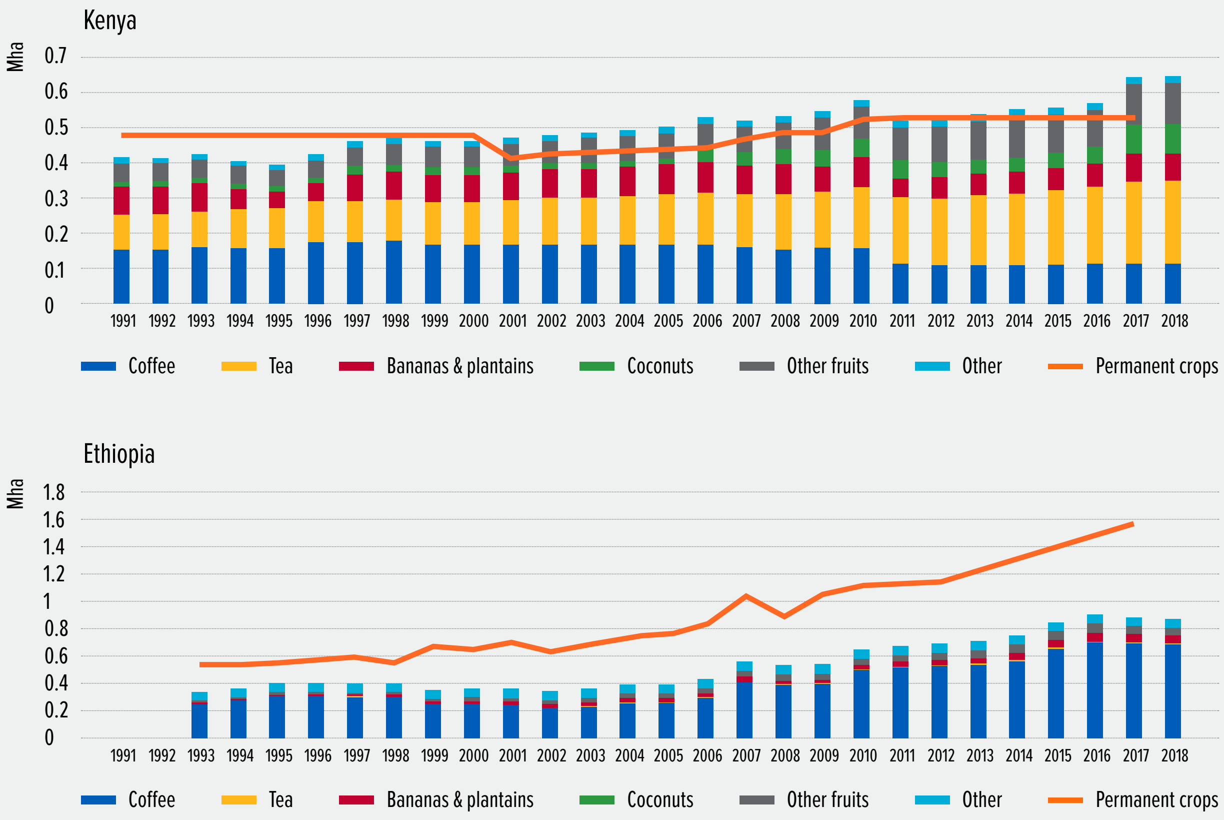




The area of arable land in these graphs tends to be systematically higher than the sum of harvested areas for all crops. This seems to be partly due to methodological differences in assessing these areas (e.g. in Ethiopia through 2002) but could also be due to a higher proportion of fallows as part of a crop rotation than of multiple harvests on the same land within one year.

Since the early 2000s, the area harvested of annual crops increased by about 35 per cent in Kenya, and by about 50 per cent in Ethiopia, whereas the arable land area increased by 16 per cent and 60 per cent in Kenya and Ethiopia, respectively. In Kenya, the narrowing difference between the area of arable land and the sum of harvested areas of all annual crops could indicate a decrease in fallows and an increase in the intensity of land use. The evolution of the areas of permanent crops for both countries is shown in Figure 3-3.

FIGURE 3-3: Areas of permanent crops in Kenya (top) and Ethiopia (bottom), 1991–2018.
Source: FAOSTAT (FAO, 2020).



In terms of land use, these permanent crops are less important than annual crops, but they are very important economically. Moreover, several of these crops (including coffee and tea) perform particularly well in the relatively cool and moist highland areas, thus competing for land with biodiverse closed forest.

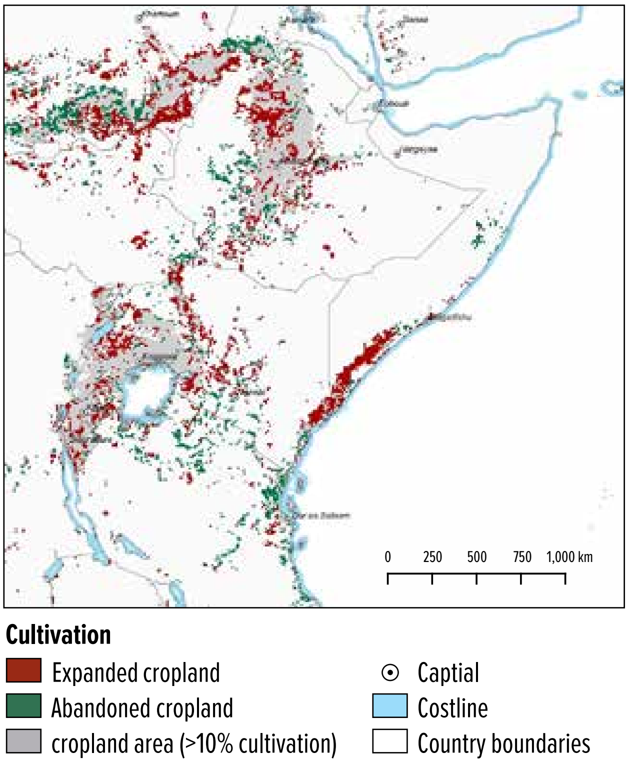
In Ethiopia, the area of permanent crops has more than doubled since the early 1990s, mainly due to the expansion of coffee plantations, whereas in Kenya the increase has been more gradual (around 50%), mainly due to the expansion of tea (but also coconuts and other fruits), which happened partly at the expense of coffee plantations. Interestingly, in the case of Ethiopia, the sum of the areas of permanent crops as given in FAOSTAT (FAO, 2020) is much lower than the permanent cropland as given by the same source, whereas the reverse holds for Kenya. For the case of Ethiopia, this is partly attributable to the fact that areas of some crops, notably chat and enset, are not reported separately.

Figure 3-4 shows the occurrence of cropland expansion and abandonment in the Horn of Africa. This map is a cut-out of a global map from the World Atlas of Desertification (Cherlet, Hutchinson et al., 2018). Mapping of agriculture area from low-resolution satellite data is dependent on the definitions used and also on the representativeness of the ground truth/observation data used for algorithm training. Zooming in at (sub)national level may therefore have substantial uncertainty. Moreover, the spatial resolution of the information presented in this map is too coarse to calculate changes in terms of hectares of land converted or abandoned, especially considering the mostly mixed landscape aspect of agriculture in Africa, leading to heterogeneous satellite observations.

Bearing these limitations in mind, the map suggests that in both countries, cropland expansion and abandonment have both been substantial. The reason for cropland expansion seems obvious: to produce more food and other products by a growing number of farmers to meet the demands of the growing population. The reason for cropland abandonment is less clear, however. This could be due to land degradation, but other factors could also be at play. For example, some of the areas marked as expansion and abandonment could possibly be part of the normal cycle of shifting cultivation. If land degradation is an overriding factor for cropland abandonment and if the map does indeed give a fairly general representation of expansion and abandonment, then this map illustrates that part of the expansion could possibly be averted if land degradation could be avoided or if degraded lands are restored.

FIGURE 3-4: Areas of cropland expansion and abandonment, 2001-2012.

Sources: (Cherlet, Hutchinson et al., 2018) (Joint Research Centre, 2020) based on MODIS land cover data at 500 m resolution.



3.1.1.2. Rangeland

According to FAOSTAT, the area of rangelands (FAO, 2020b) has remained constant over the past decades, at 21.3 million hectares in Kenya and 20 million hectares in Ethiopia. However, these figures are flagged as "manual estimation" or "FAO estimate." In addition, for Ethiopia, FAOSTAT reports data on land under temporary meadows and pastures, based on "Official data reported on FAO Questionnaires from countries," which increased from about 0.9 million hectares in the early 2000s to around 2 million hectares since 2010. Even though this remains a small fraction of the estimated total rangeland area, temporary meadows and pastures tend to be more intensively used and more productive than the traditional rangeland areas. Livestock grazing is also common in cropland areas after harvesting, when livestock feeds on the stubble, thus forming an important complementary source of feed during the dry season.

3.1.1.3. Forests

Statistics on forest area vary greatly, depending on the methods used and especially on how forests are defined, as national definitions may vary.

According to Annex 2 of the FAO *Global Forest Resources Assessment* 2020 (based on country reports), the total forest area[3] in Kenya decreased by 6.4 per cent between 1990 and 2020, from 3.86 million hectares in 1990 to 3.62 million hectares in 2010, after which it remained essentially stable, at 3.61 million hectares in 2020 (6.34% of total land area). The area of planted forest has remained stable at 0.153 million hectares since 1990. According to the same source, in Ethiopia, the total forest area decreased almost linearly from 19.26 million hectares in 1990 to 17.07 million hectares in 2020 (i.e. -11.4%), whereas the share of planted forest increased from 0.34 million hectares to 1.20 million hectares during this period.

Figure 3-5 shows tree cover in 2010 and loss of tree cover from 2001 to 2019 in the Horn of Africa (Global Forest Watch, 2020; Hansen, Potapov et al., 2013) in areas with a tree canopy density of more than 10 per cent (i.e. in line with the FAO definition), including very open woodlands; and in areas with a tree canopy density of more than 75 per cent, which, in this region, roughly corresponds with the so-called tropical moist forests (TMF) of mountain and highland areas. Even though the latter form only a small fraction of total forests in the Horn of Africa, these are particularly highly valued because of their rich biodiversity and water regulation function (often referred to as water towers).

FIGURE 3-5: Tree cover (green) and tree cover loss (red) from 2001 to 2019 in the Horn of Africa.
Source: Global Forest Watch, 2020

Areas with > 10% canopy density

Areas with > 75% canopy density

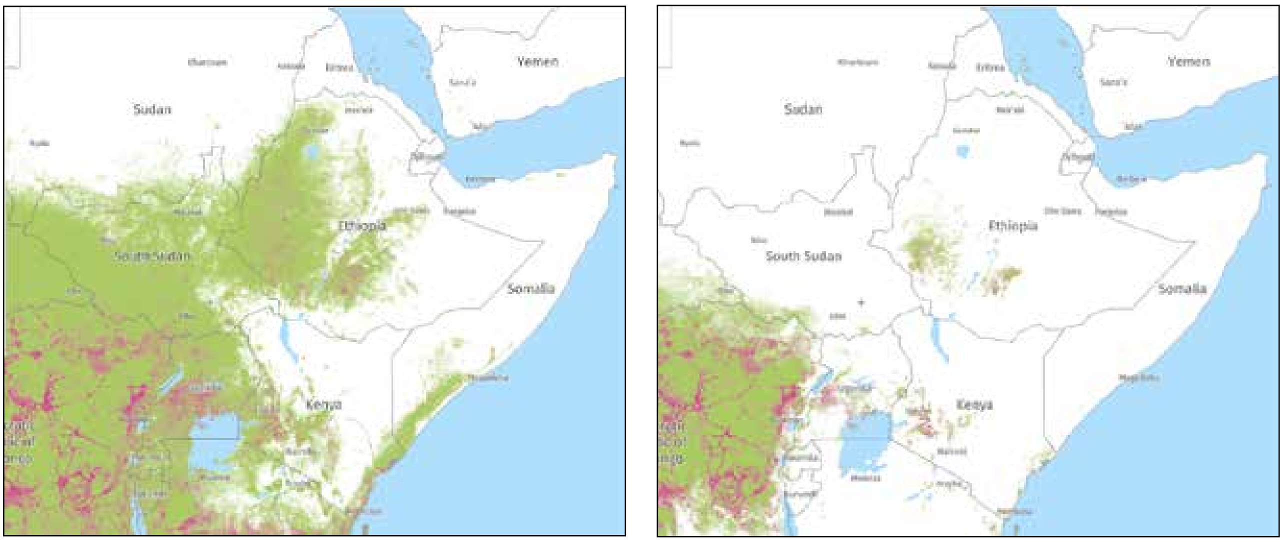


Figure 3-5 suggests that a relatively large share of the forest decline occurred in areas with high canopy density, i.e. the tropical moist forests (TMF). Results from a recent EC/JRC study (Vancutsem, Achard et al., 2021) based on the detailed analysis of Landsat imagery and focussing specifically on TMF (see examples in Figure 3-7) show that between 2001 and 2019, the total area of TMF in Ethiopia declined by 41 per cent, from 3.48 million hectares to 2.07 million hectares, whereas the area of undisturbed TMF declined by 50 per cent over this period (Figure 3-6).

3 The definition of forest employed by the FAO *Global Forest Resources Assessment* 2020 is: land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use (FAO, 2018).

FIGURE 3-6: Evolution of the area undisturbed and total tropical moist forest (TMF, millions of ha) in Kenya

Source: JRC, 2020 (in preparation)

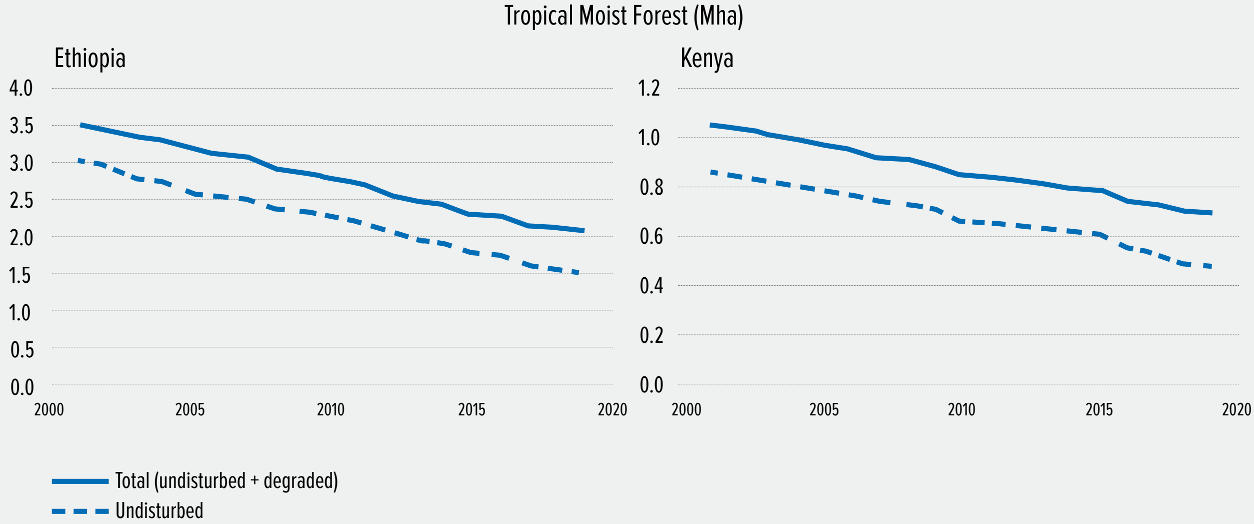
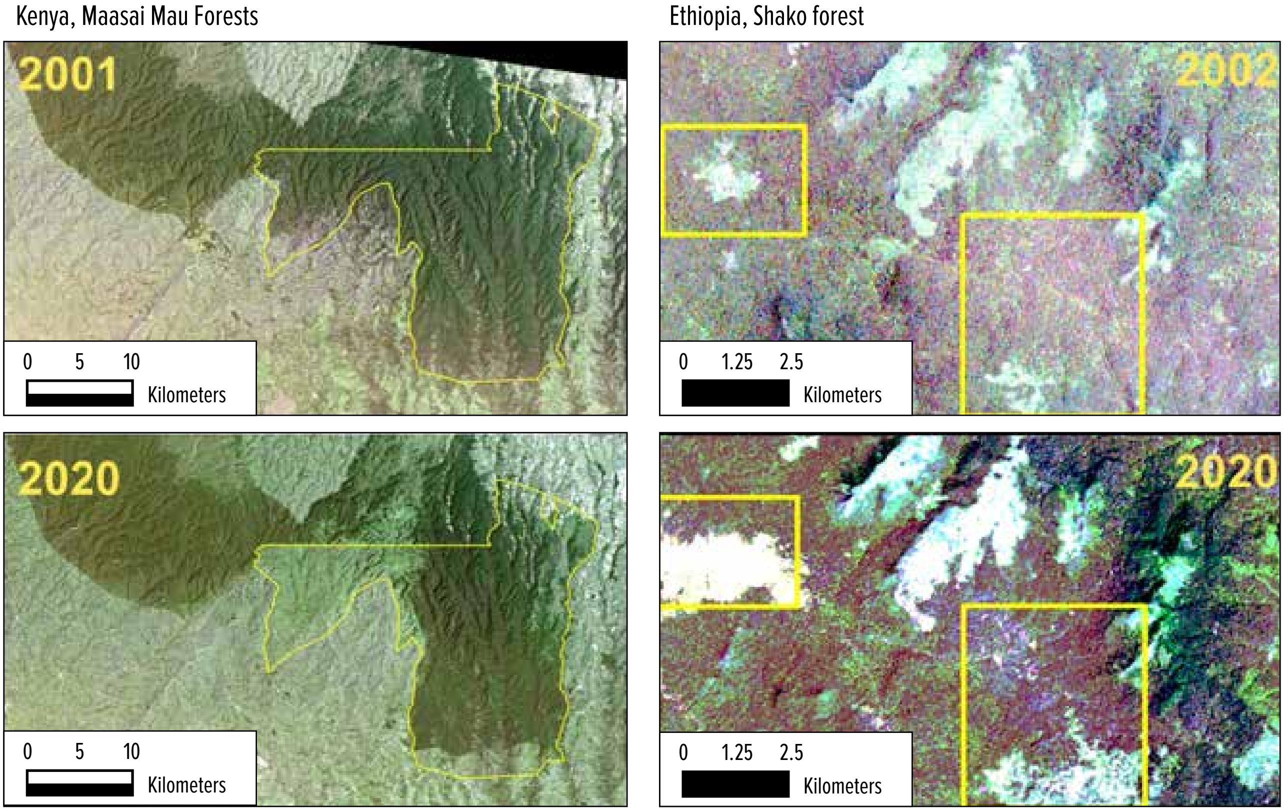


FIGURE 3-7: Examples of Landsat imagery (B1,2,3 – recent image landsat OLI, historical Landsat 7 ETM) used for the analysis of changes in tropical moist forest.The forests in the example for Kenya are upland humid forests – and therefore are greener than surrounding vegetation. In the example for Ethiopia, the forests are drier and therefore lest distinctive.

Source: Vancutsem, Achard et al., 2021.)



For Kenya, this study shows approximately 34 per cent of deforestation of TMF between 2001 and 2019, while undisturbed TMF was reduced by 44 per cent. In 2019, TMF represented 1.43 per cent of the total terrestrial land area of Ethiopia, and 8.8 per cent of Ethiopia's total forest area as indicated by FAO. In most cases, the lost forest areas are replaced by agriculture. The disappearance of these forests could affect water availability and regulation in the countries but more analysis of the water situation would be required.

3.1.2. Projections

The data in Section 3.1.1 point to a pronounced decrease in forest cover and a significant simultaneous increase in cropland over the past two decades. In order to gain an understanding of additional potential changes in land use cover through 2050, this section presents insights from three scenario projections developed by PBL and Wageningen Economic Research.

TABLE 3-1: Projected land use changes, 1980–2050

		Historic	Current	Projected 2050 (% change from 2015 brackets)		
Country	**Variable**	**1980**	**2015**	**SSP1**	**SSP2**	**SSP3**
Ethiopia	Cropland	13.0	16.2	22.4 (38%)	26.3 (62%)	31.4 (93%)
Ethiopia	Rangeland	19.6	19.6	19.6 (0%)	19.6 (0%)	19.6 (0%)
Ethiopia	Forest	6.2	5.9	5.6 (-6%)	4.9 (-17%)	4.3 (-28%)
Ethiopia	Other Natural Land	73.9	70.9	65.0 (-8%)	61.8 (-13%)	57.4 (-19%)
Kenya	Cropland	4.3	6.3	8.5 (34%)	9.5 (50%)	10.9 (73%)
Kenya	Rangeland	22.3	22.3	22.3 (0%)	22.3 (0%)	22.3 (0%)
Kenya	Forest	3.8	2.9	2.7 (-6%)	2.5 (-15%)	1.7 (-40%)
Kenya	Other Natural Land	26.7	25.6	23.7 (-8%)	22.9 (-11%)	22.2 (-13%)

Table lists historical and projected sizes of land use types (in million ha). The last columns provide percentage-wise changes from 2015 sizes in brackets. Source: Historical data (up to 2015) from (FAO, 2020), projections based on the MAGNET model implementation of the SSPs (van Zeist, Tabeau et al., in prep).

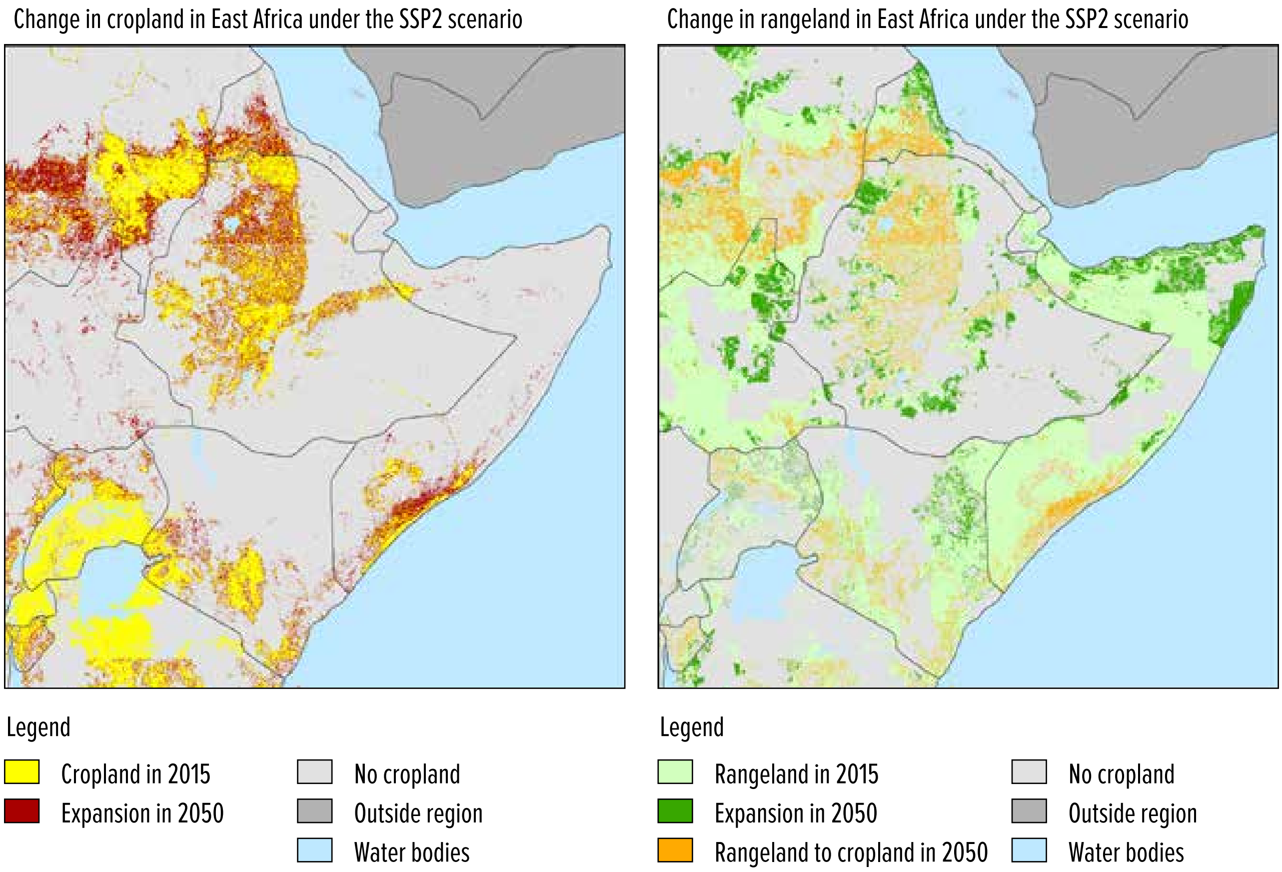
Table 3-1 shows projected evolution in land use for both countries for the three scenarios till 2050. Areas of rangeland are not predicted to change, reflecting that rangeland area does not vary in available FAO estimates. The original FAO data note the sharp drop in the combined Ethiopian and Eritrean rangeland in the early 1990s, possibly due to changed reporting or computation in both countries. Reporting of constant rangeland area is also likely to reflect the difficulties in quantifying rangeland acreages precisely. In order not to deviate from stable historical acreages, we have set the rangeland area at these values in each of the three scenarios.

