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GFA 27

June 2016

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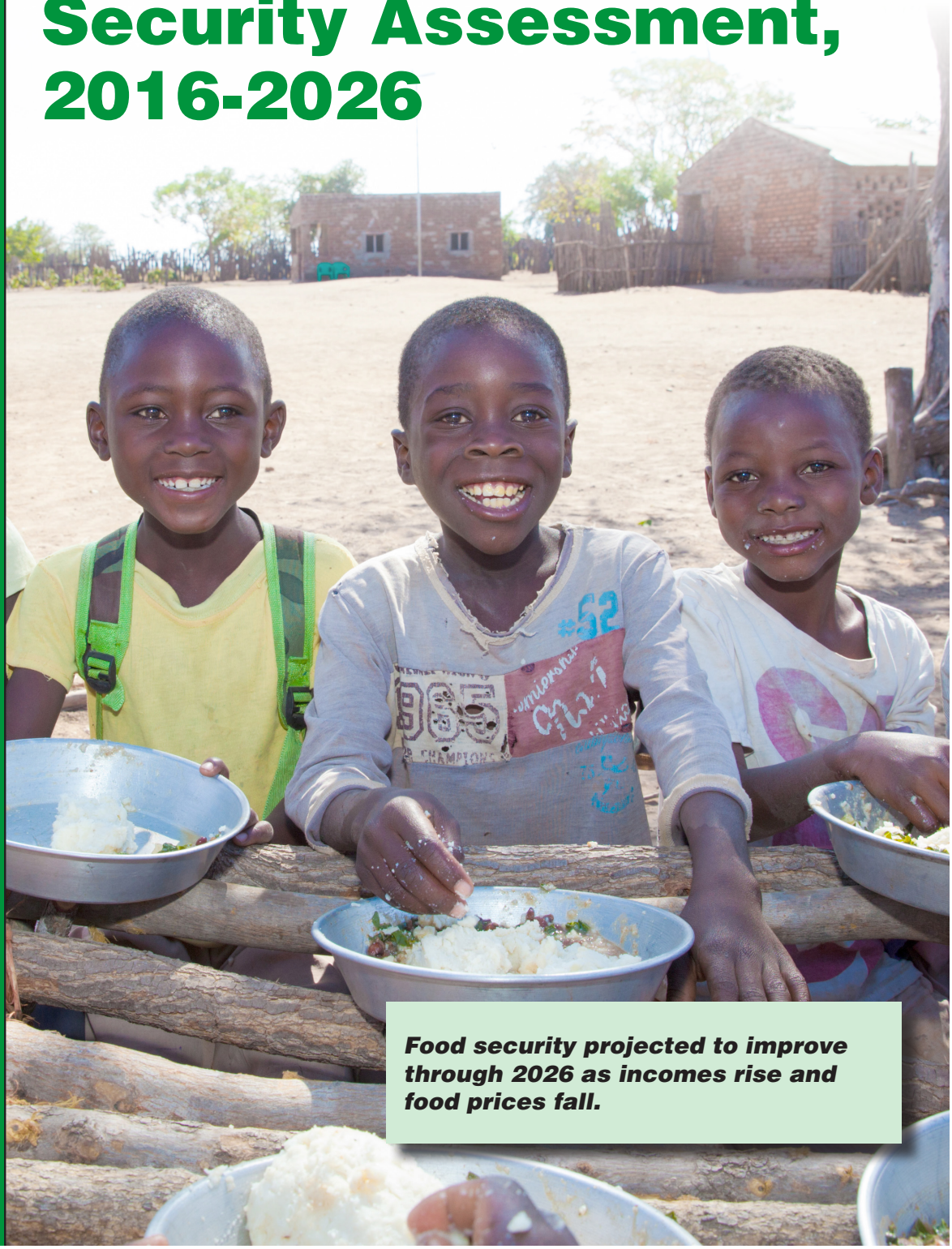
# International Food Security Assessment, 2016-2026



***Food security projected to improve through 2026 as incomes rise and food prices fall.***

**United States Department of Agriculture**

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GFA-27

June 2016

# International Food Security Assessment, 2016-2026

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## Abstract

USDA-ERS's new International Food Security Assessment model is a demand-oriented framework that includes information on domestic prices, consumer responsiveness to changes in prices and incomes, and food quality differences by income groups. Given projections for lower food prices and rising incomes, food security for the 76 low- and middle-income countries included in this demand-oriented framework is expected to improve through 2026. The share of the population that is food insecure is projected to fall from 17 percent in 2016 to 6 percent in 2026. The number of food-insecure people is projected to fall markedly, 59 percent, which matches the decline in the intensity of food insecurity, at the aggregate level.

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

## Acknowledgments

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# 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 focused on selected low- and middle-income 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.

# Contents

**Summary** . . . . . iv

**International Food Security Assessment: A New Demand-Oriented Model** . . . . . 1

Regional Outlook . . . . . 5
How Food Security Is Assessed . . . . . 11
References . . . . . 12

**International Food Security Assessment: New Demand-Oriented Versus Supply-Oriented Model** . . . . . 13

Introduction . . . . . 13
Comparing Food Security Estimates . . . . . 13
Implied Additional Supply Required . . . . . 19
Conclusions . . . . . 20

**Food Security Assessment: 2016-26, Supply-Oriented Model** . . . . . 21

References . . . . . 24

**Appendix 1—New Demand-Oriented Model: Definitions and Methodology** . . . . . 27

Structural Framework for Estimating and Projecting Aggregate Food Demand . . . . . 27
Food Security Indicators . . . . . 29
Data . . . . . 29
References . . . . . 31

**Appendix 2—Supply-Oriented Model: Definitions and Methodology** . . . . . 32

Framework for projecting food consumption in the aggregate and by income group . . . . . 32
Data . . . . . 34

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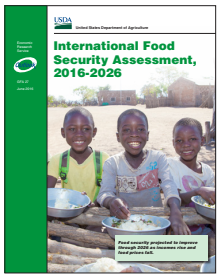



Find the full report at *www.ers.usda.gov/publications/gfa-foodsecurity-assessmentsituation-and-outlook/gfa-27.aspx*

# International Food Security Assessment, 2016-2026

Stacey Rosen, Karen Thome, and Birgit Meade

## What Is the Issue?

International food price spikes over the last decade highlighted the impact of price shocks on the food security of vulnerable populations. ERS has developed a new demand-oriented framework to analyze income and price shocks and their impact on food security. Grains comprise the bulk of the diet in most of the study countries. Prices of these commodities are projected to decline over the next decade. Conversely, incomes in nearly all the study countries are projected to rise. To understand how food prices and income affect food security, ERS researchers estimated and projected the number of food-insecure people regionally and in each of the 76 low- and middle-income countries covered in this report for 2016-26.

## What Did the Study Find?

Given projections for lower food prices and rising incomes, food security for the 76 low- and middle-income countries included in this demand-oriented framework is expected to improve through 2026. The share of population that is food insecure is projected to fall from 17 percent in 2016 to 6 percent in 2026. The number of food-insecure people is projected to fall markedly, 59 percent, to 251 million in 2026. This roughly matches the decline in the distribution gap, the amount of food needed to allow all food-insecure people to reach the nutritional target of 2,100 calories per person per day. The similar rates of decline for the two measures indicates no worsening in the intensity of food insecurity, at the aggregate level, for those people considered to be food-insecure.

