United States Department of Agriculture

Economic Research Service

Outlook

GFA 28

June 2017

International Food Security Assessment, 2017-2027

Food security projected to improve through 2027 as incomes rise and food prices remain stable.

United States Department of Agriculture

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Recommended citation format for this publication:

Birgit Meade and Karen Thome. *International Food Security Assessment, 2017-2027*, GFA-28, U.S. Department of Agriculture, Economic Research Service, June 2017.

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GFA-28

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International Food Security Assessment, 2017-2027

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Abstract

USDA-ERS's International Food Security Assessment (IFSA) model is a demand-oriented framework used to project three food security indicators: the number of food-insecure people, the share of the food-insecure population, and the food gap, a measure of the depth of food insecurity. Projections are made for the current year and 10 years out. The model includes information on domestic prices and consumer responsiveness to changes in prices and incomes. Given ongoing low food prices and rising incomes for many of the 76 low- and middle-income countries included in the IFSA model, food security is projected to improve. The share of the population that is food insecure is projected to fall from 17.7 percent in 2017 to 8.9 percent in 2027. Over the next decade, the number of food-insecure people is projected to fall from 646 million to 372 million, and the intensity of food insecurity will also decline by about 40 percent.

Keywords: Food security, food prices, income, food demand, trade, production, commercial imports, export earnings, food aid, calories, nutritional target, protein, fat, Sub-Saharan Africa, North Africa, Asia, Latin America and the Caribbean.

Acknowledgments

Thanks to Mark Jekanowski, Deputy Director for Outlook, Market and Trade Economics Division (MTED), Economic Research Service (ERS); Cheryl Christensen, Branch Chief, Food Security and Development Branch (MTED), ERS; Steven Zahniser, Acting Branch Chief, International Demand and Trade Branch, MTED, ERS; and Andrew Muhammad, Associate Director, MTED, for valuable comments. We would also like to thank the reviewers for their feedback, especially John Dyck, International Demand and Trade Branch, MTED, ERS; Maurice Landes, Food Security and Development Branch, MTED; David Stallings, USDA's World Agricultural Outlook Board; Sharon Sydow, USDA's Office of the Chief Economist; Debbie Rubas of USDA's Foreign Agricultural Service; and Cindy Holleman and Lorenzo Bellu of the UN's Food and Agriculture Organization. Special thanks to Dale Simms for editorial assistance, David Marquardt for map design, and Cynthia A. Ray for layout and cover design.

Preface

This report continues the series of food assessments in developing countries begun in the late 1970s by USDA's Economic Research Service. Global Food Assessments were done from 1990 to 1992, hence the GFA series. In 1993, the title was changed to Food Aid Needs Assessment to more accurately reflect the contents of the report, which focuses on selected developing countries with recent or ongoing food deficits. In 1997, we widened our analysis beyond the assessment of aggregate food availability to include more aspects of food security. We therefore changed the title to Food Security Assessment. Starting with the report published in July 2011, we changed the name to International Food Security Assessment to clarify that this is not an assessment of U.S. food security.

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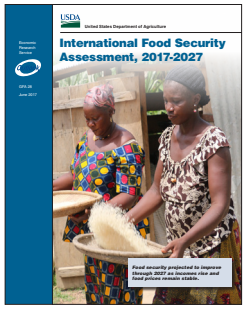

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International Food Security Assessment, 2017-2027

Birgit Meade and Karen Thome

What is the Issue?

Eliminating food insecurity is a goal shared around the globe and it requires ongoing assessments to inform decisionmakers and stakeholders about the direction and speed of progress made. Employing a uniform assessment approach to a large number of countries around the world allows for regional and country-by-country comparisons. ERS researchers assess the food security status and outlook for 76 low- and middle-income countries that are former or current food-aid recipients for the 2017-2027 period. Food prices and income changes affect international food security. The current report presents food security indicators, the number of food-insecure people, the share of population food insecure, and the food gap, projected for 2017 and 2027 based on projected food price and income changes.

What Did the Study Find?

Grains comprise the bulk of the diet in most of the study countries. Prices of these commodities are projected to remain low over the next decade. Incomes in nearly all the study countries are projected to rise, but lower prices for oil and key minerals slow income growth for exporters of these commodities.

Given projections for low food prices and rising incomes for most study countries, food security is expected to improve through 2027. The share of population that is food insecure is projected to fall from 17.7 percent in 2017 to 8.9 percent in 2027. In total for the countries studied, the number of food-insecure people is projected to fall by 42 percent, leaving 372 million food-insecure people in the 76 countries in 2027. The intensity of food insecurity is also projected to decline.

- GDP in developing ***Asian*** countries is projected to grow 6.3 percent per year—much faster than the global average of 3.8 percent—and the share of Asia's population that is food insecure is projected to decline the most of all the regions studied, from 13.5 percent in 2017 to 4.6 percent in 2027. The number of food-insecure people in Asia is projected to fall 62 percent between 2017 and 2027. In 12 of the region's 22 countries, less than 5 percent of the population is projected to be food insecure in 2027. Only three countries in the region (Yemen, Afghanistan, and DPR Korea) are projected to have more than 10 percent of the population food insecure in 2027.

- The number of food-insecure people in the ***Latin America and Caribbean*** (LAC) region is projected to fall by almost half over the next decade; the share of population that is food insecure is expected to fall from 14.8 percent in 2017 to 8.3 percent in 2027. Strong gains are expected throughout most of the region. Haiti continues to have the most food-insecure people in the region, though this number declines by 27 percent through 2027.

- ***Sub-Saharan Africa***'s (SSA) food security situation is projected to improve, but more slowly than in other regions. The number of food-insecure people is projected to fall by 22 percent and the share of population that is food insecure to drop from 31.7 in 2017 to 19.5 percent in 2027. In 23 of the 39 SSA countries, 20 percent or less of the population is projected to be food insecure in 2027. However, six countries are projected to have more than half their population food insecure in 2027, including Eritrea, Central African Republic, and Burundi with over 75 percent food insecure.

- Improvement in food security is also projected for ***North Africa***, which is the most food secure of all the regions in the study. The share of population food insecure is projected to fall from 2.5 percent in 2017 to 1.3 percent in 2027.

- Over time, diets in all regions have improved and diversified. Meat and fruits/vegetables now make up a larger share of the diet in IFSA countries, while the cereal share has fallen. Between 2000 and 2013, average caloric, protein, and fat consumption increased and all regions reached caloric and protein requirements (average fat consumption shares fell slightly short of the 20-percent recommendation in SSA and Asia). Lower income populations continue to fall short of nutritional targets in all regions.

How Was the Study Conducted?

The ERS demand-oriented International Food Security Assessment (IFSA) model projects food consumption (food demand) and food gaps in 76 low- and middle-income countries through 2027. Food security is evaluated for each country by estimating the share of the population unable to reach a caloric target of 2,100 calories per person per day. The intensity of food insecurity is measured by determining the gap between projected food consumption for those falling below the threshold and the caloric target. Food demand is expressed in grain equivalent based on caloric content to allow aggregation across four separate food groups. major grain, other grains, roots and tubers, and all other food.

Average per capita food consumption data are from the United Nation's Food and Agriculture Organization (FAO) Food Balance Sheets. Observed domestic prices are from FAO's Global Information Early Warning System (GIEWS) database. Tariff data are from the World Bank's World Integrated Trade Solution (WITS). Incomes, exchange rates, and Consumer Price Indexes are from the ERS International Macroeconomic Dataset. World prices are from USDA's ***Agricultural Projections to 2026***.

International Food Security Assessment, 2017-2027

Overview

The International Food Security Assessment (IFSA) model maintained by USDA's Economic Research Service projects per capita food demand and evaluates that against a caloric target of 2,100 calories per person per day to determine whether populations in 76 low- and middle-income countries (historic U.S. food aid recipients; see Appendix for a complete list) should be considered food secure. Demand projections are based on prices and incomes. Given projections for low food prices and rising incomes over the next 10 years, food security is expected to improve through 2027.

In 2017, 17.7 percent of the population in the 76 countries are estimated to be food insecure. This means that about 646 million people out of a population of 3.5 billion are estimated not to have access to a daily caloric target of 2,100 calories.

While projected income growth is positive, it is below last year's more optimistic outlook, and international price declines do not always translate into local price drops. For example, several countries in Sub-Saharan Africa are affected by weak currencies or disruptions along the food supply chain. Additionally, improvements in food security have slowed as the rapid economic growth in much of Asia has begun to decelerate. Those factors combined lead to a less optimistic food security assessment for 2027 than projected a year ago. The share of food-insecure people is projected to drop to 8.9 percent for the 76 countries by 2027 (figures 1,2,3a), with the number of food-insecure people dropping by 42 percent to about 372 million people (figure 3b).

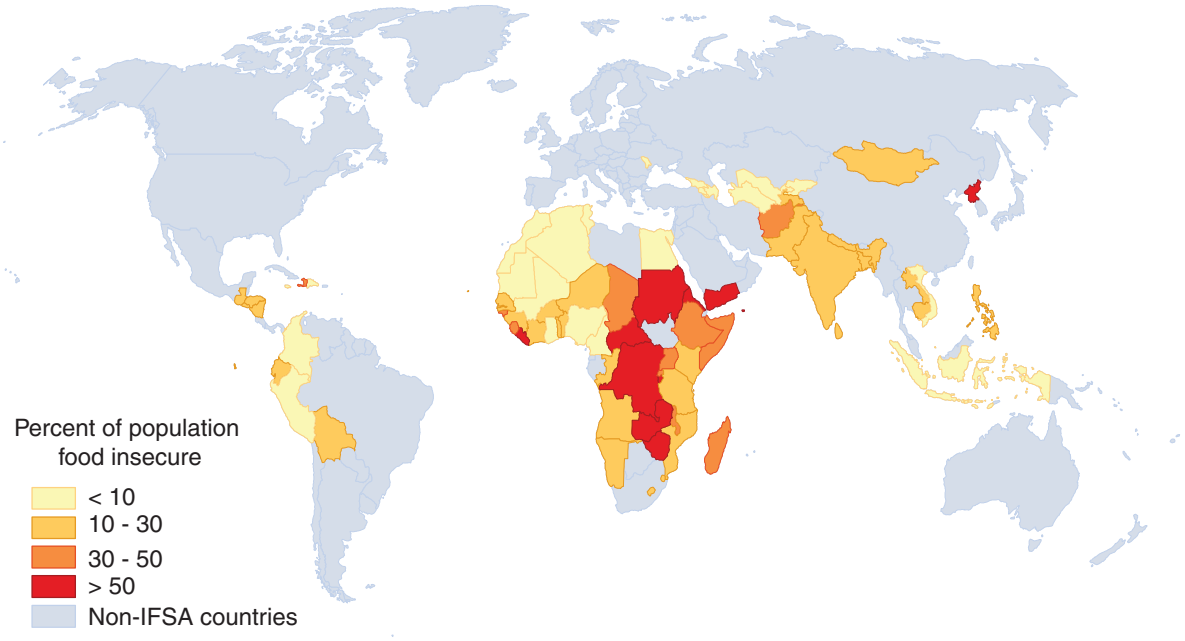
The food gap, the amount of food needed to allow all food-insecure people to reach the caloric target, is an indicator of the intensity of food insecurity. It can be expressed in calories per capita per day or in grain-equivalent quantities, either as a national annual shortfall or as a per capita shortfall. The food gap is projected to decline in all regions and in most countries, from 28.5 million tons in 2017 to 17 million tons in 2027 (figure 3c), a further demonstration of improving food security.

While food security is improving generally, indicators differ greatly by region. Sub-Saharan Africa (SSA) has the highest share of food-insecure people, at 31.7 percent. Food insecurity is estimated to affect 14.8 percent of people in Latin America and the Caribbean (LAC) and 13.5 percent in Asia. North Africa is the most food-secure region, with an estimated 2.5 percent of population food insecure in 2017.

All regions are projected to see noticeable improvements over the coming decade, with the biggest improvement projected for Asia, where the food-insecure population falls from 13.5 percent to 4.6 percent in 2027 (a 66-percent decline). Food insecurity in SSA improves by 38 percent, with a projected share of 19.5 percent in 2027. The LAC share food insecure is projected to improve to 8.3 percent by 2027, a drop of 43 percent. North Africa is on track to decrease its food insecurity further from 2.5 percent in 2017 to 1.3 percent by 2027.

Figure 1

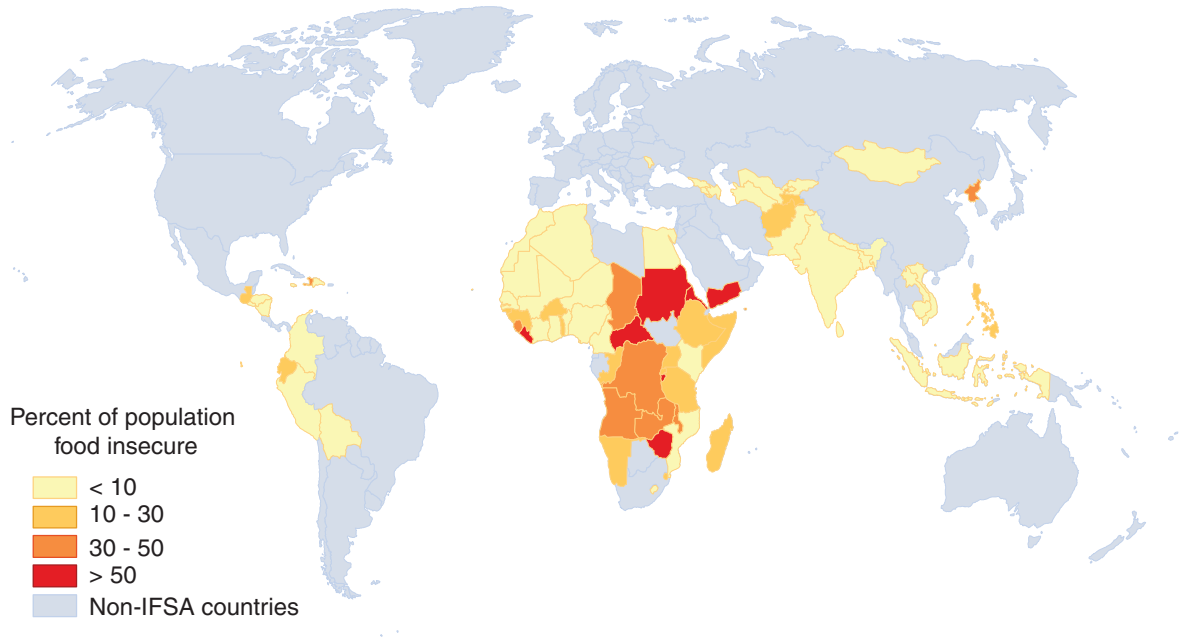
Share of population that is food insecure, 2017



IFSA = International Food Security Assessment.
Source: USDA, Economic Research Service.

Figure 2

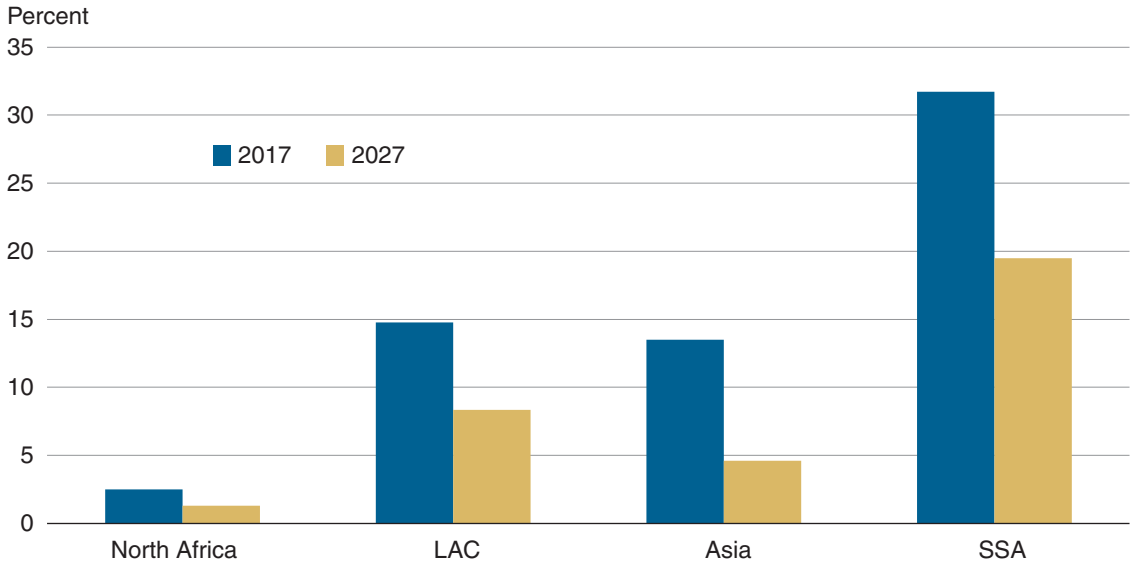
Share of population that is food insecure, 2027



IFSA = International Food Security Assessment.
Source: USDA, Economic Research Service.