The relative changes in land use are roughly comparable for Ethiopia and Kenya. For instance, projected increases in cropland for Ethiopia are 38 per cent, 62 per cent and 93 per cent for SSP1, SSP2 and SSP3, respectively. This is comparable with predicted changes in Kenya, where the extent of cropland is set to grow by 34 per cent, 50 per cent and 73 per cent, respectively. Relative changes are similar for the other land use types.

However, in absolute terms, the changes are more pronounced in Ethiopia. Cropland there is projected to increase from 16.2 million hectares to 26.3 million by 2050 under SSP2. In Kenya the increase is smaller in absolute terms from 8.5 million hectares to 9.5 million hectares. This difference highlights that suitable land for expansion of cropland is much more abundant in Ethiopia. But, cropland expansion does typically come at the expanse of forests and natural land. In Ethiopia the amount of land classified as forest is projected to decrease from 5.9 million hectares to 2.6 million in SSP2.

Considering the changes in forest (as well as other types of natural lands) reveals some of the key differences between the scenarios and the underlying drivers. The small increases in cropland projected under SSP1 reflect a combination of a smaller increase in demand (due to demographic changes discussed in Section 2) and greater assumed increases in crop and livestock productivity (see discussion in Section 4). As a result, the pressure of agricultural expansion on forests and natural lands is much smaller in scenario SSP1. This land-sparing scenario contrasts greatly with the fragmentation scenario SSP3. In the latter, the demographic pressure is much greater and the assumed productivity enhancements in the agricultural and livestock sectors are more moderate. The consequence is a large increase in the demand for agricultural land and a huge reduction in forests and natural land. These points are illustrated in the maps in Figure 3-8, Figure 3-9, Figure 3-10 and Figure 3-11 depicting projected land use changes under SSP2 and SSP3 scenarios. The data on SSP1 in Table 3-1 are not used to develop maps since, as argued in this report, actual trajectories tend to be more in line with SSP2 and SSP3.

FIGURE 3-8: Map with projected changes in cropland and grazing area (SSP2), 2015–2050.
Source: 2015 data based on (European Space Agency (ESA), 2017) projections based on the MAGNET model allocated with GLOBIO (Schipper, Hilbers et al., 2020)



First, Figure 3-8 and Figure 3-9 display spatial changes in the middle-of-the-road (SSP2) scenario, the former with respect to cropland and rangeland, the latter with respect to forest and other natural lands. In Figure 3-8, the left panel shows expansion of cropland, in the case of Kenya most observable in the coastal zones around Mombasa and the upper rift valley, north of Eldoret. In Ethiopia cropland expansion is seen across most of the western highlands. The right panel reveals some of the land use conversion implied by the left panel. In fact, much of the newly cropped areas originates from rangeland. As a result, pastoral areas – it is assumed the total area of rangeland does not change — are being pushed to other spaces. In Kenya this is noticeable in the arid north-eastern part of the country around Wajir; in Ethiopia expansion of rangeland is mostly towards the Somali region.

FIGURE 3-9: Map with changes in forest and other natural area (SSP2), 2015–2050.

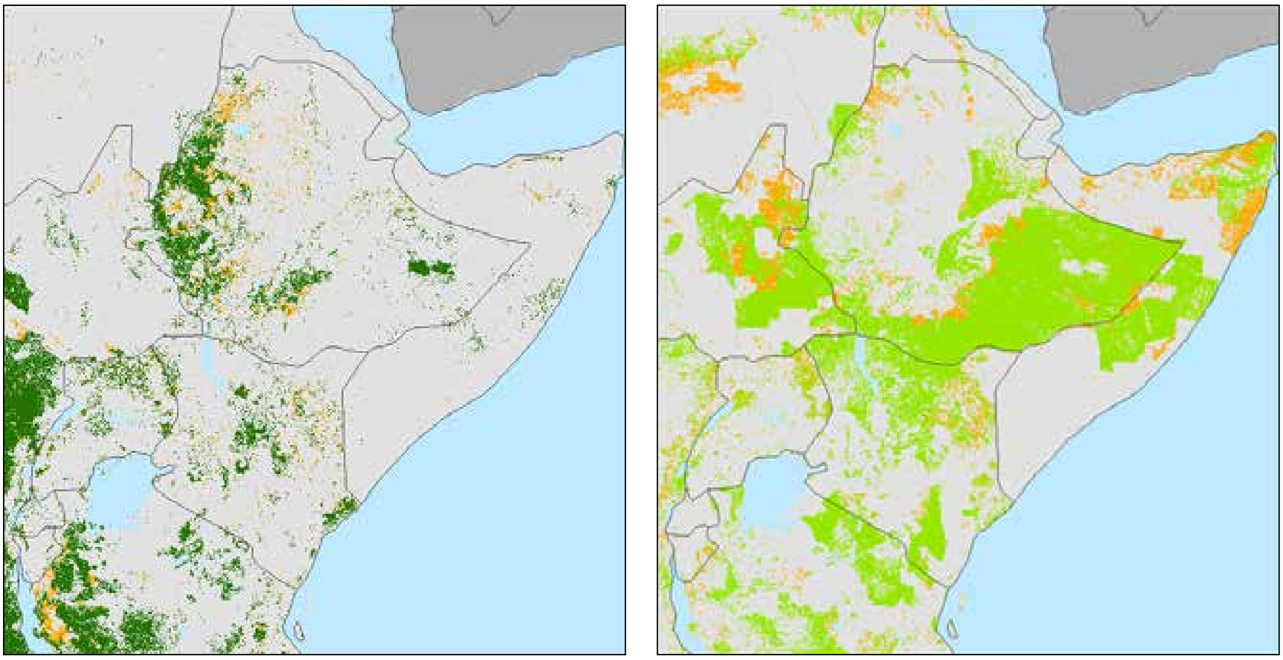


Figure 3-9 shows changes in forests and other natural lands (open savanna, shrubland and natural deserts) in the SSP2 scenario. In fact, the impact is less pronounced in Kenya's forests, but in Ethiopia part of the cropland expansion comes at the cost of conversion of forests across the western highlands. Overall, Figure 3-9 reveals that by 2050 various tracts of forests remain in both countries. Logically, the expansion of rangeland into the more arid zones of Kenya and Ethiopia (as indicated by Figure 3-8) implies that other types of natural land use in these regions are being converted, as shown in the right-hand panel.

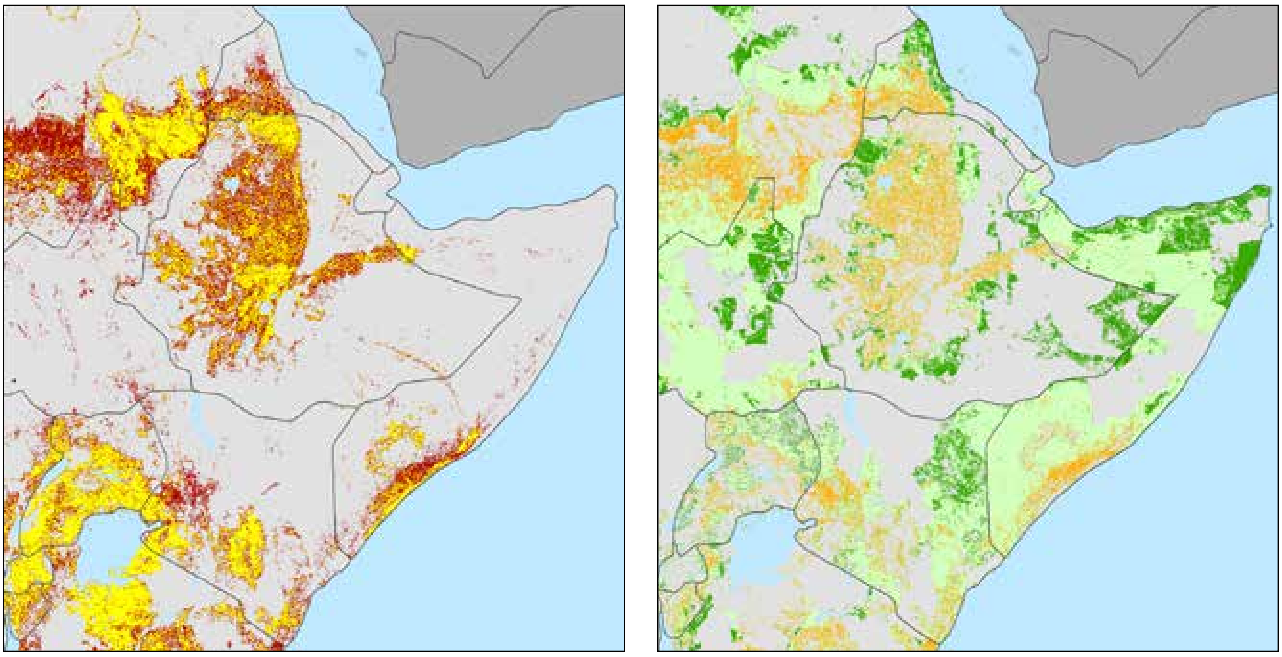
Figure 3-10 and Figure 3-11 display changes under the SSP3 scenario, with less growth in productivity and more pronounced demographic changes than in SSP1 and SSP2. Figure 3-10 shows changes in cropland and rangeland, largely in areas similar to those in Figure 3-8, but stronger in magnitude. The left panel indicates considerable expansion of cropland, mostly in the same areas as in SSP2: around the coastal cities and the Rift Valley in Kenya, and considerable expansion all across the western highlands in Ethiopia. The expansion of cropland is much greater than under the SSP2 scenario. Also, under SSP3, regions around river beds in arid zones in Ethiopia experience cropland expansion. Recall from Table 3-1 that area expansion for agriculture in Ethiopia in this scenario is around 5 million hectares greater than the SSP2 scenario.

Again, the right panel shows changes in cropland that are broadly similar in location as compared with the SSP2 scenario, albeit with a much greater intensity. Considerable tracts of the arid zones in northern Kenya and south-eastern Ethiopia are projected to be fully converted to rangeland, while cropland takes over in existing rangelands.

FIGURE 3-10: Map with projected changes in cropland and grazing area (SSP3), 2015–2050

Change in cropland in East Africa under the SSP3 scenario

Change in grazing area in East Africa under the SSP3 scenario



Legend (cropland)

- Cropland in 2015
- Expansion in 2050
- No cropland
- Outside region
- Water bodies

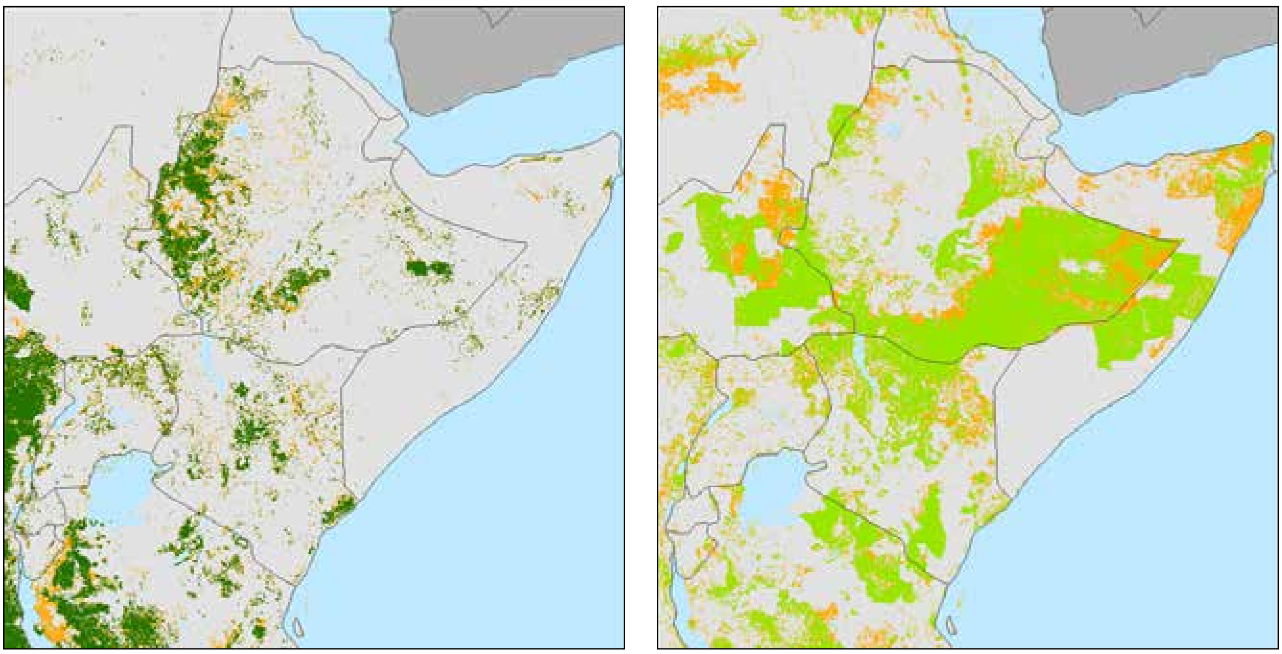
Legend (grazing area)

- Rangeland area in 2015
- Expansion in 2050
- Rangeland to cropland in 2050
- No grazing area
- Outside region
- Water bodies

FIGURE 3-11: Map with projected changes in forest and other natural area (SSP3), 2015–2050

Change in forest in East Africa under the SSP3 scenario

Change in other natural vegetation in East Africa under the SSP3 scenario



Legend (forest)

- Remaining forest area in 2050
- Change compared to 2015
- No forest
- Outside region
- Water bodies

Legend (other natural vegetation)

- Remaining other natural vegetation in 2050
- Change compared to 2015
- No natural vegetation area
- Outside region
- Water bodies

These pronounced changes in land use are also revealed by the trends in Figure 3-11 for forests and other types of natural land. As the right panel shows, the conversion of other types of natural land (not forests) to rangeland is more pronounced in this scenario as compared with Figure 3-9 (SSP2). A similar picture emerges from the left panel showing a stronger infringement on remaining forest areas in southwestern and central Ethiopia and various areas in Kenya. Note that the assumption underlying the SSP3 scenario is that areas designated as national parks or reserves (IUCN categories I-IV) remain protected from crop and pastoral encroachment, but that all other types of protected land (e.g. Controlled Hunting Areas, Forest Reserve, Community Nature Reserve) are degazetted. For SSP1 more stringent conservation policies are assumed, whereby countries set aside 30 per cent of all terrestrial areas for conservation purposes.

The data in this section highlight that achieving policy goals on increasing forest cover (as, for instance, various countries committed to in international agreements) as well as making significant progress on goals related to agriculture and food security is a daunting task. This echoes findings from other studies that equally suggest that raising agricultural productivity alone is likely insufficient for achieving food self-sufficiency in most African countries (van Ittersum, van Bussel et al., 2016).

3.2. Land degradation and drought

3.2.1. Recent trends

Land degradation is a pervasive, systemic phenomenon: it occurs in all parts of the terrestrial world and can take many forms. Land degradation occurs due to various factors, including climatic variations and/or human activities, and leads to a 'persistent decline or loss of biodiversity, ecosystem functions and services that cannot recover unaided' (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2018). The Intergovernmental Panel on Climate Change (IPCC) in its recent special report on climate change and land defines land degradation along the same lines, as "a negative trend in land condition, […] expressed as a long term reduction or loss of biological productivity, ecological integrity or value to humans" (IPCC, 2019; Cherlet, Hutchinson et al., 2018).

Because of its multi-faceted nature, land degradation cannot be expressed by a single indicator and, as a concept, is to some degree subjective. Various aspects of ongoing processes that have led or could lead to land degradation can be mapped and described. These are complex human-environment interactions which include differing drivers or processes (e.g. overgrazing, non-adapted agricultural practices, climate change, deforestation) and consequences (soil erosion, loss in land and/or food productivity, loss of biodiversity and carbon storage, water scarcity) (Cherlet, Hutchinson et al., 2018). These impacts can be direct, immediately affecting ecosystem functions such as crop yields or water productivity, for instance, or more indirect, as for instance when reduced yields or grass production due to degradation processes drives expansion of land use elsewhere.

The UNCCD-launched Land Degradation Neutrality (LDN) target, taken up in SDG 15.3, is therefore based on the concept of "a state whereby the amount and quality of land resources necessary to support the ecosystem functions and services and enhance the food security remain stable or increase within specified temporal and spatial scales and ecosystems"; hence the main goal is to maintain the land resource base. The World Atlas of Desertification (WAD) (Cherlet, Hutchinson et al. 2018) introduced a "convergence of evidence" approach that focuses on mapping cumulative pressures on land resources of ongoing processes leading to land degradation. The scenario report for GLO1 followed

Photo: UNDP Kenya

a similar approach, making projections for various indicators of change to land condition and ecosystem functions (van der Esch, ten Brink et al., 2017).

Because of the above-mentioned complexities, and the varied temporal and spatial scales at which land change processes manifest and interact, directly measuring land degradation in real-world situations is not straightforward. Several approaches exist to assess changes in land condition, land degradation, or land degradation risk at global, national and regional levels. None of these is conclusive on its own and the combined interpretation must consider contextual information regarding regional/local conditions. The WAD used mapping of important (or measured/observed/deduced) land change processes and combined these in pressure maps to assess recent trends and current state. Such issues include:

- Monitoring land use and land cover changes, e.g. using satellite imagery, as discussed in Section 3.1.1
- Using models to assess specific forms of land degradation, e.g. soil erosion
- Monitoring plant productivity as inferred from satellite imagery

These are then brought together in a "convergence" map for analysis of coinciding causal pressure factors of land degradation.

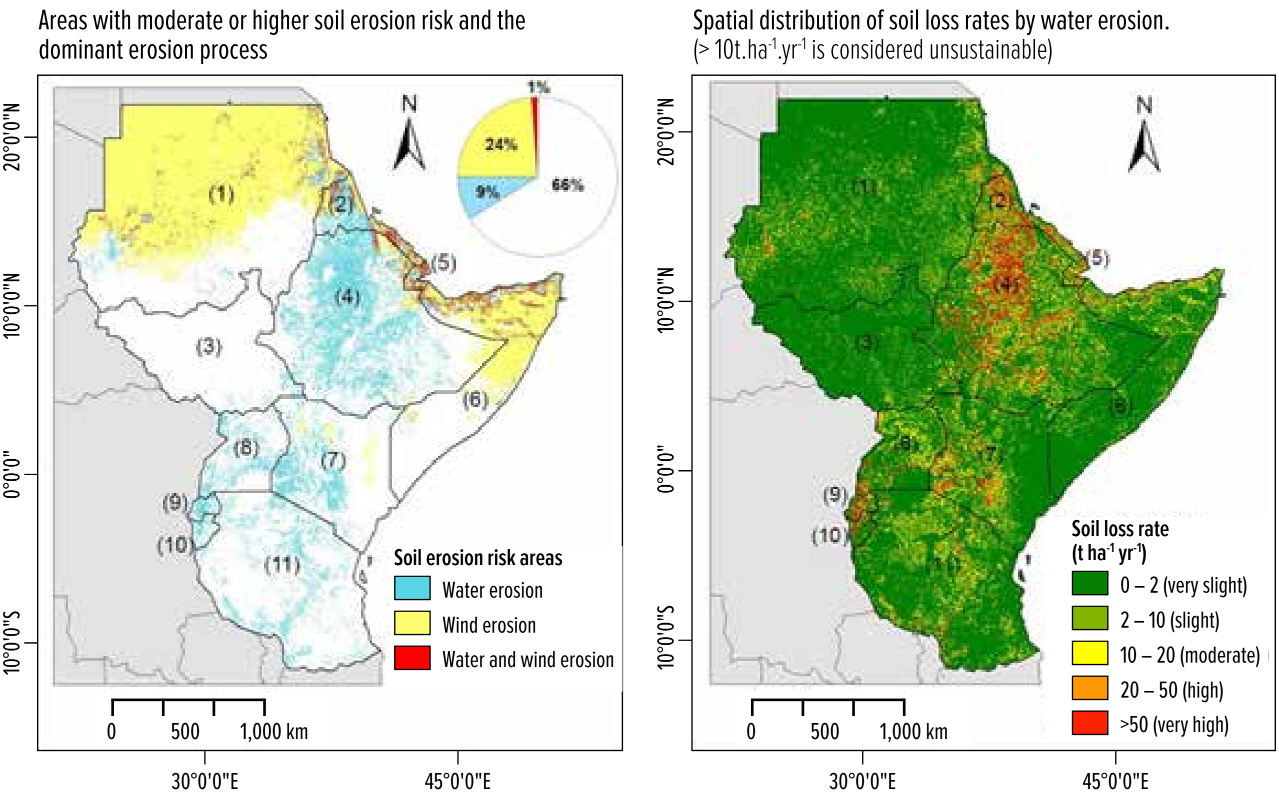
3.2.1.1. Soil erosion

Figure 3-12 presents the results of a recent study on the spatial patterns of water and wind erosion risks in East Africa using the best available data sets (Fenta, Tsunekawa et al., 2020). As shown in the left-hand panel of this figure, water erosion is clearly the most important form of erosion in Ethiopia and Kenya. Soil loss rates caused by water erosion – as presented in the right-hand panel – were calculated using the spatially distributed version of the so-called Revised Universal Soil Loss Equation (RUSLE) (Borrelli, Robinson et al., 2017) which integrates the combined effects of rainfall erosivity, slope length and steepness, soil erodibility, land cover and conservation practices. The results indicate mean annual gross soil loss by water erosion of 4 billion metric tons, with a mean soil loss rate of 6.3 metric tons per hectare per year for the region as a whole, of which about 50 per cent takes place in Ethiopia, particularly in central and western parts of the country which have relatively high frequency of intense rainfall events, large agricultural areas on relatively steep slopes and vulnerable soils of volcanic origin. In terms of land cover, about 50 per cent of the soil loss by water erosion originates from cropland (with a mean soil loss rate of 18.4 metric tons per hectare per year), which covers about 15 per cent of the region's total area.

As a rule of thumb, moderate to high soil loss rates (>10 metric tons per hectare per year) exceed the rate of natural soil formation and are therefore considered as unsustainable. These are all yellow, orange and red-coloured areas in the right-hand panel of Figure 3-12. Soil erosion causes a decrease of soil depth and loss of soil organic matter and essential plant nutrients. For example, a recent study indicates the croplands in the Kenyan and Ethiopian highlands as hotspots of depletion of phosphorus – a non-renewable essential plant nutrient – due to water erosion (Alewell, Ringeval et al., 2020).

