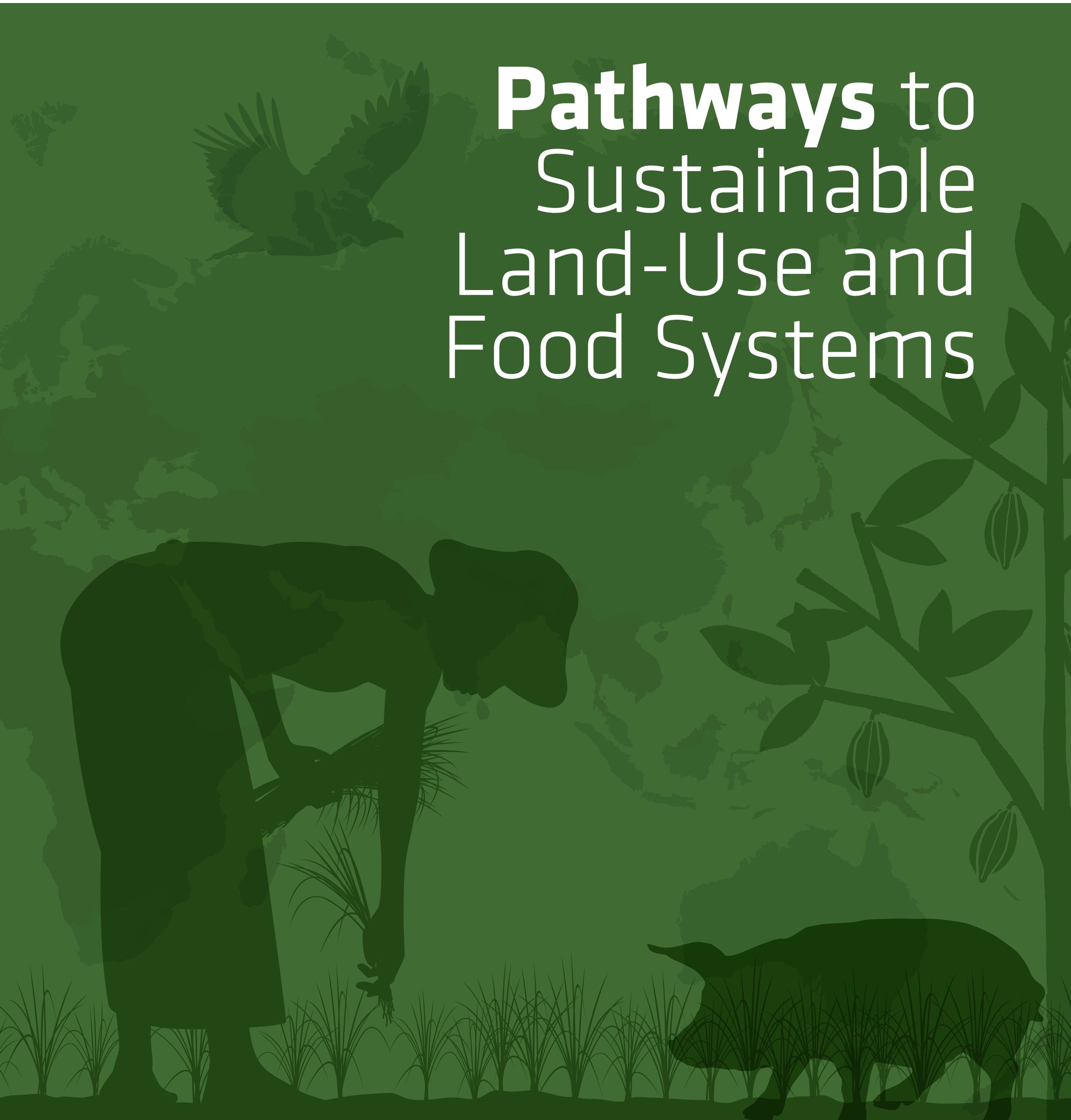
International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



Published by International Institute for Applied Systems Analysis (IIASA) and the Sustainable Development Solutions Network (SDSN) 2020

The full report is available at www.foodandlandusecoalition.org/fable.
For questions please write to info.fable@unsdsn.org

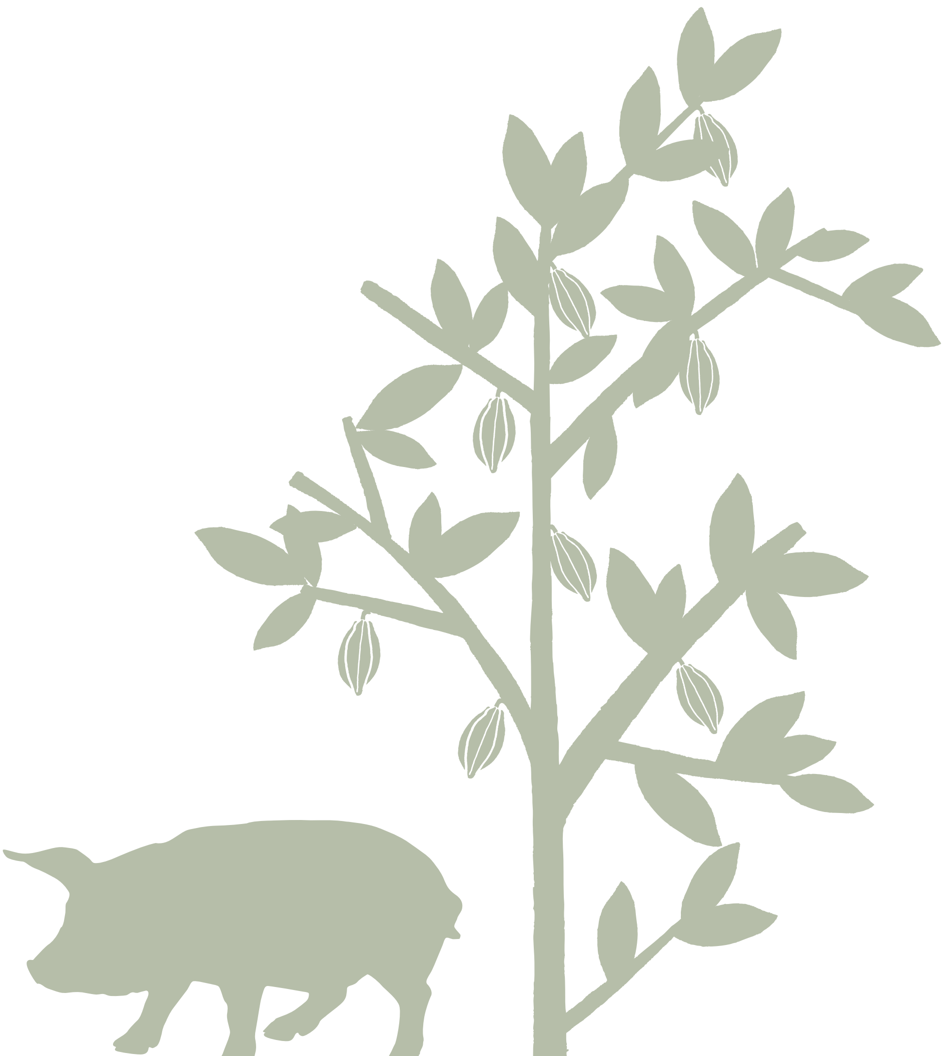
Disclaimer
The 2020 FABLE Report was written by a group of independent experts acting in their personal capacities. Any views expressed in this report do not necessarily reflect the views of any government or organization, agency, or programme of the United Nations (UN). The country chapters use maps prepared solely by the national teams. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of SDSN or IIASA concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

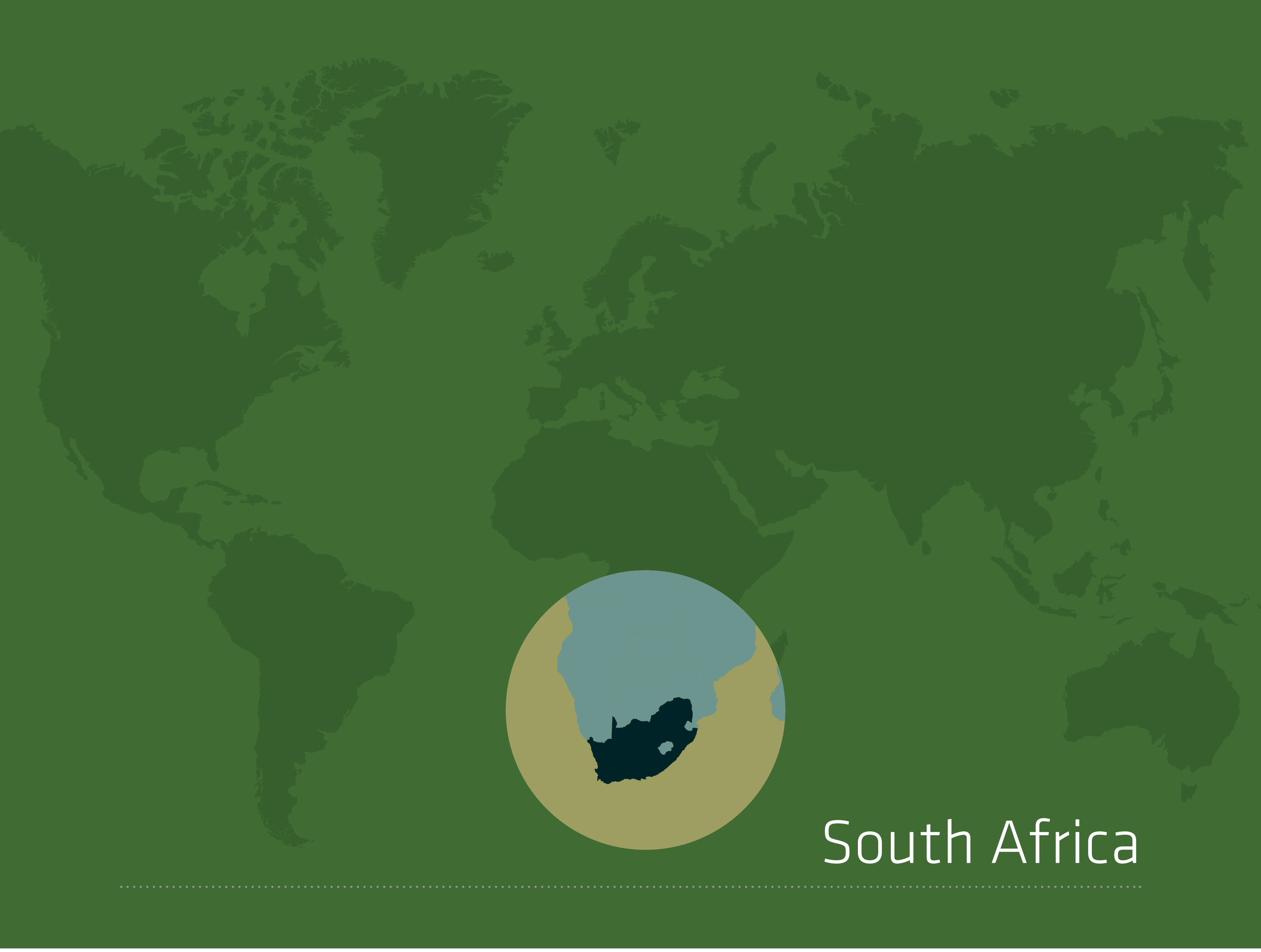
Recommended citation: Selomane O. and Reyers B. (2020), "Pathways to Sustainable Land-Use and Food Systems in South Africa by 2050" In: FABLE 2020, *Pathways to Sustainable Land-Use and Food Systems,* 2020 Report of the FABLE Consortium. Laxenburg and Paris: International Institute for Applied Systems Analysis (IIASA) and Sustainable Development Solutions Network (SDSN), pp. 568-594.
https://doi.org/10.22022/ESM/12-2020.16896