At the regional level, the greatest improvement in food security is projected for ***Asia***, where the share of population food insecure falls from 13 to 2.4 percent and the number of food-insecure people falls 80 percent between 2016 and 2026. In 16 of the region's 22 countries, less than 5 percent of the population is projected to be food insecure in 2026. The number of food-insecure people in the ***Latin America and the Caribbean*** (LAC) region is projected to fall by half over the next decade; the share of population that is food insecure falls from 14.6 percent in 2016 to 6.4 percent in 2026. Strong gains are expected throughout the region with the sole exception of Haiti, where improvement is expected to be relatively modest.

***Sub-Saharan Africa***'s (SSA) food security situation is also projected to improve, but at the slowest rate of all the regions. The number of food-insecure people is projected to fall by 36

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment,and rural America.

percent and the share of population that is food insecure falls from 29 to 15 percent. In 29 of the 39 countries included in this region for this study, 20 percent or less of the population is projected to be food insecure in 2026. Improvement in food security is also projected for ***North Africa***, which is the most food secure among all the regions in the study. The share of population food insecure falls from 2 percent in 2016 to 0.6 percent in 2026.

## How Was the Study Conducted?

The new IFSA model used in this report projects food consumption (food demand) and food gaps in 76 low- and middle-income countries through 2026. Food security of a country is evaluated by estimating what population share is unable to reach a nutritional target, which is set at 2,100 calories per capita per day. The intensity of food insecurity is measured by determining the size of the gap between projected domestic food consumption (food demand) and the nutritional 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 Nations' Food and Agriculture Organization (FAO) Food Balance Sheets. Observed domestic prices are from FAO's Global Information Early Warning System database. Price and income elasticities are from Muhammad et al. (2011). Tariff data are from World Bank WITS (World Integrated Trade Solution). Exchange rates and CPIs are from the ERS International Macroeconomic Dataset. World prices are from USDA's Agricultural Projections to 2025.

# International Food Security Assessment, 2016-2026

## International Food Security Assessment: A New Demand-Oriented Model

USDA-ERS has transitioned to a new International Food Security Assessment model, a demand-oriented framework that includes information on domestic prices, consumer responsiveness to changes in prices and incomes, and food quality differences by income groups. The international food price spikes over the last decade highlighted the impact of price shocks on the food security of vulnerable populations. The increasing availability of consumer price data in the study countries made it more feasible to develop the new IFSA model. The new demand-oriented approach provides a framework to study income and prices shocks and their impact on food security. The analysis is improved by more accurately capturing the relationship between unequal distribution of income and consumption within each country. Furthermore, it is now possible to determine the economic drivers and the extent of their contribution to changes in food demand and therefore food insecurity.

Like the supply-oriented model, the new, demand-oriented model estimates and projects per capita consumption and evaluates that against a nutritional target of 2,100 calories per person per day[1] to determine whether population groups should be considered food secure. The supply-oriented model makes the assessment by income decile whereas the new model does this continuously along the entire income distribution. The new approach leads to improved estimates of the food-insecure population, especially for the lowest income deciles, because it is based on an estimated distribution of consumption and can therefore capture food insecurity ***within*** deciles, avoiding the discrete jumps between deciles that can occur (i.e., from the 20- to 30-percent decile) in the supply-oriented model (see Methodology appendix for further detail).

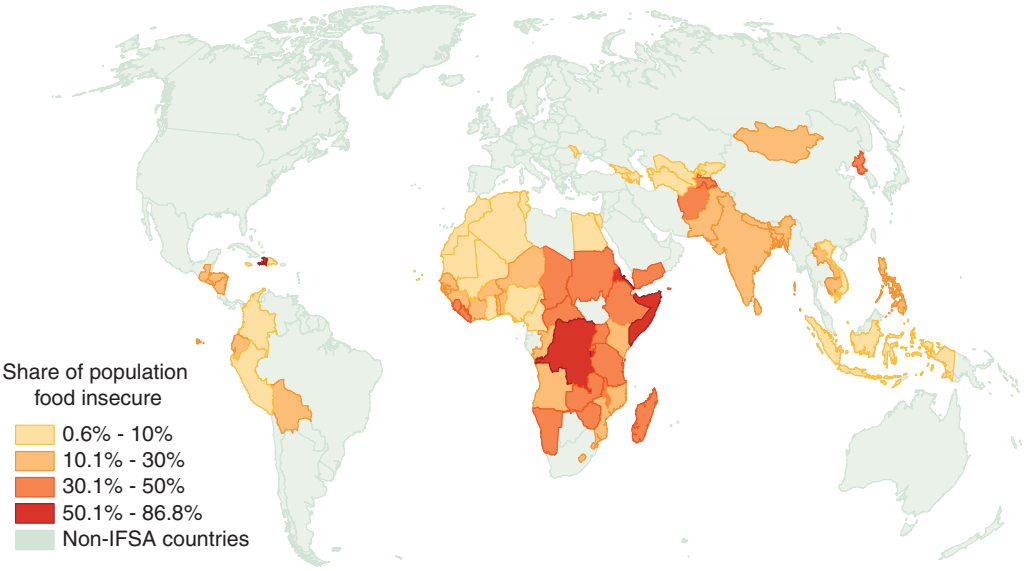
A potential weakness of the new approach is a reliance on several data series, such as consumption data for food groups and local food prices, for which the quality is not 100 percent certain. International organizations and local governments are investing to improve the quality of these data sets, but we are unable to determine their reliability. Moreover, food security projections are made under the assumption of projections for income and price changes as of late 2015/early 2016. Since that time, world economic conditions and price and income outlooks have changed: the outlook for income growth is not as optimistic in mid-2016 as it was then, and there are signs that food prices might see a slight increase rather than a decline over the next decade (World Bank, 2016). Finally, income and price projections are independent of each other and are not changed by food security or other projections generated in the model.

Food consumption for the 76 low- and middle-income countries included in the new, demand-oriented IFSA model is determined by food prices and income. These 76 countries comprise 81 percent of the population of low- and middle-income countries (excluding China). Given projections for lower food prices and rising incomes, food security is expected to improve through 2026. The share of population that is food insecure is projected to fall from 17 percent in 2016 to 6 percent in 2026. In total, for the countries studied, the number of food-insecure people is projected to fall markedly, by 59 percent.

[1]The target of 2,100 calories was chosen as an approximation for food security. A truly adequate dietary energy intake target is based on sex, age, body mass, and physical activity level. Not all people who consume less than 2,100 calories per day are food insecure, as there may be food insecure people consuming more than 2,100 calories per day.

Figure 1

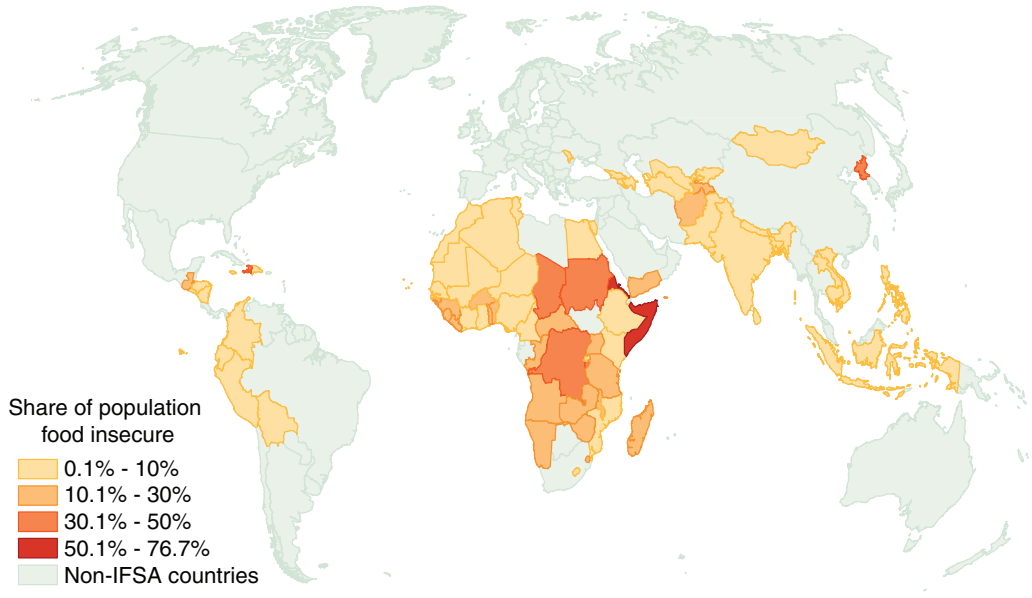
**Share of population food insecure, new (demand-driven) model, 2016**