Figure 3a

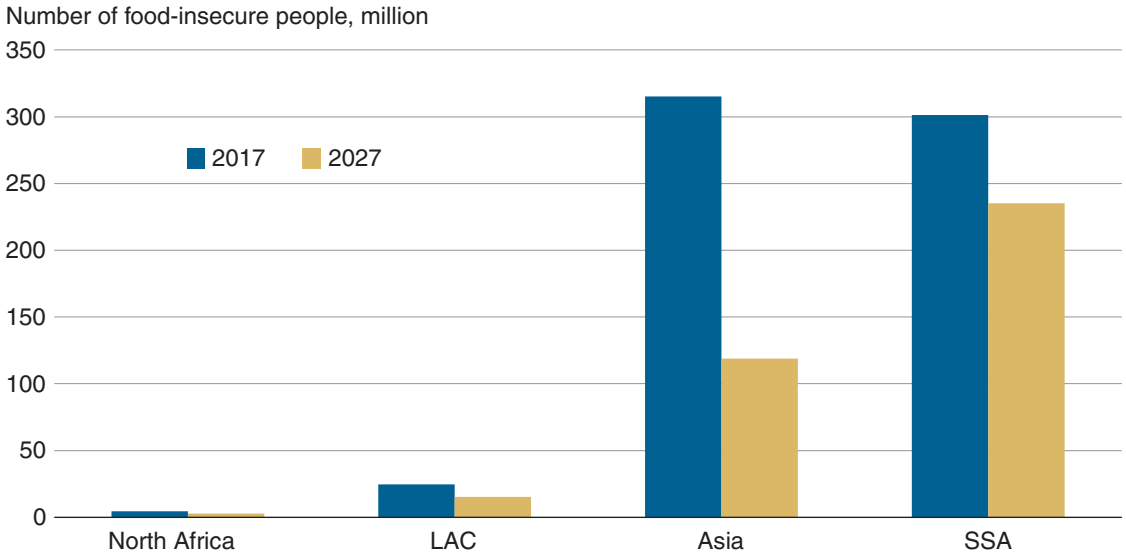
The share of the population that is food insecure is projected to decline



LAC = Latin America and the Caribbean, SSA = Sub-Saharan Africa.
Source: USDA, Economic Research Service.

Figure 3b

The number of food-insecure people is projected to decline

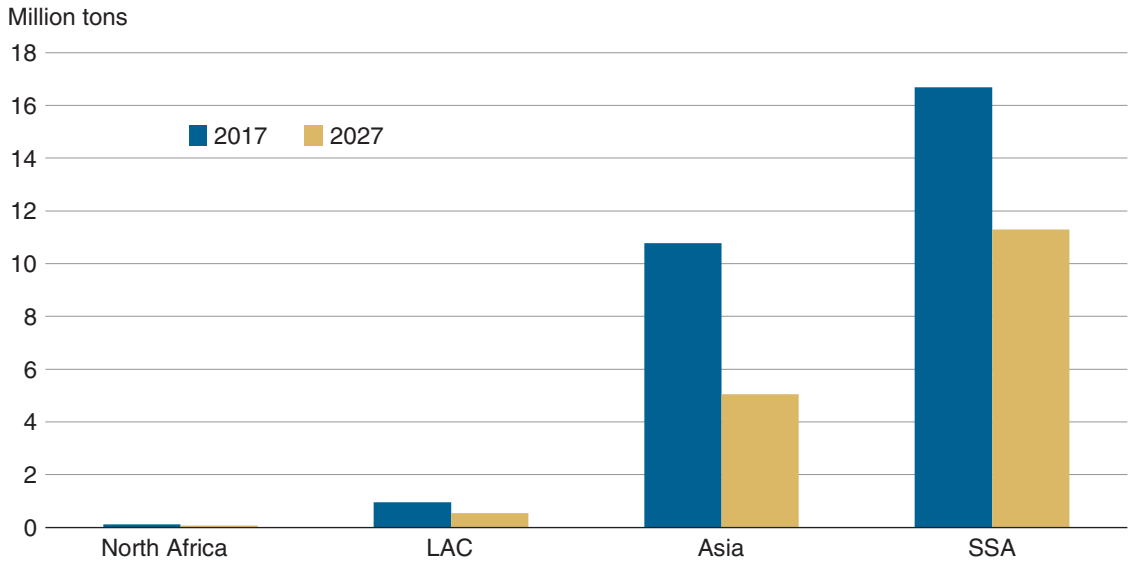


LAC = Latin America and the Caribbean, SSA = Sub-Saharan Africa.
Source: USDA, Economic Research Service.

While Asia has more than twice as many people as SSA, the number of food-insecure people is almost the same in 2017 (figure 4), which means that SSA's share of food-insecure people is more than double the share in Asia.

Figure 3c

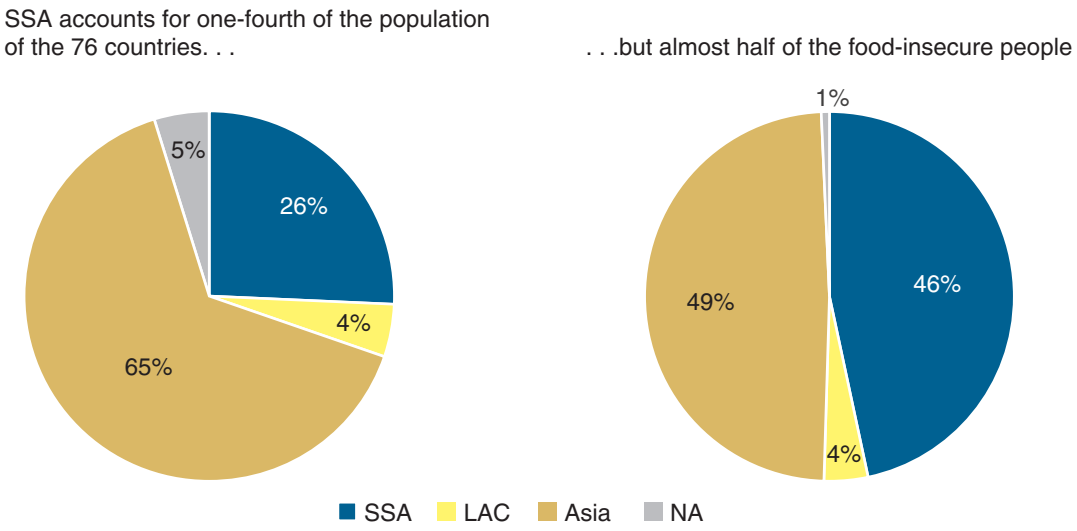
The food gap is projected to decline



LAC = Latin America and the Caribbean, SSA = Sub-Saharan Africa.
Source: USDA, Economic Research Service.

Figure 4

While SSA's share of food-insecure people is more than double the share in Asia, the number of affected people is almost the same in 2017



SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean, NA = North Africa.
Source: USDA, Economic Research Service.

Incomes are projected to increase in almost all countries over 2017-27 (figure 5). Since the beginning of the 2000s, developing countries have enjoyed increasingly strong economic growth, outpacing advanced economies and, as a group, contributing more than half of global output and consumption growth. While this growth is forecast to remain strong over the medium term, projected growth rates are below those seen in 2010-15 (International Monetary Fund, 2017, p. 67). Economic growth outpaces population growth in most cases, but depreciating currencies can lead to lower real per capita incomes over time, particularly in Central Africa.

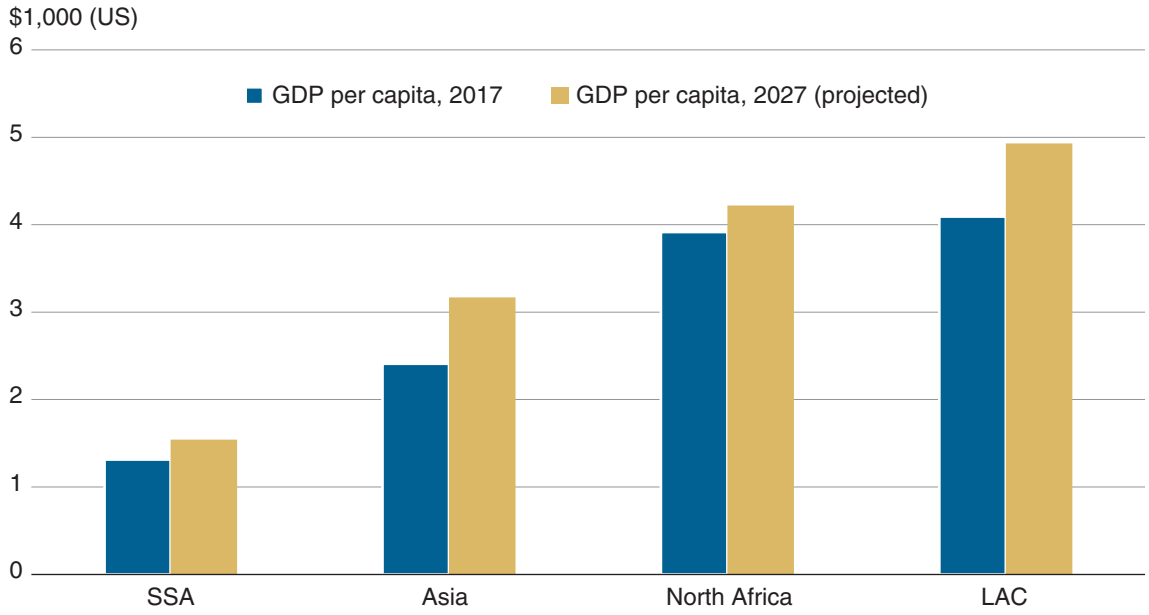
International food prices are projected to remain low and then stabilize over the next 10 years (figure 6), reflecting low energy prices and less area planted. However, in a number of countries, mostly in Sub-Saharan Africa, domestic food prices move independently of international prices, either because of minimal trade or large exchange rate movements. High inflation can also lead to increases in domestic food prices, even as world prices fall.

Average annual per capita incomes range across regions from $1,313 in SSA to $4,092 in LAC. Regions also differ in their growth prospects over the next 10 years. North Africa has relatively high per capita incomes, but is facing great uncertainties. Above-average population growth and reduced oil income for Algeria and reduced tourism income for Morocco, Tunisia, and Egypt portend lower income growth. Incomes are expected to remain strong in Asia, where India is projected to have economic growth of more than 7 percent over the foreseeable future.

International food prices differ for each country because they are converted into local currencies and therefore depend on the real exchange rate. The ongoing strengthening of the U.S. dollar has led to real exchange rate depreciations around the world—three-quarters of the 76 countries included in this study are projected to have depreciating currencies vis-à-vis the U.S. dollar—partially offsetting welfare gains achieved through higher incomes and falling food prices.

Figure 5

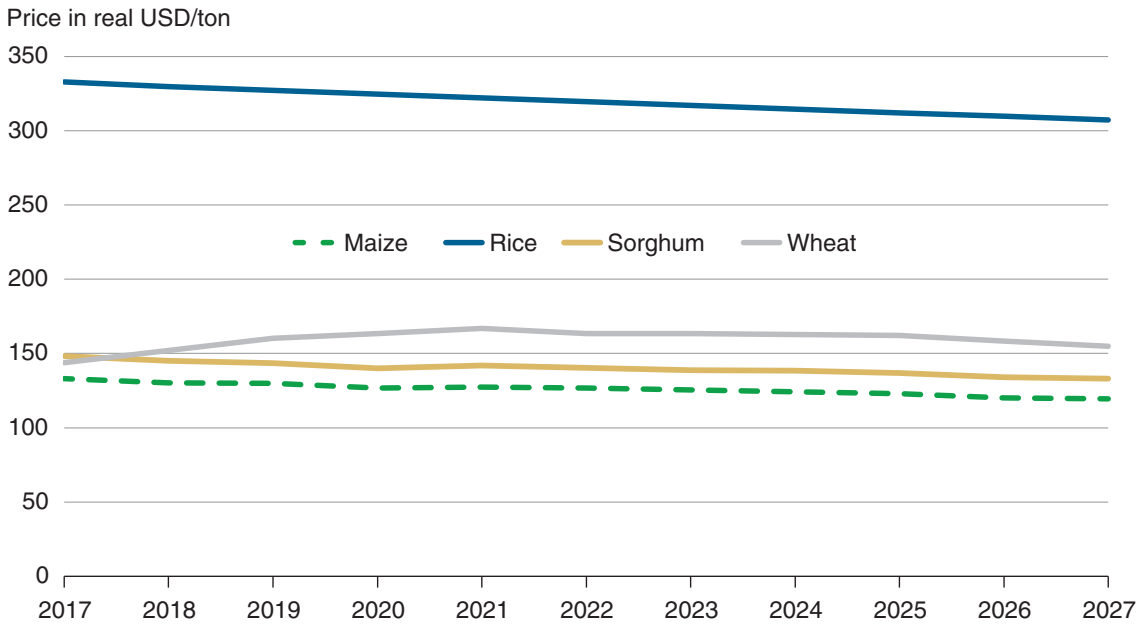
Per capita incomes by region, 2017 and 2027



SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean.
Source: USDA, Economic Research Service, International Macro Database, 2016.

Figure 6

Prices of major grains, 2017-2027



Source: USDA Agricultural Projections to 2026, Long-term Projections report OCE-2017-1.

Increasing food grain demand, as well as grain demand for feed and industrial processing, will be met by domestic production and imports. Grain production for the 76 study countries is projected to increase 5.9 percent between 2017 and 2027, mostly from higher yields (table 1). The majority of the countries are projected to have declining or stagnant growth in grain area as many countries are approaching the limit of area expansion. Growing areas of land devoted to urban uses or with degraded soil make yield increases ever more crucial.

Regions differ in their reliance on the international market for food supplies. The Latin America/Caribbean and North Africa regions depend on imports for more than 50 percent of their grain supplies, either because of domestic shortfalls or because land and water resources are instead used in higher value export crops; those export revenues may then be used to import food grains commercially. With increasing incomes, consumers tend to diversify their diets from staples toward higher value foods such as meats, dairy, and high-value fruits and vegetables. Historically, commercial import growth has outpaced production growth (appendix tables 3-7) and this trend is expected to continue.

Table 1

Indicators for total of 76 low- and middle-income countries

Projections				
	Food grain demand	Other grain demand*	Grain production	Implied additional supply required**
	Million tons			
2017	624	231	690	164
2027	768	308	735	341

*Other grain demand includes seed, feed, waste, and processing.

**The gap between grain demand and domestic grain production.

Source: USDA, Economic Research Service.

How Food Security Is Assessed: Methods and Definitions

Food consumption and food access are projected for 76 low- and middle-income countries—39 in Sub-Saharan Africa, 22 in Asia, 11 in Latin America and the Caribbean, and 4 in North Africa. Food is divided into four groups covering 100 percent of food consumption: major grain, other grains, roots and tubers, and all other food. The model projections of food demand are expressed in grain equivalent based on each food group's caloric content to allow aggregation across food groups; this grain equivalent is easily expressed in kilograms or calories.[1] (See Appendix 2—Food Security Assessment Model: Definitions and Methodology for a detailed description of the methodology and definitions of terms; appendix table 1 lists the 76 countries.)