Design, layout and production by Phoenix Design Aid A/S, a CO2 neutral company accredited in the fields of quality (ISO 9001), environment (ISO 14001) and CSR (DS 49001) and approved provider of FSC™ certified products. Printed on environmentally friendly paper without chlorine and with vegetable-based inks. The printed matter is recyclable.

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems in South Africa by 2050





South Africa

Odirilwe Selomane[1*], Belinda Reyers[2,3]

[1]Centre for Complex Systems in Transition, Stellenbosch University, Stellenbosch, South Africa. [2]Future Africa, University of Pretoria, Pretoria, South Africa. [3]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden
*Corresponding author: odirilwes@sun.ac.za

This chapter of the 2020 Report of the FABLE Consortium *Pathways to Sustainable Land-Use and Food Systems* outlines how sustainable food and land-use systems can contribute to raising climate ambition, aligning climate mitigation and biodiversity protection policies, and achieving other sustainable development priorities in South Africa. It presents two pathways for food and land-use systems for the period 2020-2050: Current Trends and Sustainable. These pathways examine the trade-offs between achieving the FABLE Targets under limited land availability and constraints to balance supply and demand at national and global levels. They were derived from policy and other documents and modeled with the FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019).

Climate and Biodiversity Strategies and Current Commitments

Countries are expected to renew and revise their climate and biodiversity commitments ahead of the 26th session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 15th COP to the United Nations Convention on Biological Diversity (CBD). Agriculture, land-use, and other dimensions of the FABLE analysis are key drivers of both greenhouse gas (GHG) emissions and biodiversity loss and offer critical adaptation opportunities. Similarly, nature-based solutions, such as reforestation and carbon sequestration, can meet up to a third of the emission reduction needs for the Paris Agreement (Roe et al., 2019). Countries' biodiversity and climate strategies under the two Conventions should therefore develop integrated and coherent policies that cut across these domains, in particular through land-use planning which accounts for spatial heterogeneity.

Table 1 summarizes how South Africa's Nationally Determined Contribution (NDC) and Long-Term Low Emissions Development Strategy treat the FABLE domains. According to the NDC, South Africa has committed to plateauing and reducing emissions starting from 2025, before which the country will increase emissions and peak at 614 MT CO_2. Although South Africa's NDC includes emissions reductions from agriculture, forestry, and other land use (AFOLU), and considers the land sector to be a net carbon sink, it also entails uncertainty about how the emission reductions from these sectors will be achieved. The current estimates are that grasslands and savannas hold three quarters of the country's carbon stocks, making them significant contributors to the national greenhouse gas budget (DEA, 2015a). South Africa is working to reduce this uncertainty in the data over time, with a view to arrive at a comprehensive

Table 1 | Summary of the mitigation target, sectoral coverage, and references to biodiversity and spatially-explicit planning in current NDC

	Total GHG Mitigation					Mitigation Measures Related to AFOLU (Y/N)	Mention of Biodiversity (Y/N)	Inclusion of Actionable Maps for Land-Use Planning[1] (Y/N)	Links to Other FABLE Targets
	Baseline		Mitigation target		Sectors included				
	Year	GHG emissions (Mt CO_2e/yr)	Year	Target					
NDC (2015)	N/A	N/A	2025-2030	398-614 Mt CO_2e	Energy, industrial processes & product use, forestry, agriculture, and other land use	N	Y	N	Food security, water, afforestation
LT-LEDS (2020)	N/A	N/A	2025-2030 (398-614 Mt CO_2e)	2050 (212 - 428 Mt CO_2e)	Forestry, agriculture	Y	Y	N	

Note. "Total GHG Mitigation" and "Mitigation Measures Related to AFOLU" columns are adapted from IGES NDC Database (Hattori, 2019)
Source. South Africa's Department of Environmental Affairs (2015b, 2020)

1 We follow the United Nations Development Programme definition, "maps that provide information that allowed planners to take action" (Cadena et al., 2019).

accounting approach for land-based emissions and removals. According to the 2015 climate change sector plan, agriculture, forestry and fisheries mitigation options include the development and implementation of policies addressing conversion of land from sink to sources, reducing enteric fermentation, reducing tillage, and reducing fossil fuel dependence in the sector (DAFF, 2015a).

Table 2 provides an overview of the targets included in the National Biodiversity Strategies and Action Plan (NBSAP) from 2016 (DEA, 2016a), as listed on the CBD website (CBD, 2020) which are related to at least one of the FABLE Targets. In comparison with FABLE Targets, the NBSAP targets have a social-ecological perspective, ranging from protected area expansion, to expanding the bio economy and public awareness raising.

Table 2 | Overview of the latest NBSAP targets in relation to FABLE Targets

NBSAP Target	FABLE Target
(1.1) **The network of protected areas and conservation areas includes a representative sample of ecosystems and species and is coherent and effectively managed. This protected network has increased to 9% of total land in 2018 (about 109 800km^2).** **Areas protected under Protected Areas Act: By 2028, 10.8 million land-based hectares are protected.** **The South African national protected area strategy (2016) sets a target of 413 163km2 to meet long-term protected area targets. The medium-term goal of this strategy is to add 255 877km^2 for both marine and terrestrial protection to the protected area network by 2036. Of this, 146 814km^2 is required for terrestrial systems (a 133% increase from the current 108 900 km^2 protected area network). The long-term strategy aims to increase protected areas by an additional 413 163km^2 (Balfour, Holness, Jackelman, & Skowno, 2016).**	**BIODIVERSITY:** At least 30% of global terrestrial area protected by 2030

Brief Description of National Pathways

Among possible futures, we present two alternative pathways for reaching sustainable objectives, in line with the FABLE Targets, for food and land-use systems in South Africa.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by low population growth (from 58 million in 2020 to 67 million in 2050), no agricultural expansion, no afforestation target, low productivity increases in the agricultural sector, an evolution towards a high-sugar-content and processed-food diet (including meats and fat), and no change in postharvest losses (see Annex 1). This corresponds to a future based on current policy, risks, and historical trends that would also see considerable progress with regards to biodiversity loss, urbanization, and soil degradation (von Bormann, 2019). Moreover, as with all FABLE country teams, we embed this Current Trends Pathway in a global GHG concentration trajectory that would lead to a radiative forcing level of 6 W/m^2 (RCP 6.0), or a global mean warming increase *likely* between 2°C and 3°C above pre-industrial temperatures, by 2100. Our model includes the corresponding climate change impacts on crop yields by 2050 for corn, rice, soyabean, and wheat (see Annex 1).

Our Sustainable Pathway represents a future in which significant efforts are made to adopt sustainable policies and practices and corresponds to an intermediate boundary of feasible action. Compared to the Current Trends Pathway, we assume that this future would lead to lower food loss but will also lead to a similar trajectory in population growth, agricultural expansion, and no afforestation target (see Annex 1). This corresponds to a future based on the adoption and implementation of new ambitious policies that would also see considerable progress with regards to reductions in food losses motivated by economic cost, input losses, and social pressure (Nahman, de Lange, Oelofse, & Godfrey, 2012; von Bormann et al., 2017). Although an unlikely pathway by 2050 for South Africa due to the required reduction in meat, we also include the healthy diet scenario recommended in the EAT-*Lancet* for the Sustainable Pathway. With the other FABLE country teams, we embed this Sustainable Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m^2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.
Land and Biodiversity

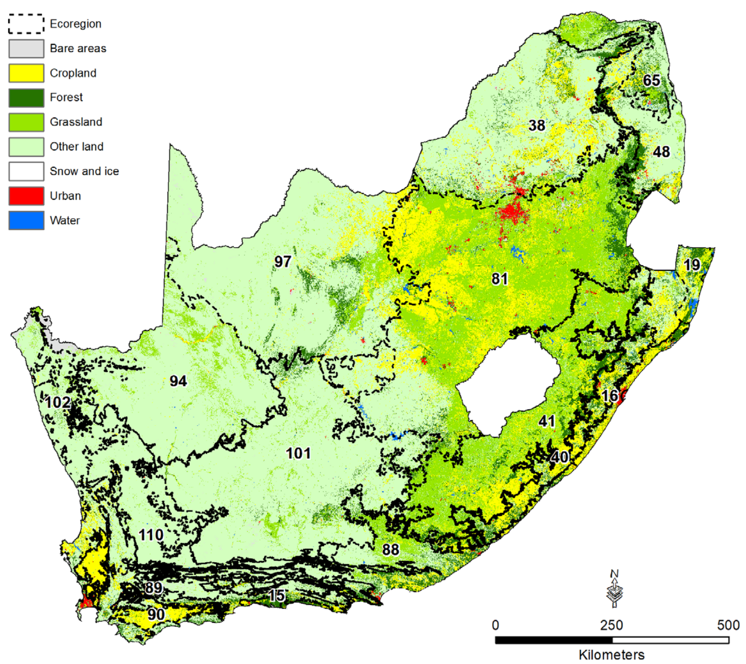
Land and Biodiversity

Current State

In 2010, South Africa was covered by 10% cropland, 69% grassland, 8% forest, 1% urban, and 12% other natural land (Map 1). Agricultural areas overlap with most natural areas and remain a major source of biodiversity loss, with land clearing for croplands being a key driver alongside human settlements, plantation forestry, mining, and infrastructure development (Skowno et al., 2019).