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

Figure 2

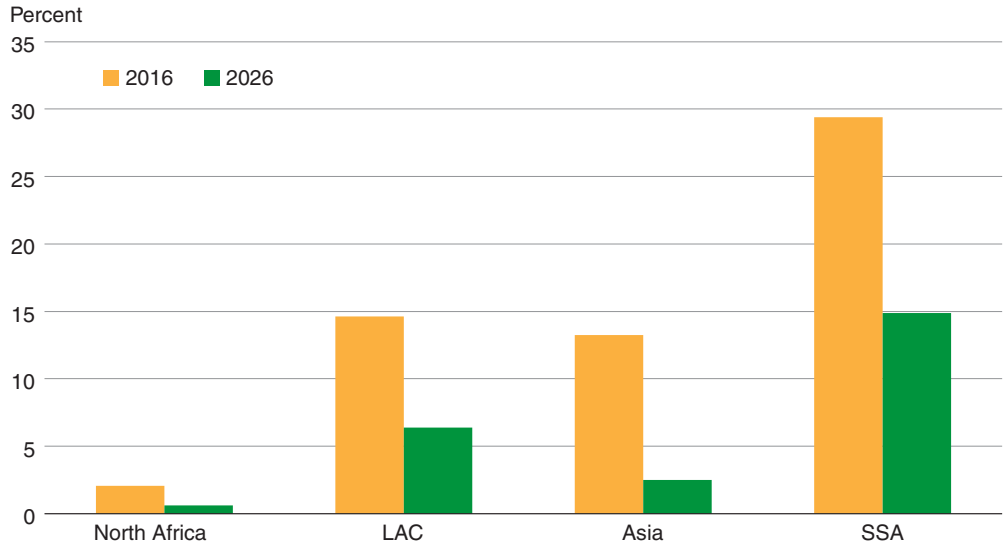
**Share of population food insecure, new (demand-driven) model, 2026**




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

Figure 3a

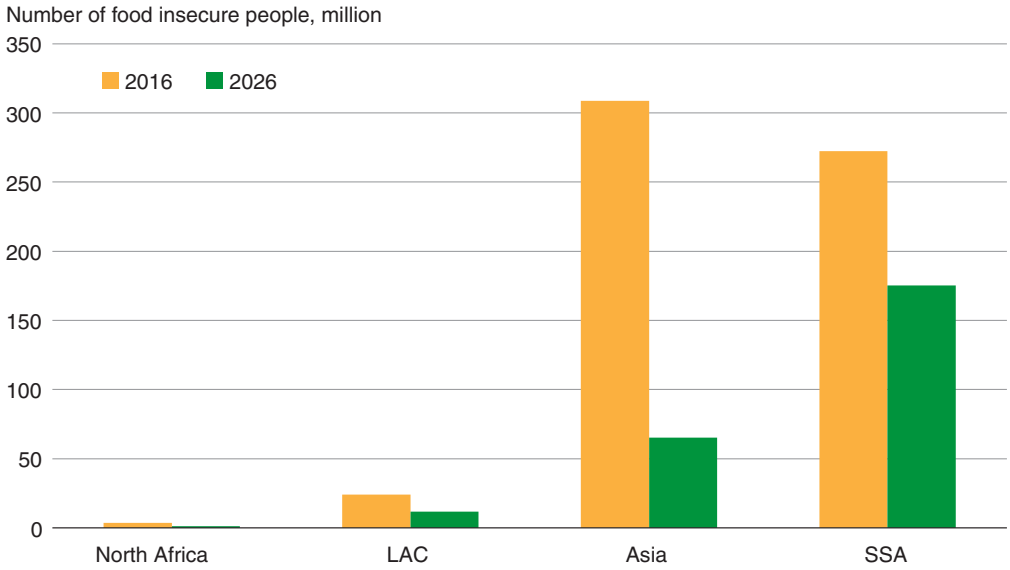
**The share of the population that is food insecure is projected to decline**




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

Figure 3b

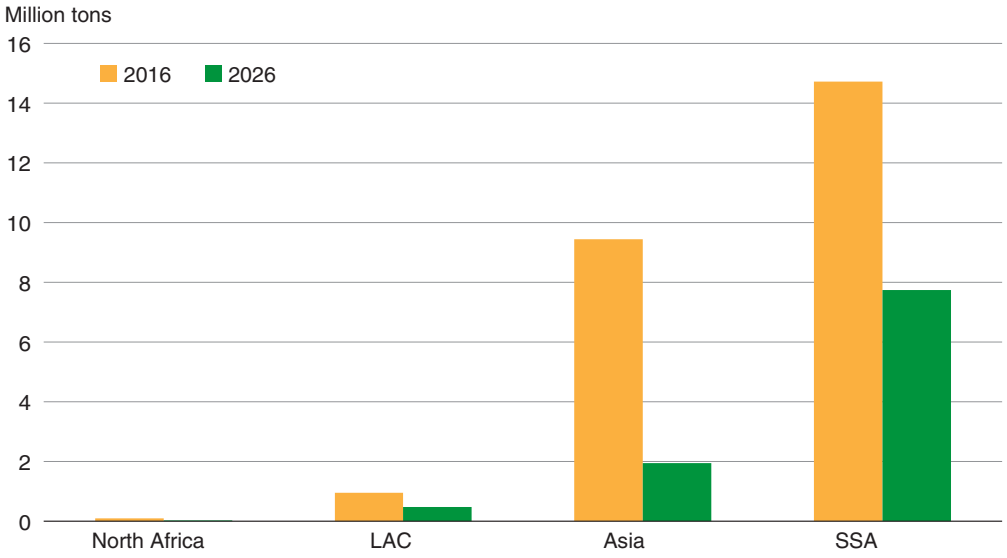
**The number of food-insecure people is projected to decline**