The model analyzes the gap between projected food demand and a caloric target of 2,100 calories per capita per day. The estimated ***food gap*** measures the food needed to raise consumption at every income level to the caloric target. In many countries, consumption along the lower part of the income distribution is significantly below average per capita consumption for the country as a whole. In these countries, the food gap provides a measure of the *intensity* of food insecurity—the extent to which the food security of already food-insecure people deteriorates as a result of income declines or other negative economic conditions. Our second food security indicator presents the ***share of the population that is food insecure***. Consumption is assessed across the entire income distribution. Finally, we calculate the ***number of food-insecure people***—those who cannot meet the caloric target—based on total population data and the population share that consumes below the caloric target.

Common terms used in this report include:

- **Food consumption**—equal to food demand.
- **Food access**—depends on a consumer's purchasing power. Estimated food consumption is based on the income level within each country (using an income-consumption relationship).
- **Food insecurity**—occurs when estimated per capita food consumption for a consumer at a certain income level falls short of the caloric target of 2,100 calories per person per day.

[1]For example, grains have roughly 3.5 calories per gram, and tubers have about 1 calorie per gram. One ton of tubers is therefore equivalent to 0.29 ton of grain.

Famine Declaration and Warnings in 2017

The United Nations (UN) declared famine in some areas of South Sudan in February 2017, covering an estimated 100,000 people with a further 1 million people judged on the brink of famine (UN, 2017). Accurate assessments are complicated by steady flows of refugees into Uganda and other neighboring countries. The last occurrence of famine was in 2011 when the UN and the Famine Early Warning Systems Network (FEWSNET) estimated that 260,000 people died of famine in the Horn of Africa, mostly in Somalia.

Famine is the most extreme form of food insecurity. Famine is declared in an area when, even with humanitarian assistance, starvation deaths have already occurred, 20 percent or more of the population are starving, and 30 percent of children under age 5 are severely malnourished (World Food Program, 2017). Areas with severe food security emergencies are often at risk of experiencing famine. UN food security agencies have highlighted the risk of starvation and potential famine in three other countries besides South Sudan—northeastern Nigeria, Somalia, and Yemen. Altogether about 20 million people in these countries have been declared at risk for famine.

Though the situation in each country is different, they all feature ongoing armed conflicts that contribute to food emergencies and complicate relief efforts. Ongoing war and civil strife have reduced the ability of local farmers and herders to produce food and disrupted local food distribution systems.

IFSA does not include South Sudan (where even basic data are lacking) nor does it cover specific regions (such as northeast Nigeria). Nevertheless, the 2017 analysis of Yemen and Somalia shows high levels of chronic food insecurity. In Yemen, 88 percent of the population is food insecure, with about 50 percent food insecure in Somalia. In both countries, the intensity of food insecurity is high, with per capita daily food gaps (shortage of calories with respect to the caloric target) of 675 and 438 calories, respectively. Yemen is not projected to improve food security by 2027, but Somalia is projected to reduce the share of the population that is food insecure to about 30 percent.

Regional Overview

The food security indicators and model projections presented here for 2017 and 2027 are based on historic data and projections from the USDA/ERS International Macroeconomic Data Set. Production data are as of December 2016; events since that time, such as drought and flooding, are not reflected in the data even though they have caused crop failures and damage in some countries.

Gains in food security vary across regions. In Asia, where income growth is strong, the share of people food insecure is projected to decline fastest. The challenge is greater in Sub-Saharan Africa (SSA), where population growth is higher and income growth slower. SSA food security is projected to improve, but more slowly. In Latin American and the Caribbean, the share of the population that is food insecure is projected to drop by almost half by 2027. Food security improvement is also projected for North Africa, which is the most food-secure region in the study.

Sub-Saharan Africa

Sub-Saharan Africa has the highest share of food-insecure people, with 31.7 percent of the population (301 million people) food insecure in 2017. While food security is projected to improve considerably, the region is expected to have the highest share of food-insecure people, at 19.5 percent, in 2027.

The 39 SSA countries vary considerably in their food security status. Nine countries have more than half of their population food insecure. Five—Burundi, Central African Republic (CAR), Democratic Republic of Congo (DR Congo), Eritrea, and Liberia—have more than 70 percent of their population food insecure in 2017. Several SSA countries, mainly in West Africa, have less than 10 percent of their population food insecure.

DR Congo has the most food-insecure people in SSA, at 68.6 million. Ethiopia, Kenya, Madagascar, Sudan, Tanzania, and Uganda each have more than 10 million food-insecure persons in 2017. Nigeria, the largest country in the region, has slightly more than 10 million food-insecure people, but that represents less than 10 percent of its total population.

The intensity of food insecurity is highest in the SSA region—at 478 calories per capita per day, representing a food gap of 55.4 kg per food-insecure person per year. The gap is deepest in the countries with the highest share of the population that is food insecure, peaking at 713 calories per capita per day in Liberia. In 2017, the region's food gap—the amount of food needed to bring each food-insecure person to the caloric target—is 16.7 million tons, which is 58 percent of the total estimated food gap for the 76 countries covered in this report.

ERS projects a 22-percent decrease in the ***number*** of food-insecure people in SSA over the next decade and a 38-percent reduction in the ***share*** of people who are food insecure, resulting in 235 million food-insecure people by 2027. The 22-percent reduction in SSA is nearly half the 42-percent reduction for all 76 countries included in IFSA over the next 10 years. This is partly because population growth is much faster in SSA than in the other regions (27 percent over the 10-year period versus 11 percent in Asia). As a result, the number of food-insecure people continues to rise even as the share of the population food insecure falls.

The food gap is also expected to decrease in the SSA region, both in aggregate and per capita. The total food gap is expected to fall from 16.7 million tons in 2017 to 11.3 million tons in 2027. Despite this progress, SSA will surpass Asia by 2027 to have the most people food insecure (63 percent of the 76-country total) and the largest food gap (66 percent of the total).

Several SSA countries are projected to reduce the number of food-insecure people by more than half by 2027. This includes countries with relatively low numbers of food-insecure people in 2017 (e.g., Ghana), but also Kenya and Tanzania, both of which have more than 12 million food-insecure people in 2017. Ethiopia is also expected to cut its food-insecure share by half, with the total falling to 26.1 million people by 2027.

Both Kenya and Ethiopia are projected to experience significant GDP growth that translates into per capita income growth of 28.5 percent and 44 percent, respectively, over the next 10 years (versus the SSA average of 17.3 percent). Mozambique, Madagascar, and Lesotho are also projected to have high per capita income growth through 2027. These economies are diversifying, with growing manufacturing and service sectors, and they are less dependent on primary product exports.

Ten SSA countries are expected to see an increase in the number of food-insecure people by 2027 (appendix table 1). This includes several countries where nonrenewable exports are a significant component of GDP (International Monetary Fund, 2016). In those countries, GDP growth is expected to slow, terms of trade to worsen, and in many cases per capita income (in local currency) to fall, making food access more difficult. Notably, both the share of population and number of people food insecure is expected to increase in Angola and Zimbabwe by 2027. Oil exporters Sudan and Central African Republic are also expected to see increases in the number of people food insecure.

Food needs are met through domestic production and imported food; shocks to production can affect food access via upward pressure on local prices, even when world prices are falling. Drought has affected recent harvests in much of SSA, and smaller harvests contribute to higher food prices in Uganda, Kenya, and Somalia. To the south, growing conditions have improved, but 2017 harvests depend on combating a pest outbreak that originated in Zambia (FAO, 2017). The Sahel had a record harvest in 2016 (FAO, 2017), and the West Africa region has recently experienced superior harvests and more stable prices than the rest of SSA. In DR Congo and Central African Republic, conflict has affected the planting and harvesting of grain (FAO, 2017a).

Grain production in SSA is expected to increase 9 percent through 2027, from 122 million tons in 2017 to 133 million tons. This production growth is faster than the 76-country average. However, projected growth in grain production lags growth in grain demand (including grain for nonfood uses). The imports required to meet SSA demand will grow 7 percent over 2017-27, to 85 million tons.

Table 2

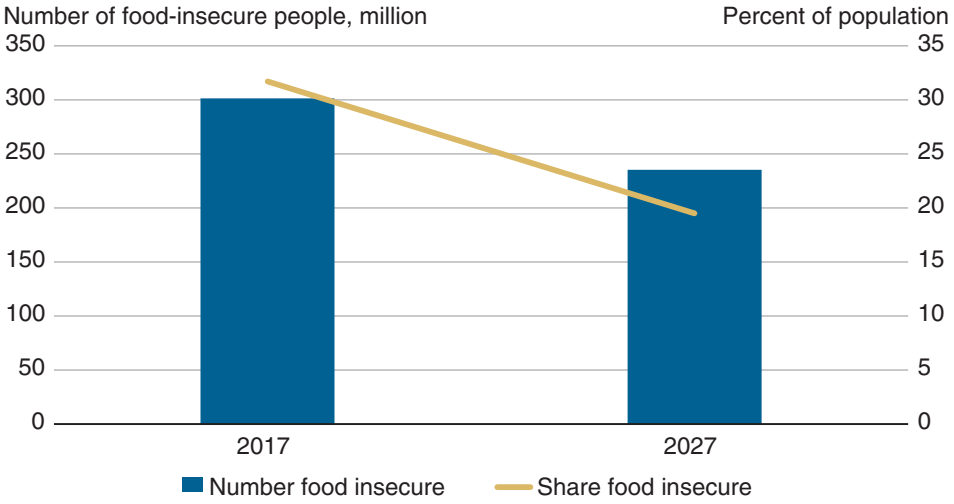
Food security indicators for Sub-Saharan Africa

Projections				
Year	Food grain demand	Other grain demand*	Grain production	Implied additional supply required**
	1,000 tons			
2017	123,688	34,518	121,660	36,546
2027	173,451	45,008	133,413	85,047

*Other grain demand includes seed, feed, waste, and processing. **The gap between grain demand and domestic grain production.

Source: USDA, Economic Research Service.

Sub-Saharan Africa indicators of food insecurity



Source: USDA, Economic Research Service.

Sub-Saharan Africa
(949 million people in 2017)

Sub-Saharan Africa (SSA) has the highest share of food-insecure people, with 31.7 percent of the population in 2017, or 301 million. We project a 22-percent decrease in the number of food-insecure people in SSA over the next decade and a 38-percent reduction in the share of people food insecure.

With strong income growth, several countries are projected to improve their food security in the next decade.

Sub-Saharan Africa (SSA) indicators of food insecurity

	Population		Population food insecure		Population share food insecure		Food gap (per capita)		Food gap* (total)	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
	Million		*Million*		*Percent*		*kcal/day*		*1,000 MT*	
SSA	**949**	**1,204**	**301.3**	**235.2**	**31.7**	**19.5**	**478**	**415**	**16,695**	**11,300**
Angola	20.7	27.0	5.3	8.1	25.5	30.1	339	357	223	361
Burundi	11.5	15.7	9.2	11.9	80.0	75.7	663	626	708	868
CAR	5.6	6.9	4.7	5.2	82.8	75.6	629	567	335	339
DR Congo	83.3	103.1	68.6	48.9	82.3	47.5	672	449	5,359	2,555
Eritrea	5.9	6.6	4.8	5.1	81.0	76.9	629	594	375	373
Ethiopia	105.4	138.3	39.8	26.1	37.8	18.9	387	313	1,705	903
Ghana	27.5	34.0	1.8	0.3	6.6	0.9	238	185	49	7
Kenya	47.6	54.5	12.7	2.5	26.6	4.6	271	187	409	55
Liberia	4.4	5.5	3.1	2.8	70.6	50.5	713	580	223	163
Madagascar	25.1	31.5	10.3	7.2	41.0	22.8	377	309	400	229
Mozambique	26.6	34.0	7.4	2.9	27.7	8.6	397	304	352	107
Nigeria	190.6	241.5	10.5	6.2	5.5	2.5	208	187	256	135
Somalia	11.0	14.0	5.5	4.1	49.9	29.0	438	353	276	164
Sudan	37.3	44.2	22.0	24.2	59.0	54.8	481	461	1,282	1,350
Tanzania	54.0	70.5	15.4	7.5	28.6	10.7	411	324	714	275
Uganda	39.6	53.7	14.5	13.4	36.8	24.9	394	347	684	555
Zambia	16.0	21.3	8.4	8.6	52.4	40.2	602	535	600	545
Zimbabwe	14.9	18.0	9.1	11.0	61.2	61.3	506	507	572	693

*Measured in grain equivalent.

Source: U.S. Census Bureau and USDA, Economic Research Service.

Asia

In 2017, the Asia region had the most food-insecure people—315.2 million—but the second lowest share of population food insecure, at 13.5 percent. Food insecurity is projected to improve in all countries in the region except Yemen due to above-average income growth in most countries. The share of Asia's population food insecure is projected to decline to 4.6 percent by 2027.

Some countries have much larger shares of their population food insecure in 2017, including Afghanistan (39 percent), the Democratic People's Republic of Korea (DPR Korea, 54 percent), and Yemen (88 percent).

The intensity of food insecurity (measured by the number of calories per capita per day required to bring consumption to a 2,100-calorie target) is relatively low for the region—289 calories per capita per day, compared with a global average of 379. The gap is higher in Yemen (675 calories) and in DPR Korea (403).

The Asia region has the second largest food gap—10.8 million tons of grain in 2017, substantially below the 16.7 million tons for SSA. This gap measures the amount of food necessary to allow all income groups to reach the caloric target. Seventy percent of the Asian food gap is accounted for by only three countries: India (3.4 million tons), Pakistan (1.7 million tons), and Yemen (2.0 million tons). India and Pakistan are large countries with relatively small per capita gaps, while Yemen is a small country with a very deep per capita gap.

Asian grain production increased from 492 million tons in 2016 to an estimated 514 million tons in 2017, mostly from record grain production in India, which accounts for about half of regional grain production. Favorable weather conditions have also increased grain production in Cambodia, Nepal, Bangladesh, and the Philippines. Vietnam and Indonesia, on the other hand, saw weather-related production declines. Asian grain production is projected to continue growing over the next decade, rising to 547 million tons by 2027, driven primarily by higher yields.

ERS projections indicate a substantial reduction in food insecurity in Asia over the next decade, with the number of food-insecure people declining rapidly. The primary driver of improved food security is robust (per capita) GDP growth for most of the region. Asia contains some of the most rapidly growing countries in the world. This growth, coupled with projected low food prices, supports improved food security.

The number of food-insecure people is projected to decline from 315 million in 2017 to 119 million by 2027, with the share of the population food insecure dropping to 4.6 percent. Asia, with a projected 2027 population of almost 2.6 billion people, would have fewer food-insecure people than SSA, with less than half as many people (1.2 billion).

The fastest growing Asian countries are India, Bangladesh, and Vietnam. India, the largest country, continues to show very strong growth in real GDP, estimated at 7.5 percent in 2016 and 2017 (USDA ERS International Macroeconomic Data Set). India's growth has been supported by strong public and private consumption, lower energy costs, and favorable monsoon rains. After a strong 6.7-percent growth in real per capita GDP in 2015, Vietnam's growth declined to 5.8 percent in 2016, but is estimated to rebound to 6.3 percent in 2017. GDP growth in Bangladesh declined 0.1 percent in 2017 but is still favorable at 6.7 percent. Factors contributing to the decline are a slowdown in remittances (primarily from Gulf States), flooding, and a weakening in Bangladeshi exports.

Food insecurity is projected to drop significantly in these three countries by 2027. In India, the number of food-insecure people declines from 133.3 million in 2017 to 16.2 million in 2027, with the share of the population food insecure falling from 10.4 to 1.1 percent. In Vietnam, the number of food-insecure people is projected to fall from 9.6 million to 2 million and the share of the population food insecure from 10 to 2 percent. Bangladesh's food-insecure population is projected to decline from 26.3 to 9.9 million, with the share of the population food insecure dropping from 16.7 percent to 5.7 percent. Taken together, these three Asian countries account for about half of the total projected global reduction in food-insecure people between 2017 and 2027.