FIGURE 3-12: Soil erosion risk in eastern Africa

Source: Fenta, Tsunekawa, et al., 2020



3.2.1.2. Trends in plant productivity

Figure 3-13 shows linear trends in annual plant productivity between 1981 and 2010 in areas vulnerable to drought.[4] Red areas indicate vegetation loss, pointing to places most vulnerable to drought. Green areas indicate increasing vegetation cover – recuperation after drought events, suggesting resilience to drought, naturally or due to crop type or through land management (in a larger part of the pixel or during a larger part of the year).

Although drought is a main cause for vegetation change as mapped in Figure 3-13, there can be many other causes for increasing or decreasing trends. For example, decreasing trends might be caused by deteriorating soil conditions due to soil erosion (e.g. wind erosion aggravated by drought conditions), nutrient depletion, overgrazing or longer-term climate change. Conversely, increasing trends might be due to recuperation of vegetation/crop due to resilience of the crop type or adapted land management practices, changes in land management (e.g. irrigation, increased fertilizer use, erosion control) as well as to natural plant resilience, or, also longer-term climate change.

FIGURE 3-13: Trends in annual plant productivity in drought affected areas, 1981–2010.
Source : Cherlet, Hutchinson et al., 2018.

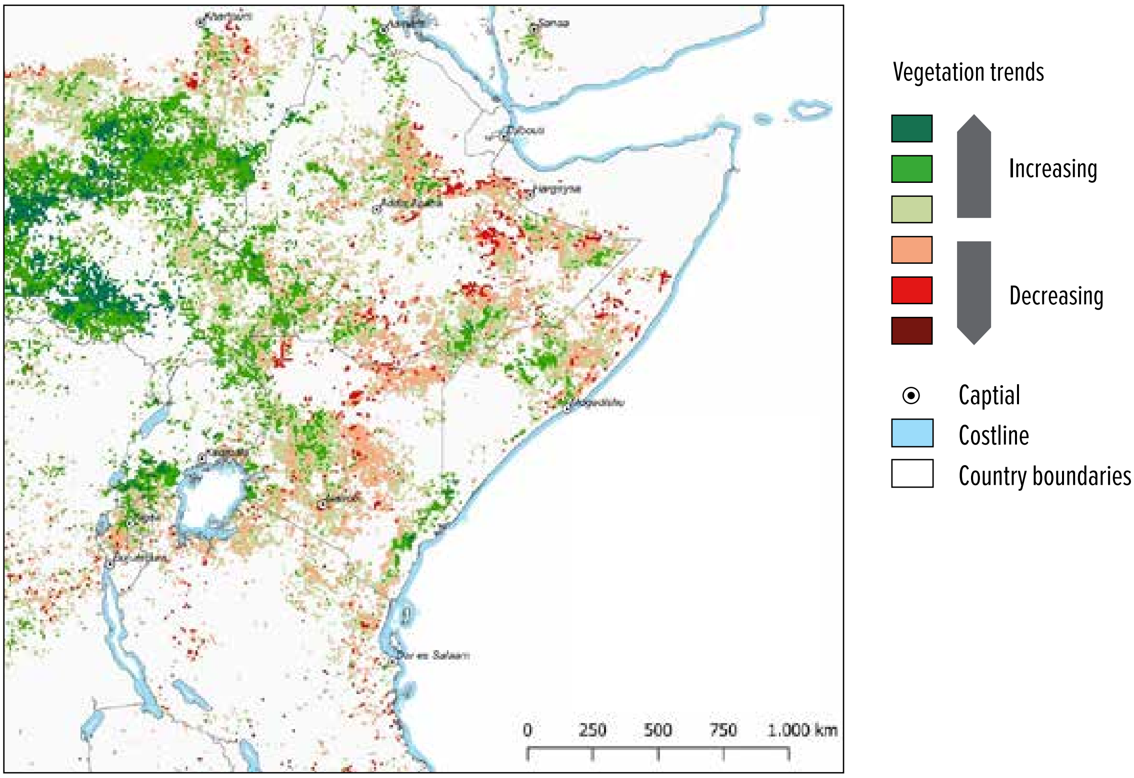


Figure 3-14 shows phenology trends, in terms of changes in the length of growing seasons, specifically for croplands and rangelands and for the first and second growing season, based on satellite observations from 2002–2016. Pixels in red indicate a significant trend of shortening of the respective growing season; pixels in green indicate a lengthening. Particularly conspicuous are the negative trends that seem to predominate in the second growing season (November-February), whereas positive trends

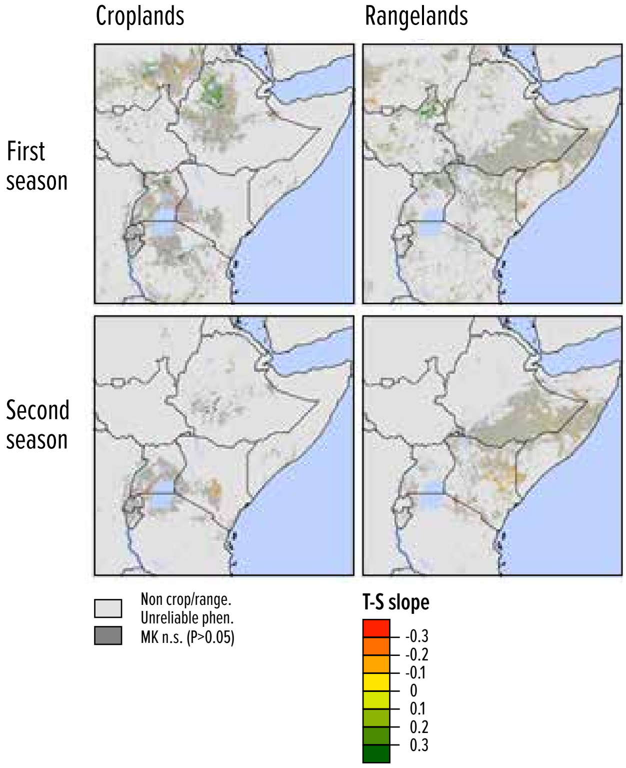
4 To define the mask of "areas vulnerable to drought" for the construction of this map, anomalies in vegetation conditions (deviation from 1981–2010 average), derived from satellite series of the fraction of Absorbed Photosynthetically Active Radiation (fAPAR), were correlated with drought intensity as indicated by the Standardised Precipitation and Evaporation Index, (SPEI, version 2.3) within the vegetation growing season. The map shows only those areas where the fAPAR x SPEI correlations are significantly positive. See: https://wad.jrc.ec.europa.eu/vegetationtrends for more methodological details.

predominate in Ethiopia, especially for croplands. More detailed analysis of the trends could possibly reveal their causes (e.g. climate change, land management).

3.2.1.3. Convergence of pressure factors

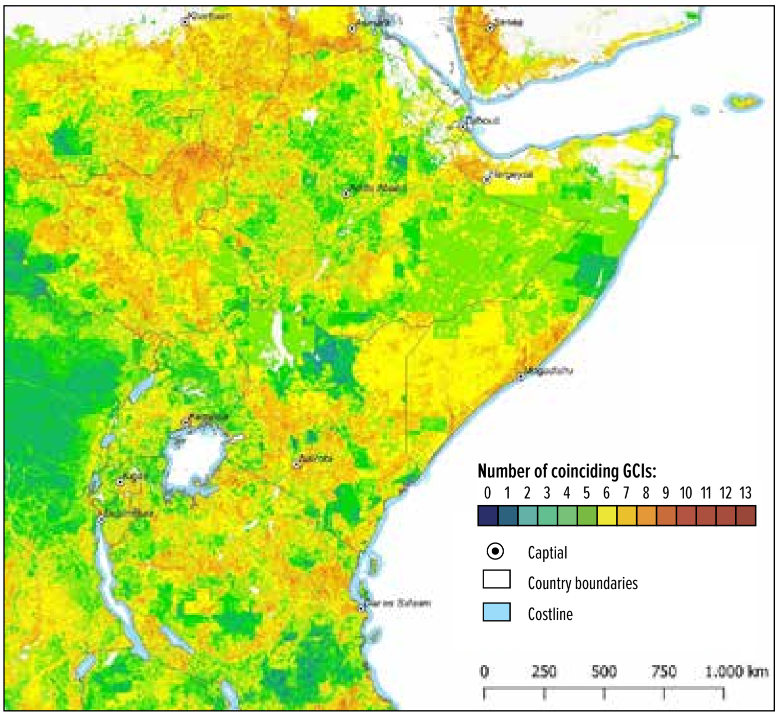
Figure 3-14 from the *World Atlas of Desertification* (WAD), depicts where pressure factors (in the WAD referred to as global change issues (GCIs) relevant to land degradation coincide. Fourteen GCIs were selected, representing a mixture of biophysical and socioeconomic factors (see list of GCIs in Figure 3-16). They were selected because of their availability as global data and their usefulness as factors associated with land degradation as documented in the scientific literature. Based on whether its value is above or below a certain threshold within a particular land cover (e.g. based on the distribution of data values in the agriculture or grassland or forest stratum),[5] each GCI is classified as being either a concern for land degradation (e.g. declining productivity) or not (e.g. stable productivity). The larger the number of coinciding GCIs, the larger the potential pressure on the land resource and the larger the challenge of averting and combating land degradation. Mapping the pressures, rather than "degradation" as such, can point to potential solutions and thus contribute to policymaking on land management.

FIGURE 3-14: Phenology trends, season length, 2002–2016.
Source: JRC.



The number of coinciding GCIs in the Horn of Africa is relatively high compared with other world regions. The extent of each GCI in Kenya and Ethiopia is shown in Figure 3-15. The most common biophysical GCIs that tend to coincide in this region are aridity and decreasing land productivity. The most common socioeconomic GCIs are (low) income level, (high) population change, population density, livestock density and low-input agriculture. As occurs in this region, serious concern for land degradation is warranted where wide yield gaps coincide with low fertilizer use

FIGURE 3-15: Convergence of "global change issues" (GCIs) relevant to land degradation.
Source: Cherlet, Hutchinson et al., 2018

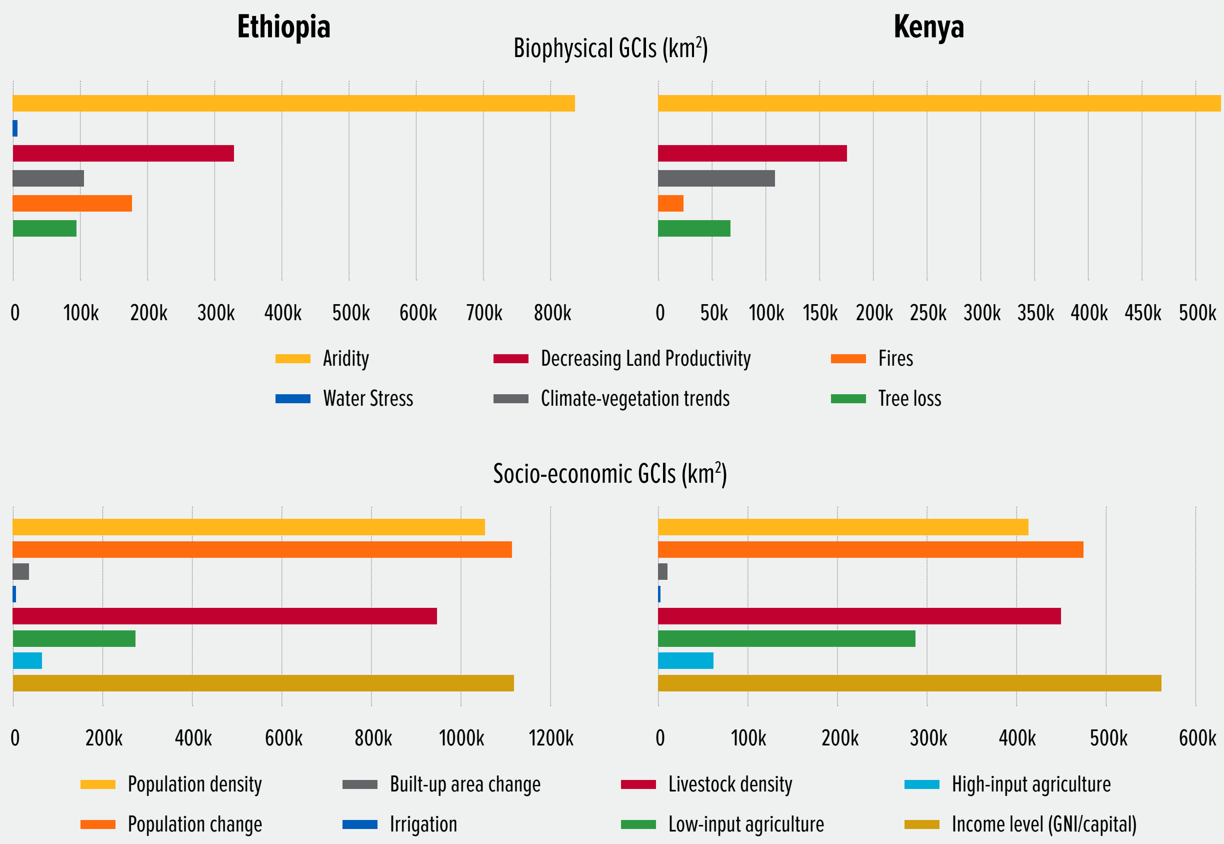


5 A detailed description is given by Cherlet, Hutchinson et al., 2018.

(i.e. low-input cultivation), persistent decline in land productivity and low incomes (Cherlet, Hutchinson et al., 2018).

The original analysis of GCIs in the WAD is at the global level. Zooming in at (sub)national level may have substantial uncertainty and contextual information and knowledge is needed for interpretation related to degradation and land use trade-offs.

FIGURE 3-16: Occurrence of global change issues (GCIs) in Kenya and Ethiopia.
Source: Cherlet, Hutchinson, et al. 2018.

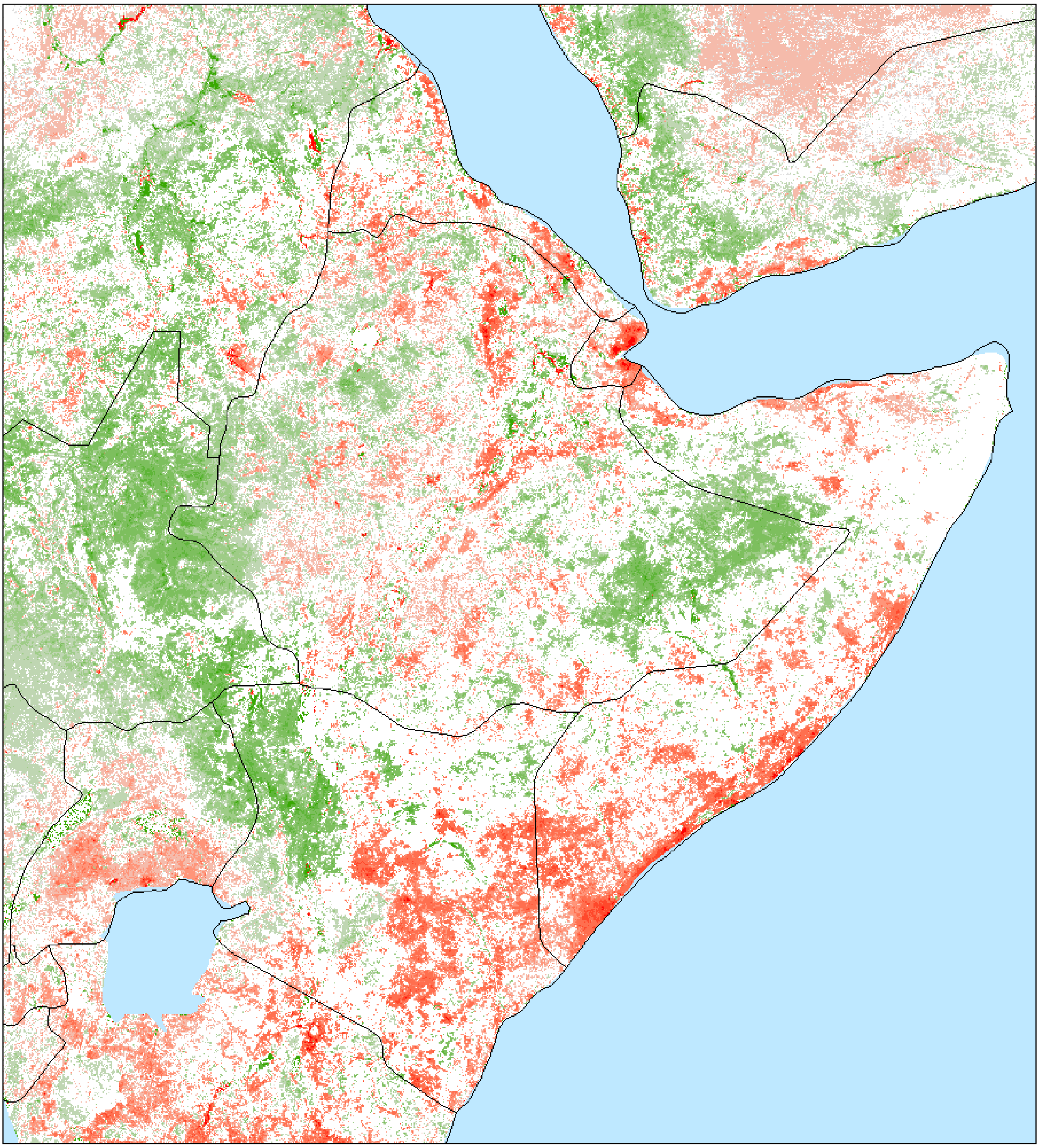


3.2.2. Projections

The scenario study developed for the first GLO explores the potential future extent and impacts of land degradation (van der Esch, ten Brink et al., 2017). Like the *World Atlas of Desertification* (Section 3.2.1), it uses a set of indicators to show changes in ecosystem functions and services under future scenarios. It does not define whether certain changes to indicators indicate land degradation although that deduction can be made from the outcomes, depending on which definition of land degradation and thresholds for indicators are applied. The study focuses on changes to these functions and services and the trade-offs involved when land condition changes.

For this regional report, two indicators are highlighted from this scenario study, in line with the UNCCD approach: land productivity (proxied by the Normalized Difference Vegetation Index (NDVI)) and soil organic carbon. The third indicator (land cover) has already been discussed in Section 3.1.2. The Land Degradation Neutrality (LDN) approach by UNCCD identifies land degradation if for a location one of these indicators is negative (see also (Trends.Earth, 2021) and the SDG15.3 indicator). The GLO1 scenario study includes additional indicators for land condition and ecosystem functions, such as

FIGURE 3-17: Satellite-observed trends in NDVI, 2001–2018.
Areas in red and green show up to –<3% and +>3% annual change respectively (MODIS).



biodiversity, nutrient levels, aridity, crop productivity and water regulation. These are out of the scope of this pilot study, but could be expanded upon in a later phase.

Land productivity is often estimated using NDVI, which is measured by satellite. There are different sensors and therefore different data sets. Figure 3-17 shows the trends in NDVI based on MODIS over the period 2000–2018 for those areas where a significant trend was observed. In north-western Kenya and eastern Ethiopia, there are areas that appear to show increases in productivity. These are arid and semi-arid areas however and the NDVI signal could be less accurate here; other indicators work better in arid areas but were not used in the global analysis. The declining trends in both countries generally show up in areas of higher primary productivity and the signal in these areas is likely more robust.

Soil organic carbon is projected in the scenarios for the GLO using a combination of projections for land use change, land use intensity, and extrapolated NDVI trends. Full methodological details are provided elsewhere (van der Esch, ten Brink et al., 2017). Figure 3-18 shows the estimated loss of soil organic carbon in 2015, compared to the natural state of an area. As expected, most losses have taken place in the agricultural areas, in the Ethiopian highlands and in Kenya north of Nairobi and in the west towards Lake Victoria.

FIGURE 3-18: Estimated loss in soil organic carbon in 2015 compared with natural state.
Source: van der Esch, ten Brink et al., 2017.

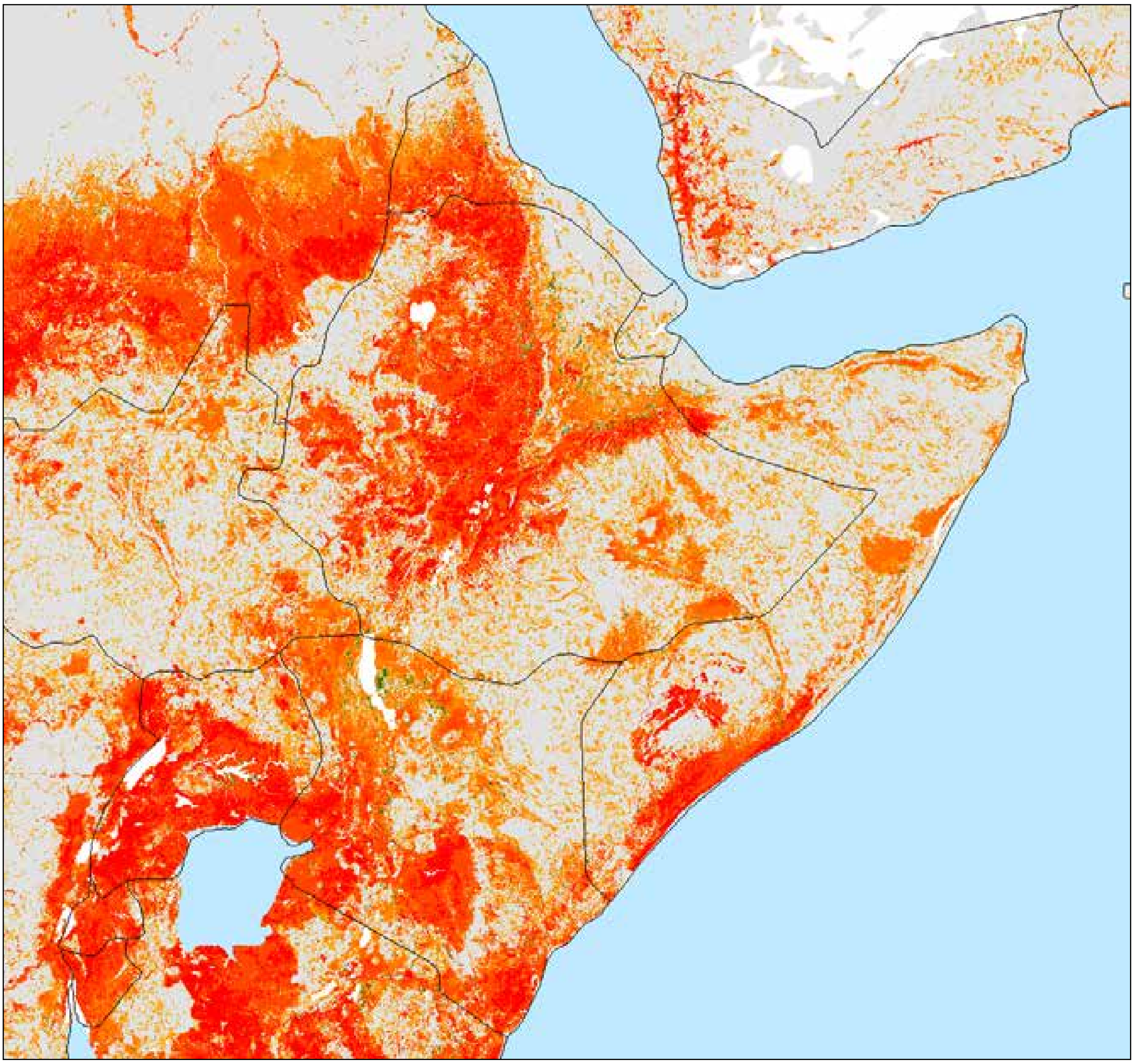


Table 3-2 provides rough estimates for the total projected loss of soil organic carbon in both countries. Because of time constraints for this pilot these estimates are not fully in line with the land use change projections shown in Section 3.1.2 but rather are based on new scenario analysis for the upcoming GLO2. It does however signal an order of magnitude.