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

Figure 3c

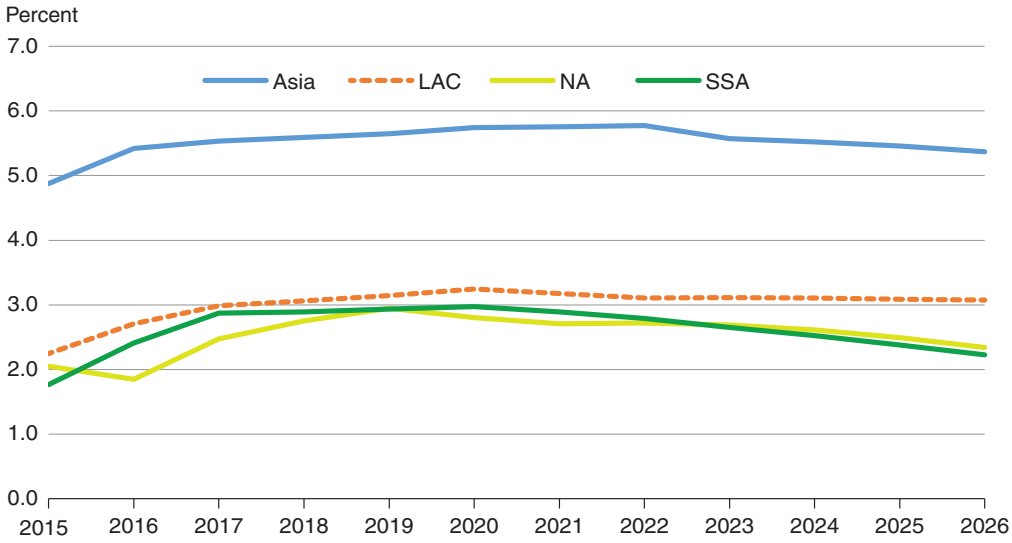
**The food gap is projected to decline**




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

Figure 4

**Per capita income growth in study regions, 2015-2026**




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

This matches the decline in the distribution gap, the amount of food needed to raise consumption to the nutritional target for all consumers. The similar rates of decline for the two measures indicate no worsening in the intensity of food insecurity, at the aggregate level, for those people considered to be food-insecure.

Macroeconomic assumptions (as of December 2015) and price projections from USDA's Agricultural Projections to 2025 (as of January 2016) are used to make these food security projections. Grains comprise the bulk of the diet in most study countries. Of the major grains, international corn prices are projected to decline fastest, roughly 1.6 percent per year in real terms, over the next decade. Real wheat prices follow closely, declining at nearly 1.3 percent per year. Rice prices are projected to decline as well, albeit at just 0.3 percent per year. Cassava, a crop that has seen rapid production growth especially in Africa, is expected to see decreases in price of 1.6 percent per year in real terms as well.

While food security assessment indicators will be based on this new demand-oriented approach, we continue to use one aspect of the supply-oriented model: grain production projections provide information on domestic availability in all 76 countries 10 years out. If estimated demand exceeds projected domestic grain production, the difference, which we call implied additional supply required (IASR), could be bridged through imports and/or improvements in agricultural productivity.

The Food and Agriculture Organization of the UN publishes an annual global food security assessment, "The State of Food Insecurity in the World (SOFI)", that estimates the prevalence of undernutrition for 140 countries. Differences in modeling framework—including caloric target (2,100 calories in IFSA versus country-specific targets), projection period, assumptions about macroeconomic conditions, and technical differences between models—make direct comparisons of the resulting projections of food security difficult and such comparisons are beyond the scope of this report. ERS plans to conduct further analysis of the sensitivity of the IFSA results to some of these differences and to other model assumptions in the near future.

## Regional Outlook

At the regional level, the greatest improvement in food security is projected for ***Asia***, where the food-insecure share of the population falls from 13.2 to 2.4 percent and the number of food-insecure people falls 80 percent between 2016 and 2026. In 16 of the region's 22 countries, less than 5 percent of the population is projected to be food insecure in 2026.

Economic growth is projected to be strong in most countries in the South Asia region. Investor confidence in Pakistan has grown following the signing of the China Pakistan Economic Corridor (CPEC) agreement in 2015, a $45-billion investment (through 2030) in transportation infrastructure and energy projects. Pakistan's growth is also expected to be bolstered by the return of Iran, a large market with newly granted access to money, to the international economic community, as well as the continuation of relatively low oil prices.

Sri Lanka's political situation is stabilizing with the formation of a reform-oriented Government at the end of 2015. Growth in the country is supported by both higher tourism revenues and remittances. Bangladesh's growth has been driven by a calmer political environment and improved export earnings. In addition, stronger labor laws that have enhanced workers' rights and workplace safety are expected to boost productivity and exports. Vietnam's strong growth prospects reflect investment growth, strong consumer demand, and increased exports as Chinese-funded projects commence operation.

The Asia region lacks strong trade links with emerging markets such as Brazil and Russia, and so is unlikely to be hurt by slow growth in those countries. Moreover, given the region's position as a net importer of oil, most countries will benefit from continued low oil prices.

India, the most populous country in the region, dominates the region's improving outlook for food security, as grain consumption jumps 33 percent due to expectations of rapid per capita income growth of 6.8 percent per year. Recent economic growth in India was bolstered by declining oil prices and government investment in infrastructure.

The most food-insecure countries in the region are North Korea, Yemen, Tajikistan, and Afghanistan. Of this group, Afghanistan, starting from a relatively food-insecure position, is projected to realize the greatest improvement: from 38 percent of the population classified as food insecure in 2016 to less than 13 percent in 2026. The improvement is driven by the downward trend (1.2 percent per year) in the price of wheat, the staple crop. In addition, per capita income is projected to increase 3.2 percent per year. North Korea, while projected to improve, will remain the most food-insecure country in the region, with 30 percent of the population consuming below the nutritional target.

Tajikistan's average daily per capita calorie consumption was roughly 2,100 calories per person in 2011, the lowest among the Commonwealth of Independent States (CIS). The share of the country's population that is food insecure is projected to fall from 35 percent in 2016 to 19 percent in 2026, reflecting a 1.8-percent annual decline in domestic wheat prices and a 1.4-percent annual increase in per capita income.

The food security of the CIS region as a whole is much better than that of Tajikistan, with the share of population food insecure projected at 8 percent for 2016 and declining to just over 3 percent by 2026. The improvements result from income growth projections of over 3 percent per year. This growth will partly depend on whether and when economic growth in Russia will resume following the ongoing economic decline stemming from international sanctions and lower oil prices. The economic contraction in Russia has spillover effects that are felt in the entire region. The CIS countries depend on Russia for trade and remittances, which can help accommodate domestic demand.

The number of food-insecure people in the ***Latin America and the Caribbean*** (LAC) region is projected to fall by half over the next decade; the share of population that is food insecure falls from 14.6 percent in 2016 to 6.4 percent in 2026. Strong gains are expected throughout the region with the sole exception of Haiti, where improvement is expected to be relatively modest.

Haiti's annual per capita GDP growth is projected at 1.3 percent. As a result, the number of food-insecure people is projected to fall nearly 14 percent through 2026 and the share of population that is food insecure to fall from 50 percent to 39 percent. Bolivia is South America's most food-insecure country, with 28 percent of the population estimated as food insecure in 2016. Thanks to forecast income growth of 5 percent per year, food security is projected to improve greatly as the share food insecure is expected to drop to less than 9 percent in 2026.

The Latin America and Caribbean economic outlook is positive, with GDP growth projections of around 4.3 percent annually in South America and 3.6 percent in Central America and the Caribbean. This translates into rising per capita incomes as LAC population growth continues to slow, projected to be just above 1 percent per year on average during the coming decade. Much of the positive outlook across Central America and the Caribbean is tied to U.S. economic growth, given that the United States is the region's largest trading partner. U.S. demand for imports—

apparel, electrical equipment, coffee, sugar, etc.—fuels the region's exports, and remittances contribute to rising domestic demand.

The South American countries are more dependent on exports of oil (Colombia and Ecuador) and copper (Peru) and their prospects are tied to those commodity prices as well as continued economic recovery in the United States and the EU, both major trading partners. In April 2016, Ecuador suffered its strongest earthquake in 40 years, which may slow the country's medium-term growth. Ecuador's grain production in 2015/16 was reduced due to El Niño-induced dryness. While world grain prices are trending downward, countries that depend on imports for a large share of their consumption have witnessed rising local corn and rice prices, in part because of local currency depreciations against the dollar. Still, food prices are projected to decline slightly in our model on the assumption that local prices are linked to world prices.