A second group of countries—including Pakistan, Indonesia, Philippines, and Cambodia—have real GDP growth rates of 4 to 5 percent projected for the next decade. Pakistan's economy remains solid, supported by lower prices for imported commodities, rising domestic demand, and an improved business climate. Steadily growing GDP in the Philippines reflects accelerated public investment projects and strong service exports. Service exports also support Cambodian growth. Indonesia, a large commodity exporter, adjusted rapidly to lower commodity prices, helped by domestic policies that lifted domestic demand and regional currencies that remain stable against the dollar.

Given projected solid income growth and low food prices, food insecurity is projected to drop by more than half in these four countries between 2017 and 2027, falling from 79.8 million food-insecure people to 33.4 million. The projected share of the population food insecure in 2027 ranges from 2 percent in Indonesia to 10 percent in the Philippines.

A third group of countries—primarily the Commonwealth of Independent States (CIS) Central Asian countries—already has relatively high per capita income, with moderate growth likely over the next decade. Collectively, this group (Armenia, Azerbaijan, Georgia, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, and Uzbekistan) has an estimated 3.3 million food-insecure people in 2017, and that total is projected to decline to 1.9 million by 2027, when all these countries are projected to have 2 percent or less of their population food insecure.

The Asia region's most compromised economies are Afghanistan, DPR Korea, and Yemen. Afghanistan's GDP growth is estimated at 1.2 percent. The country faces major challenges, including deteriorating security, adverse weather, and reductions in foreign aid. Yemen has negative real GDP growth of 4.2 percent, reflecting ongoing conflict and generally adverse conditions. These countries are not projected to make significant gains in food security over the next decade. The food-insecure population is projected to fall by 2.7 to 2.8 million in both Afghanistan and DPR Korea, but to increase by 6 million in Yemen. The share of the population food insecure remains high in 2027—24.6 percent in Afghanistan, 40.9 percent in DPR Korea, and 90.4 percent in Yemen.

Table 3

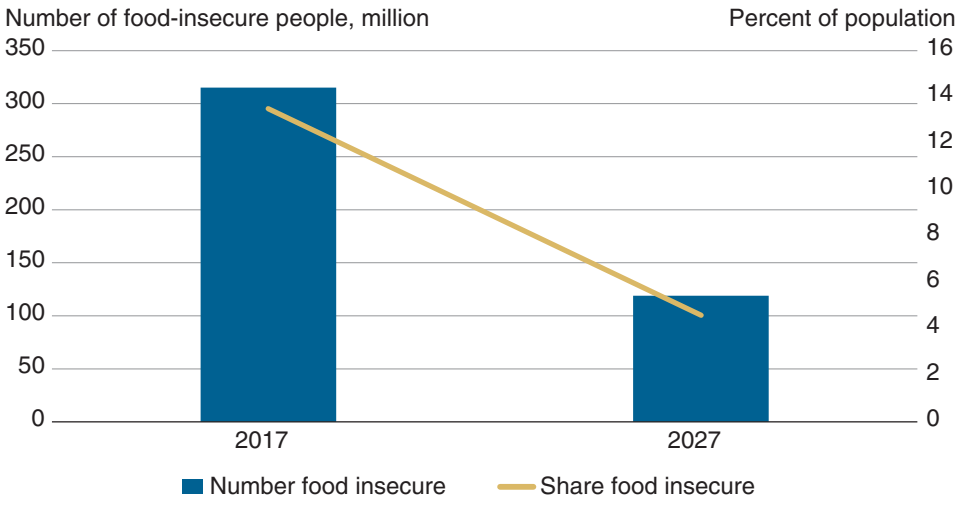
Food security indicators for Asia

Projections				
Year	Food grain demand	Other grain demand*	Grain production	Implied additional supply required**
	1,000 tons			
2017	430,762	143,491	514,082	59,997
2027	511,059	187,953	547,091	151,922

*Other grain demand includes seed, feed, waste, and processing. **The gap between grain demand and domestic grain production.

Source: USDA, Economic Research Service.

Asia indicators of food insecurity



Source: USDA, Economic Research Service.

Asia
(2,342 million people in 2017)

Food insecurity is projected to improve in all countries studied here except Yemen.

Given above-average per capita income growth projected for the region, many countries can improve food security sharply by 2027, with less than 5 percent projected food insecure for the 22 countries, on average. Ongoing conflict in Yemen gives little hope for improvements in the next 10 years.

Asia indicators of food insecurity

	Population		Population food insecure		Population share food insecure		Food gap (per capita)		Food gap* (total)	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
	Million		*Million*		*Percent*		*kcal/day*		*1,000 MT*	
Asia	**2,342**	**2,599.6**	**315.2**	**118.9**	**13.5**	**4.6**	**289**	**360**	**10,774**	**5,055**
Afghanistan	34.1	42.9	13.3	10.6	38.8	24.6	334	286	510	348
Bangladesh	157.8	173.1	26.3	9.9	16.7	5.7	267	217	713	218
India	1,281.9	1,422.6	133.3	16.2	10.4	1.1	233	170	3,386	301
Indonesia	260.6	280.3	16.8	5.8	6.5	2.1	222	189	416	121
Korea, DPR	25.2	26.4	13.6	10.8	53.8	40.9	403	353	623	435
Nepal	29.4	32	4.6	1.9	15.6	6.0	263	219	140	48
Pakistan	204.9	234.2	41.6	14.8	20.3	6.3	328	259	1,657	465
Philippines	104.3	120.8	18.6	12.3	17.8	10.2	308	273	635	372
Sri Lanka	22.4	23.8	4.5	1.5	20.0	6.5	363	289	181	49
Tajikistan	8.5	9.8	1.7	1.0	20.0	10.2	317	274	67	34
Vietnam	96.2	103.7	9.6	2.0	10.0	2.0	256	201	261	43
Yemen	28.0	34.0	24.7	30.7	88.3	90.4	675	706	1,993	2,587

*Measured in grain equivalent.

Source: U.S. Census Bureau and USDA, Economic Research Service.

Latin America and the Caribbean

Food security in the Latin America and Caribbean (LAC) region is projected to continue a 20-year trend of strong improvements. The share of the population food insecure is projected to drop from 14.8 percent in 2017 to 8.3 percent by 2027, reducing the number of food-insecure people from 24.7 million to 15.4 million. The food gap, second highest behind SSA at 348 calories per capita per day in 2017, is projected to decline to 320 calories over the decade. The largest LAC food gap by far is in Haiti, where it is projected to decrease from 639 calories to 542 calories by 2027.

The LAC region has been relying more on imports to guarantee sufficient grain supplies for food and other uses. In 2016, commercial grain exports were estimated to make up 54 percent of LAC grain supplies. Domestic production in the 11 countries is projected to stay virtually unchanged over the next 10 years. While Bolivia, Colombia, Ecuador, Haiti, and Honduras are expected to see production increases, the other six countries are projected to see grain production stagnate or decline. Increasing production of higher value products, in which many of these countries have a comparative advantage (e.g., tropical produce), often leads to higher exports of cash crops that boost export earnings to help pay for grain imports.

Long and steady economic growth has resulted in increasing per capita incomes and declining poverty rates, leading to improved food security in the region. In recent years, Central American and Caribbean countries benefited from lower energy prices and higher remittances due to the improving U.S. economy. Several South American countries were hurt by lower prices for their primary exports such as oil, minerals, and agricultural commodities (IFPRI, 2017). Except for Ecuador, which relies heavily on petroleum exports, the affected countries did not suffer worsening food insecurity as a consequence.

In 2017, Haiti is again the LAC country with the most serious food insecurity problem; almost half of the country's population is unable to reach the caloric target of 2,100 calories per capita per day. Guatemala, Bolivia, and Ecuador have seen improvements, but about one-quarter of their populations are projected to be food insecure in 2017. In Nicaragua, El Salvador, and Honduras, food insecurity rates are 17-18 percent. All other countries in the region are estimated to have reduced food insecurity to under 10 percent in 2017.

Income growth and lower prices are the drivers behind increased food demand in all countries except for Ecuador, where declines in GDP and real exchange rates are projected to suppress food demand. The food gap is projected to decline for the region and for individual countries, so those suffering from food insecurity will move closer to the caloric target over the next 10 years.

Haiti continues to suffer from natural disasters and political/economic uncertainty that makes decisive action towards poverty eradication difficult. In 2016, Hurricane Matthew hit the country with catastrophic rain flooding and storm surge, causing the death of at least 1,300 people and displacement of tens of thousands. In addition, the country is still struggling with the consequences of a cholera epidemic without sufficient funds. While Haiti's political situation has improved in recent years, it remains fragile.

Bolivia has enjoyed above-average economic growth and steady improvements in food security over the last 20 years. Food production is increasingly robust after enactment of public policies aimed at increasing productivity and strengthening the role of agriculture in food and national security (FAO, 2015). Other policies aimed at reducing malnutrition have been equally successful. Since 1990-92,

the incidence of wasting (low weight for height) has been halved to 4.5 percent and stunting (low height for age), an indicator of chronic undernutrition, has been reduced by more than one-third to 27 percent. Bolivia's Multisector Zero Malnutrition program, one of the country's flagship initiatives, is tasked with further improving the country's food security.

Despite steady improvements, food insecurity in Guatemala affects an estimated 27 percent of the population in 2017, primarily from insufficient food *access* rather than *availability*, especially in remote rural areas. The country's income distribution is becoming more equal, but it is still among the most skewed in the region and the world. Food insecurity is concentrated in the country's Western Highlands and the eastern dry areas, Guatemala's poorest territories. While urban poverty continues to be a problem, landless peasants, subsistence farmers, and traditional fishers are most likely to be food insecure. For 2017, the country's crop production is forecast above average for a second year in a row, after the most recent El Niño phenomenon led to the worst drought in Central America in 35 years. Guatemala had been increasingly relying on food imports, but the expected bumper crop would sharply reduce the need for imports.

Unlike the rest of the LAC study countries, Ecuador has suffered several years of economic decline. As an exporter of crude petroleum, the country's trade balance has suffered greatly as a consequence of the declining oil price. Poor economic growth and projections for a declining real exchange rate portend limited food demand. Food insecurity will continue to affect an estimated one-fifth of Ecuador's population over the coming decade.

Nicaragua has seen the fastest improvements in food security since 1990-92, when more than half of its population was estimated to be food insecure. This share declined to 18 percent in 2017 and is projected to decline to 6.3 percent by 2027, given strong economic growth prospects and low food prices. El Salvador and Honduras, with food insecurity rates of 17 and 18 percent, are both projected to halve these shares by 2027.

The remaining countries in this region—Colombia, the Dominican Republic, Jamaica, and Peru, all classified as upper-middle-income countries by the World Bank (World Development Indicators, 2017)—have successfully reduced their food insecurity rates to below 8 percent and are projected to reduce them to 3 percent or less over the next 10 years.

Table 4

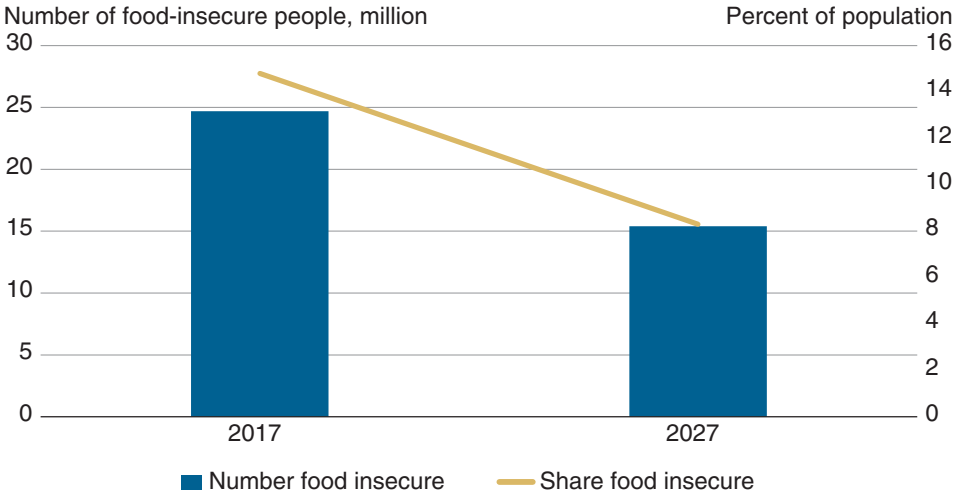
Food security indicators for Latin America and the Caribbean

Projections				
Year	Food grain demand	Other grain demand*	Grain production	Implied additional supply required**
	1,000 tons			
2017	20,460	16,906	18,313	19,053
2027	24,058	22,516	19,289	27,285

*Other grain demand includes seed, feed, waste, and processing. **The gap between grain demand and domestic grain production.

Source: USDA, Economic Research Service.

Latin America and the Caribbean indicators of food insecurity



Source: USDA, Economic Research Service.

Latin America and the Caribbean
(167 million people in 2017)

The 11 LAC countries are projected to continue improving their food security over the coming decade, with the average rate dropping below 9 percent by 2027.

Haiti continues to be the most food-insecure country in the Western Hemisphere, suffering from repeated natural disasters. Food security may drop to 31 percent by 2027.

Latin America and the Caribbean (LAC) indicators of food insecurity

	Population		Population food insecure		Population share food insecure		Food gap (per capita)		Food gap* (total)	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
	Million		*Million*		*Percent*		*kcal /day*		*1,000 MT*	
LAC	**167**	**185**	**24.7**	**15.4**	**14.8**	**8.3**	**348**	**320**	**955**	**547**
Bolivia	11.1	12.8	2.6	1.2	23.0	9.3	260	211	81	30
Colombia	47.7	51.9	2.6	1.3	5.5	2.5	224	200	68	30
Dominican Republic	10.7	11.9	0.8	0.1	7.8	1.1	212	164	20	3
Ecuador	16.3	18.2	3.3	3.5	20.6	19.5	252	248	99	104
El Salvador	6.2	6.3	1.1	0.6	17.7	9.0	271	235	32	14
Guatemala	15.5	18.1	4.1	2.9	26.5	16.2	343	301	158	99
Haiti	10.6	12.0	5.1	3.7	48.2	31.2	639	542	343	213
Honduras	9.0	10.4	1.5	0.8	16.6	8.0	312	269	52	25
Jamaica	3.0	3.2	0.2	0.1	6.1	3.0	204	184	4	2
Nicaragua	6.0	6.6	1.1	0.4	18.1	6.3	327	267	40	12
Peru	31.0	33.8	2.2	0.7	7.2	2.0	218	182	57	15

*Measured in grain equivalent.

Source: U.S. Census Bureau and USDA, Economic Research Service.

North Africa

North Africa continues to experience strong growth in average per capita calorie consumption, reaching levels close to those in high-income countries. While food availability is more than sufficient for all, unequal food access still results in food insecurity. Of the four North African countries included in this study, an estimated 4.6 million people—or 2.5 percent of the population—lack sufficient food to reach the caloric target of 2,100 calories per capita per day. This share is projected to fall by almost half by 2027. The food gap for those consuming below the caloric target is the lowest among all regions, at 208 calories per capita per day in 2017, and is projected to decline to 187 calories by 2027.

Despite this relatively favorable assessment, North African countries—like many countries in all other regions—are faced with the triple burden of malnutrition. Parts of their populations remain unable to access sufficient food and calories to reach caloric targets and, as a result, suffer from undernutrition. Others have access to sufficient calories, but their diets are insufficiently varied and they suffer from micronutrient deficiencies that can lead to a number of diseases. At the same time, the share of people who suffer from overnutrition—overweight and obesity—is growing, which can lead to illnesses such as diabetes and coronary heart disease.