We estimate that land where natural processes predominate[2] accounted for 44% of South Africa's terrestrial land area in 2010 (Map 2). The 81-Highveld grasslands hold the greatest share of land where natural processes predominate, followed by 97-Kalahari xeric savanna and 101-Nama karoo shrublands (Table 3). Across the country, while 10 Mha of land is under formal protection, falling short of the 30% zero-draft CBD post-2020 target, only 15% of land where natural processes predominate is formally protected. The country's National Biodiversity Assessment report shows that areas of poor ecosystem condition – defined by combining biodiversity information with human pressures such as mining, human settlements, and agriculture – occur across all ecosystems in the country (Skowno et al 2019).

Map 1 | Land cover by aggregated land cover types in 2010 and ecoregions

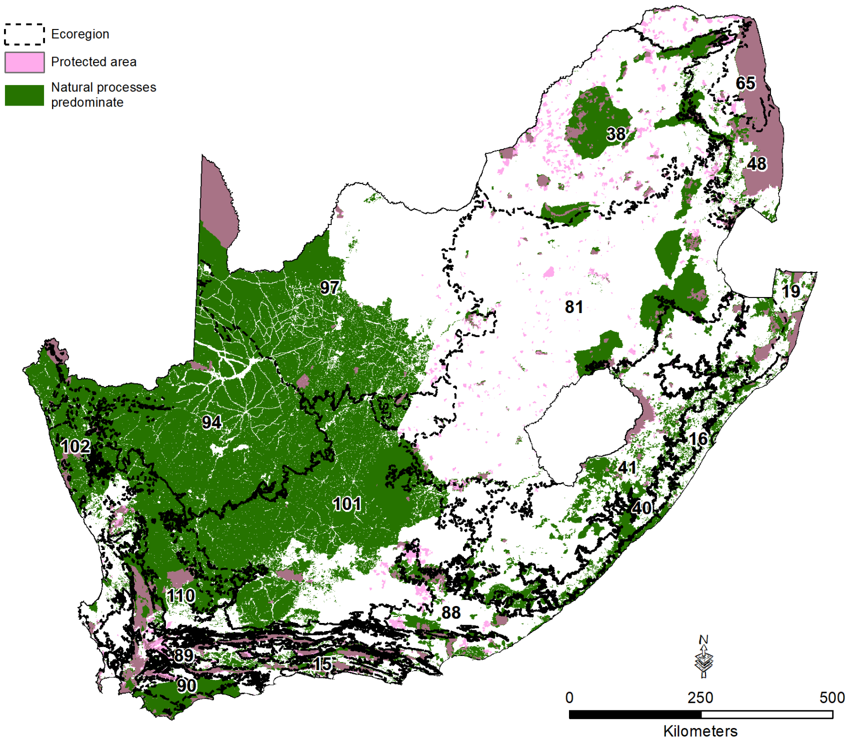


Note. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on the map can be found in Annex 2.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – ESA CCI land cover 2015 (ESA, 2017)

2 We follow Jacobson, Riggio, Tait, and Baillie (2019) definition: "Landscapes that currently have low human density and impacts and are not primarily managed for human needs. These are areas where natural processes predominate, but are not necessarily places with intact natural vegetation, ecosystem processes or faunal assemblages".

Approximately 62% of South Africa's cropland was in landscapes with at least 10% natural vegetation in 2010. These relatively biodiversity-friendly croplands are most widespread in 81-Highveld grasslands, followed by 41-Drakensberg grasslands and 38-Central bushveld. The regional differences in extent of biodiversity-friendly cropland can be explained by intensive production of key crops and extensive production of livestock.

Map 2 | Land where natural processes predominated in 2010, protected areas and ecoregions



Note. Protected areas are set at 50% transparency, so on this map dark purple indicates where areas under protection and where natural processes predominate overlap.
Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International (2019), intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

Table 3 | Overview of biodiversity indicators for the current state at the ecoregion level[3]

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with >10% Natural Vegetation within 1km² (%)
101	Nama Karoo shrublands	16224.2	2.3	62.1	1.8	98.2	238.3	69.3
102	Namaqualand-Richtersveld steppe	3292	6.3	78.3	7.8	92.2	17.9	90.1
110	Succulent Karoo xeric shrublands	5719.1	6.1	63.9	8.3	91.7	89	75
116	Southern Africa mangroves	85.2	13.8	53.2	25	75	7.2	88.7
15	Knysna-Amatole montane forests	205.7	35.6	50.4	62.4	37.6	38.7	45.7
16	Kwazulu Natal-Cape coastal forests	1098.4	3.4	50.4	6.1	93.9	329.4	58.4
19	Maputaland coastal forests and woodlands	908.9	24.5	43	55.5	44.5	120.9	87.4
38	Central bushveld	11698.1	10.3	22.2	21.7	78.3	1187.5	72.7
40	Drakensberg Escarpment savanna and thicket	3508.1	0.6	30.5	1.4	98.6	483.6	81.1
41	Drakensberg grasslands	9416.1	4.7	24.8	16.6	83.4	1446.1	83.9
48	Limpopo lowveld	4927.8	30.2	44.2	64.6	35.4	439	79.8
65	Zambezian mopane woodlands	2649.3	46.5	42.2	94.8	5.2	106.9	90
66	Zambezian-Limpopo mixed woodlands	0.06	100	100	100	0	0.01	100
81	Highveld grasslands	22878.8	3.9	13.1	14.1	85.9	5475.9	56.2
88	Albany thickets	3680.9	12.6	32	25.4	74.6	260.7	77.1
89	Fynbos shrubland	5377.7	31.9	51.5	51.2	48.8	630.3	64.6
90	Renosterveld shrubland	2843.8	3	41.6	4.7	95.3	1140.9	27.8
94	Gariep Karoo	10981.4	1.5	91.7	1.6	98.4	77.3	80.5
97	Kalahari xeric savanna	16859	7.1	54.3	12.1	87.9	1266.2	55.2

Sources. countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); cropland, natural and semi-natural vegetation – ESA CCI land cover 2015 (ESA, 2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International 2019, intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

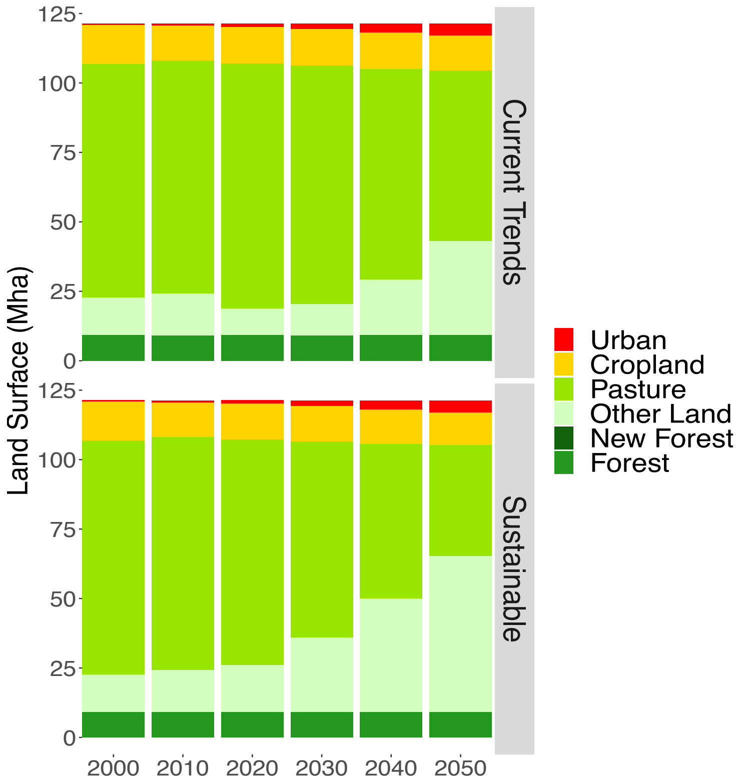
3 The share of land within protected areas and the share of land where natural processes predominate are percentages of the total ecoregion area (counting only the parts of the ecoregion that fall within national boundaries). The shares of land where natural processes predominate that is protected or unprotected are percentages of the total land where natural processes predominate within the ecoregion. The share of cropland with at least 10% natural vegetation is a percentage of total cropland area within the ecoregion.

Pathways and Results

Projected land use in the Current Trends Pathway is based on several assumptions, including constraints on the expansion of agricultural land beyond its current area, and no planned afforestation (see Annex 1).

By 2030, we estimate that the main changes in land cover in the Current Trends Pathway will result from an increase in pasture area and cropland, and a decrease in other land areas. This trend evolves over the period 2030-2050: other land areas increases dramatically while cropland and pasture areas decrease, with pastures declining significantly (Figure 1). The expansion of the planted area for sunflower and wheat explain 96% of total cropland expansion between 2010 and 2030. For sunflower, 100% of the expansion in demand is explained by non-food consumption and the expansion in supply is explained by an increase of 193% in production. For wheat, the increase in productivity and production is the main cause for the supply increase, while the rise in demand is driven by food consumption (79%) and feed (17%). Pasture decline is mainly driven by the decrease in cattle, while livestock productivity per head increases and ruminant density per hectare of pasture remains constant over the period 2020-2030. The increase in pasture between 2010 and 2030 is due mainly to an increase in the production of milk for food consumption. Between 2030-2050, a decrease in planted area is explained by a decrease in demand for wheat used as food (151%), while a decrease in pasture land is explained by a decrease in beef consumption from 149 kt to 57.9kt. This results in a reduction of land where natural processes predominate by -1% by 2030 and expansion by 42% in 2050 compared to 2010, respectively.