***Sub-Saharan Africa***'s (SSA) food security situation is also projected to improve, but more slowly than other regions. The number of food-insecure people is projected to fall by 36 percent and the share of population that is food insecure to drop from 29.4 to 14.9 percent. In 29 of the 39 countries included in the region for this study, 20 percent or less of the population is projected to be food insecure in 2026.

Sub-Saharan Africa is the world's poorest region, but economic growth (measured as growth in GDP) has averaged 5 percent per year over the last decade. This compares with growth of under 2 percent in the 1990s, when per capita income declined. Stronger growth in the last decade was largely due to improved governance, good weather (which resulted in positive per capita grain output), and higher prices for agricultural raw materials, the source of many countries' exports.

The outlook for the region remains fairly strong, with real GDP expected to grow more than 5 percent per year through 2026. Strong growth, and significant improvements in food security, are projected for countries such as Côte d'Ivoire, Ethiopia, Mozambique, Rwanda, and Tanzania due to large-scale investment projects in energy and transportation, greater consumer spending in response to lower fuel prices, and increased mining output in several countries.

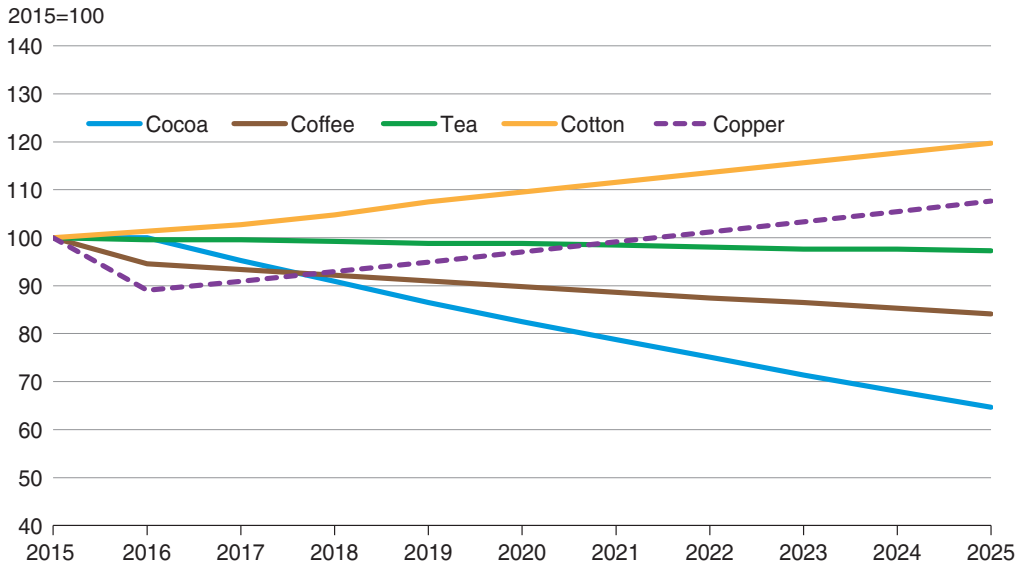
The share of the population that is food insecure in Ethiopia is projected to fall from 35 percent in 2016 to under 7 percent in 2026. Mozambique's share falls from nearly 26 percent to 5 percent. Kenya's economic growth is expected to be boosted by large-scale infrastructure projects, such as expansion of the rail system and a new port. The share of Kenya's population falling short of the nutritional target is projected to drop from 21 to 6.4 percent. Despite the fact that forecasts do not call for significant increases in the price of oil, Ghana is expected to benefit from rising oil output, a relatively new export for the country and one of the country's higher valued exports.

The projection of strong growth in the SSA region could be at risk given the recent drop in prices for many primary commodities, political instability and terrorist threats in several countries, and slow growth in China, the region's largest single trade partner. If growth rates do fall short of projected levels, the positive food security outlook for several SSA countries may be dampened.

The most food-insecure countries in the region are those that are currently or have recently experienced conflict, such as Burundi, the Democratic Republic of Congo, Eritrea, Somalia, and Sudan. The share of population food insecure in these countries in 2026 ranges from a low of 37 percent in Sudan to a high of nearly 77 percent in Eritrea.

Figure 5

**Prices for selected SSA exports, indexed (constant $)**




SSA = Sub-Saharan Africa.
Source: World Bank, online data.

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 2.1 percent in 2016 to 0.6 percent in 2026. Consumption levels in the region are high in part because of generous government programs that provide food subsidies to consumers. It recently became clear that the financial burden of these programs had become unsustainable, so programs targeted toward the poorest households have been implemented. As a result, bread consumption is down amid promotion of a more diverse diet. Food consumption levels in the region, in terms of caloric intake, remain comparable to those in high-income countries.

Future growth in the four North Africa countries is partly determined by oil prices, which according to IMF (2016) are projected to remain near current levels for the foreseeable future. Algeria, an oil exporter, is expected to experience GDP growth of close to 4 percent per year, while Egypt, Morocco, and Tunisia—all oil-importing countries benefiting from relatively low import bills—are projected to grow between 4 and 5 percent. Population growth in these countries is projected to fall below 1.5 percent per year, allowing per capita incomes to continue growing.