In North Africa, food security is linked to the countries' ability to pay for food imports and for safety net programs that give poor households access to food. This makes the region particularly vulnerable to income shocks, either from falling oil revenues, as in Algeria, or from falling tourism incomes as in Egypt, Morocco, and Tunisia. The region is susceptible to variable weather and crop production levels. Over the last decades, policies have promoted agricultural production and investment in infrastructure, particularly irrigation technology. Egypt is seeking to expand its total agricultural land by 20 percent (FAO, 2017b). Domestic grain production is projected to stagnate over the coming decade. Regional food imports, which averaged 53 percent of consumption over the last 10 years, are crucial to ensure sufficient grain supplies.

As North African countries pursue growth in domestic grain production, the increased need for irrigation has made water scarcity the region's most urgent challenge. This has led the institutions in charge of regulating water to adopt widespread modernization of irrigation systems. As a result, Egypt, Morocco, and Tunisia now have large crop areas under pressurized irrigation, which affords 90 percent efficiency versus 60 percent in the old gravitation system (FAO, 2017b). But there is much room for improvement by further conversion to drip irrigation, improved soil and water management, a change in cropping patterns, and further crop intensification (FAO, 2017b).

The countries in North Africa rely on food imports to make up for production shortfalls. In recent years, they have greatly increased their export revenue from high-value crops such as fresh fruits (dates) and vegetables (beans, tomatoes), thus earning foreign exchange to help pay for imported grains.

Table 5

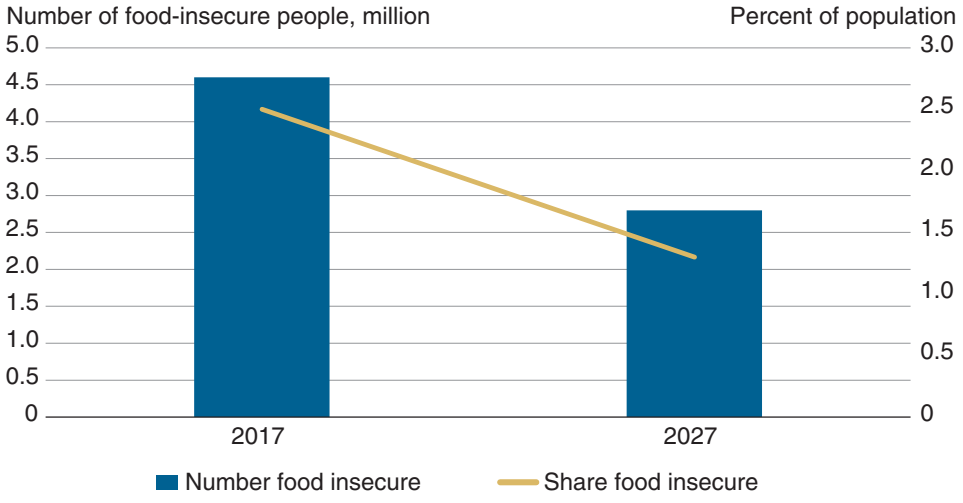
Food security indicators for North Africa

Projections				
Year	Food grain demand	Other grain demand*	Grain production	Implied additional supply required**
	1,000 tons			
2017	48,861	35,844	36,192	48,513
2027	59,874	52,897	35,631	77,140

*Other grain demand includes seed, feed, waste, and processing. **The gap between grain demand and domestic grain production.

Source: USDA, Economic Research Service.

North Africa indicators of food insecurity



Source: USDA, Economic Research Service.

North Africa
(183 million people in 2017)

The four North African countries have higher food consumption levels and lower rates of food insecurity (below 5 percent in 2017) than any other IFSA region; food insecurity is projected to fall further by 2027 despite uncertainty caused by regional unrest.

The lowest income groups, unable to afford the caloric target, experience an average food gap of just over 200 calories per capita per day.

North Africa indicators of food insecurity

	Population		Population food insecure		Population share food insecure		Food gap (per capita)		Food gap* (total)	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
	Million		*Million*		*Percent*		*kcal /day*		*1,000 MT*	
North Africa	**183.2**	**215.7**	**4.6**	**2.8**	**2.5**	**1.3**	**208**	**189**	**120**	**66**
Algeria	41.0	46.8	1.0	0.6	2.4	1.4	206	193	26	16
Egypt	97.0	119.9	2.5	1.7	2.6	1.4	208	194	59	38
Morocco	34.0	37.1	1.1	0.4	3.3	1.1	235	208	34	11
Tunisia	11.2	12.0	0.1	0.0	0.5	0.1	138	121	1	0

*Measured in grain equivalent.

Source: U.S. Census Bureau and USDA, Economic Research Service.

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Nutritional Developments Between 2000 and 2013

Income and food price changes are the main drivers of food demand in the International Food Security Assessment (IFSA) model. Given rising incomes and low prices, demand is projected to increase for all foods and among all income levels, with the exception of "inferior goods" such as roots, tubers, and cereals (in some cases) among the higher income groups. Inferior goods are those that people substitute away from as incomes rise. These staple foods make up the major part of people's diets, but much more so among lower income populations given staples' relatively low cost per calorie.

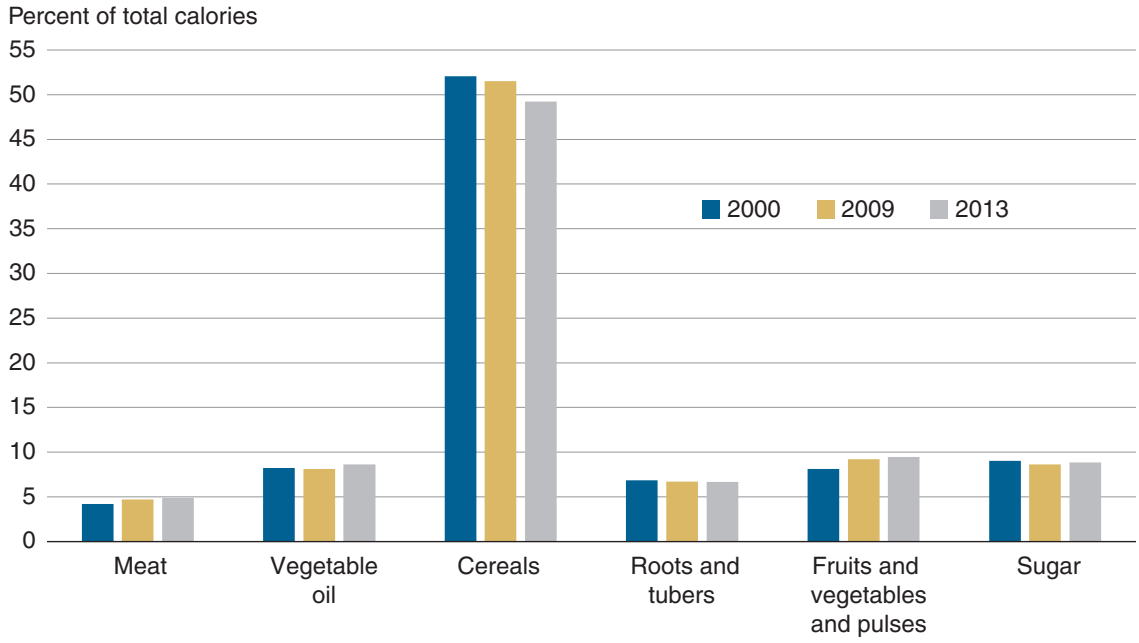
Rising incomes over the last decade have contributed to a shift in diets across all regions. These shifts are incremental and slow, but the trend confirms a convergence toward dietary patterns observed in middle- and higher income countries. Meat and fruit/vegetable consumption is growing at the expense of cereals and roots/tubers (figure S1-1). Consumption levels for vegetable oil have remained relatively stable.

Regional differences exist with respect to dietary patterns. Latin America and Caribbean (LAC) countries, with the highest average incomes, have the lowest staple food share and the highest shares in meat, vegetable oil, and sugar consumption. SSA, the poorest region, has the highest consumption shares in staples and pulses and the lowest shares in higher value products (figure S1-2).

Improved food security is linked to improved economic conditions, as defined by rising incomes and affordable food prices, but the assessment is incomplete unless nutritional quality is considered. One aspect of food insecurity is undernutrition. As such, governments are increasingly aware of the need

Figure S1-1

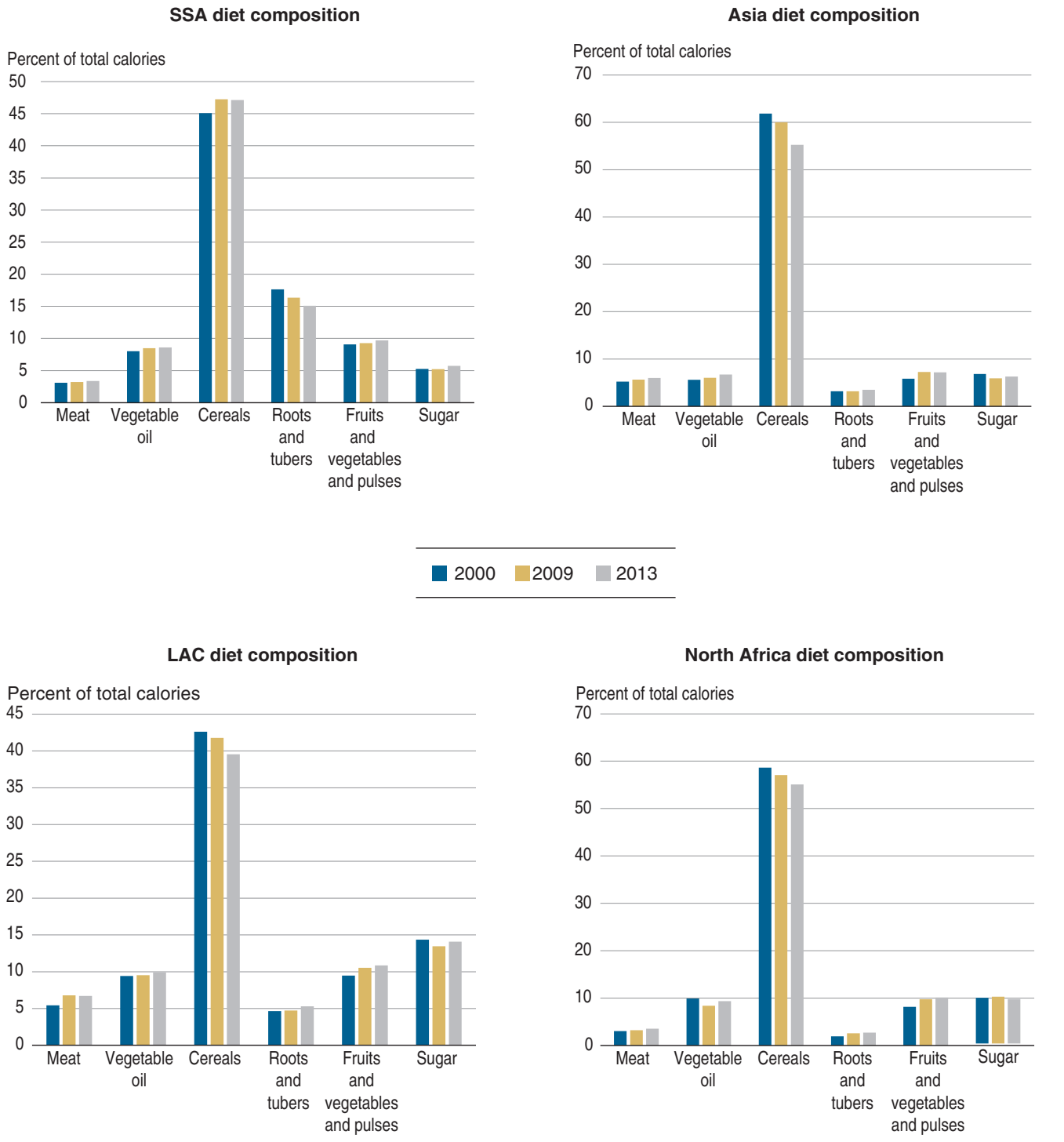
Diet composition of 76 IFSA countries



Source: USDA, Economic Research Service, based on Food and Agriculture Organization food balance sheets for 2013.

Figure S1-2

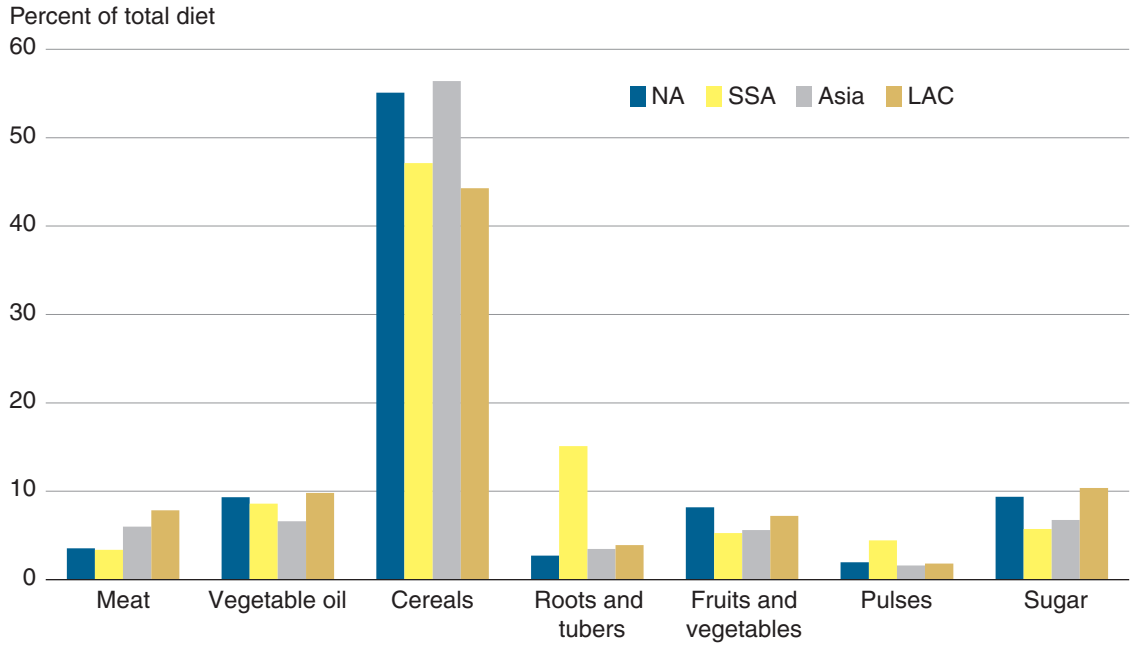
Regional diet composition



SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean.
Source: USDA, Economic Research Service calculations based on UN Food and Agriculture Organization, food balance sheets.

Figure S1-3

Diet composition in IFSA regions, 2013



NA = North Africa, SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean.
Source: USDA, Economic Research Service, based on Food and Agriculture Organization food balance sheets for 2013.

to address malnutrition, which consists not only of insufficient food, as measured by energy or calories, but also of insufficient diet diversity and micronutrients.

The evaluation of micronutrient consumption is beyond the scope of this report, but we do consider trends in macronutrient intake, represented by calories of carbohydrates, grams of protein, and grams of fat as reported in food balance sheets published by the Food and Agriculture Organization (FAO). A healthy diet aims to reach 10 percent of calories from protein content and a minimum of 20 percent from fat (USDA/USDHHS, 2010). The main source of protein besides cereals is meat, dairy, and pulses. Fat comes from meat and animal products like butter, but also from vegetables (mainly in the form of vegetable oil) and oil crops such as peanuts.

Average per capita caloric availability continues to be lowest in Sub-Saharan Africa (SSA), but the region showed significant growth from 2000 to 2013 (table S1-1). Asia, aggregated here without including the Commonwealth of Independent States (CIS) countries, had the second fastest growth over 2000-13, at 11 percent. Caloric increases slow with higher starting levels; North Africa added 260 calories per capita (8 percent) over the 13 years, nearing caloric availability in high-income countries. While protein and fat intake fell short in Asia and SSA in 2000, by 2013 all macronutrient targets were reached except for a slight shortfall in fat consumption share in SSA and Asia.