Figure 1 | Evolution of area by land cover type and protected areas under each pathway

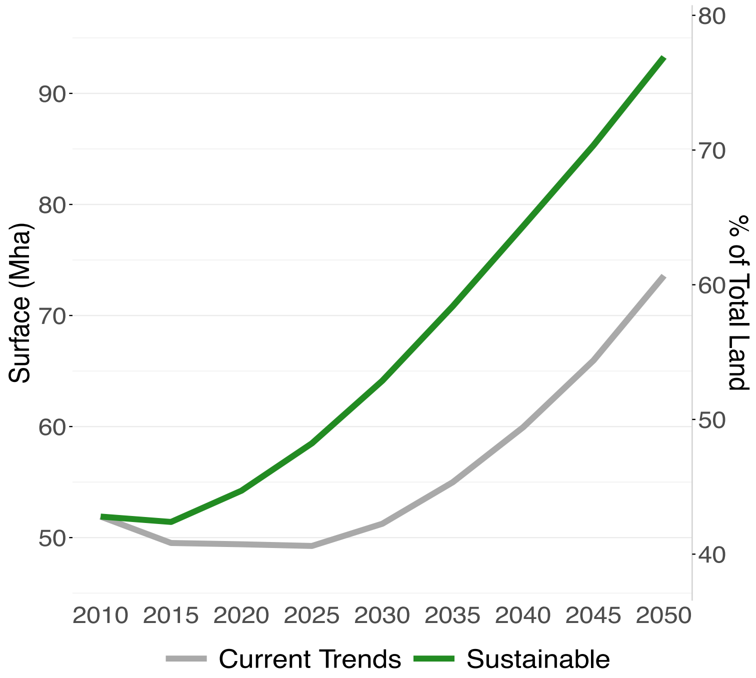


Source: Authors' computation based on FAOSTAT (FAO, 2020) for the area by land cover type for 2000.

In the Sustainable Pathway, the diet assumption is based on a hypothetical extreme, radical change (as far as meat consumption in the region), which may not be feasible given the vast suitability of South Africa for livestock production (see Annex 1).

Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in South Africa in the Sustainable Pathway: (i) no impact on deforestation, reforestation or afforestation in either pathways, (ii) a larger increase in other land during 2030 – 2050 compared to the decline in 2010 – 2030 in the Current Trends Pathway, (iii) a more dramatic decrease in pastures and a moderate decrease in cropland. In addition to the changes in assumptions regarding land-use planning, these changes compared to the Current Trends Pathway are explained by a reduction in demand for milk and beef and the reduction in the production of these products. This leads to an increase in the area where natural processes predominate: the area stops declining by 2015 and increases by a staggering 80% between 2030 and 2050 (Figure 2).

Figure 2 | Evolution of the area where natural processes predominate

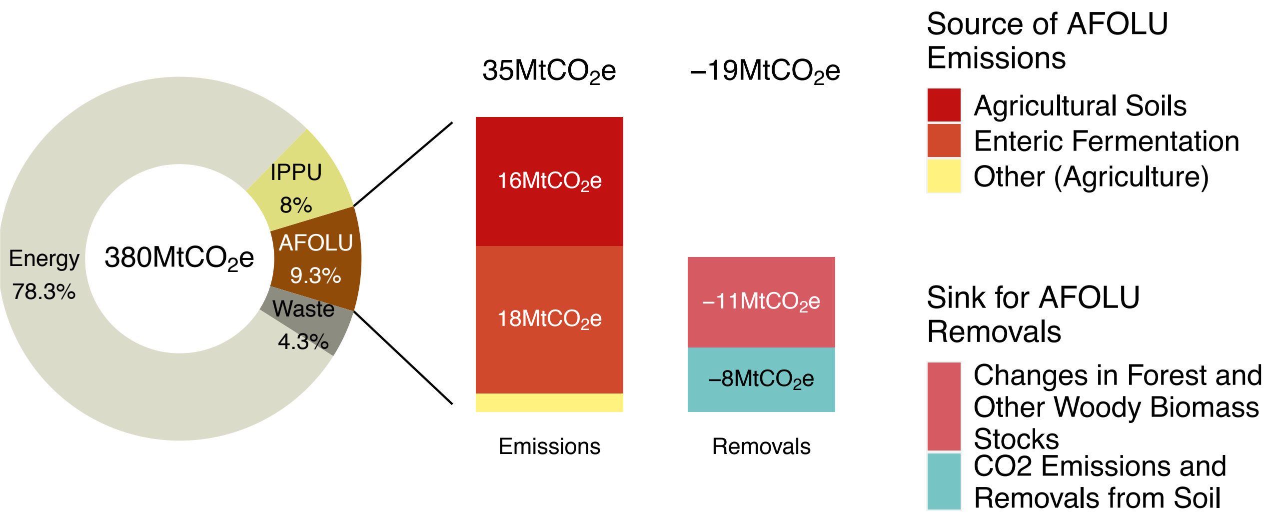


GHG emissions from AFOLU

Current State

Direct GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) accounted for 9.3% of total emissions in 1994 (Figure 3). Enteric fermentation is the principle source of AFOLU emissions, followed by agricultural soils and manure management. This can be explained by the large numbers of herds in South Africa, and the widespread suitability of land for livestock (69%) compared to 11% for crops (DEA, 2016b).

Figure 3 | Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total AFOLU emissions and removals by source in 1994



Note. IPPU = Industrial Processes and Product Use
Source. Adapted from GHG National Inventory (UNFCCC, 2020)

Pathways and Results

Under the Current Trends Pathway, annual GHG emissions from AFOLU decrease to 14.1 Mt CO_2e/yr in 2030, before dropping significantly to -96.6 Mt CO_2e/yr in 2050 (Figure 4). In 2050, CH_4 emissions from livestock is the largest source of emissions (12.1 Mt CO_2e/yr) while carbon sequestration from vegetation becomes a sink (-129.4 Mt CO_2e/yr). Over the period 2020-2050, the strongest relative increase in GHG emissions is computed for N_2O from crops (7%) while a staggering reduction in emissions is computed for carbon sequestration from vegetation (550%).

In comparison, the Sustainable Pathway leads to a reduction of AFOLU GHG emissions by -85% in 2050, compared to the Current Trends Pathway (Figure 4). The potential emissions reductions under the Sustainable Pathway is dominated by carbon sequestration from vegetation and livestock (Figure 5). Reduction in milk for food and livestock production are the most important drivers of this reduction.

Reductions in GHG emissions could be achieved in large part through the decrease in milk and meat consumption. These measures could be particularly important when considering that AFOLU baselines are still not clearly defined (DEA, 2016b)), and that these targets can potentially be incorporated into the current process to enhance the NDC.

Figure 4 | Projected AFOLU emissions and removals between 2010 and 2050 by main sources and sinks for the Current Trends Pathway

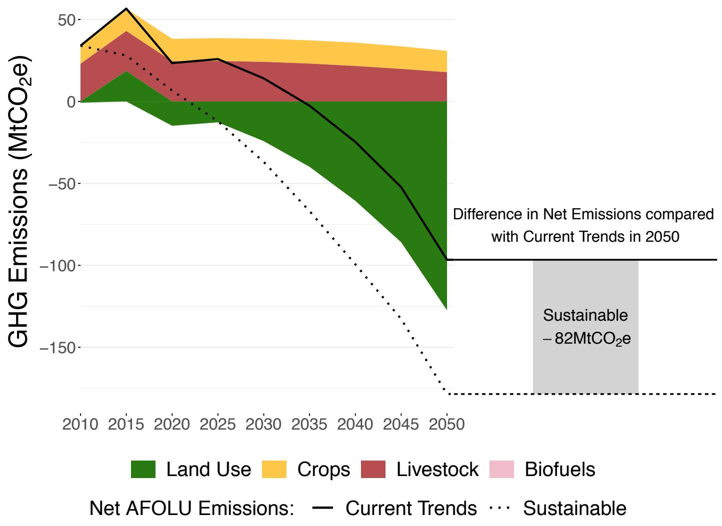
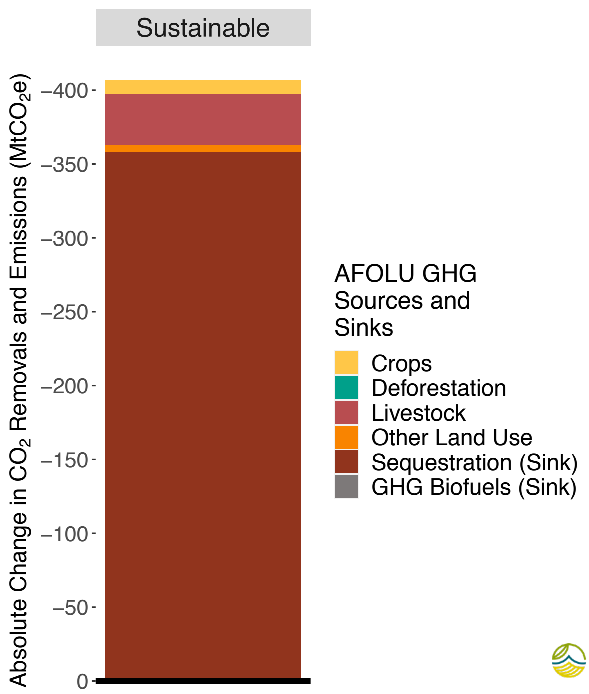


Figure 5 | Cumulated GHG emissions reduction computed over 2020-2050 by AFOLU GHG emissions and sequestration source compared to the Current Trends Pathway



Food Security

Current State

The "Triple Burden" of Malnutrition

Undernutrition

6.1% of the population undernourished in 2015-2017. This share has increased from 4.5% since 2008-2010 (FAO, 2020).

27.4% of children under 5 stunted and 2.5% wasted in 2016 (World Bank, 2016a, 2016b)

Micronutrient Deficiency

25.8% of women and 36.8% of children under 5 suffer from anemia in 2016, which can lead to maternal death (WHO, 2020).