Table 1

**Demand-oriented model projections of food insecurity, 2016 and 2026**

| | Population | | Population food insecure | | Share of population food insecure | | Distribution gap* (total) | | Distribution gap* (per capita) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 |
| | *Million* | | *Million* | | *Percent* | | *1,000 MT* | | *kg* | |
| **Total** | **3,599.8** | **4,171.0** | **607.1** | **250.7** | **16.9** | **6.0** | **25,105** | **10,052** | **7.0** | **2.4** |
| **Asia** | **2,333.2** | **2,609.5** | **307.0** | **62.6** | **13.2** | **2.4** | **9,345** | **1,815** | **4.0** | **0.7** |
| Afghanistan | 33.3 | 42.0 | 12.7 | 5.4 | 38.1 | 12.8 | 485 | 150 | 14.5 | 3.6 |
| Armenia | 3.1 | 2.9 | 0.2 | 0.0 | 5.3 | 1.1 | 4 | 1 | 1.4 | 0.2 |
| Azerbaijan | 9.9 | 10.6 | 0.2 | 0.0 | 1.6 | 0.3 | 3 | 0 | 0.3 | 0.0 |
| Bangladesh | 171.7 | 200.5 | 30.1 | 5.4 | 17.5 | 2.7 | 827 | 107 | 4.8 | 0.5 |
| Cambodia | 16.0 | 18.2 | 2.8 | 0.4 | 17.7 | 2.3 | 84 | 9 | 5.2 | 0.5 |
| Georgia | 4.9 | 4.9 | 0.4 | 0.1 | 7.7 | 2.3 | 11 | 3 | 2.3 | 0.6 |
| India | 1,266.9 | 1,409.4 | 140.3 | 4.2 | 11.1 | 0.3 | 3,609 | 69 | 2.8 | 0.0 |
| Indonesia | 258.3 | 278.5 | 17.5 | 3.6 | 6.8 | 1.3 | 438 | 72 | 1.7 | 0.3 |
| Korea, DPR | 25.1 | 26.3 | 9.8 | 7.9 | 39.2 | 30.2 | 389 | 285 | 15.5 | 10.8 |
| Kyrgyzstan | 5.7 | 6.3 | 0.2 | 0.1 | 4.3 | 1.0 | 6 | 1 | 1.1 | 0.2 |
| Laos | 7.0 | 8.1 | 1.3 | 0.2 | 19.1 | 2.4 | 39 | 4 | 5.5 | 0.5 |
| Moldova | 3.5 | 3.1 | 0.1 | 0.0 | 3.6 | 0.3 | 3 | 0 | 0.9 | 0.1 |
| Mongolia | 3.0 | 3.3 | 0.4 | 0.1 | 14.8 | 2.1 | 17 | 2 | 5.5 | 0.6 |
| Nepal | 32.1 | 37.1 | 3.7 | 1.3 | 11.6 | 3.4 | 107 | 29 | 3.3 | 0.8 |
| Pakistan | 202.0 | 231.3 | 41.6 | 12.6 | 20.6 | 5.4 | 1,660 | 386 | 8.2 | 1.7 |
| Philippines | 102.6 | 119.1 | 18.7 | 9.5 | 18.3 | 8.0 | 645 | 275 | 6.3 | 2.3 |
| Sri Lanka | 22.2 | 23.7 | 4.2 | 1.1 | 19.0 | 4.7 | 168 | 34 | 7.6 | 1.4 |
| Tajikistan | 8.3 | 9.6 | 2.9 | 1.8 | 35.3 | 18.9 | 137 | 70 | 16.5 | 7.3 |
| Turkmenistan | 5.3 | 5.8 | 0.2 | 0.0 | 3.5 | 0.7 | 4 | 1 | 0.8 | 0.1 |
| Uzbekistan | 29.5 | 32.1 | 1.3 | 0.3 | 4.5 | 1.1 | 31 | 7 | 1.1 | 0.2 |
| Viet Nam | 95.3 | 103.1 | 7.0 | 0.6 | 7.4 | 0.6 | 181 | 11 | 1.9 | 0.1 |
| Yemen | 27.4 | 33.4 | 11.1 | 8.0 | 40.5 | 23.9 | 497 | 298 | 18.2 | 8.9 |
| **LAC** | **165.0** | **183.1** | **24.1** | **11.7** | **14.6** | **6.4** | **947** | **469** | **5.7** | **2.6** |
| Bolivia | 11.0 | 12.6 | 3.1 | 1.1 | 28.1 | 8.6 | 105 | 28 | 9.6 | 2.2 |
| Colombia | 47.2 | 51.6 | 2.3 | 0.6 | 4.8 | 1.2 | 58 | 13 | 1.2 | 0.2 |
| Dominican Republic | 10.6 | 11.8 | 0.8 | 0.1 | 8.0 | 0.8 | 21 | 2 | 1.9 | 0.1 |
| Ecuador | 16.1 | 18.0 | 2.4 | 0.9 | 15.1 | 4.8 | 66 | 19 | 4.1 | 1.1 |
| El Salvador | 6.2 | 6.3 | 1.1 | 0.5 | 17.4 | 7.3 | 32 | 11 | 5.1 | 1.8 |
| Guatemala | 15.2 | 17.8 | 3.8 | 2.2 | 25.3 | 12.3 | 146 | 70 | 9.6 | 3.9 |
| Haiti | 10.2 | 11.4 | 5.1 | 4.4 | 50.3 | 39.1 | 352 | 273 | 34.4 | 24.0 |
| Honduras | 8.9 | 10.3 | 1.6 | 0.9 | 18.1 | 8.5 | 57 | 26 | 6.4 | 2.6 |
| Jamaica | 3.0 | 3.2 | 0.2 | 0.1 | 7.1 | 2.4 | 5 | 2 | 1.7 | 0.5 |
| Nicaragua | 6.0 | 6.5 | 1.1 | 0.4 | 17.8 | 6.3 | 39 | 12 | 6.5 | 1.9 |
| Peru | 30.7 | 33.5 | 2.6 | 0.6 | 8.3 | 1.8 | 67 | 12 | 2.2 | 0.4 |
| **North Africa** | **175.1** | **200.2** | **3.6** | **1.2** | **2.1** | **0.6** | **95** | **28** | **0.5** | **0.1** |
| Algeria | 40.3 | 46.3 | 1.0 | 0.4 | 2.5 | 0.9 | 27 | 10 | 0.7 | 0.2 |
| Egypt | 90.1 | 105.2 | 1.4 | 0.4 | 1.6 | 0.4 | 31 | 7 | 0.3 | 0.1 |
| Morocco | 33.7 | 36.8 | 1.2 | 0.4 | 3.4 | 1.1 | 36 | 11 | 1.1 | 0.3 |
| Tunisia | 11.1 | 11.9 | 0.1 | 0.0 | 0.6 | 0.1 | 1 | 0 | 0.1 | 0.0 |