TABLE 3-2: Estimates for soil organic carbon totals for Ethiopia and Kenya, 2015–2050

	Soil organic carbon in Gt		
	Natural land condition	2015 land use and land condition	Land condition in 2050 under SSP2 projection
Ethiopia	12.2	11.3	10.5
Kenya	5.6	5.1	4.8

Ethiopia has lost an estimated 1 gigaton (Gt) of soil organic carbon compared to the natural situation, and is projected to lose close to another 1 Gt over the coming decades because of land use change and declines in primary productivity. Kenya has lost about half a Gt up to 2015 and is projected to lose about 0.3 Gt between 2015 and 2050. These figures also provide indications of the potential to prevent the projected future loss through improved land management and to restore part of the historically lost soil organic carbon.

3.3. Reflection on relevant policies

In both countries, changes in land use cover as well as trends in land degradation have been recognized and have inspired policy action. But, as pointed out in the preceding sections, the projected changes in land use, land cover and degradation may still be considerable in the foreseeable future. Planning for such changes may, or may not have been, explicit in the development of current policies. It is therefore worthwhile to review current policy ambitions, as well as progress towards achieving these, and contrast these with projected scenarios in order to explore whether current policies are fit for purpose.

3.3.1. Ethiopia

In 2016, the government of Ethiopia adopted the second National Growth and Transformation Plan (GTP2) as the strategic framework for the country's development in 2016–2020 (Government of Ethiopia, 2016). The overall objective for the agricultural sector is to achieve an annual growth rate of 8 per cent over this period by: extending the surface of land under irrigation from 2.3 million to 4.1 million hectares; raising the production of staple crops from 27 million metric tons to 40 million metric tons; increasing the number of farmers receiving extension services by 60 per cent to reach 17 million; and rehabilitating 22 million hectares of land. Agriculture remains a key driver of economic growth, which is expected to contribute 33 per cent to the national GDP in 2016-2020.

The government has invested significant resources to support smallholder agriculture and expand the country's extension services. In line with the commitment made by African heads of states to allocate 10 per cent of their national budget for agriculture, Ethiopia has surpassed this target by allocating 15 per cent of its budget for the sector in 2003–2013 (Welteji, 2018). The agricultural extension programme – the largest and fastest growing in the continent – has been central to the country's agricultural development strategy (Berhanu and Poulton, 2014).

In 2016, Ethiopia developed Land Degradation Neutrality (LDN) Targets (Government of Ethiopia, 2016) as per its commitments under the UNCCD and SDG target 15.3 on halting and reversing land degradation. These include ambitious targets to improve the productivity of 14 million hectares of croplands by 2031, 12.5 million hectares of grasslands by 2040 and 2.4 million hectares of forests by 2036.

The LDN targets reflect the government's strategic goal to increase agricultural production to meet the country's expanding food demand. They point to policy ambitions on land use and management that are in line with the SSP1 scenario, which assumes the adoption of sustainable, land-saving and highly productive agricultural practices. If these policy ambitions were to be met, the land saved (SSP1 versus SSP3) could amount to 9 million hectares by 2050.

However, the rapid population growth in line with the SSP3 projections, along with the degradation of croplands and grasslands reported in the LDN baseline study, present a serious challenge for achieving these ambitions. Moreover, land property rights in Ethiopia – vested in the state with only usufruct rights granted to farmers – tend to hinder private investment in land to halt degradation and improve productivity (Zerga, 2016). This calls for a critical review of the implementation of agricultural and land use policies to identify the challenges faced and actions needed to reduce pressure on land resources and increase their productivity.

3.3.2. Kenya

The Kenya Agricultural Sector Development Strategy 2010–2020 (Government of Kenya 2010) was adopted to guide the overall national policy for the agricultural sector. The strategy is anchored in two strategic thrusts: increasing productivity, commercialization and competitiveness of agricultural commodities and enterprises; and developing and managing key factors of production. It addresses key constraints and challenges, including: reduced effectiveness of extension services; inadequate infrastructure; insufficient water storage infrastructure; low and declining soil fertility; lack of coherent land policy; heavy livestock losses to diseases and pests; pre- and post-harvest crop losses; and limited access to capital.

As noted in Section 2, Kenya Vision 2030 (Government of Kenya, 2008) is the national long-term development policy that aims to transform Kenya into a newly industrializing, middle-income country. It emphasizes the role of agriculture as a key driver in achieving economic growth and the importance of developing agricultural land-use master plans to ensure more effective and sustainable use of Kenya's land resources.


Photo: UNDP Kenya

Kenya's LDN targets (Government of Kenya, 2020a), adopted in 2020, commit the country to achieve LDN or SDG target 15.3 by 2030 compared to 2015, with an additional 9 per cent improvement in degraded lands. This ambitious endeavour includes specific targets to improve the productivity of agriculture through sustainable land management, while halting the conversion of forests to other land cover classes by 2030.

The National Land Use Policy provides a comprehensive framework for the optimal utilization and sustainable productivity of publicly and privately owned land in Kenya at national, county and community levels (Ministry of Lands and Physical Planning, 2017). Moreover, the Land Use Commission has a clear mandate to administer and manage public land on behalf of the national and county governments and support planning, productive use and security of rights to improve livelihoods and promote sustainable land management (National Land Commission, 2020).

If the above policies were implemented effectively, the productivity of agricultural land would increase and the conversion of forests and grasslands to croplands would be halted. However, the LDN baseline study reveals that 40 per cent of croplands are showing a decline in productivity, while the forest cover decreased from 7 per cent in 2000 to 5.9 per cent in 2015. The conversion of forests to croplands is prevalent in the humid and sub-humid parts of Kenya, despite the restrictions imposed the Forest Conservation and Management Act, which aims to increase forest cover to 10 per cent (Government of Kenya, 2016). Community- and private-sector-led efforts on reforestation and afforestation, including the use of multi-purpose trees to enhance soil productivity and crop, fodder and timber production, have achieved limited progress to date. Incentives are needed to stimulate investment to scale up these efforts.

According to the LDN study, the arid and semi-arid lands (ASALs), dominated by grasslands, shrubs and sparsely vegetated areas, have also experienced a rapid conversion of land cover to croplands, with the local population being pushed onto marginal lands. Around 80 per cent of Kenyan soils have low organic carbon. This is particularly true in the ASALs, where soils are also of low fertility and are subject to compaction, capping and erosion.

In order to address declining soil fertility and crop productivity, the Government of Kenya is currently developing a National Agricultural Soil Management Policy (Government of Kenya 2020b). The policy recognizes that "the agricultural sub-sector policies and strategies that have been developed have failed to directly address soil as an important resource for sustained agricultural production."

The recognition of declining soil fertility, coupled with high population growth and increased conversion of forests and grasslands to croplands, points to a development pathway more in line with the projections of SSP3. In this scenario, the demographic pressure is greater than in SSP1 and SSP2, and the assumed productivity enhancements in the agricultural and livestock sectors are more moderate. The result is a large increase in the demand for agricultural land for crop and livestock production (32 million ha) and a huge reduction in forests (65%) and natural land (72%) by 2050.

The government's policy ambitions as reflected in Vision 2030, the National Land Use Policy, the Land Degradation Neutrality Targets and the National Agricultural Soil Management Policy are more in line with the outcomes of SSP1, which arise from sustainable, land-saving and highly productive agricultural practices. This calls for a critical review of the implementation of agricultural and population policies to identify the challenges faced and actions needed to reduce pressure on land resources and increase productivity, thus strengthening the alignment between the achievements on the ground and the ambitions envisioned in these policies.

4

EVOLUTION OF AGRICULTURAL PRODUCTION AND PRODUCTIVITY

While the population and economic dynamics highlighted in Section 2.3 are key drivers of land use change, these are not the only factors to take into account. At least as important are developments in crop and livestock productivity. After all, a considerable increase in productivity is likely to offset, at least partially, additional pressures on remaining natural areas. This section explores both recent trends as well as future changes in crop productivity (Section 4.1) as well as livestock productivity (Section 4.2) and discusses key policy initiatives for supporting productivity growth (Section 4.3).

4.1. Crop production

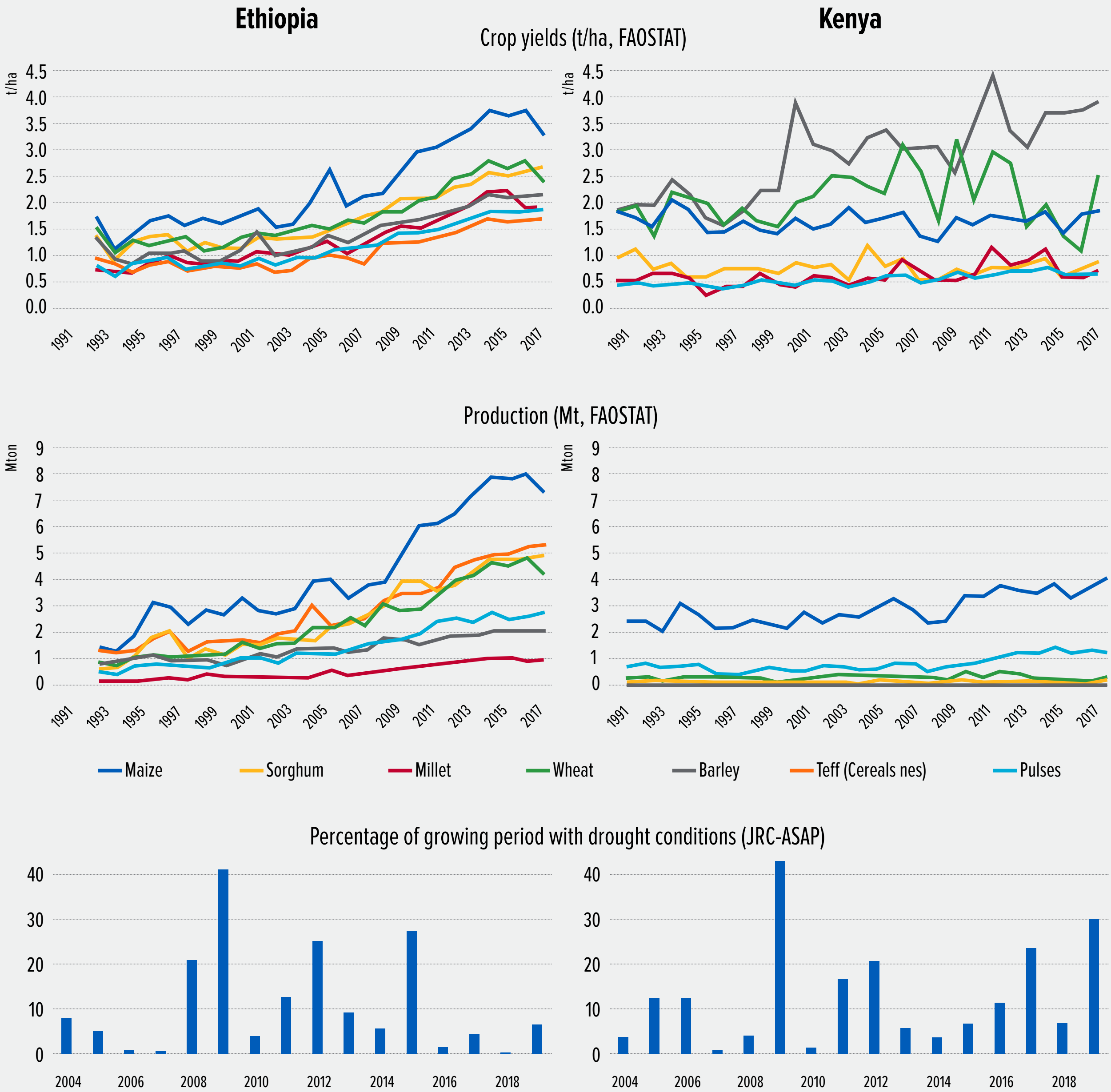
4.1.1. Recent trends

Figure 4-1 (top panel) shows that yields of all key crops in Ethiopia, as reported by FAOSTAT, have increased by more than 100 per cent since 2000. The occurrence of droughts (bottom panel), as indicated by JRC-ASAP[6], is not or only weakly reflected in these national data.

In Kenya, cereal yields are highly variable, with no evident long-term trend (except for barley and, perhaps, millet). Yields of wheat, which is typically produced during the second (short) growing season, are particularly volatile. Drought occurrences (e.g. in 2009, 2011 and 2017) are clearly reflected in the yield data. In contrast, yields of pulses show a statistically significant, albeit modest, upward trend with relatively little inter-annual variation.

6 JRC-ASAP is an online decision-support system (https://mars.jrc.ec.europa.eu/asap/) for early warning about hotspots of agricultural production anomaly (crop and rangeland), developed by the JRC for food security crises prevention and response planning anticipation. A comprehensive description of the system is given by Rembold et al. (2019). ASAP data and manuals can be downloaded from https://mars.jrc.ec.europa.eu/asap/download.php

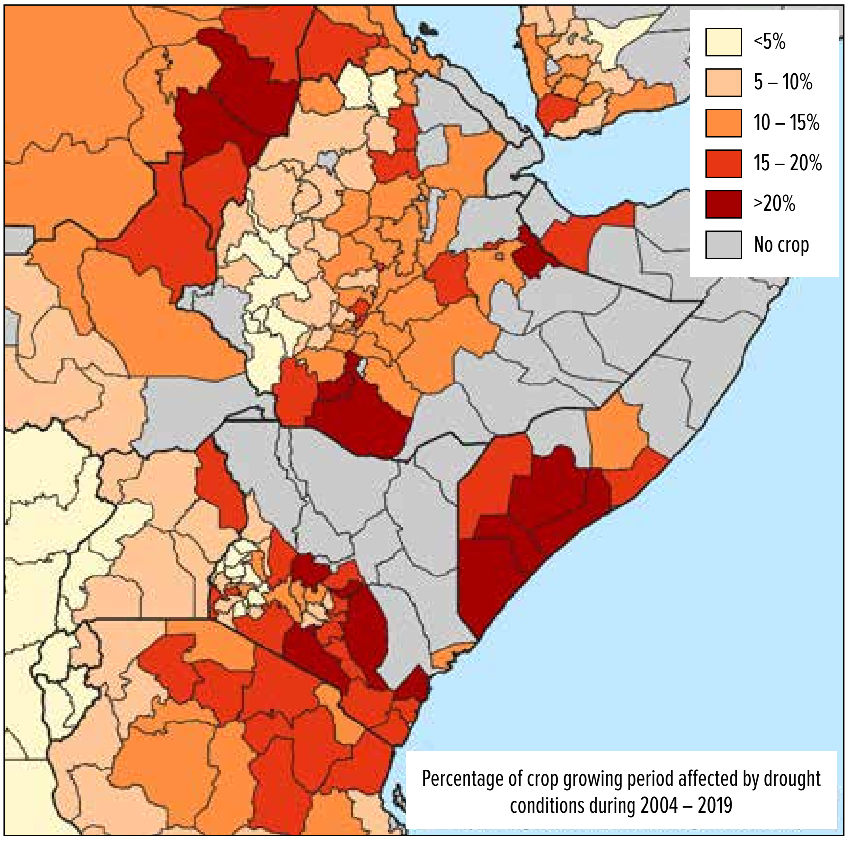
FIGURE 4-1: Evolution of yields and production of main cereal crops and pulses in Ethiopia and Kenya, 1991–2017. The bottom panel indicates the occurrence of drought conditions in croplands between 2004 and 2019.



Consequently, crop production in Ethiopia presents a steep increase of more than 200 per cent since 2000 for all cereals combined, as well as for pulses, despite the more modest (about 50%) increase of the areas harvested of these crops. In Kenya, the increase in cereal production of 86 per cent over the same period, is practically totally attributable to increases in the areas of these crops.

In both countries, maize is the main staple crop, but other cereal crops also have a substantial share in production in Ethiopia, whereas in Kenya these are hardly significant at the national level. The exception among annual crops in Kenya is pulses, which have maintained or even increased their share compared to cereals, due to a combined increase in yields (43% from 2000-2018) and areas, by respectively 43 per cent and 62 per cent between 2000 and 2018.

FIGURE 4-2: Spatial distribution of percentage of growing period affected by drought conditions in croplands[7], 2004–2019.
Source: JRC-ASAP.s



Even though drought is a major factor impacting crop production in both countries, the occurrence of droughts (bottom panel of Figure 4-1) is not or only weakly reflected in the national data for Ethiopia. For Kenya, drought occurrences (e.g. in 2009, 2011 and 2017) are clearly reflected in the cereal yield data, but the yields of pulses present relatively little inter-annual variation compared to the long-term trend. The spatial distribution of drought occurrences between 2004 and 2019 is presented in Figure 4-2.

4.1.2. Projections

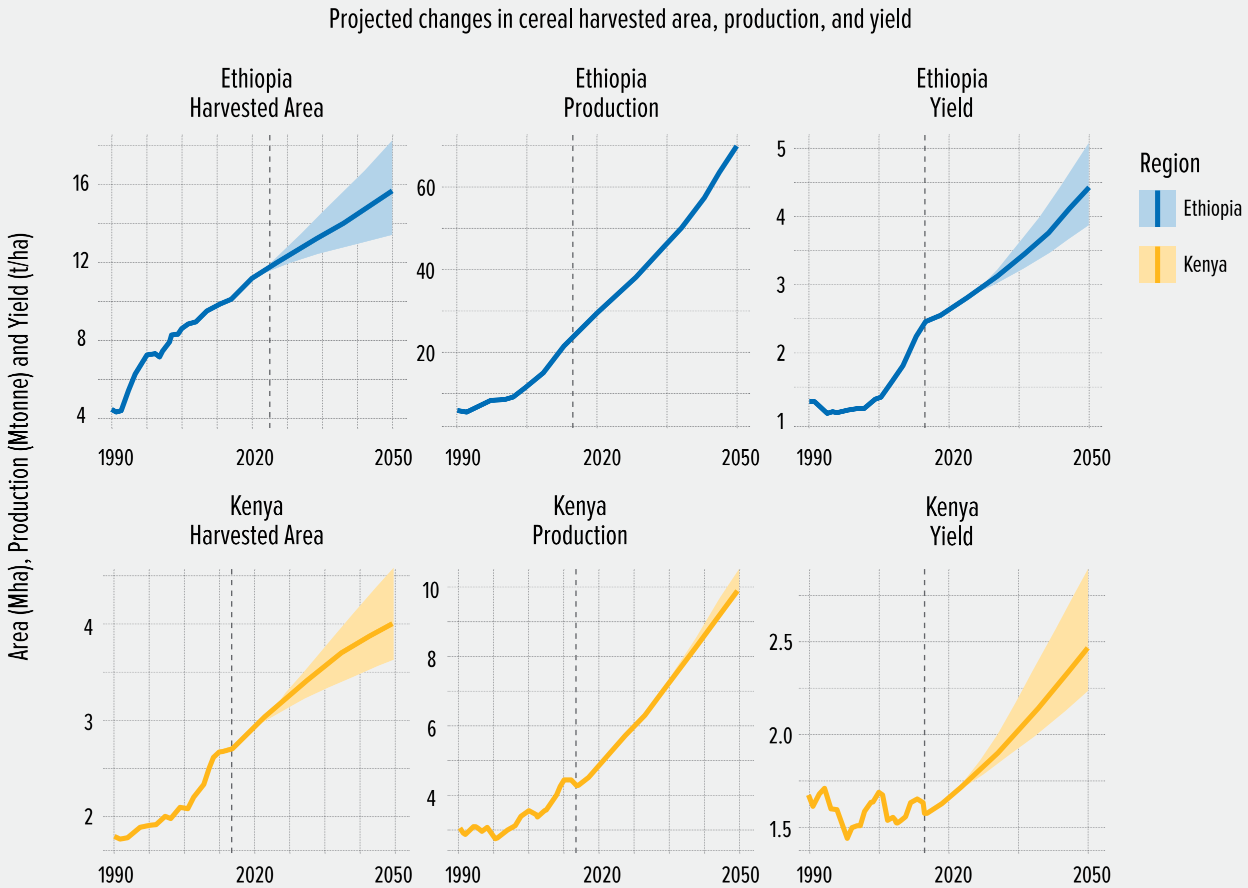
Considering projected future changes in crop production and productivity, Figure 4-3 shows a continuation of this upward trend. There is little variation with respect to crop production among the three scenarios; food supply and demand are, by and large, shaped by demographic changes as discussed in Section 2. In both countries, agricultural production is projected to increase by more than 100 per cent. In Ethiopia the increase is from 43 million metric tons (Mt) to between 115 Mt and 123 Mt, depending on the scenarios, while in Kenya production increases from 22 Mt to 53–60 Mt.

However, there are striking contrasts in productivity developments across the three scenarios. Also recall from Section 3.1.2 that the projected areas under agriculture for the scenarios vary substantially. These data reveal clear differences in how rising food demand can be met. On one hand, there is the option of relying on low-intensity agriculture and, as a consequence, large area expansions

7 Here expressed as the percentage of 10-day periods with active vegetation, with distinctly negative vegetation index (NDVI) anomalies (drought warnings), for more than 25 per cent of the cropland) areas in the administrative region considered, as signaled by the JRC-ASAP system.

FIGURE 4-3: Cereal area, production and yield, 1990–2050. The solid lines represent SSP2. For harvested area, SSP3 defines the upper bound and SSP1 the lower bound of the shaded region., while SSP1 and SSP3 define the boundaries of the shaded region. For production and yield, SSP1 defines the upper bound and SSP3 the lower bound of the shaded region.

Source: IMAGE/MAGNET computations.



(SSP3). On the other hand, a much greater effort on agricultural intensification and more productive agriculture results in an overall lower demand for land (SSP1). These differences in productivity developments can be inspected by considering key crops in closer detail.

For instance, Figure 4-3 displays developments in cereal-harvested area and crop yields for both countries. The left pane shows cereal-harvested area and the right panel cereal yields. The left and the right panes depict the key differences between more and less intensive agriculture, with minimal variation across the scenarios in the overall level of production (middle pane). The lower bounds in the left panel illustrate lower area expansion under SSP1, due to higher productivity increase for SSP1 (upper bounds in the right panel). Cereal productivity is projected to double in both countries by 2050 under the SSP1 scenario. But even such jumps in productivity cannot fully meet the steep rise in demand and cereal area expands by an order of 30–40 per cent, from 10 million hectares to around 13 million hectares in Ethiopia, and from around 2.75 million hectares to around 3.75 million hectares in Kenya. Yet, this area expansion is much smaller than in SSP3, where productivity growth in cereal production is assumed to be smaller (around 65%) as reflected by the lower bounds in the right panels. Crop yields in this scenario will rise from 2.5 metric tons per hectare to nearly 4 metric tons per hectare in Ethiopia and in Kenya from slightly over 1.6 metric tons per hectare to around 2.25 metric tons per hectare. As a result, the areas projected for cereal production increase by around 8 million hectares (80%) in Ethiopia and 1.75 million hectares (63%) in Kenya for SSP3.

4.2. Livestock production

4.2.1. Recent trends

The other key pillar of the agricultural sector is livestock production. Figure 4-4 shows that livestock numbers and meat production have increased substantially in both Ethiopia and Kenya in recent years. The data for Kenya suggest a very abrupt rise in livestock numbers in 2007, which is considered an artefact, as livestock was incorporated in the Kenya Population and Housing Census for the first time in 2009, and no baseline data were collected before this time.

FIGURE 4-4: Livestock numbers (top) and meat production (middle) from different types of animals in Ethiopia (1993–2018) and Kenya (1991–2018). The bottom panel indicates the occurrence of drought conditions in rangelands between 2004 and 2019.