Around 18.9% of pregnant women and 16.9% of children had a poor vitamin A status in 2005 (Ritchie, 2017)

Overweight/ Obesity

28.3% of adults were obese in 2016 (Ritchie, 2017). These shares have increased since 1990 (Ritchie, 2017).

51.9% of adults and 31.8% of children were overweight in 2016 (Global Nutrition Report, 2019). These shares have increased since 2000 (Ritchie, 2017)

Disease Burden due to Dietary Risks

9.4% of deaths are attributable to dietary risks (Institute for Health Metrics and Evaluation, 2020)

12.7% of the adult population suffers from diabetes (World Bank, 2019)

9.4% of premature deaths were attributed to obesity in 2017 (Ritchie, 2017)

Table 4 | Daily average fats, proteins and kilocalorie intake under the Current Trends and Sustainable Pathways in 2030 and 2050

	2010	2030		2050	
	Historical Diet (FAO)	Current Trends	Sustainable	Current Trends	Sustainable
Kilocalories (MDER)	2,958 (1,827)	3,009 (1,845)	2,812 (2,073)	3,060 (1,852)	2,665 (2,079)
Fats (g) (recommended range)	79 (66-99)	91 (68-100)	78 (62-94)	106 (68-102)	78 (59-88)
Proteins (g) (recommended range)	81 (74-259)	82 (75-263)	78 (70-246)	87 (76-268)	77 (66-233)

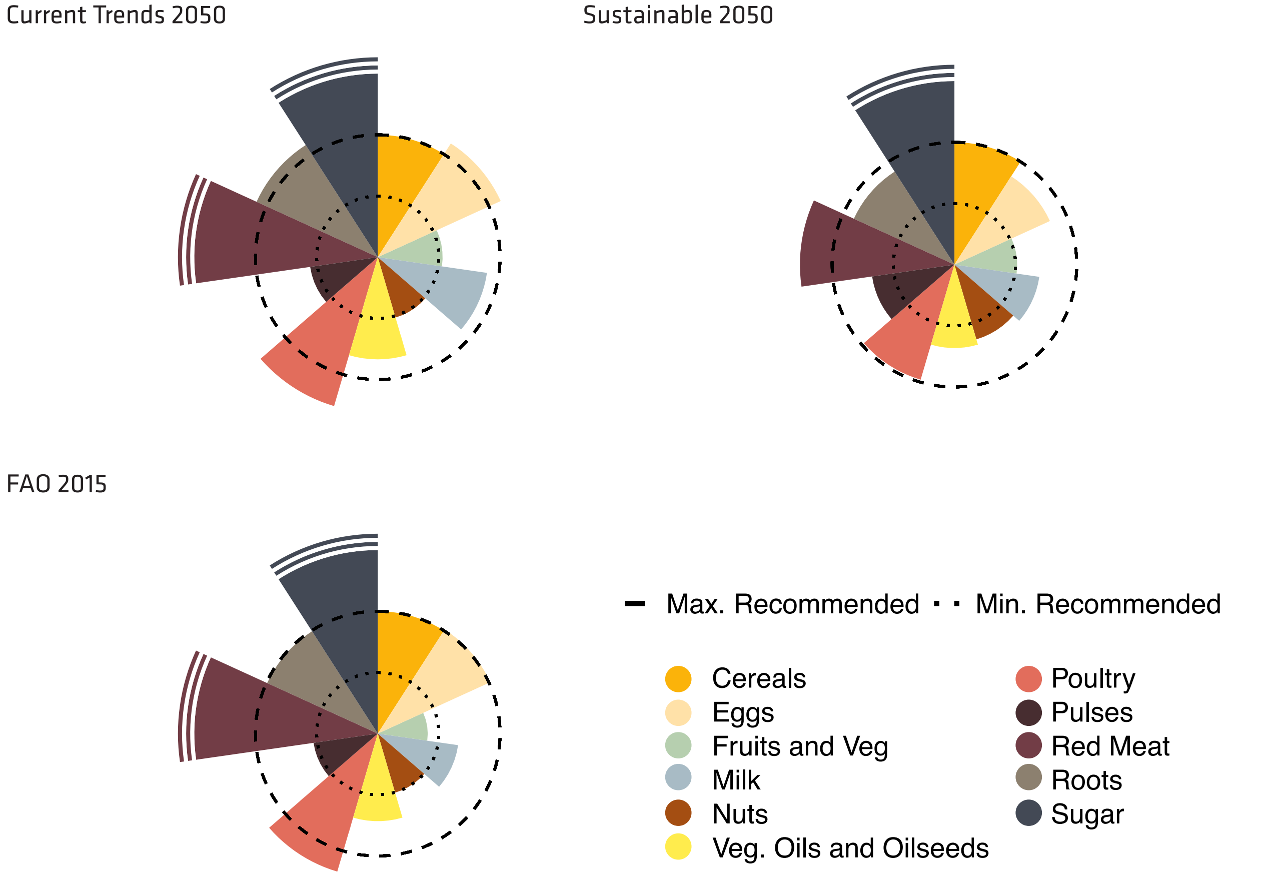
Notes. Minimum Dietary Energy Requirement (MDER) is computed as a weighted average of energy requirement per sex, age class, and activity level (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) and the population projections by sex and age class (UN DESA, 2017) following the FAO methodology (Wanner et al., 2014). For fats, the dietary reference intake is 20% to 30% of kilocalories consumption. For proteins, the dietary reference intake is 10% to 35% of kilocalories consumption. The recommended range in grams has been computed using 9 kcal/g of fats and 4kcal/g of proteins.

Pathways and Results

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 57% higher in 2030 and 64% higher in 2050 (Table 4). The current average intake is mostly satisfied by cereals, oils, and sugar, and animal products represent 16% of the total calorie intake. We assume that the consumption of animal products, and in particular milk, will increase by 77% and pork by 56% between 2020 and 2050. The consumption of nuts (90%), beverages and spices (51%), fruits and vegetables (38%) will also increase while cereals and red meat consumption will decrease. Compared to the EAT-*Lancet* recommendations (Willett et al., 2019), red meat, sugar, poultry, eggs, and roots are over-consumed in 2050 (Figure 6). Moreover, fat and protein intake per capita are in line with the dietary reference intake (DRI) in 2030, although fat exceeds the dietary reference intake (DRI) in 2050. This can be explained by an increase in consumption of milk and pork between 2020 – 2050 (Figure 6).

Under the Sustainable Pathway, we assume that diets will transition towards the EAT-*Lancet* diet (Willett et al., 2019). The ratio of the computed average intake over the MDER decreases to 34% in 2030 and 27% in 2050 under the Sustainable Pathway. Compared to the EAT-*Lancet* recommendations, only the consumption of sugar and red meat remains outside of the recommended range with the consumption of poultry, eggs, and roots being within the range (Figure 6). Moreover, the fat and protein intake per capita are within the recommended ranges in 2030 and 2050, showing some improvement compared to the Current Trends Pathway. This diet was mainly selected for illustrative purposes as it is unlikely to fit the South African context.

Figure 6 | Comparison of the computed daily average kilocalorie intake per capita per food category across pathways in 2050 with the EAT-*Lancet* recommendations



Notes. These figures are computed using the relative distances to the minimum and maximum recommended levels (i.e. the rings), therefore different kilocalorie consumption levels correspond to each circle depending on the food group. The EAT-Lancet Commission does not provide minimum and maximum recommended values for cereals: when the kcal intake is smaller than the average recommendation it is displayed on the minimum ring and if it is higher it is displayed on the maximum ring. The discontinuous lines that appear at the outer edge of sugar and red meat indicate that the average kilocalorie consumption of these food categories is significantly higher than the maximum recommended.

Water

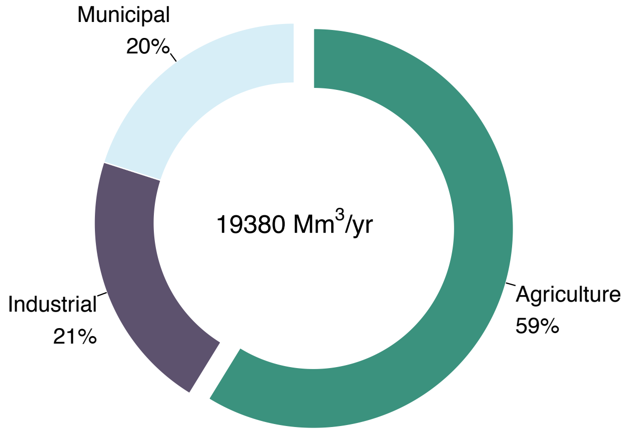
Current State

South Africa is characterized as a water scarce country with 470 mm average annual precipitation. The agricultural sector represented 60% of total water withdrawals in 2017 (Figure 7; FAO, 2017). The three most important irrigated crops, corn, wheat, and sugarcane account for 48%, 18%, and 14% of total harvested irrigated area. South Africa exported 11% of corn in 2015, and 75% of sugar in 2016.

Pathways and Results

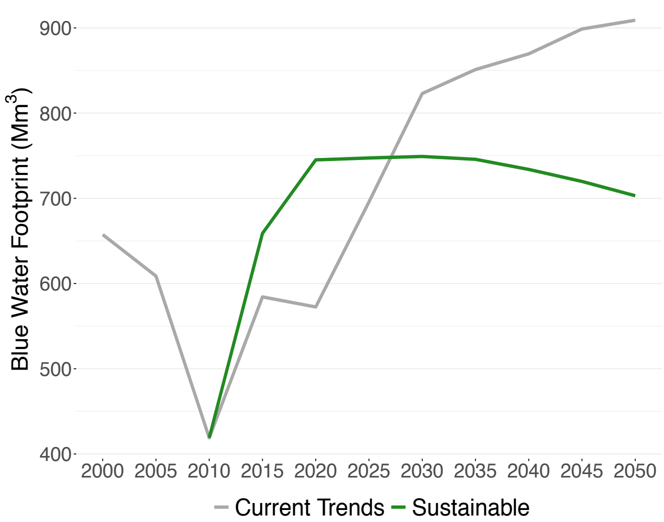
Under the Current Trends Pathway, annual blue water use decreases between 2000-2015 (657 and 584 Mm³/yr), before increasing to 823 Mm³/yr in 2030 and 909 Mm³/yr in 2050, respectively (Figure 8), with wheat, oats, and barley accounting for 78%, 9%, and 7% of computed blue water use for agriculture by 2050[4]. In contrast, under the Sustainable Pathway, the blue water footprint in agriculture decreases and reaches 749 Mm³/yr in 2030 and 703 Mm³/yr in 2050, respectively. This is explained by a rise in imports of beans and pulses, an increase in productivity of soybeans, and a decrease in the production of corn and sugarcane.