Continued—

Table 1

**Demand-oriented model projections of food insecurity, 2016 and 2026—continued**

| | Population | | Population food insecure | | Share of population food insecure | | Distribution gap* (total) | | Distribution gap* (per capita) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 |
| | *Million* | | *Million* | | *Percent* | | *1,000 MT* | | *kg* | |
| **SSA** | **926.5** | **1178.2** | **272.3** | **175.2** | **29.4** | **14.9** | **14,718** | **7,740** | **15.9** | **6.6** |
| Angola | 20.2 | 26.3 | 4.4 | 2.9 | 21.8 | 11.2 | 177 | 102 | 8.8 | 3.9 |
| Benin | 10.7 | 13.9 | 1.5 | 1.5 | 14.2 | 10.9 | 47 | 44 | 4.4 | 3.1 |
| Burkina Faso | 19.5 | 26.1 | 3.7 | 3.0 | 19.2 | 11.6 | 188 | 136 | 9.6 | 5.2 |
| Burundi | 11.1 | 15.3 | 6.7 | 6.3 | 60.1 | 41.3 | 402 | 314 | 36.2 | 20.6 |
| Cabo Verde | 0.6 | 0.6 | 0.0 | 0.0 | 8.0 | 2.3 | 1 | 0 | 2.0 | 0.5 |
| Cameroon | 24.4 | 31.3 | 2.2 | 1.6 | 9.1 | 5.2 | 58 | 38 | 2.4 | 1.2 |
| Central African Republic | 5.5 | 6.8 | 2.1 | 1.9 | 38.0 | 28.1 | 92 | 75 | 16.6 | 11.1 |
| Chad | 11.9 | 14.2 | 4.9 | 5.5 | 41.4 | 39.1 | 285 | 314 | 24.0 | 22.2 |
| Congo | 4.9 | 6.1 | 1.0 | 1.1 | 21.3 | 17.4 | 33 | 32 | 6.9 | 5.3 |
| Congo, DR | 81.3 | 101.1 | 70.6 | 50.5 | 86.8 | 50.0 | 5,949 | 2,707 | 73.1 | 26.8 |
| Côte d'Ivoire | 23.7 | 28.1 | 3.4 | 2.2 | 14.1 | 7.8 | 138 | 80 | 5.8 | 2.8 |
| Eritrea | 6.7 | 8.1 | 5.0 | 6.2 | 75.1 | 76.7 | 360 | 457 | 53.9 | 56.2 |
| Ethiopia | 102.4 | 134.7 | 36.0 | 9.1 | 35.2 | 6.8 | 1,502 | 256 | 14.7 | 1.9 |
| Gambia | 2.0 | 2.4 | 0.1 | 0.0 | 3.4 | 0.1 | 2 | 0 | 0.8 | 0.0 |
| Ghana | 26.9 | 33.3 | 1.2 | 0.2 | 4.4 | 0.5 | 31 | 3 | 1.1 | 0.1 |
| Guinea | 12.1 | 15.6 | 3.2 | 2.0 | 26.1 | 13.0 | 118 | 64 | 9.8 | 4.1 |
| Guinea-Bissau | 1.8 | 2.1 | 0.3 | 0.2 | 19.7 | 11.5 | 11 | 7 | 6.3 | 3.2 |
| Kenya | 46.8 | 53.8 | 9.9 | 3.4 | 21.2 | 6.4 | 300 | 81 | 6.4 | 1.5 |
| Lesotho | 2.0 | 2.0 | 0.2 | 0.0 | 11.0 | 1.3 | 6 | 1 | 3.3 | 0.3 |
| Liberia | 4.3 | 5.4 | 1.8 | 1.3 | 41.0 | 24.5 | 95 | 60 | 22.1 | 11.1 |
| Madagascar | 24.4 | 30.8 | 10.1 | 6.2 | 41.4 | 20.0 | 396 | 190 | 16.2 | 6.2 |
| Malawi | 18.6 | 25.8 | 5.9 | 5.3 | 32.0 | 20.4 | 254 | 197 | 13.7 | 7.7 |
| Mali | 17.5 | 23.1 | 1.1 | 0.7 | 6.2 | 2.9 | 29 | 16 | 1.6 | 0.7 |
| Mauritania | 3.7 | 4.5 | 0.3 | 0.0 | 7.4 | 0.8 | 8 | 1 | 2.1 | 0.2 |
| Mozambique | 25.9 | 33.1 | 6.7 | 1.6 | 25.7 | 5.0 | 312 | 55 | 12.0 | 1.7 |
| Namibia | 2.2 | 2.3 | 0.7 | 0.3 | 33.2 | 11.5 | 28 | 7 | 12.4 | 3.3 |
| Niger | 18.6 | 25.4 | 2.2 | 0.8 | 11.7 | 3.2 | 78 | 24 | 4.2 | 0.9 |
| Nigeria | 186.1 | 236.0 | 16.5 | 5.6 | 8.9 | 2.4 | 437 | 122 | 2.3 | 0.5 |
| Rwanda | 13.0 | 16.4 | 4.1 | 1.6 | 31.7 | 9.4 | 188 | 53 | 14.5 | 3.2 |
| Senegal | 14.3 | 18.0 | 1.9 | 1.6 | 13.3 | 9.1 | 53 | 42 | 3.7 | 2.4 |
| Sierra Leone | 6.0 | 7.7 | 2.3 | 1.4 | 38.1 | 18.3 | 108 | 53 | 17.9 | 6.8 |
| Somalia | 10.8 | 13.6 | 7.0 | 7.7 | 64.7 | 56.4 | 396 | 399 | 36.6 | 29.3 |
| Sudan | 36.7 | 43.5 | 13.3 | 16.1 | 36.2 | 37.0 | 591 | 720 | 16.1 | 16.6 |
| Swaziland | 1.5 | 1.6 | 0.4 | 0.2 | 27.1 | 15.1 | 13 | 7 | 8.9 | 4.3 |
| Tanzania | 52.5 | 68.7 | 16.3 | 11.0 | 31.0 | 16.0 | 772 | 437 | 14.7 | 6.4 |
| Togo | 7.8 | 10.0 | 1.6 | 1.6 | 20.2 | 16.4 | 58 | 57 | 7.4 | 5.7 |
| Uganda | 38.3 | 52.2 | 11.7 | 7.6 | 30.5 | 14.6 | 517 | 277 | 13.5 | 5.3 |
| Zambia | 15.5 | 20.7 | 6.3 | 4.5 | 40.5 | 21.8 | 401 | 237 | 25.9 | 11.5 |
| Zimbabwe | 14.5 | 17.7 | 5.7 | 2.1 | 39.2 | 11.8 | 286 | 75 | 19.7 | 4.3 |

* Measured in grain equivalent.

Source: USDA, Economic Research Service.

## How Food Security Is Assessed

Food consumption and food access are projected for 76 low- and middle- income countries—39 in Sub-Saharan Africa, 4 in North Africa, 11 in Latin America and the Caribbean, and 22 in Asia. The model analyzes the gap between projected food consumption and a nutritional target of 2,100 calories per capita per day. The estimated ***distribution gap*** measures the food needed to raise consumption of each individual to the nutritional target. In many countries, consumption in the lower income groups is significantly below the average (per capita) consumption for the country as a whole. In these countries, the distribution gap provides a measure of the intensity of hunger—the extent to which the food security of already hungry 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. In the new demand-oriented model, consumption is assessed continuously across all income levels. In the supply-oriented model, consumption is measured by income decile. When average consumption for the poorest 10 percent of the population is above the 2,100-calorie threshold, we consider the country food secure despite the fact that food insecurity may exist (for less than 10 percent of the population). Because the supply-oriented estimates compare average consumption of each income decile to the threshold, the marginal decile may be considered food-secure (insecure) even though some individuals in that decile are below (above) the threshold.

Finally, we calculate the number of food insecure people—those who cannot meet the nutritional target—based on total population data and the population share that consumes below the nutritional target. Common terms used in this report include:

- **Food consumption**—Equal to food availability (supply-oriented model) or food demand (new model).
- **Food access**—Affordability of food, depends on purchasing power. In the supply-oriented model food access—given projected food availability—is estimated by income decile, while the demand-oriented approach allows food access to vary continuously across the income spectrum.
- **Food insecurity**—Occurs when per capita food consumption falls short of the nutritional target of 2,100 calories per person per day.

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*Special Article*

# International Food Security Assessment: New Demand-Oriented Versus Supply-Oriented Model

*The USDA-ERS International Food Security Assessment (IFSA) model is used to analyze food security for 76 low- and middle-income countries. This article will briefly describe the two models ERS is using to assess food security and then compare the results of the two frameworks. The supply-oriented model was originally created in 1995. It provides an estimate of food security by projecting production and commercial import capacity for each study country. ERS has transitioned to a new demand-oriented framework that includes information on domestic prices and income, consumer responsiveness to changes in prices and incomes, and food quality differences by income group.*

## Introduction

The IFSA supply-oriented model was developed for the 1996 World Food Summit (WFS), where a pledge was made to halve the number of food-insecure people by 2015. In response to this goal, ERS built a food security model that projected indicators for a 10-year time horizon. This supply-oriented model has been used to project food insecurity in low- and middle-income countries and evaluate progress made toward the WFS goal. This model's primary focus is on the availability pillar of food security.[1] The model projects production of grains and root crops, and includes a measure of import capacity. Production and imports of these foods (including food aid, minus nonfood use and exports) comprise food availability, which we assume is equal to consumption in a country. Consumption of other foods is assumed to grow at the same rate as grains and root crops. Food access is derived by allocating available food across income deciles.

The international food price spikes over the last decade highlighted the importance of prices and incomes in determining the food security of vulnerable populations. This, coupled with the recent availability of consumer price data in the study countries, prompted the development of the new food security assessment model. The new demand-oriented model projects consumption as it responds to movements in domestic prices and income. Explicit incorporation of income and consumption distributions within countries allows the model's demand projections to better reflect food access and food insecurity among the lower income population.

## Comparing Food Security Estimates

The new demand-oriented and supply-oriented IFSA models differ in their approach to estimating and projecting food demand. To allow for comparisons of the two models, projections from the supply-oriented approach were also used and these results and a brief discussion are presented in the following chapter. The next section examines the major differences between the estimates and projections for the 76 study countries and explains the main drivers of these differences.