Table S1-1

Caloric availability and protein and fat consumption, 2000 and 2013

	Consumption per capita per day			Ratio to requirement (per capita daily)		
	Energy kcal	Protein grams	Fat grams	2,100 kcal energy	10 percent protein[1]	20 percent fat[2]
2000						
76-country average	**2,210**	**55**	**46**	**1.05**	**1.00**	**0.93**
SSA	2,137	52	41	1.02	0.97	0.86
Asia (w/o CIS)	2,251	54	43	1.07	0.96	0.86
LAC	2,316	58	60	1.10	1.00	1.16
NA	3,133	86	69	1.49	1.10	0.99
2013						
76-country average	**2,532**	**67**	**58**	**1.21**	**1.05**	**1.03**
SSA	2,404	61	52	1.11	1.01	0.98
Asia (w/o CIS)	2,493	65	53	1.19	1.04	0.96
LAC	2,530	65	68	1.23	1.01	1.21
NA	3,393	98	75	1.62	1.15	1.00

[1]Based on USDA/U.S. Department of Health and Human Services recommended threshold target of 10 percent of diet.
[2]Based on USDA/U.S. Department of Health and Human Services recommended threshold target of 20 percent of diet.
SSA = Sub-Saharan Africa; LAC = Latin America and Caribbean; NA = North Africa.
CIS=Commonwealth of Independent States.

Source: USDA, Economic Research Service calculations based on FAO food balance sheets.

Nutritional Improvements Vary by Income

Improvements in average diets are welcome developments, but lower income households continue to fall short of caloric targets. Here we take a closer look at consumption of protein, fat, and fruits/vegetables for the three most food-insecure regions: SSA, LAC and Asia (without the CIS countries).

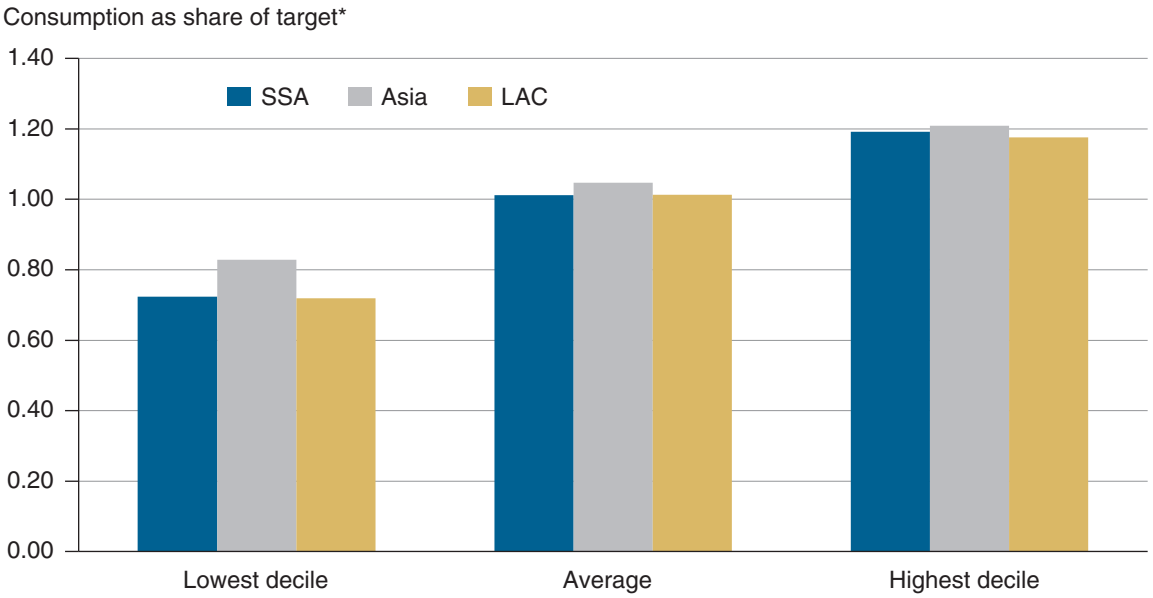
The disparity between low-income and high-income intake levels is pronounced for protein. Here, average consumption in all three regions is close to the recommended level of 10 percent of total diets, with SSA's consumption slightly below the threshold. While the highest income decile for each region has a protein share 20 percent above the target, the lowest income consumers are, on average, 20-30 percent below the target (figure S1-4).

Fat consumption differs even more widely across income groups. The lowest income consumers in all three regions fall short of the target (fat consumption comprising 20 percent of total diet), with SSA reaching just half the target and LAC three-quarters (figure S1-5). Average consumption levels are below the target in SSA and Asia.

Further improvements in the area of diet diversification are clearly needed. While lower income consumers need to increase their protein and fat consumption, they also need to consume more fruits and vegetables. LAC is the only region with average consumption reaching the World Health Organization recommendation of 400 grams per capita of fruit and vegetable consumption per day. SSA falls short of the threshold for all income groups; in Asia, only the highest income consumers exceeded the target in 2013.

Figure S1-4

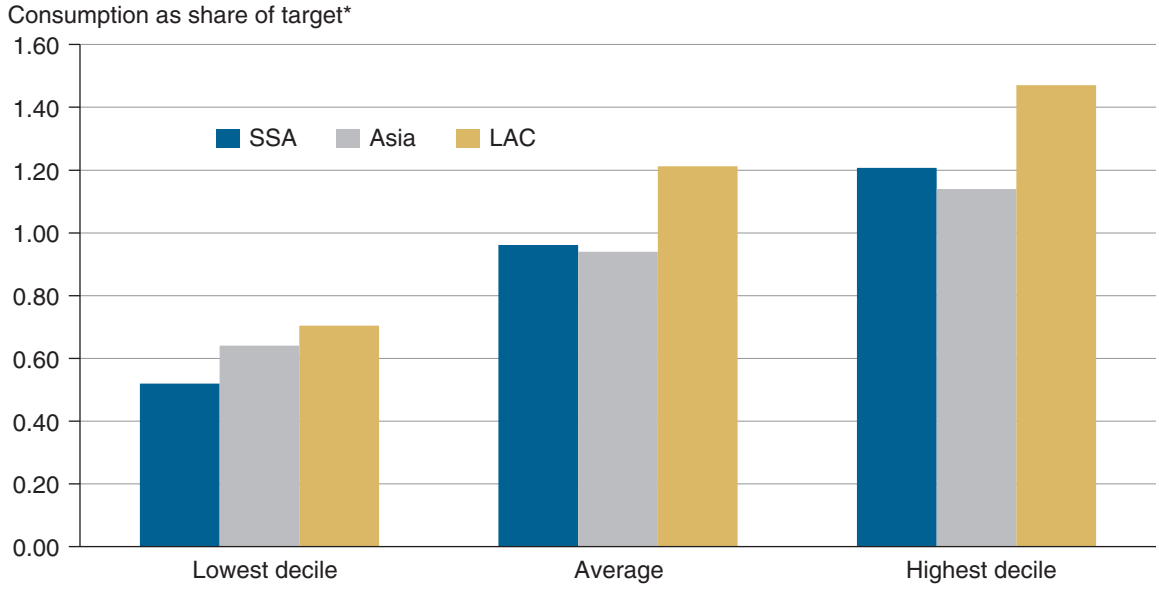
Protein consumption by income level, 2013



*Protein target of 10 percent of total diet as used in this study.
SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean.
Source: USDA, Economic Research Service, based on Food and Agriculture Organization food balance sheets for 2013.

Figure S1-5

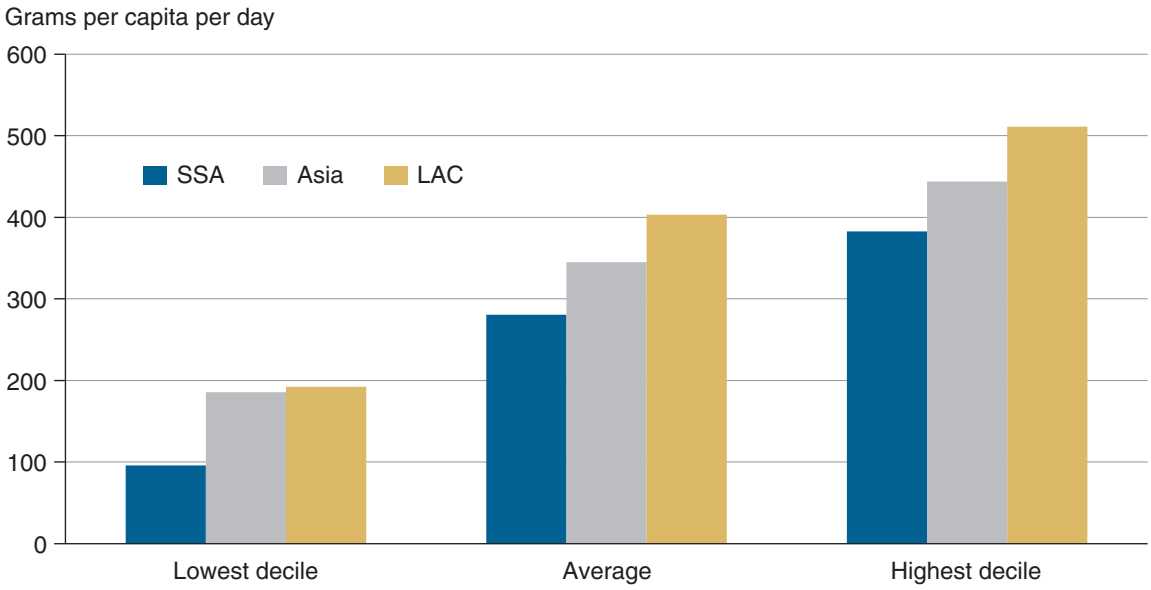
Fat consumption by income level, 2013



*Fat target of 20 percent of total diet as used in this study.
SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean.
Source: USDA, Economic Research Service, based on Food and Agriculture Organization food balance sheets for 2013.

Figure S1-6

Average fruit and vegetable consumption* by income level, 2013



SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean.
*A target of 400 grams per person per day is recommended by the World Health Organization.
Source: USDA, Economic Research Service, based on Food and Agriculture Organization food balance sheets for 2013.

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Appendix: Food security measures for IFSA countries, 2017 and 2027

Appendix table 1

2017 IFSA model results

	Population		Population food insecure		Share of population food insecure		Food gap (per capita)		Food gap* (total)	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
	Million		*Million*		*Percent*		*kcal/day*		*1,000 MT*	
GRAND TOTAL	3,642	4,205	646	372	17.7	8.9	379	392	28,544	16,968
Asia	2,342	2,600	315	119	13.5	4.6	289	360	10,774	5,055
Afghanistan	34.1	42.9	13.3	10.6	38.8	24.6	334	286	510	348
Armenia	3.0	2.9	0.1	0.0	3.9	0.7	191	155	3	0
Azerbaijan	10.0	10.6	0.0	0.0	0.3	0.1	128	118	1	0
Bangladesh	157.8	173.1	26.3	9.9	16.7	5.7	267	217	713	218
Cambodia	16.2	18.4	2.8	0.5	17.3	2.5	279	200	82	10
DPR Korea	25.2	26.4	13.6	10.8	53.8	40.9	403	353	623	435
Georgia	4.9	4.9	0.1	0.0	2.9	0.6	191	160	4	1
India	1,281.9	1,422.6	133.3	16.2	10.4	1.1	233	170	3,386	301
Indonesia	260.6	280.3	16.8	5.8	6.5	2.1	222	189	416	121
Kyrgyzstan	5.8	6.3	0.3	0.1	5.7	2.2	210	184	9	3
Laos	7.1	8.2	1.2	0.2	16.8	2.6	249	180	34	4
Moldova	3.5	3.1	0.3	0.0	9.3	1.6	214	165	9	1
Mongolia	3.1	3.3	0.7	0.3	24.0	7.7	324	252	30	8
Nepal	29.4	32.0	4.6	1.9	15.6	6.0	263	219	140	48
Pakistan	204.9	234.2	41.6	14.8	20.3	6.3	328	259	1,657	465
Philippines	104.3	120.8	18.6	12.3	17.8	10.2	308	273	635	372
Sri Lanka	22.4	23.8	4.5	1.5	20.0	6.5	363	289	181	49
Tajikistan	8.5	9.8	1.7	1.0	20.0	10.2	317	274	67	34
Turkmenistan	5.4	5.9	0.2	0.0	3.3	0.6	186	153	4	1
Uzbekistan	29.7	32.3	0.7	0.2	2.5	0.7	173	150	17	4
Viet Nam	96.2	103.7	9.6	2.0	10.0	2.0	256	201	261	43
Yemen	28.0	34.0	24.7	30.7	88.3	90.4	675	706	1,993	2,587
LAC	167	185	24.7	15.4	14.8	8.3	348	320	955	547
Bolivia	11.1	12.8	2.6	1.2	23.0	9.3	260	211	81	30
Colombia	47.7	51.9	2.6	1.3	5.5	2.5	224	200	68	30
Dominican Republic	10.7	11.9	0.8	0.1	7.8	1.1	212	164	20	3
Ecuador	16.3	18.2	3.3	3.5	20.6	19.5	252	248	99	104
El Salvador	6.2	6.3	1.1	0.6	17.7	9.0	271	235	32	14
Guatemala	15.5	18.1	4.1	2.9	26.5	16.2	343	301	158	99
Haiti	10.6	12.0	5.1	3.7	48.2	31.2	639	542	343	213
Honduras	9.0	10.4	1.5	0.8	16.6	8.0	312	269	52	25
Jamaica	3.0	3.2	0.2	0.1	6.1	3.0	204	184	4	2
Nicaragua	6.0	6.6	1.1	0.4	18.1	6.3	327	267	40	12
Peru	31.0	33.8	2.2	0.7	7.2	2.0	218	182	57	15
North Africa	183	216	4.6	2.8	2.5	1.3	208	189	120	66
Algeria	41.0	46.8	1.0	0.6	2.4	1.4	206	193	26	16
Egypt	97.0	119.9	2.5	1.7	2.6	1.4	208	194	59	38
Morocco	34.0	37.1	1.1	0.4	3.3	1.1	235	208	34	11
Tunisia	11.2	12.0	0.1	0.0	0.5	0.1	138	121	1	0

Continued—

Appendix table 1

2017 IFSA model results—continued

	Population		Population food insecure		Share of population food insecure		Food gap (per capita)		Food gap* (total)	
	2017	2027	2017	2027	2017	2027	2017	2027	2017	2027
	Million		*Million*		*Percent*		*kcal/day*		*1,000 MT*	
SSA	949	1,204	301.3	235.2	31.7	19.5	478	415	16,695	11,300
Angola	20.7	27.0	5.3	8.1	25.5	30.1	339	357	223	361
Benin	11.0	14.2	1.4	1.3	12.3	8.9	267	250	40	35
Burkina Faso	20.1	26.8	5.1	4.5	25.4	16.9	433	390	276	221
Burundi	11.5	15.7	9.2	11.9	80.0	75.7	663	626	708	868
Cabo Verde	0.6	0.6	0.1	0.1	22.6	10.8	289	243	4	2
Cameroon	25.0	32.0	2.0	1.5	8.1	4.6	214	195	52	34
Central African Republic	5.6	6.9	4.7	5.2	82.8	75.6	629	567	335	339
Chad	12.1	14.4	5.9	6.1	49.2	42.3	507	473	373	357
Congo	5.0	6.2	1.3	1.6	25.4	24.9	288	287	43	53
Côte d'Ivoire	24.2	28.5	3.5	2.1	14.4	7.2	360	317	143	74
DR Congo	83.3	103.1	68.6	48.9	82.3	47.5	672	449	5,359	2,555
Eritrea	5.9	6.6	4.8	5.1	81.0	76.9	629	594	375	373
Ethiopia	105.4	138.3	39.8	26.1	37.8	18.9	387	313	1,705	903
Gambia	2.1	2.4	0.4	0.1	18.7	4.3	284	216	12	3
Ghana	27.5	34.0	1.8	0.3	6.6	0.9	238	185	49	7
Guinea	12.4	16.0	2.7	1.8	21.4	11.3	333	287	94	55
Guinea-Bissau	1.8	2.1	0.6	0.4	31.1	19.4	340	296	20	13
Kenya	47.6	54.5	12.7	2.5	26.6	4.6	271	187	409	55
Lesotho	2.0	2.0	0.2	0.0	10.4	2.1	250	196	6	1
Liberia	4.4	5.5	3.1	2.8	70.6	50.5	713	580	223	163
Madagascar	25.1	31.5	10.3	7.2	41.0	22.8	377	309	400	229
Malawi	19.2	26.6	9.3	9.3	48.4	34.8	444	386	477	413
Mali	18.0	23.8	1.0	0.5	5.6	2.2	224	198	26	12
Mauritania	3.8	4.6	0.3	0.1	7.5	1.4	243	194	8	1
Mozambique	26.6	34.0	7.4	2.9	27.7	8.6	397	304	352	107
Namibia	2.5	3.0	0.7	0.5	26.8	15.2	282	243	23	13
Niger	19.2	26.1	2.8	1.8	14.6	7.0	277	240	105	59
Nigeria	190.6	241.5	10.5	6.2	5.5	2.5	208	187	256	135
Rwanda	13.3	16.8	4.0	2.2	30.0	13.1	388	313	180	80
Senegal	14.7	18.3	2.1	1.3	14.3	7.1	240	209	59	32
Sierra Leone	6.2	7.9	3.0	2.4	48.8	31.0	469	392	155	105
Somalia	11.0	14.0	5.5	4.1	49.9	29.0	438	353	276	164
Sudan	37.3	44.2	22.0	24.2	59.0	54.8	481	461	1,282	1,350
Swaziland	1.5	1.6	0.4	0.3	28.4	15.6	298	254	14	7
Tanzania	54.0	70.5	15.4	7.5	28.6	10.7	411	324	714	275
Togo	8.0	10.2	1.7	1.5	20.9	14.7	312	286	62	51
Uganda	39.6	53.7	14.5	13.4	36.8	24.9	394	347	684	555
Zambia	16.0	21.3	8.4	8.6	52.4	40.2	602	535	600	545
Zimbabwe	14.9	18.0	9.1	11.0	61.2	61.3	506	507	572	693

*Measured in grain equivalent.