Figure 7 | Water withdrawals by sector in 2016



Source. Adapted from AQUASTAT Database (FAO, 2017)

Figure 8 | Evolution of blue water footprint in the Current Trends and Sustainable Pathways



4 We compute the blue water footprint as the average blue fraction per ton of product times the total production of this product. The blue water fraction per ton comes from Mekonnen and Hoekstra (2010a, 2010b, 2011). In this study, it can only change over time because of climate change. Constraints on water availability are not taken into account.

Resilience of the Food and Land-Use System

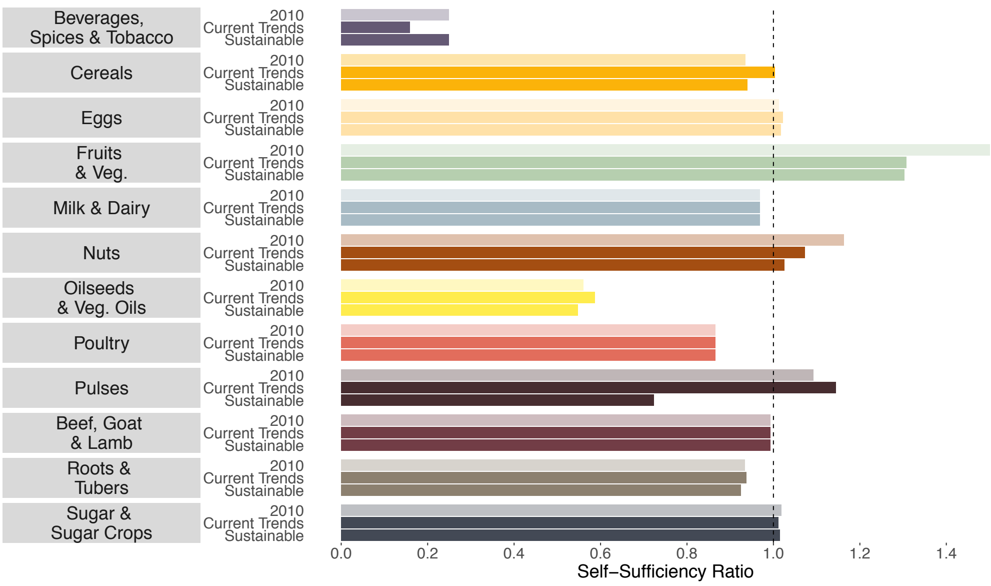
The COVID-19 crisis exposes the fragility of food and land-use systems by bringing to the fore vulnerabilities in international supply chains and national production systems. Here we examine two indicators to gauge South Africa's resilience to agricultural-trade and supply disruptions across pathways: the rate of self-sufficiency and diversity of production and trade. Together they highlight the gaps between national production and demand and the degree to which we rely on a narrow range of goods for our crop production system and trade.

Self-Sufficiency

In 2010, South Africa was not self-sufficient in one of its main staple crops: corn. This is significant because a large part of the population depends on this crop for daily use. Interestingly, South Africa is self-sufficient in fruits and vegetables, which are primarily export oriented.

Under the Current Trends Pathway, we project that South Africa would be self-sufficient in fruits and vegetables, pulses, nuts, eggs, sugar, and cereals (cereals only in 2050), with self-sufficiency by product group remaining stable for the majority of products from 2010–2050 (Figure 9). The product groups where the country depends the most on imports to satisfy internal consumption are beverages, spices and tobacco, and oilseeds and vegetable oils, and this dependency will remain relatively stable until 2050. In contrast, under the Sustainable Pathway, South Africa remains self-sufficient in fruits and vegetables, nuts, sugar, and eggs but would no longer be self-sufficient in pulses and cereals by 2050, representing lower self-sufficiency.

Figure 9 | Self-sufficiency per product group in 2010 and 2050



Note. In this figure, self-sufficiency is expressed as the ratio of total internal production over total internal demand. A country is self-sufficient in a product when the ratio is equal to 1, a net exporter when higher than 1, and a net importer when lower than 1.

Diversity

The Herfindahl-Hirschman Index (HHI) measures the degree of market competition using the number of firms and the market shares of each firm in a given market. We apply this index to measure the diversity/concentration of:

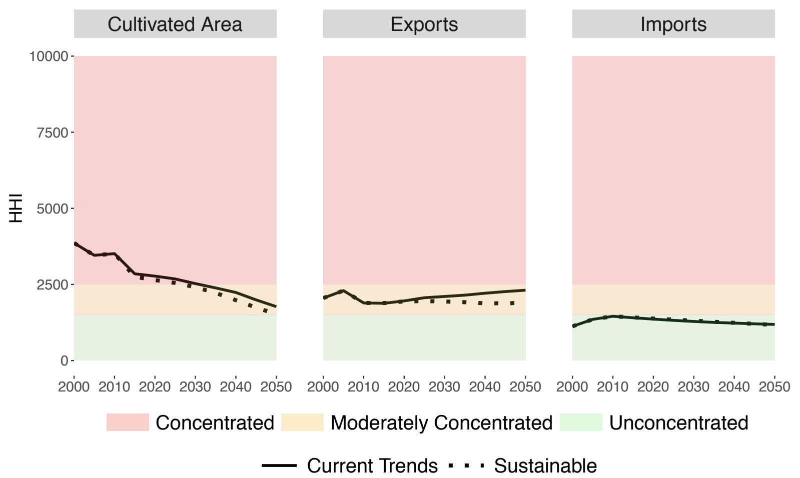
- **Cultivated area:** where concentration refers to cultivated area that is dominated by a few crops covering large shares of the total cultivated area, and diversity refers to cultivated area that is characterized by many crops with equivalent shares of the total cultivated area.
- **Exports and imports:** where concentration refers to a situation in which a few commodities represent a large share of total exported and imported quantities, and diversity refers to a situation in which many commodities account for significant shares of total exported and imported quantities.

We use the same thresholds as defined by the U.S. Department of Justice and Federal Trade Commission (2010, section 5.3): diverse under 1,500, moderate concentration between 1,500 and 2,500, and high concentration above 2,500.

According to the HHI, cultivated area for crops was highly concentrated in 2010. During the same period, imports were highly diversified while exports were moderately diversified.

Under the Current Trends Pathway, we project medium concentration of crop exports, low concentration of crop imports, and medium concentration of planted crops in 2050. Exports and imports remain relatively stable, with exports remaining moderately concentrated and imports remaining unconcentrated from 2010 to 2050. This indicates moderate levels of diversity for exports and high levels of diversity for imports. Planted crop area changes from high concentration in 2010 to moderate concentration by 2050. Under the Sustainable Pathway, we project similar concentration of exports with a slight decrease in diversity of exports. Similarly, there is no change in the concentration of imports, while planted crops become more diverse (moderate concentration) in 2050, compared to the Current Trends Pathway (Figure 10). The change in concentration of planted area is explained by the reduction of consumption of milk and beef, substituted by increased consumption of nuts and pulses, and a decrease in the production of main crops (corn and sugarcane).

Figure 10 | Evolution of the diversification of the cropland area, crop imports and crop exports of the country using the Herfindahl-Hirschman Index (HHI)



Discussion and Recommendations

The two pathways described in this chapter represent a comparison between the Current Trends, which illustrates the implementation of a few current policies but not all (e.g. no protected area expansion; and medium Sustainable Pathway, which shows the implementation of several current and aspired policy targets. Both pathways lead to a reduction in land needed for agriculture in 2050, an increase in biodiversity protection, and reductions in emissions from the AFOLU sectors. The changes in biodiversity and GHG emissions are driven by a dietary shift, exemplified in the adoption of the EAT-Lancet recommended diet (Willett et al., 2019). While this recommended diet might not fit with the South African context where much of the land is suitable for livestock production, it is nevertheless an interesting exercise to explore what the implementation of this diet could mean for the country.

The South African protected area strategy aims to increase the terrestrial protected area by an additional 146,814 km^2 by 2036 (the 20-year target period from the publication of the strategy) (Balfour et al., 2016). This is a 133% increase from today's 108,900 km^2, and an increase from 10% of total land in 2018 to 21% by the 2030s. This will require unprecedented efforts in the design and implementation of policies. It is obviously a tall order but not entirely insurmountable. For example, during the period 2010 – 2018, South Africa's terrestrial mainland protected area increased by 11%. To achieve this new target, the protected area network will have to grow by similar rates over the next 15 years.

The FABLE Calculator estimates that by 2035, protected areas could grow by up to 117,860 km^2, which is only 28,954 km^2 short of the target expressed in the protected area expansion strategy. When we account for land where natural processes predominate, an additional 64,677 km^2 becomes available for biodiversity conservation – even though this land is outside of protected areas. This highlights the importance of conservation beyond protected areas. Both the intention to incorporate these areas into formal protection as expressed by the protected area expansion strategy (Balfour et al., 2016) and the fact that biodiversity intactness scores in South Africa are high in rangelands (Biggs, Reyers, & Scholes, 2006), attest to this importance.

South Africa does not have an explicit baseline to start reducing GHG emissions included in the Nationally Determined Contribution (NDC) but it has a target to reduce GHG emissions to between 398 Mt CO_2e and 614 Mt CO_2e over the period 2025 – 2030. Although there is no explicit target for the AFOLU sector expressed in the NDC, the Department of Environmental Affairs started a process to define these targets (Department of Environmental Affairs, 2016; Stevens et al., 2016). The AFOLU emissions baselines defined for agriculture in this document indicate that emissions will continue to increase up to 2050, whereas the FABLE Calculator shows that up until 2030 (for the Current Trends Pathway) emissions from the sector will increase and then decline, with the decline starting earlier in 2020 for the Sustainable Pathway. The reason for this – as far as the model calculations and the baselines defined in the baseline documents are concerned – is that land-based emissions differ significantly between the two.