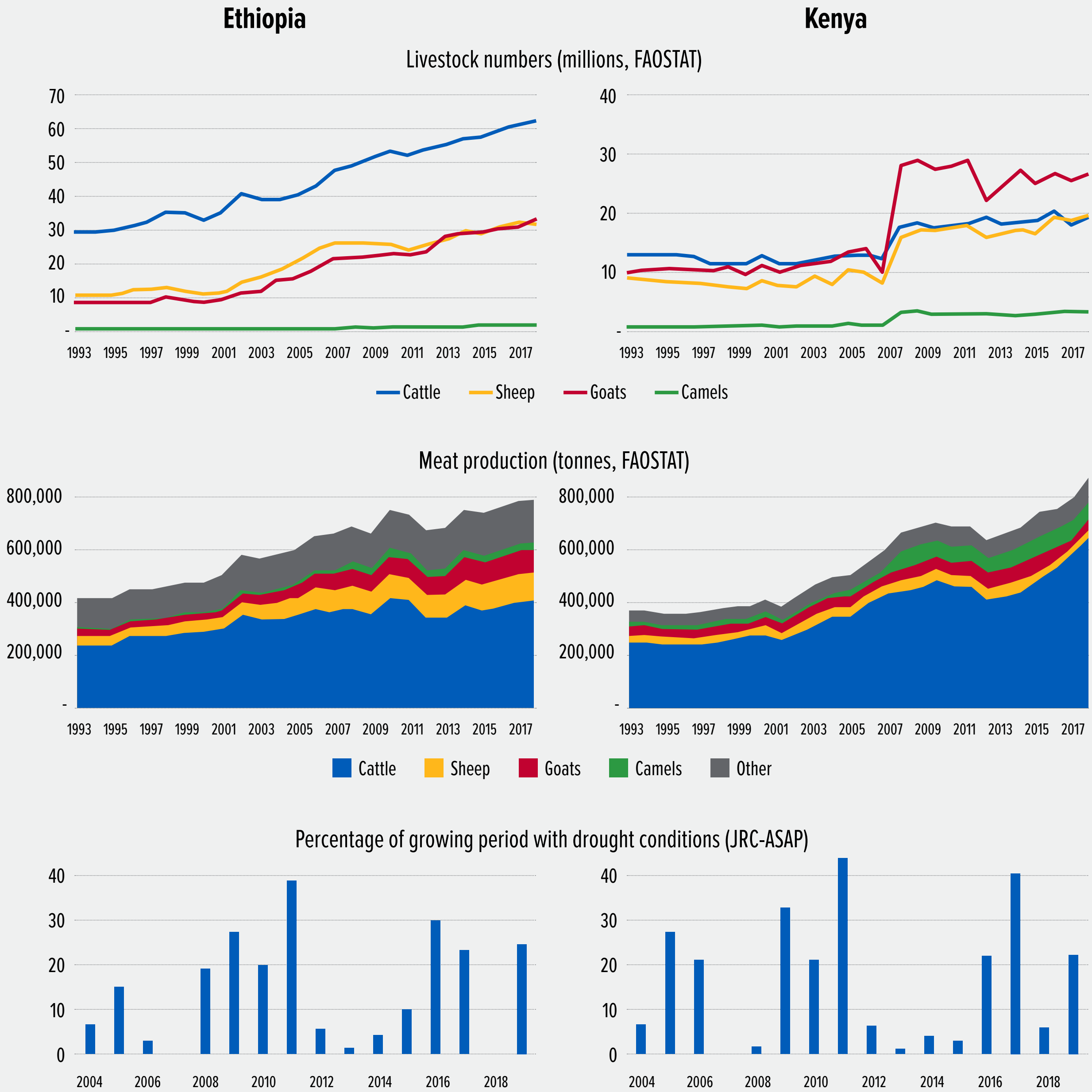
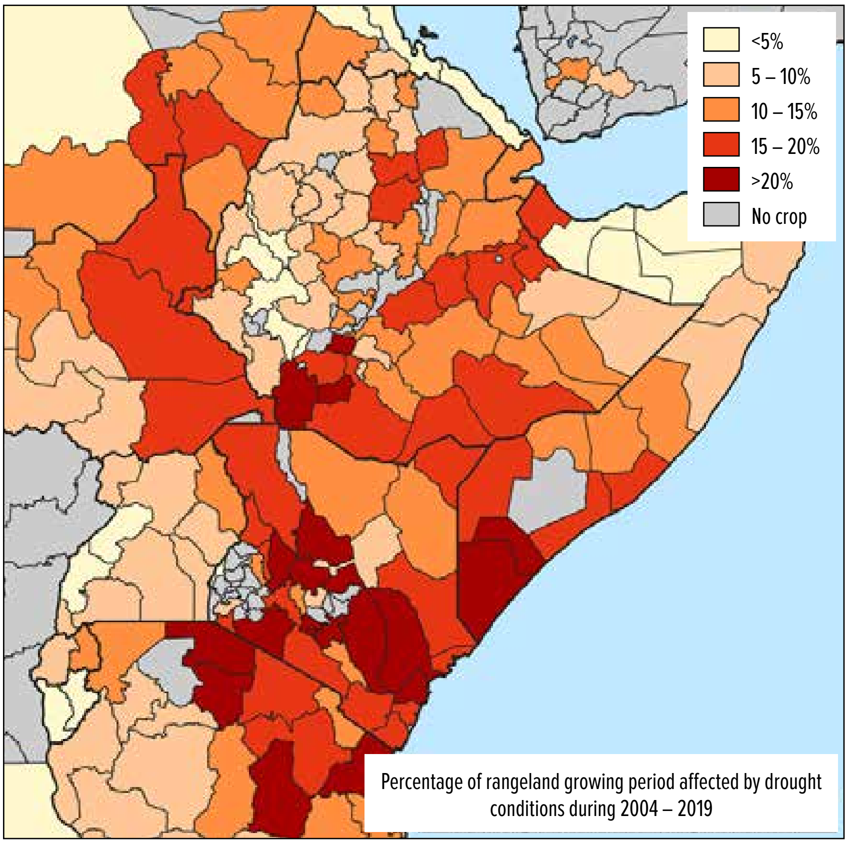


FIGURE 4-5: Spatial distribution of percentage of growing period affected by drought conditions in rangelands[8], 2004–2019.
Source: JRC-ASAP.



The meat production category "other" refers to game and non-grazing domestic animals, such as pigs and poultry. This composite category is increasing in volume but meat (and milk) from grazing animals clearly remains dominant in both countries.

The bottom panel in Figure 4-4 indicates the occurrence of drought in rangelands. In several instances (e.g. in 2009, 2011 and 2017), the occurrence of drought is reflected in livestock numbers and/or meat production in the same year or in the following year. These effects seem to be relatively small — at least at a national level — compared to the long-term increasing trends, especially in Ethiopia.

Nevertheless, in both countries, drought is generally perceived as the main factor impacting the livestock sector, but the relation between drought and number of animals or animal production is very complex, especially in remote and/or poor areas such as ASALs. For example, animals can survive but produce less milk, can die, but can also be sold in a destocking attempt (resulting in a production spike). Variations in drought conditions are not only large from year to year, but also from place to place, as shown in Figure 4-5, which presents the spatial distribution of drought conditions in rangelands across the region, 2004–2019.

4.2.2. Projections

The upward trend in livestock production and productivity is maintained across all scenarios, albeit with some minimal variation (Figure 4-6). Recall that rangeland area is set constant in the scenarios (as discussed in Section 3.1.2), implying that percentage changes in livestock production and productivity are equal. Furthermore, note from Section 2 that in scenario SSP1 population size will grow by at least 50 per cent and coupled with income growth will lead to an even greater demand for livestock products. On the other hand, population growth will be higher in SSP3, but a slower pace of income growth implies that overall demand for livestock products in SSP3 is not projected to be greatly different than in SSP1.

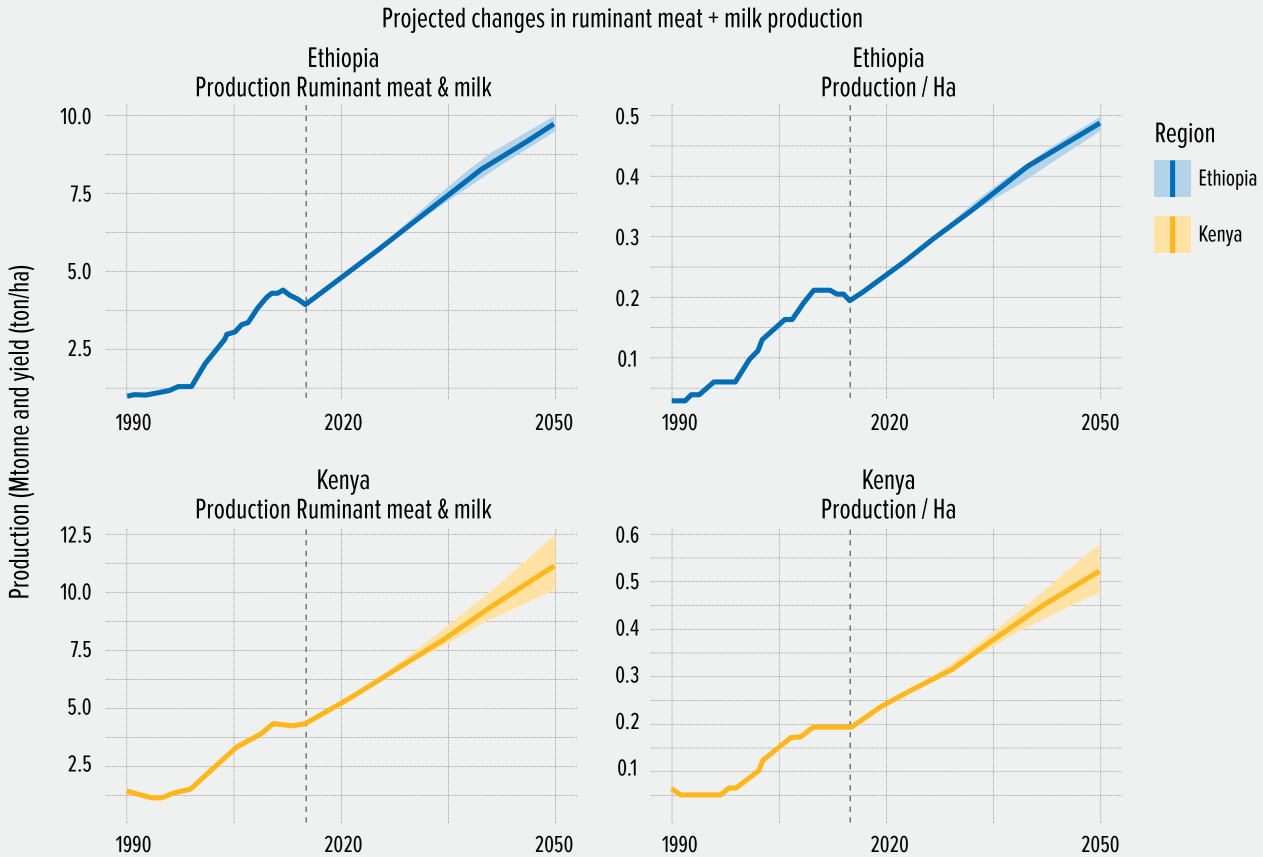
Livestock and livestock products are an important source of proteins in human consumption. Under the scenario projections, meat and dairy production increase, by and large, from 4 Mt to 10 Mt in the case of Ethiopia for all three scenarios. In the case of Kenya, the increase is from around 5 Mt to 10 Mt.

8 Here expressed as the percentage of 10-day periods with active vegetation, with distinctly negative vegetation index (NDVI) anomalies (drought warnings), for more than 25 per cent of the rangeland areas in the administrative region considered, as signaled by the JRC-ASAP system.

Hence, in both countries livestock production and productivity are projected to increase by around 100 per cent by 2050. This implies an annual growth rate in productivity of around 2 per cent per year.

FIGURE 4-6: Ruminant production and productivity, 1990–2050. The solid lines represent SSP2. SSP1 and SSP3 define the upper and lower boundaries of the shaded region, respectively.

Source: IMAGE/MAGNET computations.



4.3. Reflection on relevant policies

Set against recent changes in crop and livestock productivity and production, it is useful to consider current policy initiatives in these domains. To what degree can changes in productivity be traced back to specific policy initiatives, and are initiatives geared up for fostering additional productivity enhancements?

4.3.1. Ethiopia

4.3.1.1. Crop production

According to the second National Growth and Transformation Plan (GTP2), the total production of staple crops during the *meher* season (main growing season) increased from 18 million metric tons in 2010 to 27 million metric tons in 2015. The GTP2 target was to raise staple crop production to 40.6 million metric tons by 2020 but these data were not yet available at the time of publication.

The performance of staple crops has been the major contributor to the overall growth in agriculture given its relative importance in crop production. The production of staple crops has surpassed the target set by the government, enabling the country to become food self-sufficient at the national level. This is considered to be one of the most significant achievements of the first Growth and Transformation Plan (GTP1) in 2011–2015.

Much of the increase in crop production is due to the expansion of cultivated area, which has increased by 27 per cent since 2004. This trend is expected to continue with croplands projected to increase from 16.2 million hectares in 2015 to 26.3 million hectares by 2050 for the middle-of-the-road scenario (SSP2). This contrasts with 22.4 million and 31.4 million hectares for SSP1 and SSP3, respectively. These changes are associated with a drastic increase in crop production, which is projected to reach 118.0 million metric tons in 2050 according to SSP2.

The government attributed the shortfall in achieving the GTP1 targets for crop productivity to the failure to fully implement the scaling-up strategy of the agricultural extension system. However, significant resources have been allocated under GTP2 to increase crop productivity in 2015-2020, including from 2.1 to 3.1 metric tons per hectares for cereals, from 1.7 to 2.3 metric tons per hectares for pulses, and from 0.9 to 1.3 metric ton per hectares for oil seeds. These objectives feed into the achievement of SDG target 2.4 on doubling smallholder productivity.

Increasing the number of farmers benefiting from extension services, expanding the land area under irrigation, and increasing the supply and use of fertilizers and improved seeds are the key strategies employed to raise crop productivity.

Policy ambitions to increase crop productivity are in line with the findings of this study, which reveal that increases in crop yields are substantial, even under scenario SSP3. Cereal yields in the SSP2 scenario are projected to increase from 2.5 metric tons per hectare to nearly 4.3 metric tons per hectare by 2050. This is an increase on the order of 70 per cent but nonetheless smaller than the yield increase assumed for the SSP1 scenario, which indicates around a doubling of cereal yields by 2050.

4.3.1.2. Livestock production

The Ethiopia Livestock Sector Analysis (LSA) conducted in 2017 revealed that livestock production represents 17 per cent of national GDP and 39 per cent of agricultural GDP (Government of Ethiopia and International Livestock Research Institute (ILRI) 2017). This rises to about 21 per cent and 49 per cent respectively if the contribution of processing and marketing is taken into account. If the contribution in organic fertilizer and traction is included, the share of livestock production in the national GDP rises to 25 per cent.

The LSA showed that the current demand for meat and milk is mainly met from domestic production. However, the 15-year projections disclosed a deficit of 1.3 million metric tons (53%) of meat and 3,185 million litres (29%) of milk by 2028, due to increasing demand from rapid population growth and rising per capita income. Per capita meat consumption will reach 24.5 kilograms per year, a level comparable to countries at a similar stage of development.

Meeting this gap will require substantial investments in the sector to increase productivity by addressing feed deficits, animal health and genetics. The LSA proposed policy and investment actions to increase productivity encompass the enhancement of veterinary coverage, the increase of fodder production and the accelerated introduction of improved genetics. A recent analysis of the Ethiopian economy revealed that investing in the livestock sector has the greatest employment generation capacity, which is critical for addressing the lack of job opportunities in rural areas, especially for young people (Boulanger, Ferrari et al., 2019).

Policy targets were established in GTP2 for improving livestock health coverage, fodder production and livestock genetics by 2020. These include, among others, increasing the production of quality vaccines, extending the coverage of animal clinical services, expanding feed and perennial fodder seed production, improving the number of cattle with improved genetics and increasing the efficiency of field artificial insemination.

This study shows that the upward trend in livestock production is likely to continue. Livestock production and productivity are projected to increase in Ethiopia by around 100 per cent until 2050, with ruminant meat and dairy production increasing from 4 million to 10 million metric tons. However, the study cannot conclude that this large increase is sufficient to meet the demand of Ethiopia's growing population, which is expected to expand by 73 per cent and 98 per cent by 2050 according to SSP2 and SSP3, respectively. Also, it remains to be seen whether the increase in livestock productivity can be achieved with limited negative effects on land use and land condition.

4.3.2. Kenya

4.3.2.1. Crop production

According to the National Food and Nutrition Security Implementation Framework 2017–2022 (Government of Kenya, 2017), population growth, unsustainable production systems and climate change pose the biggest challenges to sustainable food production in Kenya. The country experiences a 20–30 per cent deficit in staple crops every year as overall production has not increased in tandem with population growth. This scenario is likely to continue, especially with the current annual population growth rate of 2.9 per cent. At this rate, the Kenyan population may reach 95 million by year 2050. Thus, more effort is needed to increase crop production and productivity to satisfy future demand for food.

Photo: UNDP Ethiopia

This study indicates that crop production in Kenya is projected to increase from 22 Mt in 2015 to 53–60 Mt by 2050. However, the projected areas for crop production differ significantly depending on the development pathway that the country follows. This is coupled with a considerable difference in productivity among the three pathways.

In the case of SSP1, with assumed high growth in cereal productivity, the average yield almost doubles from slightly over 1.6 tons per hectare to around 3 tons per hectare by 2050. For SSP2 and SSP3, the increase in productivity is assumed to be small, reaching 2.25 and 2.5

tons per hectare, respectively. Even with this increase in productivity, the cereal areas expand from 2.75 million hectares in 2015 to 3.75 million hectares and 4.25 million hectares by 2050 for SSP1 and SSP3, respectively.

Increasing crop production is a strategic objective of the Government of Kenya as stated Agricultural Sector Development Strategy and the Nutrition Security Implementation Framework. The SSP1-SSP3 scenarios provide insights on how the demand can be met. On one hand, there is the alternative of relying on low-intensity agriculture and, as a consequence, large area expansions (SSP3). On the other hand, a much greater effort toward agricultural intensification and more productive agriculture results in an overall lower demand for land (SSP1). The middle-of-the-road pathway (SSP2) provides another alternative based on a moderate increase in productivity and demand for land.

4.3.2.2. Livestock production

Kenya's livestock sector is projected to grow significantly over the next three decades in response to rapid population growth and increase in GDP per capita (FAO, 2019). By 2050 the livestock sector will supply an additional 7.8 million metric tons of milk, beef and chicken meat to the population, an increase of about 150 percent over today's levels. The cattle and chicken population will increase by 94 percent and 375 percent respectively and will be accompanied by major productivity gains. Cattle and poultry contribute about 70 per cent to total animal production, estimated at $US1.6 billion in 2016.

This study confirms that this upward trend in livestock production is assumed to continue. Livestock production and productivity are assumed to increase in Kenya by around 100 per cent by 2050, with meat and dairy production increasing from 5 million metric tons to 10 million metric tons. These projections are in line with national goals regarding livestock production and productivity. As such, the country is on track to meet its meat and dairy needs. Efforts should be pursued to strengthen the implementation of existing policies through adequate budgetary allocation and technical support.

Photo: Shutterstock

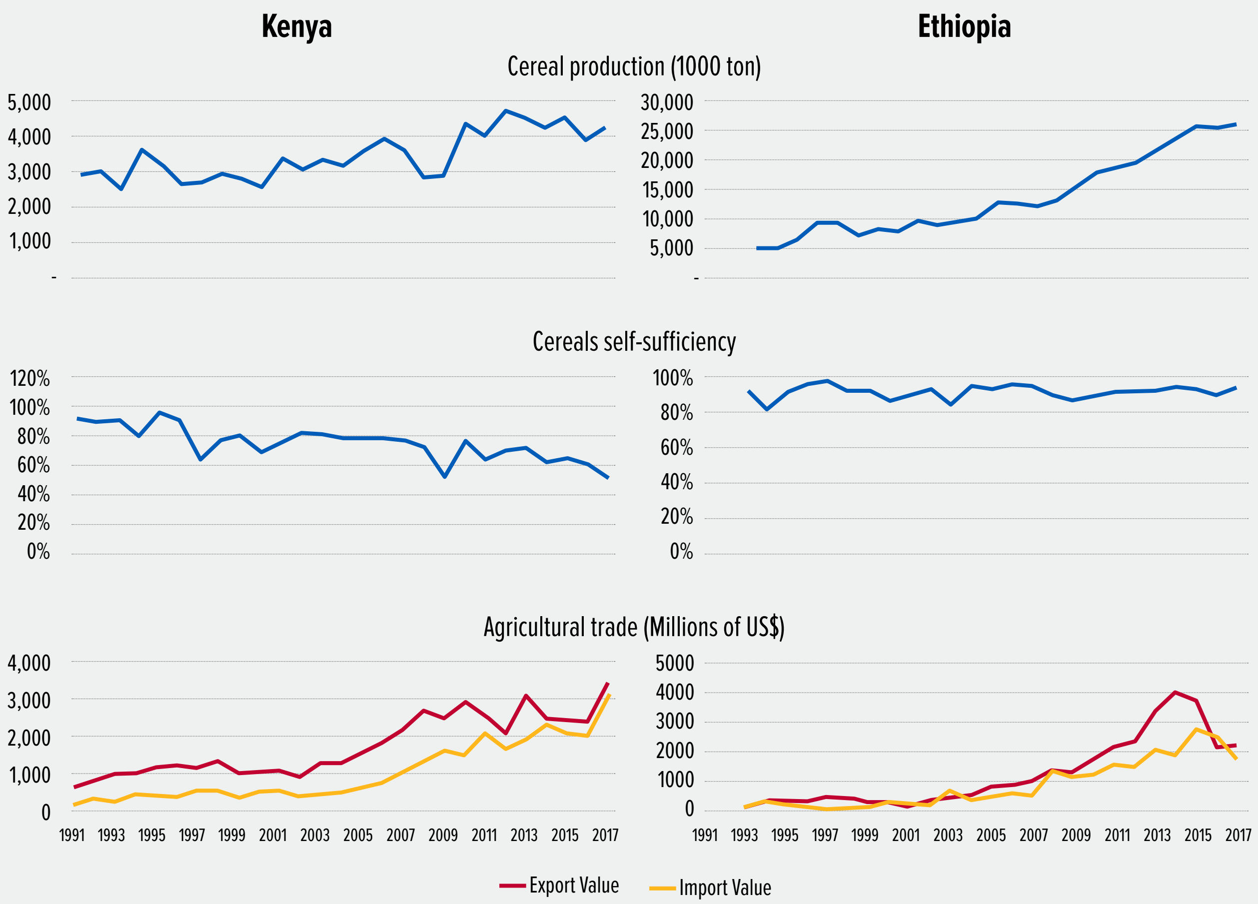
5

CHANGES IN FOOD SELF-SUFFICIENCY, UNDER-NOURISHMENT AND TRADE

5.1. Recent trends

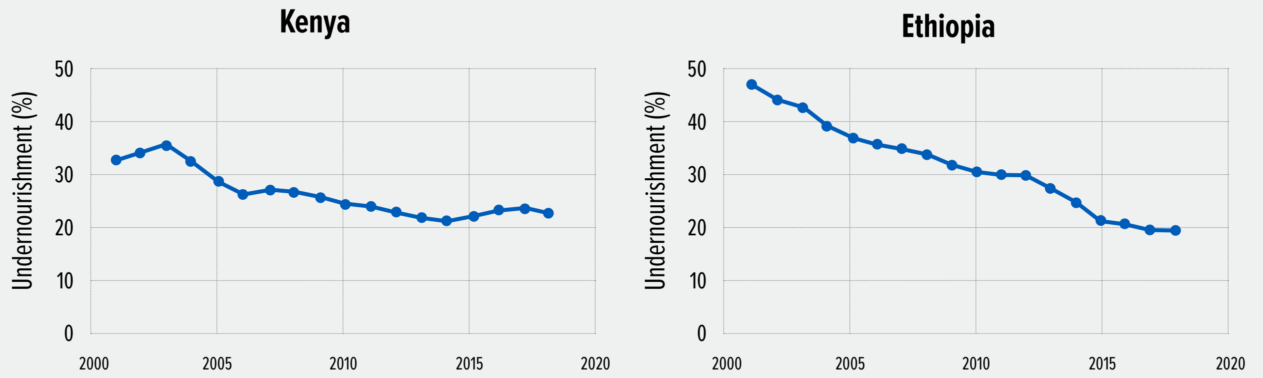
Neither Kenya nor Ethiopia is food-self-sufficient currently; i.e. they are net importers of basic food stuff, in particular cereals, which in both countries provide more than 50 per cent of caloric intake.