Source: USDA, Economic Research Service.

Appendix table 2

Nutritional indicators

	Total kcal per capita per day		kcal change since 2000	Share of total consumption					Percent of recommended nutritional target		
				Grains and roots/ tubers	Veg- etable oil	Meat	Sugar and sweet- eners	Fruits and veg- etables	En- ergy[1]	Pro- tein[2]	Fat[3]
	2013	2000	*Percent*								
Total	**2,532**	**2,288**	**10.7**	**59**	**8**	**4.69**	**8**	**5.75**	**121**	**105**	**104**
Asia	2,608	2,291	13.8	59	7	6.40	7	5.74	124	111	107
Afghanistan	2,090			75.4	4.3	3.3	4.2	3.3	100	111	72
Armenia	2,928	2,133	37.3	39.5	7.9	8.6	11.1	11.6	139	123	149
Azerbaijan	3,118	2,406	29.6	61.9	2.3	5.4	5.9	6.3	148	119	86
Bangladesh	2,450	2,125	15.3	80.1	6.3	0.7	3.1	2.2	117	91	55
Cambodia	2,477	2,076	19.3	70.2	2.7	3.8	7.3	2.3	118	106	65
Democratic People's Republic of Korea	2,094	2,131	-1.7	68.6	7.4	3.9	1.8	7.0	100	105	78
Georgia	2,905	2,374	22.4	57.3	5.3	4.1	11.6	3.3	138	111	100
India	2,459	2,314	6.3	57.8	8.4	0.6	9.3	5.3	117	98	96
Indonesia	2,777	2,498	11.2	69.1	8.9	2.6	5.9	4.0	132	90	94
Kyrgyzstan	2,817	2,396	17.6	52.3	5.6	6.4	9.5	5.3	134	121	108
Lao People's Democratic Republic	2,451	2,119	15.7	67.9	2.0	5.8	2.4	10.0	117	112	71
Mongolia	2,510	2,184	14.9	46.4	6.5	18.1	5.8	2.5	120	129	162
Nepal	2,673	2,252	18.7	68.3	8.8	1.6	1.7	5.6	127	103	91
Pakistan	2,440	2,316	5.4	49.4	10.8	2.9	11.1	2.5	116	107	138
Philippines	2,570	2,407	6.8	60.4	4.6	9.1	8.7	7.3	122	93	90
Republic of Moldova	2,714	2,544	6.7	44.1	11.3	6.7	7.7	5.2	129	105	142
Sri Lanka	2,539	2,331	8.9	56.7	3.1	0.9	10.6	4.5	121	94	88
Tajikistan	2,201	1,912	15.1	58.5	10.8	7.2	8.4	7.1	105	115	123
Turkmenistan	2,840	2,605	9.0	58.1	7.3	12.7	3.1	5.7	135	127	133
Uzbekistan	2,760	2,381	15.9	54.9	9.4	8.0	3.6	11.7	131	121	119
Viet Nam	2,745	2,493	10.1	58.1	2.6	15.3	3.3	6.6	131	119	118
Yemen	2,223	2,014	10.4	62.0	9.0	4.5	12.3	4.0	106	106	97
LAC	2,530	2,316	9.2	45	10	6.70	14	6.71	120	103	122
Bolivia (Plurinational State of)	2,256	2,147	5.1	50.7	4.0	13.1	12.0	5.7	107	117	106
Colombia	2,804	2,657	5.5	33.9	12.9	8.2	20.1	9.6	134	92	132
Dominican Republic	2,614	2,185	19.6	31.9	16.3	7.3	12.8	14.0	124	89	154
Ecuador	2,344	2,226	5.3	36.5	16.3	10.5	9.5	7.1	112	105	182
El Salvador	2,577	2,571	0.2	47.5	4.7	4.2	15.5	4.6	123	112	109
Guatemala	2,419	2,092	15.6	48.8	7.6	4.0	19.3	4.5	115	105	104
Haiti	2,091	1,929	8.4	52.7	12.1	4.2	8.1	5.4	100	91	105
Honduras	2,641	2,421	9.1	45.7	10.9	5.6	17.1	5.1	126	98	124
Jamaica	2,746	2,749	-0.1	39.7	9.0	8.0	17.0	6.7	131	112	129
Nicaragua	2,638	2,137	23.4	50.8	8.7	5.0	15.0	1.7	126	106	108
Peru	2,700	2,367	14.1	55.2	6.4	3.7	8.3	9.4	129	111	85
North Africa	3,393	3,133	8.3	58	9	3.53	9	8.17	162	115	100
Algeria	3,296	2,922	12.8	54.7	10.9	2.9	8.0	10.3	157	112	105
Egypt	3,522	3,318	6.1	65.3	4.3	3.5	8.0	8.3	168	117	81
Morocco	3,403	3,056	11.4	60.4	8.5	4.1	11.3	6.3	162	115	92
Tunisia	3,349	3,236	3.5	50.8	13.6	3.7	10.1	7.8	159	118	123

Continued—

Appendix table 2

Nutritional indicators—continued

	Total kcal per capita per day		kcal change since 2000	Share of total consumption					Percent of recommended nutritional target		
				Grains and roots/ tubers	Veg- etable oil	Meat	Sugar and sweet- eners	Fruits and veg- etables	En- ergy[1]	Pro- tein[2]	Fat[3]
	2013	2000	*Percent*								
SSA	2,404	2,184	10.0	62	9	3.37	6	5.26	114	101	98
Angola	2,473	1,763	40.3	58.5	8.7	7.7	5.9	6.7	118	93	97
Benin	2,619	2,419	8.3	70.4	6.1	3.0	3.0	3.3	125	98	86
Burkina Faso	2,720	2,483	9.5	65.4	6.2	2.2	2.6	0.8	130	117	102
Co´te d'Ivoire	2,799	2,424	15.5	65.0	11.2	1.9	3.6	7.4	133	84	95
Cabo Verde	2,609	2,370	10.1	49.1	8.9	6.7	7.1	6.4	124	113	123
Cameroon	2,671	2,138	24.9	54.1	8.8	2.2	3.6	10.4	127	105	96
Central African Republic	1,879	1,917	-2.0	55.2	15.2	7.3	4.0	4.4	89	98	143
Chad	2,110	1,918	10.0	69.6	3.6	2.5	4.9	0.9	100	119	100
Congo	2,208	2,291	-3.6	58.9	10.4	4.7	7.8	6.8	105	94	96
Ethiopia	2,131	1,810	17.7	77.1	3.3	1.7	3.0	1.3	101	113	55
Gambia	2,628	2,288	14.9	62.5	15.1	1.0	9.8	0.9	125	94	122
Ghana	3,016	2,596	16.2	62.9	5.8	1.8	4.7	13.1	144	86	69
Guinea	2,566	2,465	4.1	64.3	13.8	1.9	3.7	8.8	122	87	109
Guinea-Bissau	2,292	2,247	2.0	62.0	15.0	4.8	4.6	4.5	109	77	125
Kenya	2,206	2,048	7.7	58.5	6.4	3.3	7.0	5.1	105	112	98
Lesotho	2,529	2,418	4.6	80.6	0.8	4.2	6.1	1.5	120	116	57
Liberia	2,204	2,181	1.1	66.1	18.4	3.3	2.5	4.4	105	68	122
Madagascar	2,052	2,085	-1.6	79.9	2.7	3.8	3.3	3.5	98	91	54
Malawi	2,367	2,099	12.8	71.6	3.2	3.6	3.4	5.2	113	109	78
Mali	2,890	2,335	23.8	66.9	6.3	3.7	3.5	2.4	138	118	100
Mauritania	2,876	2,758	4.3	52.5	11.0	4.2	12.2	1.9	137	118	115
Mozambique	2,283	1,959	16.5	72.1	9.2	2.9	4.8	2.0	109	80	83
Namibia	2,171	2,275	-4.6	54.6	7.4	5.1	9.4	4.1	103	106	102
Niger	2,547	2,134	19.4	62.7	4.3	3.0	2.1	3.6	121	127	93
Nigeria	2,700	2,571	5.0	66.2	10.1	1.5	3.9	4.4	129	94	94
Rwanda	2,228	1,923	15.9	49.9	2.4	1.6	2.3	24.7	106	102	48
Senegal	2,456	2,151	14.2	62.1	16.7	3.0	7.1	2.8	117	95	131
Sierra Leone	2,404	1,966	22.3	63.6	14.5	1.7	2.4	3.4	114	93	110
Sudan	2,336	2,105	11.0	39.6	7.0	3.0	14.7	8.5	111	121	133
Swaziland	2,329	2,268	2.7	55.9	4.7	5.4	14.9	4.1	111	101	90
Togo	2,454	2,012	22.0	71.6	8.1	2.2	4.7	1.3	117	97	87
Uganda	2,130	2,250	-5.3	44.7	9.2	3.7	5.4	13.7	101	99	98
United Republic of Tanzania	2,208	1,929	14.5	56.6	7.5	2.2	4.6	6.7	105	105	94
Zambia	1,930	1,892	2.0	71.6	6.1	3.1	5.2	1.6	92	114	98
Zimbabwe	2,110	1,960	7.7	54.8	12.9	4.0	12.7	3.4	100	92	122

[1]Based on 2100 kcal per capita per day.
[2]Based on USDA/U.S. Department of Health and Human Services recommended threshold target of 10 percent of diet.
[3]Based on USDA/U.S. Department of Health and Human Services recommended threshold target of 20 percent of diet.

Source: USDA, Economic Research Service, based on UN Food and Agriculture Organization, food balance sheets.

Appendix table 3

Food availability for all 76 IFSA countries, 2008-16

Year	Grain production*	Commercial imports (grains)	Root production *(grain equivalent)*	Food aid receipts *(grain equivalent)*
	1,000 tons			
2008	562,130	103,433	97,820	6,736
2009	574,245	103,211	96,937	6,592
2010	600,541	113,337	105,715	7,513
2011	617,463	119,929	113,125	5,122
2012	636,045	109,324	109,569	4,982
2013	650,490	136,900	114,094	1,880
2014	663,066	145,500	118,381	1,603
2015	645,153	152,856	na	1,298
2016(e)	659,330	160,949	na	na
Average annual	*Percent*			
growth	2.16	6.95	3.50	-11.35

(e) estimate. *Grain production includes rice expressed in milled-rice equivalent. na = not available.

Sources: USDA, Economic Research Service, using data from FAOSTAT, UN Food and Agriculture Organization, and World Food Programme.

Appendix table 4

Food availability for Sub-Saharan Africa, 2008-16

Year	Grain production*	Commercial imports (grains)	Root production *(grain equivalent)*	Food aid receipts *(grain equivalent)*
	1,000 tons			
2008	90,889	22,839	65,049	4,561
2009	95,928	23,263	63,799	4,469
2010	112,139	23,442	70,771	4,527
2011	104,605	27,258	74,778	3,288
2012	111,276	26,697	70,563	3,218
2013	110,899	32,227	73,634	1,114
2014	124,420	30,510	77,308	1,262
2015	117,941	31,491	na	1,012
2016(e)	121,852	34,064	na	na
Average annual	*Percent*			
growth	4.26	6.14	3.14	-11.12

(e) estimate.*Grain production includes rice expressed in milled-rice equivalent. na = not available.

Sources: USDA, Economic Research Service, using data from FAOSTAT, UN Food and Agriculture Organization, and World Food Programme.

Appendix table 5

Food availability for Asia, 2008-16

Year	Grain production*	Commercial imports (grains)	Root production *(grain equivalent)*	Food aid receipts *(grain equivalent)*
	1,000 tons			
2008	426,076	32,919	26,894	1,743
2009	422,204	34,063	26,903	1,698
2010	441,092	38,383	28,411	2,275
2011	462,100	38,092	31,608	1,337
2012	474,055	33,333	31,706	1,469
2013	486,303	44,760	32,715	654
2014	489,882	52,036	33,375	232
2015	473,024	54,526	na	212
2016(e)	492,025	59,540	na	na
Average annual	*Percent*			
growth	1.93	10.11	4.02	-12.55

(e) estimate. *Grain production includes rice expressed in milled-rice equivalent. na = not available.

Sources: USDA, Economic Research Service, using data from UN Food and Agriculture Organization and World Food Programme.

Appendix table 6

Food availability for Latin America and the Caribbean, 2008-16

Year	Grain production*	Commercial imports (grains)	Root production *(grain equivalent)*	Food aid receipts *(grain equivalent)*
	1,000 tons			
2008	15,706	15,246	3,903	393
2009	16,200	15,505	4,190	403
2010	15,555	16,863	4,211	670
2011	15,547	16,990	4,118	437
2012	17,099	16,428	4,496	252
2013	16,952	19,283	4,783	110
2014	16,006	20,271	4,718	107
2015	17,143	21,121	na	74
2016(e)	17,154	20,233	na	na
Average annual	*Percent*			
growth	1.15	4.09	3.48	-11.61

(e) estimate. *Grain production includes rice expressed in milled-rice equivalent. na = not available.

Sources: USDA, Economic Research Service, using data from UN Food and Agriculture Organization and World Food Programme.

Appendix table 7

Food availability for North Africa, 2008-16

Year	Grain production*	Commercial imports (grains)	Root production *(grain equivalent)*	Food aid receipts *(grain equivalent)*
	1,000 tons			
2008	29,459	32,430	1,974	39
2009	39,913	30,380	2,044	22
2010	31,756	34,649	2,322	41
2011	35,211	37,590	2,622	60
2012	33,615	32,867	2,804	43
2013	36,336	40,630	2,962	2
2014	32,758	42,684	2,980	2
2015	37,045	45,718	na	0
2016(e)	28,299	47,112	na	na
Average annual	*Percent*			
growth	-0.49	5.66	8.49	-14.29

(e) estimate.*Grain production includes rice expressed in milled-rice equivalent. na = not available.