In the baseline document of the Department of Environmental Affairs, the capacity of land to sequester carbon ranges from 22.9 Mt CO_2e in 2010 to 32.4 Mt CO_2e in 2050 (DEA, 2016b). In contrast, the FABLE Calculator estimates the land to sequester 08 Mt CO_2e in 2010 and a staggering 127 Mt CO_2e in 2050 for the Current Trends Pathway; and up to 200 Mt CO_2e for the Sustainable Pathway. In the Current Trends Pathway, this decline is explained primarily by productivity gains in livestock production, which may be overstated. The productivity growth assumed to stay constant as 2000-2010 levels until 2050 might not be realistic. In addition to productivity gains, the Sustainable Pathway's declines in pastures are further explained by the significant decreases in meat and milk consumption determined by the shift towards the EAT-Lancet recommended diet, which will require a substantial adjustment to the South African diet. The emissions declines are therefore directly explained by the reduction in herd size, reducing enteric fermentation which accounts for 60% of agricultural emissions in South Africa (DEA, 2016b).

Most changes in land use in the Sustainable Pathway were driven by the change in diet, which reduced the amount of beef consumption and other animal products such as milk. Given that this diet might not be feasible for South Africa, the next steps will be to define a diet scenario that is feasible in the South African national context. Changes driven by a diet that respects this context will reflect more feasible (and realistic) changes in reaching emissions and biodiversity targets. Currently, much of the potential biodiversity and emissions gains depend significantly on the chosen diet. Overall, the pathways defined for South Africa did not benefit from a broader stakeholder engagement (due to COVID-19 primarily). Therefore, it would be beneficial for future projections to consult relevant stakeholders to guide the selection of scenarios.

Annex 1. Underlying assumptions and justification for each pathway

POPULATION Population projection (million inhabitants)

Current Trends Pathway	Sustainable Pathway
The population is expected to reach 67 million by 2050 (UN DESA, 2019). (SSP2 scenario selected)	

LAND Constraints on agricultural expansion

Current Trends Pathway	Sustainable Pathway
We assume no expansion of agricultural land beyond 2010 agricultural area levels. (No productive land expansion beyond 2010 value) (BFAP 2018)	

LAND Afforestation or reforestation target (1000 ha)

We do not expect afforestation/reforestation
(DEA, 2015a; Driver et al. 2015).

BIODIVERSITY Protected areas (1000 ha or % of total land)

Current Trends Pathway	Sustainable Pathway
Protected areas remain stable: by 2050 they represent 10 million ha. (Skowno et al 2019, 2019).	Protected areas increase to 13 million ha in 2050. We used the by-default assumption in the FABLE Calculator which is that in the ecoregions where current level of protection is between 5% and 17%, the natural land area under protection increases up to 17% of the ecoregion total natural land area by 2050.

PRODUCTION Crop productivity for the key crops in the country (in t/ha)

Current Trends Pathway

In the calculator, we obtain the following values of crop productivity by 2050:
- 11.31 tons per ha for corn.
- 2.71 tons per ha for wheat.
- 2.22 tons per ha for soybean.

According to other sources, by 2050 crop productivity reaches:
- 6 tons per ha by 2030 for white maize; 6.5 per ha by 2030 for yellow maize.
- 5.5 tons per ha by 2030 for wheat for summer area, and 3 tons per ha by 2030 for winter area.
- Soybean is projected to grow by 2.2% per annum based on current trajectories.

(Balfour, 2016; BFAP 2018).

Sustainable Pathway

In the calculator, we obtain the following values of crop productivity by 2050:
- 9.89 tons per ha for corn.
- 2.79 tons per ha for wheat.
- 2.22 tons per ha for soybean.

According to other sources, by 2050 crop productivity reaches:
- 6 tons per ha by 2030 for white maize; 6.5 per ha by 2030 for yellow maize.
- 5.5 tons per ha by 2030 for wheat for summer area, and 3 tons per ha by 2030 for winter area.
- Soybean is projected to grow by 2.2% per annum based on current trajectories.

(Balfour, 2016; BFAP 2018).

PRODUCTION Livestock productivity for the key livestock products in the country (in t/head of animal unit)

By 2050, livestock productivity reaches:
- 0.2 t/head for cattle.
- 0.1 t/head sheep and goat.
- 2.0 t/head for pig.

(BFAP, 2018).

PRODUCTION Pasture stocking rate (in number of animal heads or animal units/ha pasture)

By 2050, the average ruminant livestock stocking density is 0.15 TLU/ha. (BFAP, 2018).

PRODUCTION Post-harvest losses

By 2050, the share of production and imports lost during storage and transportation is 33% (von Bormann et al 2017; Oelofse & Naham 2013).

TRADE Share of consumption which is imported for key imported products (%)

Current Trends Pathway

Sustainable Pathway

By 2050, the share of total consumption which is imported is:
- 100% for rice.
- 46% for wheat.
- 5% for sunflower.

(BFAP, 2018).

TRADE Evolution of exports for key exported products (tonnes)

Current Trends Pathway

In the calculator, we obtain the following 2050 values of exports:
- 2,699 tons for corn.
- 457 tons of apples.
- 167 tons of groundnut.

According to other sources, by 2050 the volume of exports is:
- 1286 tons for corn.
- 239 tons for apples.
- 138 tons for groundnut.

(DAFF, 2017).

Sustainable Pathway

In the calculator, we obtain the following 2050 values of exports:
- 2,699 tons for corn.
- 288 tons of lemons.
- 1,312 tons of oranges.

According to other sources, by 2050 the volume of exports is:
- 107 tons by 2050 for corn.
- 112 tons by 2050 for lemons.
- 61 tons by 2050 for oranges.

(DAFF, 2017).

FOOD Average dietary composition (daily kcal per commodity group or % of intake per commodity group)

Current Trends Pathway	Sustainable Pathway
In the calculator, by 2030, the average daily calorie consumption per capita is 3,009 kcal and is: • 1,367 kcal from cereals. • 377 kcal from oilseeds and vegetable oils. • 317 kcal from sugar. • 145 kcal from milk. According to other sources, by 2030, the average daily calorie consumption per capita is 3,060 kcal and is: • 438 kcal for cereals. • 269 kcal for fruits and vegetables. • 254 kcal for milk. • 99 kcal for poultry. (Vorster et al., 2013; Venter et al., 2013).	In the calculator, by 2030, the average daily calorie consumption per capita is 2,812 kcal and is: • 1,344 kcal from cereals. • 311 kcal from oilseeds and vegetable oils. • 277 kcal from sugar. • 94 kcal from milk. According to other sources, by 2030, the average daily calorie consumption per capita is 2,665 kcal and is: • 1,344 kcal for cereals. • 277 kcal for sugar. • 94 kcal for milk. • 115 kcal for poultry. (Willett et al., 2019).

FOOD Share of food consumption which is wasted at household level (%)

Scenario selected: Same share as in 2010. Source: Nahman et al 2012	Scenario selected: Reduced share compared to 2010. Source: No relevant information found for South Africa.

BIOFUELS Targets on biofuel and/or other bioenergy use

Current Trends Pathway	Sustainable Pathway
Scenario selected: Stable biofuel demand as 2010. Source: Pradhan and Mbhowa 2014; Blanchard et al 2011	

CLIMATE CHANGE Crop model and climate change scenario

Current Trends Pathway	Sustainable Pathway
By 2100, global GHG concentration leads to a radiative forcing level of 6 W/m2 (RCP 6.0). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO_2 fertilization effect.	By 2100, global GHG concentration leads to a radiative forcing level of 2.6 W/m2 (RCP 2.6). Impacts of climate change on crop yields are computed by the crop model GEPIC using climate projections from the climate model HadGEM2-E without CO_2 fertilization effect.

Annex 2. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on Map 1

FABLE classes	ESA classes (codes)
Cropland	Cropland (10,11,12,20), Mosaic cropland>50% - natural vegetation <50% (30), Mosaic cropland<50% - natural vegetation >50% (40)
Forest	Broadleaved tree cover (50,60,61,62), Needleleaved tree cover (70,71,72,80,82,82), Mosaic trees and shrub >50% - herbaceous <50% (100), Tree cover flooded water (160,170)
Grassland	Mosaic herbaceous >50% - trees and shrubs <50% (110), Grassland (130)
Other land	Shrubland (120,121,122), Lichens and mosses (140), Sparse vegetation (150,151,152,153), Shrub or herbaceous flooded (180)
Bare areas	Bare areas (200,201,202)
Snow and ice	Snow and ice (220)
Urban	Urban (190)
Water	Water (210)

Units

°C – degree Celsius

% – percentage

/yr – per year

cap – per capita

CO_2 – carbon dioxide

CO_2e – greenhouse gas expressed in carbon dioxide equivalent in terms of their global warming potentials

g – gram

GHG – greenhouse gas

Gt – gigatons

ha – hectare

kcal – kilocalories

kg – kilogram

km^2 – square kilometer

km^3 – cubic kilometers

kt – thousand tons

m – meter

Mha – million hectares

mm – millimeters

Mm^3 – million cubic meters

Mt – million tons

t – ton

TLU –Tropical Livestock Unit is a standard unit of measurement equivalent to 250 kg, the weight of a standard cow

t/ha – ton per hectare, measured as the production divided by the planted area by crop by year

t/TLU, kg/TLU, t/head, kg/head- ton per TLU, kilogram per TLU, ton per head, kilogram per head, measured as the production per year divided by the total herd number per animal type per year, including both productive and non-productive animals

USD – United States Dollar

W/m^2 – watt per square meter

yr – year

References

Balfour, D., Holness, S., Jackelman, J., & Skowno, A. (2016). National Protected Area Expansion Strategy of South Africa (p. 138). Pretoria, South Africa: Department of Environmental Affairs.

BFAP. (2018). Bureau for Food and Agricultural Policy Baseline: Agricultural Outlook 2018—2027. Bureau for Food and Agricultural Policy.