FIGURE 5-1: Cereal production, cereals self-sufficiency and agricultural trade in Kenya (left) and Ethiopia (right), 1991–2017.
Source: FAOSTAT, 2020.



As shown in Figure 5-1, the degree of self-sufficiency for cereals in Kenya has steadily declined, as the trend in demand (mainly driven by population increase) outpaced the trend in production (mainly driven by area increase, as was shown in Section 3.1.1.1). In Ethiopia, self-sufficiency for cereals remained approximately constant, just above 90 per cent on average, as the steep increase in production (achieved by area increase and substantial yield increases) kept pace with the equally steeply increasing demand.

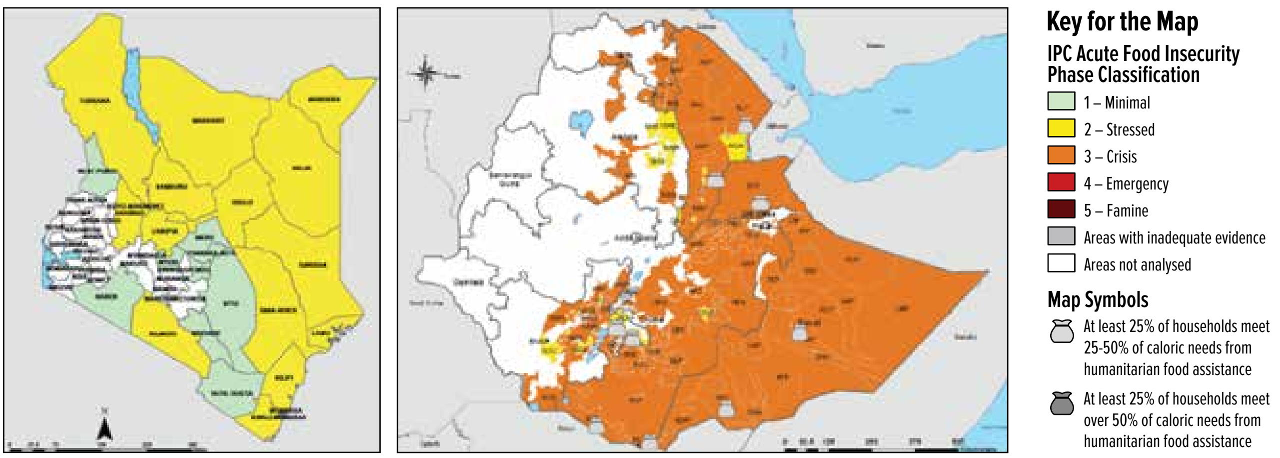
FIGURE 5-2: Evolution of undernourishment in Kenya (left) and Ethiopia (right), 2000–2018.
Source: FAO.



However, in monetary terms, both countries are net exporters of agricultural products. The main export crops are coffee in Ethiopia and tea in Kenya. In addition, both countries are significant net exporters of several other products, such as vegetables, fruits, vegetable oils and spices. The sharp decrease in export value in Ethiopia in 2016 is mostly due to a drop in coffee production and a low volume of vegetables exported in 2016 and 2017.

Figure 5-2 shows the evolution of the prevalence of undernourishment in both countries. In Ethiopia, the degree of undernourishment has steadily declined, from 40 per cent in 2005 to 20 per cent in 2018. In Kenya, undernourishment declined from 32 to 35 per cent in the early 2000s to 23 per cent in 2012, but has stagnated since then.

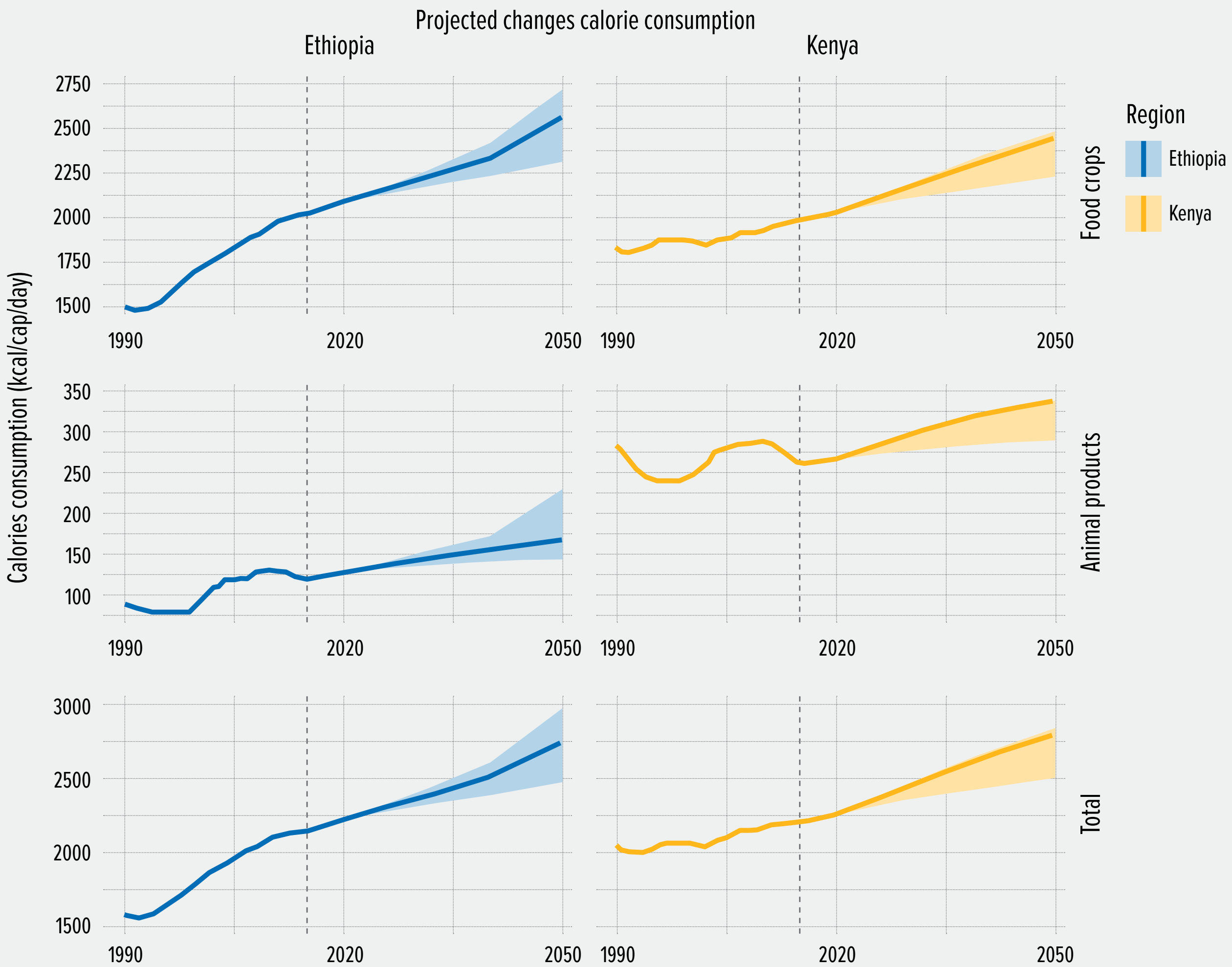
FIGURE 5-3: IPC Acute Food Insecurity Phase Classification. Left: Kenya, February-July 2020; Right: Ethiopia, July 2019-June 2020.
Sources: IPC Acute Food Insecurity and Acute Malnutrition Analysis, issued April 2020 (Kenya); IPC Acute Food Insecurity Analysis, issued November 2019.



It must be stressed that on the basis of these figures alone no conclusion can be drawn concerning the reasons for these developments. Even if we focus on farm households only, food self-sufficiency and food security are not directly related to each other, as farmers' livelihoods come from food crops and cash crops, complemented in many cases by off-farm income. Other types of crops, and livestock, should also be taken into account, as well as changes in consumption habits. Also, z not all farmers have the ability to grow alternative crops, and the main food-insecure regions in both countries are outside the most suitable areas for crop production, as illustrated in Figure 5-3.

5.2. Projections

FIGURE 5-4: Calorie consumption projections. The solid lines represent SSP2, while SSP1 and SSP3 define the upper and lower boundaries of the shaded region, respectively.
Source: IMAGE/MAGNET computations.



The projected increases in agricultural production, as discussed in Section 4, translate into increased aggregate food availability in both countries. Figure 5-4 displays projected food calories available from both crops and animal products, as well as the total. At the minimum (in SSP3) available calories (kcal) increase to around 2,500 kcal per capita per day. This is well above the absolute minimum set by FAO of around 1,800 kcal per capita per day.

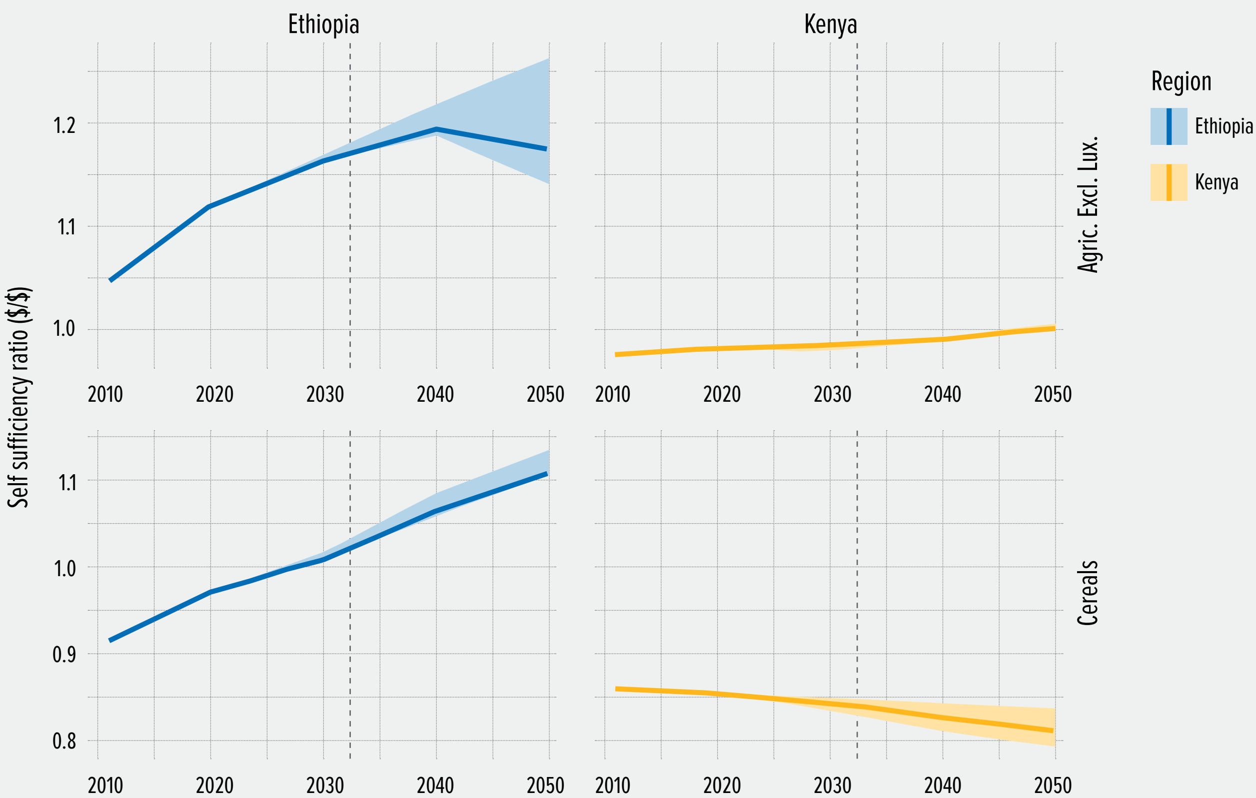
It is important to highlight that the data presented in Figure 5-4 only capture one of the dimensions that are associated with food security, namely food availability and then only at an aggregate scale.

Food security is further described by affordability and food safety as for example captured by the Global Food Security Index (Global Food Security Index, 2021). Moreover, there is a need to define food security more broadly, focusing not only on calories or proteins derived from staple crops, but accounting for a broader range of nutrients derived from multiple food crops (Willett, Rockström et al., 2019; HLPE, 2017). While the figures presented in this section do not capture such broader definitions (or their spread across specific income groups), they nonetheless provide a valuable snapshot into calorie availability at a national level.

While part of food demand is being met by increased domestic production, part of this demand may also be met by increased imports. Note that one of the assumed differences between the SSPs relates to trade. Under SSP1 all import tariffs and export subsidies are assumed to be eliminated by 2030, whereas SSP3 assumes an increase in trade taxes. The impact of such assumptions, in part, is shown by Figure 5-5, depicting projected changes in domestic food self-sufficiency and net exports respectively. Note that overall regional trade between the two countries is modest. In 2018, exports from Kenya to Ethiopia amounted to $US63 million (1.03% of Kenya's total exports). Ethiopia exported $US23 million to Kenya (1.52% of Ethiopia's total exports).

Food self-sufficiency, based on the monetized values of production and consumption (Figure 5-5), is the ratio of domestic production over domestic consumption. A value below one implies a country is reliant on imports as it produces less than it consumes. Conversely, a value greater than one implies the country is a net exporter. The top row in Figure 5-5 shows the full agricultural sector, but with

FIGURE 5-5: Food self-sufficiency ratios, 2010–2050. The solid line represents SSP2, while SSP1 and SSP3 define the upper and lower boundaries of the shaded region, respectively.
Source: IMAGE/MAGNET computations.



major export commodities (tea and coffee) excluded. The bottom row shows food self-sufficiency for cereal commodities only.

The pattern between Kenya and Ethiopia is clearly different. Ethiopia (left column) is projected to experience a steady increase in the self-sufficiency ratio under all three scenarios. In fact, the ratio bypasses the value of one by 2030, implying that Ethiopia will become self-sufficient and a net exporter of cereals over time. For Kenya a decline in the rate of cereal self-sufficiency over time is projected. In part this difference originates from the the ample room for agricultural expansion in Ethiopia compared with Kenya. However, in the case of Kenya, the value of exports of other agricultural products is set to increase. Thus, limited spaces for agricultural expansion, and associated higher land prices, may induce Kenyan producers to specialize in production for certain export markets. Nonetheless, for Kenya the self-sufficiency ratio for the full agricultural sector is projected to increase slightly to about one by 2050.

5.3. Reflection on relevant policies

5.3.1. Ethiopia

Addressing food insecurity remains a major challenge for Ethiopia. Around 31 per cent of households, or more than 30 million people, have inadequate energy intake (<2,550 kcal per adult-equivalent per day) (World Food Programme (WFP) and Agency, 2019). Since 2005, 14 million people on average received food assistance every year under the Productive Safety Net Programme and the Humanitarian Response Plan (World Food Programme (WFP), 2020). The rate of undernourishment has steadily declined, from 40 per cent in 2005 to 20 per cent in 2018. Despite this important decline, the national rate remains high, with some regions (e.g. Somali, Amhara) reporting higher rates in terms of stunting and wasting (Central Statistical Agency, 2020). As such, significant additional efforts are still needed to achieve SDG 2 – Zero Hunger and ensure access to adequate food for all people all year round by 2030.

Ethiopia's food system is evolving rapidly due to urbanization, income growth and shifting diets. Communication, transport and storage capacities have expanded, but logistics and supply chain management are still insufficient. Post-harvest grain losses are a persistent challenge, reaching 2.04 million metric tons per year while import requirements are estimated at 1.16 million metric tons per year. Consumers have limited purchasing power and some basic food items are heavily subsidized. Tax-free food imports reduce local food prices for consumers but constrain local market growth.

Ethiopia's cultivated area has increased by 27 per cent since 2004 but production growth has not fully matched expanding demand. Cereal yields grew significantly from 1 metric ton per hectare in 1995 to 2.5 metric tons per hectare in 2015. This trend is expected to continue with cereal yields in the SSP2 scenario assumed to increase from 2.5 metric tons per hectare to around 4.3 metric tons per hectare by 2050. This is an increase on the order of 70 per cent but nonetheless smaller than the yield increase projected for the SSP1 scenario, which will see doubling of cereal yields by 2050 to reach 5 metric tons per hectare.

This study reveals that self-sufficiency for cereals has remained approximately constant, around 90 per cent on average over the past 15 years, as the steep increase in production kept pace with increasing demand. Ethiopia is on its way to becoming self-sufficient in cereals by 2030 and will evolve into a net exporter over time. In addition, the country will increasingly export commodities, reaching $US5,000 billion by 2050 according to SSP2. This will be achieved through significant expansion in agricultural area and production, possibly making Ethiopia the regional breadbasket for Eastern Africa. This, however, would require upgrading the infrastructure for regional trade.


Photo: Shutterstock

Moreover, the upward trend in food availability will continue over the next 30 years. Despite population growth, the availability of calories is expected to increase to the range of 2,500 to 3,000 kcal per capita per day in all three scenarios, well above the FAO minimum of about 1,800 kcal per capita per day.

Ambitious targets were adopted by the government to improve food security under GTP2 in 2015–2020. These included, among others: increasing the amount of contingent food reserves from 405,000 metric tons to 1.5 million metric tons; increasing the number of productive safety net programme beneficiaries from 3.4 million to 8.3 million; and increasing the number of male- and female-headed households who graduate from the safety net programme from about 50,000 in 2015to around 1 million in 2020.

The government has demonstrated strong leadership in enhancing the food security of Ethiopia's population. However, the execution and implementation of policy directives are often limited by capacity constraints (United Nations, 2019). Key gaps include monitoring and evaluation, collection and analysis of disaggregated data, and accountability mechanisms. Interventions and investments should be aligned with successive growth and transformation plans. The cycle of the current growth and transformation plan ended in 2020. The next plan will be based on the Ten-Year Perspective Plan (2020–2030) and the Homegrown Economic Reform agenda, which together signal the government's clear policy priorities on food security.

5.3.2. Kenya

Kenya's past policies have had limited success in addressing the country's food insecurity. This is mainly attributed to inadequate budgetary allocations for agriculture, limited involvement of the private sector, inadequate sectoral coordination, ineffective monitoring and evaluation systems and lack of a clear strategy for food security (Government of Kenya, 2017a).

Even though agricultural output has increased over the past four decades, Kenya has experienced serious food deficits. A 20–30 per cent deficit in staple foods was reported in recent years (Kenya Agricultural Research Institute (KARI), 2017), as national food production has not increased in tandem with population growth. Currently, the country is a net importer of staple foods, in particular cereals. The degree of self-sufficiency for cereals has steadily declined from 80 per cent to around 60 per cent over the past 20 years.

In December 2017, the President of Kenya established the "Big Four" priorities for his term of government ending in 2022: increasing manufacturing; achieving universal health care; expanding affordable housing; and achieving 100 percent food security (Government of Kenya, 2017b). To meet its commitment to 100 percent food and nutrition security and achieve SDG2 on "zero hunger," the Government intends to enhance large-scale production, drive smallholder productivity and reduce the cost of food. Specific targets were achieved, among others, placing an additional 700,000 acres of cropland under production, reducing post-harvest losses from 20 per cent to 15 per cent, increasing access to credit to an additional 500,000 farmers and reducing power cost and levies on agricultural fuel by 50 per cent.

The Agricultural Sector Growth and Transformation Strategy (ASGTS) 2019–2029 was adopted by the government to stimulate agricultural productivity, alleviate poverty and deliver 100 per cent food and nutrition security (Government of Kenya, 2019). The strategy has three anchors: Anchor 1 – Increase small-scale farmers' income; Anchor 2 – Increase agricultural output and value addition; and Anchor 3 – Boost household food security.

Specific targets were established to monitor progress towards the achievement of the intended results of the ASGTS. These include improving the access of small farmers to inputs and equipment including for irrigation, processing and post-harvest aggregation; setting up agroprocessing hubs across Kenya; establishing new large-scale private farms (> 1,000 hectares) with expanded acreage under irrigation; restructuring the Strategic Food Reserve to better serve high-needs Kenyans; and boosting food resilience of dryland households through community-driven interventions. Securing the necessary resources for the effective implementation of the ASGTS will be generally positive for Kenya's economic growth and food security (Boulanger, Hasan et al., 2018).

The projected increases in agricultural production and productivity indicated by this study suggest that the government's policy ambitions to transform the agricultural sector and boost food security are achievable, conditional on substantial increases in crop productivity. The projections for the entire agricultural sector, based on monetary values of production and demand excluding major export commodities, show that Kenya will become food self-sufficient by 2040. This will be achieved through a moderate increase in agricultural area and production. However, this expansion will be devoted in large part to export commodities, which could lead to an increased reliance on cereal imports.

Moreover, the study forecasts an increase in aggregate food availability by 2050. Projected food calories, available from both crops and animal products, will increase to 2,500 to 3,000 calories per capita per day, depending on the scenario under consideration. However, these figures are national aggregates and do not convey information on food security in specific income groups.

National policies, strategies and regulatory frameworks provide the foundation for Kenya's aspiration to achieve food security for all. However, their implementation is often incomplete because of inadequate resource allocation and weak coordination and linkages among sectors (World Food Programme (WFP), 2020). Effective institutions are essential for the successful implementation of these policies and strategies. Planning and implementation capacities in many counties remain limited. The complementarity between national and county institutions is not fully established yet, and financial resource flows to counties are insufficient. Addressing these critical gaps is fundamental for meeting the country's policy ambitions and drive towards sustainability.

6

CONCLUSIONS AND RECOMMENDATIONS

This pilot study has sought to analyse current trends and project future changes to land use and related challenges in Ethiopia and Kenya. It has involved extensive discussion with government representatives and other stakeholders from both countries. The results shed considerable light on the outlook for land use and the kind of risks and trade-offs that are on the horizon. Overall, six main conclusions can be drawn from the analysis and are discussed below.

1 **The active engagement of scientists and government officials from both Ethiopia and Kenya strengthened ownership of this pilot study.** They confirmed the pilot's usefulness and identified opportunities for it to inform ongoing processes of policy development in both countries. Sharing and discussing current trends together with forward-looking scenario projections has proven to be useful in highlighting trade-offs, challenging and updating common assumptions and more generally fostering forward-looking scenario-based reflection. Scenarios allow stakeholders to identify key future challenges that warrant action today and build understanding of the impact of current policies on future outcomes. Similar conclusions have been reached in other scenarios-based projects in the region (Chaudhury, Vervoort et al., 2013).

2 **The data put forward in this pilot study could play an important role in devising ways to mitigate trade-offs or as the basis for difficult choices.** For example, the maps presented in this study point to areas most at risk of land use conversion, and could inform policymakers in revising forest and nature conservation strategies and/or targeting compensation policies in such areas. A platform in which key stakeholders discuss and share data, and possibly develop scenarios, is likely to be a fruitful starting point for identifying where trade-offs arise and how these can be mitigated. This applies to trade-offs in domestic or regional policy, such as potential conflicts between forestry and food production goals formulated in different government departments. Such a platform may stimulate a more integrated approach to national and regional policymaking. Key insights then can potentially inform multiple layers or spheres of government policy. Trialling such a platform has been a key aim of this pilot study, organized within the framework of the African Initiative to Combat Desertification (AI-CD).