Sources: USDA, Economic Research Service, using data from UN Food and Agriculture Organization and World Food Programme.

Appendix—Food Security Assessment Model: Definitions and Methodology

The IFSA model used in this report projects food consumption (food demand), food access, and food gaps in 76 low- and middle-income countries through 2027. Food is divided into four groups covering 100 percent of food consumption: major grain (determined by calorie share), other grains, roots and tubers, and all other food.

The food security of a country is evaluated based on the gap between projected domestic food consumption (food demand) and a caloric target, which we set at 2,100 calories per capita per day—a level necessary to sustain life at a moderate level of activity. The model projections of food demand are expressed in grain equivalent based on each food group's caloric content to allow aggregation across food groups; this grain equivalent is easily expressed in either kilograms or calories.[1]

Three food security indicators are provided: (1) the share food insecure, which is the share of the total population unable to reach the caloric target; (2) the number of food-insecure people; and (3) the food gap, or the amount of food needed to allow each individual consuming below the threshold level to reach the caloric target. This caloric measure indicates relative well-being and helps quantify unequal food access within a country.

Projection results provide a baseline for the food security situation in each country, and results depend on the specification of the model and underlying assumptions. The simulation framework used for projecting food demand is based on partial-equilibrium models for each country in the assessment. The methodology and demand system is introduced in Beghin et al. (2015a); Beghin et al. (2015b) provides more detail on price transmission and food security projections.

Each country model comprises a price-independent generalized log-linear (PIGLOG) demand system for each of the four food groups (Muellbauer, 1975). The demand system is calibrated on a 3-year (2014-2016) average of prices and incomes, on observed consumption levels, a measure of income inequality, and on income and price elasticities. Demand projections are based on projected prices and incomes; the model implicitly assumes that the preferences represented by the demand system, as well as the income distribution embedded in the calibration and projection, are constant over time.

The distribution of consumption used to calculate food security measures is described by a constant coefficient of variation, which implies an increasing standard deviation of consumption as consumption rises over the projection period, but does not account for potential structural changes in an economy. The implied price and income elasticities evolve over the projection period as prices and incomes change; generally, food groups become more income-inelastic because incomes rise.

[1]For example, grains have roughly 3.5 calorie per gram, and tubers have roughly 1 calorie per gram. One ton of tubers is therefore equivalent to 0.29 ton of grain.

Structural Framework for Estimating and Projecting Food Demand in the Aggregate

Demand system definition and calibration

We specify demand q_i^h for a given food group *i*, for income-decile *h* as:

$$q_i^h = (x_i^h / p_i)(A_i(p_i) + B_i(p_i) ln(x^h)) \quad (1)$$

where p_i is the price (expressed in real local currency) and x^h is the decile-level income. We further specify $A_i(p_i) = a_{i0} + a_{i1} p_i$, and $B_i(p_i) = b_{i0} + b_{i1} p_i$.

The PIGLOG demand formulation allows for aggregation of income decile-level demands in equation (1) into average per capita market demand for each food group *i*:

$$\bar{q}_i = \left(\frac{x_i}{p_i}\right)\left((a_{i0} + a_{i1}p_i) + (b_{i0} + b_{i1}p_i)(\ln(\bar{x}) + \ln(\frac{10}{z})\right). \quad (2)$$

The latter is a function of average per capita income $\bar{x}$ and Theil's entropy measure of income inequality *z*.

We also define average expenditure share for food group *i* as:

$$\bar{w}_i = (a_{i0} + a_{i1}p_i) + (b_{i0} + b_{i1}p_i)(\ln(\bar{x}) + \ln(\frac{10}{z})). \quad (3)$$

The elasticity of average demand for food group *i* with respect to average income (or total expenditure) is:

$$\varepsilon_{\bar{q}_i\bar{x}} = 1 + (b_{i0} + b_{i1}p_i) / \bar{w}_i. \quad (4)$$

The own-price elasticity of the average demand is:

$$\varepsilon_{\bar{q}_i p_i} = -1 + \left(\frac{p_i}{\bar{w}_i}\right)\left(a_{i1} + b_{i1}(\ln(\bar{x}) + \ln(\frac{10}{z}))\right). \quad (5)$$

In each country, consumers at different income levels have similar underlying preferences over food group *i* as embodied in parameters a_{i0}, a_{i1}, b_{i0}, b_{i1}, but their respective consumptions vary because their respective incomes vary.

With a system of three linear equations (equations 3-5) with four unknown variables, one parameter remains free. The free parameter (chosen to be b_{i0}) is used to ensure that decile demands behave consistently with stylized facts of food security as follows: price sensitivity and income responsiveness decline with rising income levels; own-price elasticities must be negative; and food expenditure shares tend to fall with increasing income. A range of values for the free parameters ensures that these stylized facts are satisfied by the calibrated demand system. Here, we pin down b_{i0} such that the ratio of price elasticities for the bottom and top deciles is equal to the ratio of the natural logarithm of their national income shares.

For any given free parameter value, the system of equations is solved for parameters b_{i1}, a_{i1}, and a_{i0} as a function of the free parameter. Once these three parameters are recovered, parameters $\tilde{a}_{i0}, \tilde{a}_{i1}, \hat{b}_{i0}, \text{and } \tilde{b}_{i1}$ along with income x^h and price p_i, are used to generate the consumption level of food group i for each decile specified in equation (1). In this initial calibration, the quality of any food group i is assumed constant across the income distribution.

For each country, we calibrate a demand system for each of the four food groups based on income, consumption levels, and prices from the 3 years preceding the projection period (2014-16). We determine the major grain (which varies across countries) based on caloric share in the diet. The "other grains" food group contains all other grains; the prices for this food group are weighted by its components' caloric shares. At the calibration stage, we either observe domestic food prices (including the components of a price index for other grains that is weighted by caloric share) or create synthetic prices.

For unobserved food prices, we create a synthetic domestic price, $p_i^{dom,syn}$ that is linked to the world price $p_i^{world,}$ expressed in local currency. The parameter θ is the price transmission slope, which we assume is 0.7. The parameter trc_{int} represents international transportation and market costs (e.g., Cost, Insurance and Freight (CIF) and Free on Board (FOB)), which we assume are 10 percent, and trc_{dom} are domestic trade costs, which we assume are $20 (U.S.) per ton in real terms.

$$(6) \qquad p_i^{dom,syn} = \theta\, p_i^{world} \left(1 + trc_{int} / \theta\right)\left(1 + tariff / \theta\right) + trc_{dom}$$

At this stage, we also calibrate a price transmission equation that links the domestic price (either observed or synthetic) to the world price. The generic price transmission equation is:

$$(7) \qquad p_i^{dom} = \theta\, p_i^{world} + \widehat{intercept}$$

During the calibration stage, we solve for the intercept, and hold it constant in real terms during the projection period.

Projection of food demand calculation and food security indicators

Food security indicators presented in the IFSA are the share of population food insecure, the number of food-insecure people, and the food gap.

For each country, we use the calibrated demand parameters and projected income x_t and prices p_{it} to project mean food demand for each of the four food groups i in each year t so that $q_{it} = (x_t / p_{it})\left(\hat{A}_i(p_{it}) + \hat{B}(p_{it})\ln(x_t)\right)$. We aggregate demand for the four food groups into total food demand expressed in calories, so that $\sum q_{it} = Q_t$, which we also refer to as food or calorie consumption. We use this measure of total demand to calculate food security indicators.

We follow FAO (2015) to estimate the distribution of caloric consumption beginning with a coefficient of variation (CV) for food availability, which characterizes consumption distributed with a mean m and variance v, so that $CV = \left(\sqrt{v} / m\right)$.[2] Given the CV as indicated in the appendix of FAO (2015), and

[2]See the appendix of Beghin et al. (2015b) for more detail.

the projected mean caloric consumption (Q_t), we can recover the variance, v, of the empirical distribution for a given year t.

Assuming food consumption (Q_t) is distributed lognormal, then $ln(Q_t)$ is distributed $N(\mu,\sigma^2)$ with $\mu = \ln\left(\frac{m^2}{\sqrt{v+m^2}}\right)$ and $\sigma^2 = ln(1+v/m^2)$. Once μ and σ^2 are computed, we recover the proportion of the population that falls below the calorie target (2,100 calories per capita per day) using the standard normal CDF, Φ: $\Phi^{insecure} = \Phi\left(\frac{\ln(2100-\mu)}{\sigma}\right)$. Here, $\Phi^{insecure}$ indicates **the share of the population that is food insecure**. Using this share and total population in the respective country, we obtain the total **number of food-insecure people** in this country.

Next, the expected average food intake of food-insecure people, $q_{cal}^{insecure}$, can be recovered using the partial mean of caloric availability below the target (2,100 calories), $q_{cal}^{insecure} = e^{\mu-\sigma/\Phi\text{^}2100\left[\phi((\ln(2100)-\mu)/\sigma\right]}$, where ϕ is the standard normal density function.

The **food gap** is computed by calculating the difference between the target of 2,100 calories and the average calorie availability for food-insecure consumers. This provides a gap in calories per day per food-insecure person. The latter can be multiplied by the population at risk and converted into volume of grain equivalent per year to arrive at a gap indicator based on annual grain volume.

Data

The model is calibrated for each of the four food groups based on average prices and income from 2014 to 2016. Prices are expressed in real local currency units. Quantities are expressed in grain-equivalent units.

Calibrated parameters and variables:

Demand parameters ($\tilde{a}_{i0}, \tilde{a}_{i1}, \hat{b}_{i0}$, and $\tilde{b}_{i1}$), price intercepts, and domestic price (synthetic)

Projections are based on data from the ERS International Macroeconomic Data Set and USDA's Agricultural Projections to 2026, and use the calibrated demand parameters and price transmission intercept between world and domestic prices.

Endogenous projection variables:

Food demand, domestic prices

Exogenous variables used in calibration and projection:

Average consumption per capita – FAO Food Balance Sheet[3]

Grain shares – FAO Food Balance Sheet[4]

Elasticities of price and income – unpublished calculations by Jim Seale using 2011 International Comparison Program (ICP) data, following the methodology in Muhammad et al., 2011[5]

Domestic prices (Observed) – FAO Global Information and Early Warning System (GIEWS, annual average; market depends on reporting)

Tariffs – World Bank's World Integrated Trade Solution (WITS)[6]

Exchange rates and Consumer Price Indexes (CPIs) – ERS International Macroeconomic Data Set.[7]

Population – U.S. Census Bureau

World Prices – ERS Agricultural Projections through 2026[8]

Per capita income – generated using GDP and population from ERS International Macroeconomic Data Set[9]

Income Distribution – World Bank Data Bank.[10] Assumed constant during the projection period.

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[3]Food Balance Sheets (FBS) are for 2013. There are no recent FBS for Somalia, Eritrea, Burundi, or DR Congo. Instead, we use grain consumption levels and share of grains in total calories as reported by FAO-GIEWS Cereal Supply and Demand Balance for Sub-Saharan African Countries (November 2016) to generate per capita consumption for each food group. We scale up the reported consumption from the FBS using FAO's grain supply data.

[4]There are no recent FBS for Somalia, Eritrea, Burundi, or DR Congo. We access preliminary FBS for Somalia from the original FAOSTAT, which is no longer maintained. We use FBS of neighboring countries (Burundi-Rwanda; DRC-Congo; Eritrea-Ethiopia) to approximate the shares of grains and roots/tubers in total calories for the other countries.

[5]Elasticities are not available for all countries. We use Ethiopia for Somalia and Eritrea; an average of Tunisia and Morocco for Algeria; an average of Tajikistan and Pakistan for Afghanistan; an average of Tajikistan, Kyrgyzstan, and Kazakhstan for Turkmenistan and Uzbekistan. We use less-elastic values for rice (major grain) in Vietnam, Philippines, Indonesia, India, and Bangladesh, and for wheat (other grain) in India.

[6]Tariffs are available through 2015. Somalia and DPR Korea do not report to the World Trade Organization. Somalia tariffs are the means observed for Sub-Saharan African IFSA countries, and DPR Korea tariffs are the maximum observed tariffs for IFSA countries.

[7]We modeled Ecuador and El Salvador in $U.S.; CPI growth rates are from the International Monetary Fund (IMF). Somalia's CPI changes are from IMF report CR16136, and nominal exchange rates are from IMF. DPR Korea's CPI is from "other east Asia," with assumed 2-percent currency depreciation annually.

[8]The world price series are: maize (US gulf #2 yellow); rice (Thai, B, fob Bangkok); sorghum (US Gulf, #2 yellow); wheat (gulf, #2 HRW); barley (EC, French, Rouen); oats (US Farm); roots and tubers (cassava; tapioca, hard pellets, Rotterdam, fob); and other food (represented by soybean oil, Dutch fob, ex-mill). World price projections are not available for all cereals represented in the FAO Food Balance Sheets and the FAO GIEWS price database. We use the world price of sorghum to represent millet, wheat to represent rye, and sorghum to represent all other cereals (e.g., teff, fonio).

[9]Ecuador, El Salvador, and Zimbabwe GDP are from IMF. Somalia GDP is from IMF report CR16136. DPR Korea GDP follows Bank of Korea published real growth rates.

[10]Income distributions are not available for all countries. We use Ethiopia for Eritrea and Somalia; Zambia for Zimbabwe; an average of Uzbekistan, Pakistan, and Tajikistan for Afghanistan; and Mongolia for DPR Korea.

Coefficient of Variation (CV) of Food Consumption – FAO (2015); assumed constant during the projection period.[11]

Modeling Staple Production

Agricultural production is decomposed into yield (production per hectare), and area for grains and roots/tubers. Production (PR) for a given country c in year t is obtained by multiplying projected yield (YL) and area (AR):

$$PR_{ct} = AR_{ct} YL_{ct} .$$

The projections cover 2015-27 and are based on producer price projections in local currency units derived from world price projections from USDA's *Agricultural Projections to 2026*.

Yield

Yield projections are based on parameters estimated econometrically using panel data, and are calibrated to observed yields for 2012-14. Yields respond to expected relative return ratios per hectare (RR), autonomous technical change over time (T), and include a country-specific effect:

$$YL_{ct} = f(RR_{ct}, T_t) .$$

The return ratio is the ratio of the return per hectare (price, p_{ct}, times yield) divided by the price of fertilizer, $RR_{ct} = p_{ct} Y_{ct} / p_t^{fert}$. The expected return ratios include a contemporaneous and a long-term expectation component and are expressed in real local currency (rlcu). We use USDA A*gricultural Projections* (to 2025) prices for superphosphate, cassava (for root and tubers), and the major grain by production volume (for grain). We express the international price in rlcu, and then use the transmission equation, $p^{domestic} = 0.7 p^{world} + 0.3I$, to model the domestic price. The intercept, *I*, is the mean of the price over the regression time period. Production data are from FAO.

Area

Area projections are based on a numerically calibrated Nerlovian specification.

Following the typical older Nerlovian specification, we specify area as a function of lagged area, and of expected relative prices (output price and fertilizer price):

$$AR_{ct} = f(p_{ct}, p_{ct}^{fert}, A_{ct-1}, T) .$$

The expectation takes the average of contemporaneous and lagged relative prices. We also include a time trend in area to capture nonprice shifters in area decisions, and a country fixed effect. We numerically calibrate the area equation to the base-year average (2012-14) using consensus estimates for price and lagged acreage responses.

[11]FAO does not calculate CV for all countries. We use Ethiopia for Eritrea and Somalia; Former Sudan for Sudan; an average of Armenia, Azerbaijan, and Georgia for Moldova; and an average of Uganda, Rwanda, Zambia, Congo, CAR, and Angola for DR Congo.

IASR

The implied additional supply required (IASR) quantifies total grain demand in each country that is not projected to be met through domestic production (PR). Total grain demand (TD) is made up of food demand (FD), generated by our demand-driven model, and nonfood use (NFD), which comprises seed, feed, processing, and other uses. The IASR for grains thus can be expressed as IASR = TD-PR.

We assume that demand for grain for processing and other uses grows at the same rate as production. The demand for grain for seed and feed grows at the average rate observed from 1989 to 2014.

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