Biggs, R., Reyers, B., & Scholes, R. J. (2006). A biodiversity intactness score for South Africa: Science policy. South African Journal of Science, 102(7–8), 277–283.

BirdLife International. (2019). Digital boundaries of Important Bird and Biodiversity Areas from the World Database of Key Biodiversity Areas. Retrieved February 8, 2019, from BirdLife International website: http://datazone.birdlife.org/site/requestgis

Blanchard, R., Richardson, D. M., O'Farrell, P. J., & von Maltitz, G. P. (2011). Biofuels and biodiversity in South Africa. South African Journal of Science, 107(5–6), 19–26. https://doi.org/10.4102/sajs.v107i5/6.186

Cadena, M., Supples, C., Ervin, J., Marigo, M., Monakhova, M., Raine, P., & Virnig, A. (2019). Nature is counting on us: Mapping progress to achieve the Aichi Biodiversity Targets. United Nations Development Programme.

CBD. (2020). South Africa—National Targets. Retrieved May 8, 2020, from Convention on Biological Diversity website: https://www.cbd.int/countries/targets/?country=za

DEA. (2015a). South African National Terrestrial Carbon Sink Assessment. Department of Environmental Affairs. https://www.environment.gov.za/sites/default/files/reports/nationalterrestrial_carbonsinks_synopsisreport.pdf

DEA. (2015b). South Africa's Intended Nationally Determined Contribution. Department of Environmental Affairs. https://www.environment.gov.za/sites/default/files/docs/sanational_determinedcontribution.pdf

DEA. (2016a). South Africa's National Biodiversity Strategy and Action Plan 2015—2025. Department of Environmental Affairs. https://www.environment.co.za/wp-content/uploads/2018/08/SA_national_biodiversity_strategy_action_plan_2015_2025.pdf

DEA. (2016b). Towards the development of a GHG emissions baseline for the agriculture, forestry, and other land use (AFOLU) sector in South Africa. Department of Environmental Affairs. https://www.environment.gov.za/sites/default/files/docs/afolu_research_report.pdf

DEA. (2020). South Africa's Low Emission Development Strategy 2050. Department of Environmental Affairs. https://www.environment.gov.za/sites/default/files/docs/2020lowemission_developmentstrategy.pdf

DAFF. (2015). Draft Climate Change Sector Plan for Agriculture, Forestry and Fisheries. Department of Agriculture, Forestry and Fisheries. https://static.pmg.org.za/150603climatechangeadaptation.pdf

DAFF. (2017). Abstract of Agricultural Statistics. Department of Agriculture, Forestry and Fisheries. https://www.dalrrd.gov.za/Portals/0/Statistics%20and%20Economic%20Analysis/Statistical%20Information/Abstract%202017.pdf

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., ... Saleem, M. (2017). An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm. Bioscience, 67(6), 534–545. https://doi.org/10.1093/biosci/bix014

Driver, A., Nel, J. L., Smith, J., Daniels, F., Poole, C. J., Jewitt, D., & Escott, B. J. (2015). Land and Ecosystem Accounting in KwaZuluÐNatal, South Africa Discussion Document. South Africa, 107.

ESA. (2017). Land Cover CCI Product User Guide Version 2. Tech. Rep. Retrieved from maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

FAO. (2017). AQUASTAT [Database]. Retrieved from http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en

FAO. (2020). FAOSTAT [Database]. Retrieved from http://www.fao.org/faostat/en/#home

GADM. (2020). Global Administrative Areas. Version 3.6. Retrieved from https://gadm.org/data.html

Global Nutrition Report. (2019). South Africa. Global Nutrition Report. Retrieved from Global Nutrition Report website: https://globalnutritionreport.org/media/profiles/3.0.3/pdfs/south-africa.pdf

Hattori, T. (2019). IGES NDC Database v7.1. Retrieved from https://www.iges.or.jp/en/pub/iges-indc-ndc-database/en

Institute for Health Metrics and Evaluation. (2020). Global Burden of Disease results tool [Database]. Retrieved from http://ghdx.healthdata.org/gbd-results-tool

Jacobson, A. P., Riggio, J., M. Tait, A., & E. M. Baillie, J. (2019). Global areas of low human impact ('Low Impact Areas') and fragmentation of the natural world. Scientific Reports, 9(1), 14179. https://doi.org/10.1038/s41598-019-50558-6

Mekonnen, M.M. and Hoekstra, A.Y. (2010a). The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands. Retrieved from http://www.waterfootprint.org/Reports/Report47-WaterFootprintCrops-Vol1.pdf

Mekonnen, M.M. and Hoekstra, A.Y. (2010b). The green, blue and grey water footprint of farm animals and animal products, Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands.

Mekonnen, M.M. and Hoekstra, A.Y. (2011) National water footprint accounts: the green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands.

Mosnier, A., Penescu, L., Thomson, M., Perez-Guzman, K. (2019). Documentation of the FABLE Calculator: SDSN/IIASA. Retrieved from https://www.abstract-landscapes.com/fable-calculator

Nahman, A., de Lange, W., Oelofse, S., & Godfrey, L. (2012). The costs of household food waste in South Africa. Waste Management https://doi.org/10.1016/j.wasman.2012.04.012

Oelofse, S. H., & Nahman, A. (2012). Estimating the magnitude of food waste generated in South Africa. Waste Management & Research, 31(1), 80–86. https://doi.org/10.1177/0734242X12457117

Potapov, P., Hansen, M. C., Laestadius, L., Turubanova, S., Yaroshenko, A., Thies, C., … Esipova, E. (2017). The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. Science Advances, 3(1). https://doi.org/10.1126/sciadv.1600821

Pradhan, A., & Mbohwa, C. (2014). Development of biofuels in South Africa: Challenges and opportunities. Renewable and Sustainable Energy Reviews, 39, 1089–1100. https://doi.org/10.1016/j.rser.2014.07.131

Ritchie, H., (2017) - *"Micronutrient Deficiency". Published online at OurWorldInData.org.* Retrieved from: https://ourworldindata.org/micronutrient-deficiency [Online Resource]

Ritchie, H., (2017) - "Obesity". *Published online at OurWorldInData.org.* Retrieved from: 'https://ourworldindata.org/obesity' [Online Resource]

Roe, S., Streck, C., Obersteiner, M., Frank, S., Griscom, B., Drouet, L., … Lawrence, D. (2019). Contribution of the land sector to a 1.5 °C world. Nature Climate Change, 9(11), 817–828. https://doi.org/10.1038/s41558-019-0591-9

Skowno, A., Poole, C., Raimondo, D., Sink, K., Van Deventer, H., Van Niekerk, L., … Driver, A. (2019). National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis Report. Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries, Pretoria. Pretoria, South Africa: South African National Biodiversity Institute.

Stevens, L. B., Henri, A. J., Nierop, M. V., Staden, E. van, Lodder, J., & Piketh, S. (2016). Towards the development of a GHG emissions baseline for the Agriculture, Forestry and Other Land Use (AFOLU) sector, South Africa. Clean Air Journal, 26(2), 34–39. https://doi.org/10.17159/2410-972X/2016/v26n2a11

U. S. Department of Justice, & Federal Trade Commission. (2010). Horizontal Merger Guidelines. Retrieved from https://www.justice.gov/atr/horizontal-merger-guidelines-08192010#5c

U.S Department of Health and Human Services and U.S. Department of Agriculture. (2015). 2015-2020 Dietary Guidelines for Americans, 8th Edition (p. 144). Retrieved from U.S. Department of Health and Human Services website: http://health.gov/dietaryguidelines/2015/guidelines/

UN DESA. (2017). World Population Prospects: The 2017 Revision, Key Findings and Advance Tables [Working Paper]. Retrieved from United Nations website: https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf

UNEP-WCMC, & IUCN. (2020). Protected Planet: The World Database on Protected Areas (WDPA). Retrieved from UNEP-WCMC and IUCN website: www.protectedplanet.net

UNFCCC. (2020). Greenhouse Gas Inventory Data—Flexible Queries Non-Annex I Parties [Database]. Retrieved from https://di.unfccc.int/flex_non_annex1

United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, Volume I: Comprehensive Tables (ST/ESA/SER.A/426)

von Bormann, T. (2019). Agri-food Systems: Facts and Futures. How South Africa can produce 50% more by 2050. Cape Town, South Africa: WWF South Africa.

von Bormann, T., de Vries, L., Jenkins, N., Tian, N., Modau, I., Pillay, P., … Notten, P. (2017). Food Loss and Waste: Facts and Futures.

Vorster, H. H., Badham, J. B., & Venter, C. S. (2013). 1. An introduction to the revised food-based dietary guidelines for South Africa. South African Journal of Clinical Nutrition, S5–S12.

Venter, C. S., Vorster, H. H., Ochse, R., & Swart, R. (2013). 5. "Eat dry beans, split peas, lentils and soya regularly": A food-based dietary guideline. South African Journal of Clinical Nutrition, S36–S45.

Wanner, N., Cafiero, C., Troubat, N., & Conforti, P. (2014). Refinements to the FAO Methodology for estimating the Prevalence of Undernourishment Indicator. ESS Working Paper No. 14-05. Retrieved from http://www.fao.org/3/a-i4046e.pdf

WHO. (2020). Nutrition Landscape Information System (NLIS) Country Profile—South Africa. Retrieved July 17, 2020, from https://apps.who.int/nutrition/landscape/report.aspx?iso=ZAF&rid=1620

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., Vries, W. D., Sibanda, L. M., … Murray, C. J. L. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, 393(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

World Bank. (2016a). Prevalence of stunting, height for age (% of children under 5)—South Africa. Retrieved July 17, 2020, from https://data.worldbank.org/indicator/SH.STA.WAST.ZS?locations=ZA

World Bank. (2016b). Prevalence of wasting, weight for height (% of children under 5)—South Africa. Retrieved July 17, 2020, from https://data.worldbank.org/indicator/SH.STA.WAST.ZS?locations=ZA

World Bank. (2019). Diabetes prevalence (% of population ages 20 to 79)—South Africa. Retrieved July 17, 2020, from https://data.worldbank.org/indicator/SH.STA.DIAB.ZS?locations=ZA