3 Many recent trends are in line with the more pessimistic forward-looking scenario (SSP3), with high growth in population and low growth rates of agricultural productivity. This is despite clear national policy aspirations that are more aligned with the more optimistic scenario SSP1 (low population growth and high growth in agricultural productivity), or the middle-of-the road scenario SSP2. An outcome closer to the SSP3 scenario implies a much greater claim on land by agriculture. The conversion of forests, natural savannas and, in some instances, rangeland is already apparent in current trends. And, in each of the scenario projections further conversion is anticipated, with the most pronounced changes under the SSP3 scenario. The outlook entails a near doubling of cropland and conversion of 75 per cent of remaining forests in the case of Ethiopia. While projected conversion of forests and natural lands in Kenya is much smaller in absolute terms, the trade-off between food production and nature conservation could be stronger, as less forest remains to begin with.

Conversely, SSP1 documents a scenario with much smaller expansion of agriculture, but nonetheless a robust increase in agricultural production. Improved global trade integration allows Ethiopia to set itself on a course towards becoming a net food exporter, while Kenya further specializes in the export of high-value agricultural products. Food availability per capita in both countries is highest in this scenario. The strong productivity increases in agriculture in recent trends and in the projections also imply more pressure on the condition of land and soils, requiring attention to sustainable management to prevent further degradation and to limit vulnerability to droughts. In Ethiopia, much of the agricultural expansion appears to take place on vulnerable soils on steep slopes. Such production sites may be particularly susceptible to land degradation, erratic rainfall and drought cycles.

4 The land-related challenges facing Ethiopia and Kenya are well recognized in the policy responses developed. On the one hand, policies aim to address pressures such as population growth and land degradation; on the other, interventions have been developed to raise agricultural productivity and to prevent forest loss as much as possible. Ethiopia, for instance, is one of the few countries in Africa to surpass the New Partnership for Africa's Development/Comprehensive African Agriculture Development Programme (NEPAD/CAADP) target of spending 10 per cent of its annual budget on agriculture. In Kenya, achieving 100 per cent food and nutrition security is one the "Big Four" priorities adopted by the government in 2017–2022. Yet, the gap between stated aspirations and actual trends is substantial.

5 The gap between ambitions and trends means that goals are in place but implementation is crucial. In the short run, there is a need to strengthen capacities (including at the local level), institutional coordination and funding flows to bridge the gaps between policy ambitions and trends on the ground. In Ethiopia, the government has demonstrated strong leadership in enhancing the food security of its population. However, the implementation of policy directives is often limited by capacity constraints. Key gaps include monitoring and evaluation, collection and analysis of disaggregated data, and accountability mechanisms. In Kenya, decentralization has devolved responsibility for many aspects related to land use policy to counties, but many counties lack capacity (in terms of funding and expertise) to develop effective long-term policies. And, local priorities and incentives may not align well with national objectives. This may not be directly problematic as long as institutional mechanisms are in place to identify discrepancies, learn from policy failures and update and revise policy instruments where needed.

In the long run, greater focus should be placed on addressing and mitigating trade-offs highlighted by this study. This will not be an easy process, however. Even in the optimistic scenario (SSP1), some conversion of natural areas to agriculture occurs in order to meet future demand for food, even though this is at odds with policy objectives in both countries. For instance, Kenyan policies aim for a 10 per cent increase in forest cover by 2030. Goals for increasing forest cover imply less space for accommodating food production by a burgeoning rural population. Mitigating such a trade-off implies giving consideration as to how to compensate groups in society that may lose out.

6 As highlighted in the preceding sections, there are several promising avenues to expand on this pilot study.

Deepening scenario development. There may be scope to deepen the scenario development in this exercise in a participative and interactive manner. Current scenarios were based on internationally developed reference scenarios (Shared Socioeconomic Pathways) but could be modified to account for country-specific challenges, policy options or debates. To create maximum effectiveness in a follow-up project, such modifications should be linked to actual and current policy discussions in the countries or region involved. In other words, a follow-up should be demand-driven.

The exercise may also be used to navigate trade-offs between countries or foster collective actions for joint management of cross-boundary resources (forests or water bodies). It may offer scope for enhanced or coordinated regional policies based on a joint recognition of challenges such as climate change, population growth, trade and migration, the impacts of which are not confined to country boundaries. Data can inform the scope for enhancing trade relations in order to address regional food security challenges, as increased trade may reduce aggregate demand for land. It may allow countries to better learn from each other's policy successes and failures, or build a common position in multilateral negotiations.

It does, however, require clear consideration of how to include stakeholders. Ideally, the stakeholder platform should include participants who can easily bridge underlying scientific thinking with ongoing policy development and processes. Typically, this implies the participation of senior-level policymakers and science-for-policy think tanks, but involvement should not be exclusively government employees.

Expanding coverage. Possibly building on the above, there are options to expand coverage to themes that were not or only partially addressed in the current pilot. These may include biophysical topics such as climate change, water resources and biodiversity, but could also address current socioeconomic themes in greater detail, for instance, broader food security measures, migration, fragmentation of farm sizes or the long-term impact of COVID-19. Limited capacity and time constraints curtailed the options to cover these topics, while a follow-up may also build on the insights generated by scenario-based studies on climate change (Chaudhury, Vervoort et al., 2013) and water use in the region (in particular the Lake Victoria basin) (Tramberend, Burtscher et al., 2019).

While the COVID-19 crisis shifted most of the activities in this pilot study online, the actual impact of COVID-19 is not included in the scenario projections as they were developed preceding the pandemic. Elaboration of the long-term possible impacts of COVID in a follow-up study may possibly be informed


Photo: UNDP Kenya

by a recently published scenario-based study on the economic impact of COVID in Africa (Verhagen, Bohl et al., 2021).

Climate change, the precise impact of which is uncertain for East Africa, has not been dealt with explicitly, but ranges of impacts could be explored by considering ensemble projections (as is becoming standard practice in agro-meteorological assessments). These ideally should account for the effects of heavier but more irregular rainfall and increased interannual variations, as well as the knock-on effects on erosion and other forms of land degradation, for which quantitative data sources are becoming increasingly available (Alewell, Ringeval et al., 2020; Borrelli, Robinson et al., 2020).

Expanding to other AI-CD countries. Finally, a follow-up of this project may expand to other AI-CD countries. Based on country demand, an expansion to other countries in East Africa, or a similar exercise in West Africa could be envisioned. Again, this should be based on clear demands emerging from partner countries.

Photo: Shutterstock

7 REFERENCES

Aguiar, A., B. Narayanan and R. McDougall (2016). "An Overview of the GTAP 9 Data Base." *Journal of Global Economic Analysis* **1**(1): 28.

Alewell, C., B. Ringeval, C. Ballabio, D. A. Robinson, P. Panagos and P. Borrelli (2020). "Global Phosphorus Shortage Will Be Aggravated by Soil Erosion." *Nature Communications* **11**(1): 4546.

Berhanu, K. and C. Poulton (2014). "The Political Economy of Agricultural Extension Policy in Ethiopia: Economic Growth and Political Control." *Development Policy Review* **32**(s2): s197-s213.

Borrelli, P., D. A. Robinson, L. R. Fleischer, E. Lugato, C. Ballabio, C. Alewell, K. Meusburger,(S. Modugno, B. Schütt, V. Ferro, V. Bagarello, K. V. Oost, L. Montanarella and P. Panagos (2017). "An Assessment of the Global Impact of 21st Century Land Use Change on Soil Erosion." *Nature Communications* **8**(1): 2013.

Borrelli, P., D. A. Robinson, P. Panagos, E. Lugato, J. E. Yang, C. Alewell, D. Wuepper, L. Montanarella and C. Ballabio (2020). "Land Use and Climate Change Impacts on Global Soil Erosion by Water (2015–2070)." *Proceedings of the National Academy of Sciences* **117**(36): 21994-22001.

Boulanger, P., E. Ferrari, A. Mainar Causape, M. Sartori, M. Beshir, K. Hailu and S. Tsehay (2019). *Policy Options to Support the Rural Job Opportunities Creation Strategy in Ethiopia.* JRC Science for Policy Report. Luxembourg: European Union.

Boulanger, P., D. Hasan, E. Ferrari, A. Mainar Causape, J. Balie and L. Battaglia (2018). *Policy Options to Support the Agriculture Sector Growth and Transformation Strategy in Kenya: A CGE Analysis. JRC* Science for Policy Report. Luxembourg, European Union.

Buchhorn, M., M. Lesiv, N.-E. Tsendbazar, M. Herold, L. Bertels and B. Smets (2020). "Copernicus Global Land Cover Layers—Collection 2." *Remote Sensing* **12**(6): 1044.

Central Statistical Agency (Ethiopia) (2020). Demographic and Health Surveys for 2000, 2005, 2011, 2014 and 2016. Addis Ababa, Ethiopia.

Chaudhury, M., J. Vervoort, P. Kristjanson, P. Ericksen and A. Ainslie (2013). "Participatory Scenarios as a Tool to Link Science and Policy on Food Security under Climate Change in East Africa." *Regional Environmental Change* **13**(2): 389-398.

Cherlet, M., C. Hutchinson, J. Reynolds, J. Hill, S. Sommer and G. von Maltitz (2018). *World Atlas of Desertification.* Luxembourg: European Union.

Copernicus (2020a). "Copernicus Global Land Service." Retrieved December 11th, 2020, from https://land.copernicus.eu/global/products/lc.

Copernicus (2020b). "Global Land Cover – Ethiopia." Retrieved December 15th, 2020, from https://lcviewer.vito.be/2019/Ethiopia.

Doelman, J. C., E. Stehfest, A. Tabeau, H. van Meijl, L. Lassaletta, D. E. H. J. Gernaat, K. Hermans, M. Harmsen, V. Daioglou, H. Biemans, S. van der Sluis and D. P. van Vuuren (2018). "Exploring SSP Land-use Dynamics Using the IMAGE Model: Regional and Gridded Scenarios of Land-use Change and Land-based Climate Change Mitigation." *Global Environmental Change* **48:** 119-**135.**

Dosio, A. (2017). "Projection of Temperature and Heat Waves for Africa with an Ensemble of CORDEX Regional Climate Models." *Climate Dynamics* **49**(1): 493-519.

Dosio, A., R. G. Jones, C. Jack, C. Lennard, G. Nikulin and B. Hewitson (2019). "What Can We Know about Future Precipitation in Africa?: Robustness, Significance and Added Value of Projections from a Large Ensemble of Regional Climate Models." *Climate Dynamics* **53**(9): 5833-5858.

European Space Agency (ESA) (2017). "Land Cover CCI Product, User Guide Version 2.0." Retrieved from European Space Agency (ESA).

Food and Agriculture Organization of the United Nations (FAO) (2019). *The Future of Livestock in Kenya: Opportunities and Challenges in the Face of Uncertainty.* Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO) (2020a). "FAOSTAT." Retrieved December 11th, 2020, from http://www.fao.org/faostat/en/#home.

Food and Agriculture Organization of the United Nations (FAO) (2020b). "FAOSTAT Land under Permanent Meadows and Pastures." Retrieved November 3rd, 2020.

Fenta, A. A., A. Tsunekawa, N. Haregeweyn, J. Poesen, M. Tsubo, P. Borrelli, P. Panagos, M. Vanmaercke, J. Broeckx, H. Yasuda, T. Kawai and Y. Kurosaki (2020). "Land Susceptibility to Water and Wind Erosion Risks in the East Africa Region." *Science of the Total Environment* **703:** 135016.

Fitch Ratings. (2020). "Fitch Affirms Ethiopia at 'B': Outlook Negative." Retrieved December 11th, 2020, from https://www.fitchratings.com/research/sovereigns/fitch-affirms-ethiopia-at-b-outlook-negative-30-06-2020.

Friedl, M. A., D. Sulla-Menashe, B. Tan, A. Schneider, N. Ramankutty, A. Sibley and X. Huang (2010). "MODIS Collection 5 Global Land Cover: Algorithm Refinements and Characterization of New Datasets." *Remote Sensing of Environment* **114**(1): 168-182.

Gilbert, M., G. Nicolas, G. Cinardi, T. P. Van Boeckel, S. O. Vanwambeke, G. R. W. Wint and T. P. Robinson (2018). "Global Distribution Data for Cattle, Buffaloes, Horses, Sheep, Goats, Pigs, Chickens and Ducks in 2010." *Scientific Data* **5**(1): 180227.

Global Food Security Index. (2021). "Global Food Security Index." Retrieved January 12th, 2021, from https://foodsecurityindex.eiu.com/.

Global Forest Watch. (2020). "Global Forest Watch Map." Retrieved December 11th, 2020.

Government of Ethiopia (1993). *National Population Policy of Ethiopia.* Addis Ababa.

Government of Ethiopia (2016a). *Ethiopia: Land Degradation Neutrality National Report.* Addis Ababa, Ethiopia.

Government of Ethiopia (2016b). *Growth and Transformation Plan II (GTP II) (2015/16 - 2019/20). Volume 1: Main Text*. N. P. Commission. Addis Ababa, Ethiopia.

Government of Ethiopia and International Livestock Research Institute (ILRI) (2017). *Ethiopia Livestock Sector Analysis*. Addis Ababa, Ethiopia.

Government of Kenya. (2008). *Kenya Vision 2030*. Downloaded from https://vision2030.go.ke/.

Government of Kenya (2010). *Agricultural Sector Development Strategy 2010-2020.* Nairobi.

Government of Kenya (2016). *Forest Conservation and Management Act.*

Government of Kenya (2017a). *Kenya National Food and Nutrition Security Implementation Framework 2017-2022.* Nairobi, Kenya: Ministry of Agriculture, Fisheries and Cooperatives.

Government of Kenya (2017b). *"The Big Four": Immediate Priorities and Actions.* Nairobi, Kenya.

Government of Kenya (2019). *Agriculture Sector Growth and Development Strategy 2019 - 2029.* Nairobi, Kenya.

Government of Kenya (2020a). *Land Degradation Neutrality Target Setting.* Final Report. Nairobi, Kenya.

Government of Kenya (2020b). *National Agricultural Soil Management Policy.* Nairobi, Kenya: Ministry of Agriculture, Fisheries and Cooperatives.

Hailemariam, A., S. Alayu and C. Teller (2011). "The National Population Policy (NPP) of Ethiopia: Achievements, Challenges and Lessons Learned, 1993–2010." *in The Demographic Transition and Development in Africa: The Unique Case of Ethiopia,* C. Teller, 303-321. Dordrecht, Springer Netherlands.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice and J. R. G. Townshend (2013). "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* **342**(6160): 850-853.

Hertel, T. W. (1997). *Global Trade Analysis: Modeling and Applications.* Cambridge University Press.

HLPE (2017). *Nutrition and Food Systems.* A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome, Italy.

International Monetary Fund (IMF) (2020). "IMF Staff Completes Virtual Mission to Kenya." Retrieved December 11th, 2020, from https://www.imf.org/en/News/Articles/2020/11/20/pr20351-kenya-imf-staff-completes-virtual-mission.

Intergovernmental Panel on Climate Change (IPCC) (2019). *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems.* IPCCS.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2018). *The IPBES Assessment Report on Land Degradation and Restoration.* Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Bonn, Germany.

Joint Research Centre (JRC) (2020). *World Atlas of Desertification: Expanding Cultivation.* Retrieved November 3rd, 2020, from https://wad.jrc.ec.europa.eu/expandingcultivation.

Kenya Agricultural Research Institute (KARI) (2017). *Food Security Report.* KARI.

Kenya National Bureau of Statistics (KNBS) (2012). *Analytical Report on Population Projections*. Nairobi, Kenya, Kenya National Bureau of Statistics.

Leroux, L., A. Jolivot, A. Bégué, D. L. Seen and B. Zoungrana (2014). "How Reliable is the MODIS Land Cover Product for Crop Mapping Sub-Saharan Agricultural Landscapes?" *Remote Sensing* **6**(9): 8541-8564.

Ministry of Lands and Physical Planning (Kenya) (2017). "Sessional Paper No. 1 on National Land Use Policy." Nairobi, Kenya.

Ministry of State for Planning (Kenya) (2012). "Sessional Paper No. 3 of 2012 on Population Policy for National Development. Nairobi, Kenya.

National Council for Population and Development (NCPD) (Kenya) (2013). *Kenya Population Situation Analysis.* Nairobi, Kenya.

National Land Commission (Kenya) (2020). *Strategic Plan 2020-2025.* Nairobi, Kenya.

Nikulin, G., C. Lennard, A. Dosio, E. Kjellström, Y. Chen, A. Hänsler, M. Kupiainen, R. Laprise, L. Mariotti, C. F. Maule, E. van Meijgaard, H.-J. Panitz, J. F. Scinocca and S. Somot (2018). "The Effects of 1.5 and 2 Degrees of Global Warming on Africa in the CORDEX Ensemble." *Environmental Research Letters* **13**(6): 065003.

Odhiambo, K., J. Lewis, N. Tefera, A. Thomas, M. Meroni, M. Dimou and F. Rembold (2021). *Impacts of Covid-19 and Desert Locusts on Smallholder Farmers Food Systems and Value Chains in Kenya: Reporting period: March - August 2020*. JRC Science for Policy Report (in press). P. O. o. t. E. Union. Luxembourg.

Osima, S., V. S. Indasi, M. Zaroug, H. S. Endris, M. Gudoshava, H. O. Misiani, A. Nimusiima, R. O. Anyah, G. Otieno, B. A. Ogwang, S. Jain, A. L. Kondowe, E. Mwangi, C. Lennard, G. Nikulin and A. Dosio (2018). "Projected Climate over the Greater Horn of Africa under 1.5°C and 2°C Global Warming." *Environmental Research Letters* **13**(6): 065004.

Popp, A., K. Calvin, S. Fujimori, P. Havlik, F. Humpenöder, E. Stehfest, B. L. Bodirsky, J. P. Dietrich, J. C. Doelmann, M. Gusti, T. Hasegawa, P. Kyle, M. Obersteiner, A. Tabeau, K. Takahashi, H. Valin, S. Waldhoff, I. Weindl, M. Wise, E. Kriegler, H. Lotze-Campen, O. Fricko, K. Riahi and D. P. v. Vuuren (2017). "Land-use Futures in the Shared Socio-economic Pathways." *Global Environmental Change* **42:** 331-345.

Riahi, K., D. P. van Vuuren, E. Kriegler, J. Edmonds, B. C. O'Neill, S. Fujimori, N. Bauer, K. Calvin, R. Dellink, O. Fricko, W. Lutz, A. Popp, J. C. Cuaresma, S. Kc, M. Leimbach, L. Jiang, T. Kram, S. Rao, J. Emmerling, K. Ebi, T. Hasegawa, P. Havlik, F. Humpenöder, L. A. Da Silva, S. Smith, E. Stehfest, V. Bosetti, J. Eom, D. Gernaat, T. Masui, J. Rogelj, J. Strefler, L. Drouet, V. Krey, G. Luderer, M. Harmsen, K. Takahashi, L. Baumstark, J. C. Doelman, M. Kainuma, Z. Klimont, G. Marangoni, H. Lotze-Campen, M. Obersteiner, A. Tabeau and M. Tavoni (2017). "The Shared Socioeconomic Pathways and their Energy, Land Use, and Greenhouse Gas Emissions Implications: An Overview." *Global Environmental Change* **42:** 153-168.

Robinson, T. P., P. Thornton, G. Franceschini, R. Kruska, F. Chiozza, A. Notenbaert, G. Cecchi, M. Herrero, M. Epprecht, S. Fritz, L. You, G. Conchedda and L. See (2018). Global Distribution of Ruminant Livestock Production Systems V5 (5 minutes of arc), Harvard Dataverse.

Russo, S., A. F. Marchese, J. Sillmann and G. Immé (2016). "When Will Unusual Heat Waves Become Normal in a Warming Africa?" *Environmental Research Letters* **11**(5): 054016.

Schipper, A. M., J. P. Hilbers, J. R. Meijer, L. H. Antão, A. Benítez-López, M. M. J. de Jonge, L. H. Leemans, E. Scheper, R. Alkemade, J. C. Doelman, S. Mylius, E. Stehfest, D. P. van Vuuren, W.-J. van Zeist and M. A. J. Huijbregts (2020). "Projecting Terrestrial Biodiversity Intactness with GLOBIO 4." *Global Change Biology* **26**(2): 760-771.

Stehfest, E., D. van Vuuren, L. Bouwman and T. Kram (2014). *Integrated Assessment of Global Environmental Change with IMAGE 3.0: Model Description and Policy Applications.* PBL Netherlands Environmental Assessment Agency.

Tabeau, A., W.-J. Van Zeist, E. Berkhout, J. Doelman, S. van der Esch, H. van Meijl and E. Stehfest (2019). "Projections of African Agricultural Land and Agri-food Sector Development: How Much Regional Aggregation of Africa Matter." 22nd Annual Conference on Global Economic Analysis. Warsaw, Poland.

Tramberend, S., R. Burtscher, P. Burek, T. Kahil, G. Fischer, J. Mochizuki, Y. Wada, R. Kimwaga, P. Nyenje, R. Ondiek, N. Prossie, C. Hyandye, C. Sibomana and S. Langan (2019). *East Africa Future Water Scenarios to 2050.* Laxenburg, Austria, IIASA.

Trends.Earth. (2021). "Trends.Earth Tracking Land Change." Retrieved February 4th, 2021, from http://trends.earth/docs/en/.

United Nations Conference on Trade and Development (UNCTAD) (2020). "COVID-19 Accelerates Greater Trade Coordination in East Africa." Retrieved December 11th, 2020, from https://unctad.org/news/covid-19-accelerates-greater-trade-coordination-east-africa.

UNCTAD (2020). *Impact of the COVID-19 Pandemic on Trade and Development: Transitioning to a New Normal.* New York, United Nations Conference on Trade and Development.

United Nations (2019). *Common Country Analysis Ethiopia.* United Nations.

United Nations Convention to Combat Desertification (UNCCD) (2017a). *Evaluation of the Global Land Outlook.* Final Report.

United Nations Convention to Combat Desertification (UNCCD) (2017b). *Global Land Outlook*, first edition. Bonn, Germany.

United Nations Population Fund (UNFPA). (2020). "World Population Dashboard." Retrieved December 28th, 2020, from https://www.unfpa.org/data/world-population-dashboard.

van der Esch, S., B. ten Brink, E. Stehfest, M. Bakkenes, A. Sewell, A. Bouwman, J. Meijer et al. (2017). Exploring Future Changes in Land Use and Land Condition and the Impacts on Food, Water, Climate Change and Biodiversity. The Hague, The Netherlands, PBL Netherlands Environmental Assessment Agency.

van Ittersum, M. K., L. G. J. van Bussel, J. Wolf, P. Grassini, J. van Wart, N. Guilpart, L. Claessens, H. de Groot, K. Wiebe, D. Mason-D'Croz, H. Yang, H. Boogaard, P. A. J. van Oort, M. P. van Loon, K. Saito, O. Adimo, S. Adjei-Nsiah, A. Agali, A. Bala, R. Chikowo, K. Kaizzi, M. Kouressy, J. H. J. R. Makoi, K. Ouattara, K. Tesfaye and K. G. Cassman (2016). "Can Sub-Saharan Africa Feed Itself?" *Proceedings of the National Academy of Sciences* **113**(52): 14964-14969.

van Zeist, W.-J., A. Tabeau, E. Berkhout, J. C. Doelman, S. van der Esch, H. Van Meijl and E. Stehfest (in prep). "Land Use in Africa under the SSPs: A Regional Integrated Assessment."

Vancutsem, C., F. Achard, J.-F. Pekel, G. Vieilledent, S. Carboni, D. Simonetti, J. Gallego et al. (2021). "Long-term (1990–2019) Monitoring of Forest Cover Changes in the Humid Tropics." *Science Advances* **7**(10): eabe1603.

Verhagen, W., D. K. Bohl, J. Cilliers, B. B. Hughes, S. Kwasi, K. McNeil, M. Oosthuizen et al. (2021). Analysing Long-term Socio-economic Impacts of COVID-19 Across Diverse African Contexts. New York, USA, UNDP

Wageningen University and Research (2020). Rapid Country Assessment – Ethiopia: The Impact of COVID-19 on the Food System. Wageningen, The Netherlands, Wageningen University & Research (WUR).

Wageningen University and Research and SNV Netherlands Development Organization (2020). Rapid Country Assessment – Kenya: The Impact of COVID-19 on the Food System. Wageningen, The Netherlands, Wageningen University & Research (WUR).

Welteji, D. (2018). "A Critical Review of Rural Development Policy of Ethiopia: Access, Utilization and Coverage." *Agriculture & Food Security* **7**(1): 55.

Willett, W., J. Rockström, B. Loken, M. Springmann, T. Lang, S. Vermeulen, T. Garnett, D. Tilman, F. DeClerck, A. Wood, M. Jonell, M. Clark, L. J. Gordon, J. Fanzo, C. Hawkes, R. Zurayk, J. A. Rivera, W. De Vries, L. Majele Sibanda, A. Afshin, A. Chaudhary, M. Herrero, R. Agustina, F. Branca, A. Lartey, S. Fan, B. Crona, E. Fox, V. Bignet, M. Troell, T. Lindahl, S. Singh, S. E. Cornell, K. Srinath Reddy, S. Narain, S. Nishtar and C. J. L. Murray (2019). "Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems." *The Lancet* **393**(10170): 447-492.

Woltjer, G. B., M. Kuiper, A. Kavallari, H. van Meijl, J. Powell, M. Rutten, L. Shutes and A. Tabeau (2014). The MAGNET Model: Module Description. LEI Wageningen UR.

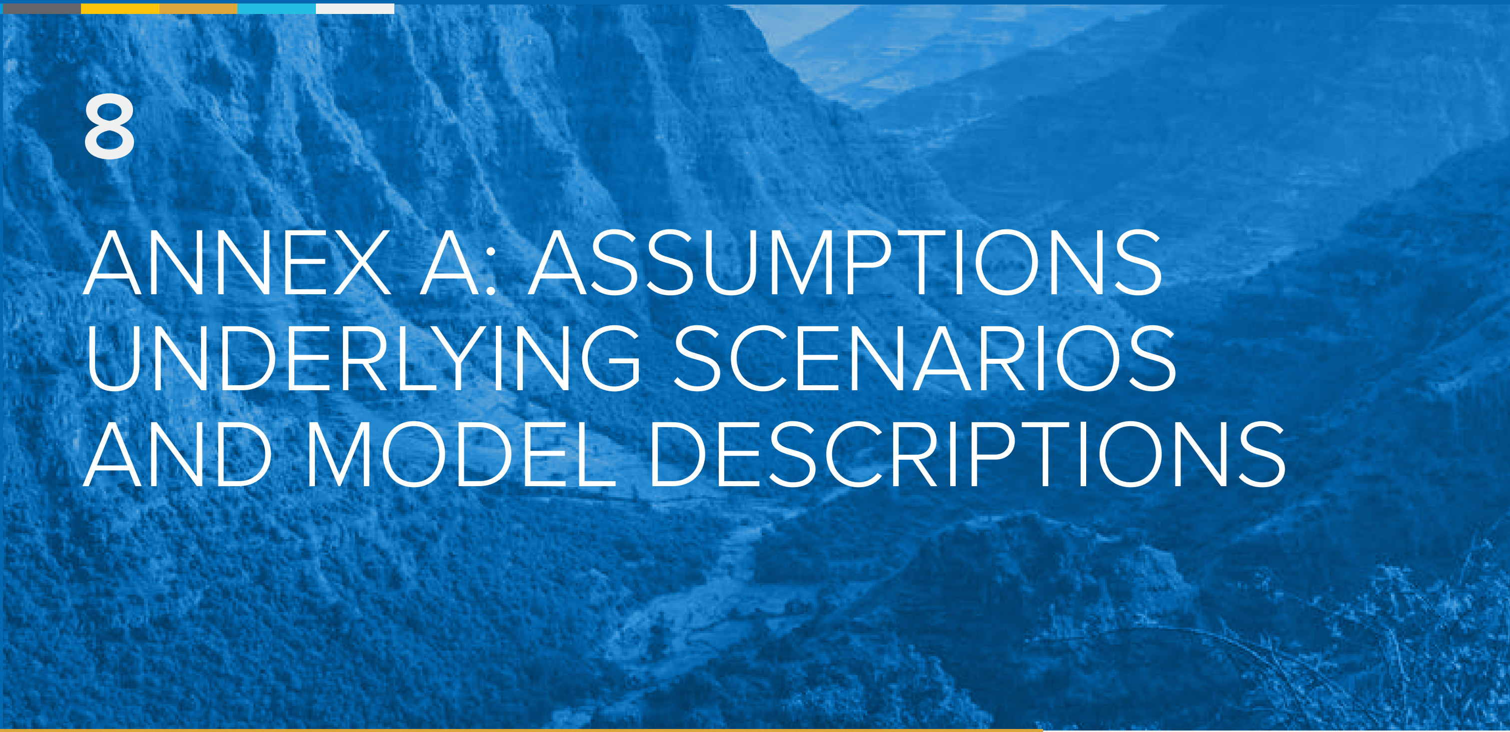
World Bank (2021). "World Bank Development Indicators." from https://databank.worldbank.org/source/world-development-indicators.

World Food Programme (WFP) (2020). Ethiopia Country Strategic Plan (2020–2025). Rome, Italy.

World Food Programme (WFP) (2020). Kenya Country Strategic Plan (2018–2023). Rome, Italy.

World Food Programme (WFP) and C. S. Agency (2019). Comprehensive Food Security and Vulnerability Analysis (CFSVA). Addis Ababa, Ethiopia.

Zerga, B. (2016). "Land Resource, Uses, and Ownership in Ethiopia: Past, Present and Future." *Journal of Scientific Research Engineering Technology* **2**(1).



8

ANNEX A: ASSUMPTIONS UNDERLYING SCENARIOS AND MODEL DESCRIPTIONS

For projections on future changes to land up to 2050, the study uses the PBL computer model framework IMAGE and is coupled with an economic model (MAGNET) developed by Wageningen Economic Research, part of Wageningen University and Research (WUR). This general equilibrium model simulates global agricultural supply and demand. For this study, the model was disaggregated to account for country-specific production and intracountry trade in Sub-Saharan Africa in greater detail, including the focus countries of this pilot (Tabeau, Van Zeist et al., 2019; van Zeist, Tabeau et al., in prep). Projected changes in land use were modelled using the GLOBIO model.

Detailed insights into regional land use changes are provided by three scenarios, the so-called **Shared Socioeconomic Pathways** (SSPs), which were developed jointly by several key organizations that conduct global scenarios analyses (e.g. IPCC, IIASA, IFPRI), PBL being one of them. Overall, five SSPs have been developed and the first three, which are employed here, can be described as: a sustainability scenario with moderate population growth and fair increase in agricultural productivity (SSP1 – Sustainability) , a middle-of-the-road scenario by and large maintaining current trends (SSP2 – Middle-of-the-road) and a scenario with faster increases in population and with limited development of technology and trade (SSP3 – Fragmentation). Table 8-1 provides key assumptions of the underlying scenarios in greater detail. For more information and background details of the SSPs development, see Riahi, van Vuuren et al., 2017; Popp, Calvin et al., 2017; and Doelman, Stehfest et al., 2018.

TABLE 8-1: Operationalising three SSP scenarios

Scenario	SSP1 – Sustainability	SSP2 – Middle of the road	SSP3 - Fragmentation
Population (billion, 2050, World)	8.5 (low)	9.2 (medium)	10.0 (high)
GDP (thousand 2005 $US per capita, 2050, World)	34 (high)	25 (medium)	18 (low)
Trade in agricultural commodities	Abolishment of import tariffs and export subsidies by 2030	Current tariffs and subsidies	Introduction of a 10% import tax for all agricultural products by 2050, for self-sufficiency concerns
Meat consumption	Low – Consumption of animal products 30% lower than model outcome without diet shifts	Medium – Model outcome without additional diet shifts, in line with GDP increase	High – Consumption of animal products 30% higher than outcome without diet shifts
Losses in food supply chain including waste at household level	Reduction of food losses by 33%	Current levels of food losses (a third in the supply chain is lost, according to FAO, 2011).	Food losses increase by 33%
Land-use change regulation	Strong – Protected areas achieve 30% of terrestrial area by 2050	Medium – Assuming current protected areas (WDPA IUCN all categories)	Low – Protected areas decrease from current to only WDPA IUCN categories 1-4
Agricultural productivity crops	High – crop yield increase as a function of GDP	Medium – following largely the projections by FAO's Agricultural Outlook	Low – Crop yield increase as a function of GDP
Agricultural productivity livestock	High – Efficiency parameters (e.g. feed use efficiency) achieve 50% convergence to the levels of the most efficient regions in SSP2	Medium – following largely the projections by FAO's Agricultural Outlook	Low – Efficiency stagnates at current regional levels
Irrigation area and efficiency	Irrigation area growth rate 50% lower than SSP2; irrigation efficiency increases by 0.1%/yr for all irrigated areas	Irrigation area increases following the FAO agricultural outlook of irrigated harvested area; irrigation efficiency increases by 0.2%/yr for newly irrigated areas	Irrigation area growth rate 50% higher than SSP2; irrigation efficiency remains at current levels
Nutrient management	High efficiency – Fertilizer use efficiency 20% higher than SSP2, fertilizer application rates increase in countries with nutrient mining	Medium efficiency – Fertilizer use efficiency rates largely follow FAO agricultural outlook	Low efficiency – Fertilizer use efficiency 20% lower than SSP2

Source: Adapted from Doelman, Stehfest et al., 2018.

Scenarios were quantified by using the computer models MAGNET, IMAGE and GLOBIO, using input from the GTAP database.

The **MAGNET model** (Woltjer, Kuiper et al., 2014) is a multiregional, multisectoral, applied general equilibrium model based on neo-classical microeconomic theory. It is an extended version of the standard Global Trade Analyses Project (GTAP) model (Hertel, 1997). It covers all main sectors of the economy (agriculture, manufacturing and services) and all regions and major countries in the world. The core of MAGNET is an input–output model, which links industries in value-added chains from primary goods to final goods and services for consumption. Input and output prices are endogenously determined by the markets to achieve supply and demand equilibrium.

The analysis used an adjusted version 9 of the **GTAP database** (Aguiar, Narayanan et al., 2016). The original GTAP database contains detailed bilateral trade, transport and protection data characterizing economic linkages among regions, and consistent individual country input-output databases which account for intersectoral linkages. All monetary values of the data are in millions of US dollars and the base year is 2011. It distinguishes 140 regions and 57 sectors. For MAGNET applications, the database was adjusted in order to implement two new sectors or by-products of sectors concerning agriculture, fishery, bio-based economy and electricity. So, the MAGNET database includes 94 sectors and 105 traded commodities.

IMAGE is an integrated assessment modelling framework that simulates the interactions between human activities and the environment (Stehfest, van Vuuren et al., 2014) to explore long-term global environmental change and policy options in the areas of climate, land and sustainable development. IMAGE consists of various sub-models describing land use, agricultural economy, the energy system, natural vegetation, hydrology, and the climate system. Most socioeconomic processes are modelled at the level of 26 regions. Most environmental processes are modelled on the grid level at 30 or 5 arc-minutes resolution. Data exchange takes place either through hard-coupling with annual exchange of data, or soft-coupling using an iterative approach of scenario data exchange. Land supply, suitability and potential agricultural yields are evaluated on a grid scale in IMAGE and provided to MAGNET and used to model land as a production factor described by a land supply curve.

GLOBIO is designed to inform and support policymakers by quantifying global human impacts on biodiversity and ecosystems. The model calculates local terrestrial biodiversity intactness, expressed by the mean species abundance (MSA) indicator, as a function of six human pressures: land use, road disturbance, fragmentation, hunting, atmospheric nitrogen deposition and climate change (Schipper, Hilbers et al., 2020). The core of the model consists of quantitative pressure-impact relationships that have been established based on extensive terrestrial biodiversity databases. GLOBIO combines the pressure-impact relationships with data on past, present or future pressure levels, retrieved from IMAGE. This results in maps with MSA values corresponding with each pressure. These maps are then combined to obtain overall MSA values. GLOBIO also includes a routine to downscale coarse-grained land-use data to more fine-grained maps (currently with a resolution of 10 arc-seconds; ~300 meters (m) at the equator). The downscaling routine requires regional totals or demands ("claims") of each land use type and allocates these to grid cells within the region in order of decreasing suitability for that land use type.

9

ANNEX B: DATA SOURCES ON RECENT TRENDS IN LAND USE AND LAND COVER

General sources

FAOSTAT (FAO, 2020) provides free access to food and agriculture data for over 245 countries and territories, from 1961 to the most recent year available (the reporting lag is about three years). FAOSTAT provides harmonised data sets (at country level) which, as much as possible, are based on official national statistics, as reported to FAO by its member states. The domain "land use" distinguishes 46 categories, subcategories and main features of land use. Main strengths of FAOSTAT as a source of land use information are its general acceptance as a standard reference, its ease of use and the many categories considered. Aspects that limit its utility for change assessments include: lack of spatial explicitness within countries; varying data quality across countries, and within countries over time; and large number of blank or estimated values with unknown accuracy, especially for older data (see e.g. bottom panel of Figure 3-2).

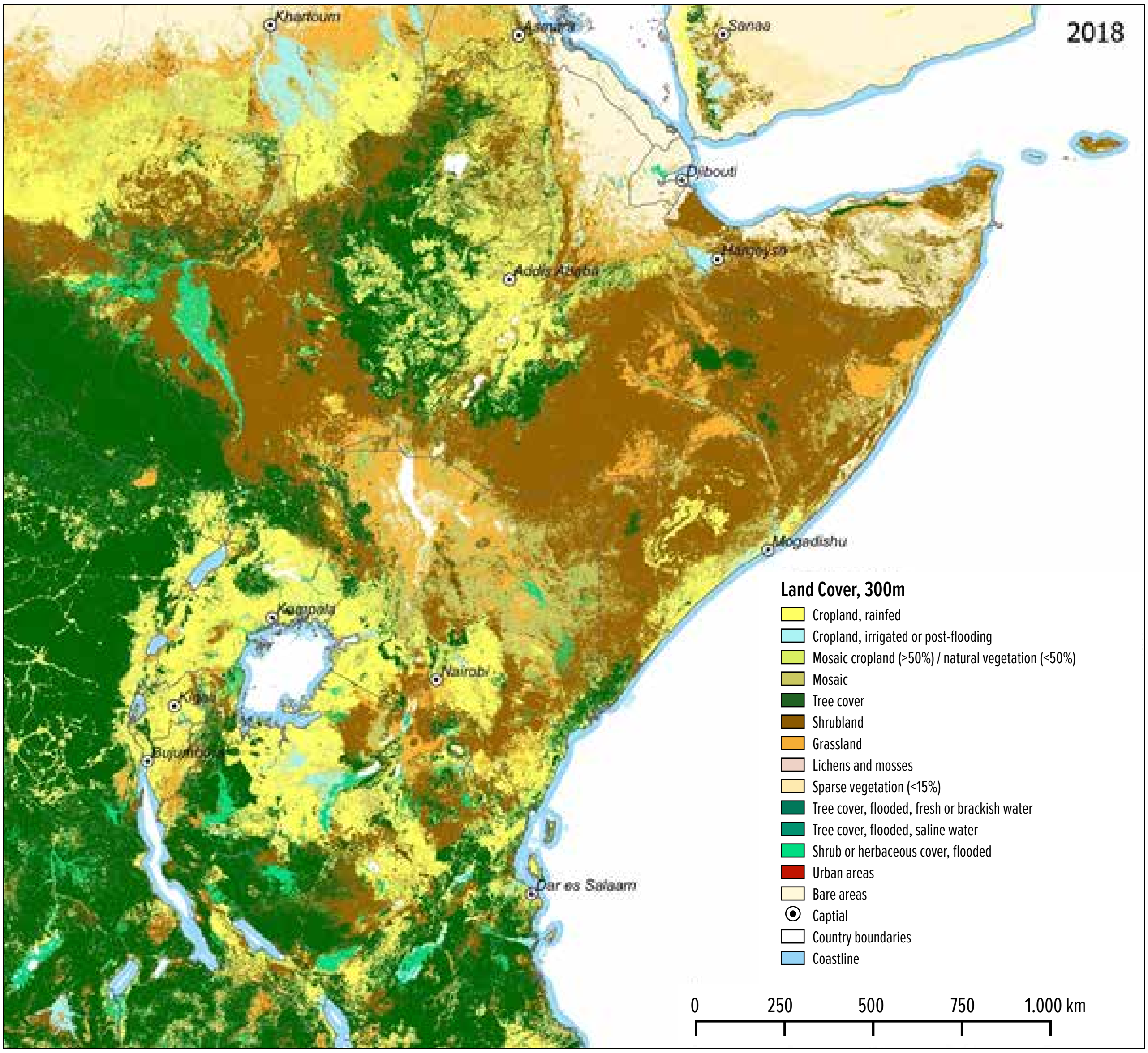
The **Copernicus Global Land Service** (Copernicus, 2020a) provides detailed land cover information and is based on PROBA-V data at 100 m resolution. This service, with land cover and change products from 2015 to 2019, became available in September 2020. The online[9] interactive service allows for the presentation of maps at several levels of aggregation (e.g. up to six classes of forests, and to display information in the form of tables or bar diagrams at national level or, within countries, at the level of large administrative regions. A cut out for the Horn of Africa of the 2018 map is presented in Figure 3-1. Obviously, the 2015-2019 monitoring period is too short to detect general trends of land use or land cover change at national level, but some significant changes can be detected at regional level. The maps have an overall accuracy of 80.2 per cent (Buchhorn, Lesiv et al., 2020).

The **European Space Agency (ESA) Climate Change Initiative (CCI) Land Cover time series**[10] consists of annual maps, based on MERIS and SPOT data at 300 m resolution for 1992-2015, extended

9 https://lcviewer.vito.be
10 http://maps.elie.ucl.ac.be/CCI/viewer/index.php

to 2018 in the framework of the Copernicus Climate Change Service (C3S). A cut out for the Horn of Africa of the 2018 map is presented in Figure 9-1. These maps describe the land surface in 22 classes, and although mainly intended for climate-modelling communities, this data set's long-term consistency, yearly updates and high thematic detail on a global scale make it attractive for several other applications. However, while land cover changes in global hotspots, such as the Congo Basin, are well depicted, this product is not suitable for more local assessments, as it is rather conservative in terms of land cover change, (European Space Agency (ESA), 2017, p. 42–44). The maps have a reported overall accuracy of 73 per cent (European Space Agency (ESA), 2017, p. 38–41).

FIGURE 9-1: Land cover in the Horn of Africa, 2018, according to ESA-CCI



The Terra and Aqua combined Moderate Resolution Imaging Spectroradiometer (**MODIS**) Land Cover Type (MCD12Q1 V6) data product provides global land cover types at yearly intervals from 2001 to 2019 at a resolution of 500 m. The primary land cover scheme identifies 17 classes defined by the International Geosphere-Biosphere Programme (IGBP), including 11 natural vegetation classes, three human-altered classes, and three non-vegetated classes. The overall accuracy was reported as 75 per cent (Friedl, Sulla-Menashe et al., 2010), but Leroux et al. (2014) found much lower levels of accuracy for cropland classes across Sub-Saharan Africa, particularly in eastern regions.

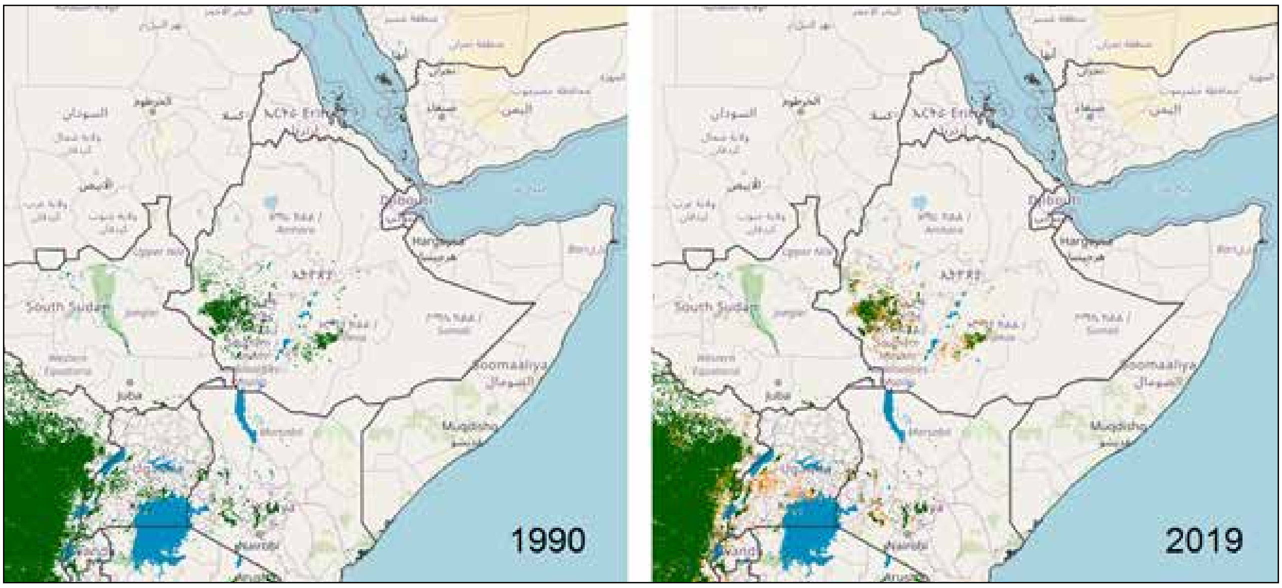
Forest dynamics

The standard reference for forest resource information at the global scale is the **FAO Global Forest Resources Assessment (FRA)**. The FRA is published every ten years, most recently in 2020. The data presented – at national level – are mainly based on information provided by the FAO member states. While the FRA is the internationally mandated forest database, it has several limitations – similar to FAOSTAT – that limit its utility for change assessments. These include: lack of spatial explicitness; methodological inconsistencies between countries, and within countries over time; and changes in forest area are reported as net values only.

The maps of the **Global Forest Watch**[11] present global forest losses and gains since 2000, based on Landsat data at a spatial resolution of 30 m. The methodology is described by Hansen et al. (2013). Forests, in this product, are defined on the basis of tree cover, with trees defined as all vegetation taller than 5 m in height. The interactive user interface allows depiction of changes in areas with >10% tree cover up to >75% tree cover, for any period between 2001 and 2020. Examples for the Horn of Africa are given in Figure 3-5.

Long-term monitoring of tropical moist forests (TMF) are provide by Vancutsem et al. (2021) who assessed forest cover changes in the humid tropics from January 1990 to December 2019, based on Landsat imagery at 30 m resolution. The resulting publicly accessible maps[12] depict TMF extent, related disturbances (deforestation and degradation) and post-deforestation recovery (or forest regrowth) through two complementary thematic layers: a transition map and an annual change collection over the period considered. Deforestation refers to a change in land cover (from forest to non-forested land) while degradation refers to a temporary disturbance such as selective logging, fires and unusual weather events (hurricanes, droughts, blowdown). Comparison with an independently assessed data set of 5,250 sample plots (0.82 ha each) showed an overall accuracy of 91.4 per cent. Compared with the Global Forest Watch (only considering the humid tropics and the overlapping 2001–2019 period), the TMF assessment shows substantially higher rates of deforestation and degradation, particularly in Africa, which is attributed to more refined processing.

FIGURE 9-2: Tropical moist forest (green) in the Horn of Africa, in 1990 and 2019. Yellow and orange colours in the right-hand map represent areas where TMF was degraded or lost since the start of the observation period.
Source: Vancutsem, Achard et al. 2021.



11 https://www.globalforestwatch.org/map/

12 https://forobs.jrc.ec.europa.eu/TMF/

Global Policy Centre on Resilient Ecosystems and Desertification (GC-RED).

United Nations Development Programme. United Nations Office at Nairobi. Gigiri, Block M, Middle Level. Nairobi, Kenya

For more information: www.undp.org