[1]Food security stands on four major pillars: food must be *available*; people must be able to afford, or have *access* to food; people must be able to *utilize* food (i.e., retain nutrients); and these conditions must be reliably met in a *stable* environment.

The results of the new ***demand***-oriented IFSA model indicate that food security of the 76 study countries is expected to ***improve*** over the next decade, reflecting strong income growth and lower food prices. While the share of population that is food insecure, 17 percent in 2016, is higher than in the supply-oriented model, it is projected to fall to 6 percent in 2026. The number of food-insecure people is projected to fall markedly to 251 million people, a 59-percent drop, matching the drop in the distribution gap (the food needed to raise consumption for all food-deficit consumers to the nutritional target). The proportionate reductions mean no change in the intensity (extent to which per capita consumption is falling below the nutritional target) of food insecurity.

Results from the ***supply***-oriented IFSA model paint quite a different picture for the projection period, suggesting that food security in the 76 study countries will ***deteriorate*** over the next decade. The share of population that is food insecure is expected to rise from 12 percent in 2016 to 13.6 percent in 2026. The total number of food-insecure people is projected to rise 32 percent to 570 million in 2026. This increase matches the increase in the distribution gap, indicating no change in the intensity of food insecurity at the aggregate level. Deterioration in supply-oriented food security over time is driven by only a handful of countries, as most countries are projected to maintain their current levels of food security or improve. In most cases, domestic food production and the commercial import capacity of these countries are expected to match their population growth rates, resulting in steady per capita food consumption.

In both models, per capita consumption is estimated and projected and evaluated against a nutritional target of roughly 2,100 calories per person per day to determine whether populations should be considered food secure. The supply-oriented model makes the assessment by income decile whereas the new model does this along a continuous distribution of income. Evaluating food security using the decile approach implies that all households within a decile are food insecure when the estimated daily per capita consumption for that decile falls below the target consumption level. Conversely, if consumption levels are just above this threshold, the entire decile is considered food secure. The continuous approach in the demand-oriented model avoids the discrete jumps between deciles that can occur in the supply-oriented model (i.e., from the 20- to 30-percent decile) and leads to more precise estimates of the prevalence and depth of food insecurity (see Methodology appendix for further detail).

The demand-oriented model finds food-insecure people in each of the 76 countries, whereas the supply-oriented model classifies 39 countries as being food secure (as measurement below the 10-percent income decile is not possible) in 2016. The North Africa region is the most food-secure region under both models: none of the countries are food insecure in the supply-oriented model, while the demand-oriented model finds 2.1 percent of the NA population, on average, food insecure in 2016.

Similarly, most of the 39 countries that are considered food secure in the supply-oriented framework have relatively low percentages (less than 20 percent) of food-insecure people in the new, demand-oriented model. In particular, countries in the Commonwealth of Independent States (CIS, a subregion of Asia) have low levels of food insecurity under both frameworks, with the exception of Tajikistan. While the supply-oriented model shows no food insecurity in any of the region's countries except in Tajikistan, the demand-oriented approach estimates that 8 percent of the population are food insecure in 2016, a share that is projected to decline to 3 percent by 2026. The same is true for the Latin American and Caribbean region: all countries exhibit some degree of food insecurity in the demand-oriented model, generally affecting less than 10 percent of their populations. Those same countries are considered food secure in the supply-oriented framework.

Box S1-1
**Model Comparison**

| Model feature | Demand-oriented | Supply-oriented |
|---|---|---|
| Main projection focus | Food demand (access to food) is projected and equated to consumption | Food supply (production and imports) is projected and equated to consumption |
| Unequal income distribution: How is it accounted for? | 1. Per capita food demand includes a measure of inequality.<br>2. Per capita demand is projected across a continuous income distribution. | Food supply is distributed across 10 income deciles. |
| Main drivers of food consumption changes 10 years out | Projections of<br>• per capita income<br>• food prices | Assumptions about<br>• food production growth<br>• import capacity |
| Impact on current assessment → | Strong income growth projections coupled with projected decreasing food prices for many countries result in robust growth in food demand and therefore improved food security | Growth projections for food supply tend to be pessimistic, often lagging population growth and resulting in slow improvement or deterioration of food insecurity in many countries |
| How are food security indicators calculated? | Indicators are calculated by comparing a continuous distribution of demand to the calorie threshold. | If average consumption of an income decile falls below the caloric threshold, the whole decile is considered food insecure |
| Impact on current assessment → | Precise measures of food security, including within the lowest income decile | Food insecurity not captured if estimate is less than 10 percent |
| Link between approaches | Food demand projections (based on the new demand-oriented approach) are compared to domestic production projections (based on the supply-oriented approach).<br><br>If demand is greater than domestic production, the difference is called the implied additional supply required (IASR) | |

In Asia and Africa, the new demand-oriented model projects significant numbers of food-insecure people for 2016 in many countries that had been classified as food secure in the supply-oriented approach. According to data used in the supply-oriented model, these countries have ample food supplies, either due to strong domestic production or import capacity, conferring food-secure status. However, income and inequality data suggest insufficient access to food among the lower income populations, which is captured more minutely in the new demand-oriented model.

Under the new demand-oriented modeling framework, the greatest improvement in food security is projected for the Asia region, where the share of population food insecure falls from 13.2 to 2.4 percent and the number of food-insecure people falls 79 percent over the next decade. India, the most populous country in the region (just over half the region's population resides in India), drives the results. In India, projected consumption rises rapidly in response to falling world prices (assumed to be transmitted locally) and the region's highest per capita income growth of nearly 7 percent per year.

In contrast, under the supply-oriented model, Asia's food security situation is projected to deteriorate over the next decade. However, 90 percent or more of the population in 17 of the region's 22 countries are projected to be food secure (i.e., no measurable food insecurity). These countries have lower levels of food security in the demand-oriented model, and show great improvement over time. Among the countries that have food-insecure populations in both modeling frameworks, North Korea, India, Mongolia, Tajikistan, and Yemen show improvements in food security in the demand-oriented framework and either improve or stay the same in the supply-oriented framework. With the exception of Yemen, per capita income growth and falling domestic prices drive the results in the demand-oriented framework. In the supply-oriented model, population growth is low enough that food supply can maintain consumption means, even with larger amounts of waste and feed use. Only in Afghanistan and the Philippines do the shares of population that are food insecure move in opposite directions, with both countries exhibiting worsening food security in the supply-oriented model.

In the new, demand-oriented model, the number of food-insecure people in the Latin America and the Caribbean (LAC) region is projected to fall by half over the next decade. As a result, the share of population that is food insecure falls from 14.6 percent in 2016 to 6.4 percent in 2026. Under the supply-oriented model, the share of the LAC population that is food insecure is projected to fall from 21 percent in 2016 to 13 percent in 2026.

In the supply-oriented model, 90 percent or more of the LAC population is projected to be food secure in 9 of the region's 11 countries. LAC countries exhibit strong improvements and low levels of food insecurity in 2026 in the demand-oriented model as well. Guatemala and Haiti continue to be the most food-insecure countries in the region.

Improvement in Haiti is expected to be modest. The country's income growth is projected at 4 percent per year over the next decade, versus the LAC average of more than 5 percent. As a result, the number of food-insecure people is projected to fall less than 14 percent through 2026 (compared to the regional decline of 50 percent in the new demand-oriented model), and the share of population insecure falls from 50 percent to 39 percent. While the supply-oriented model shows higher rates of food insecurity in Haiti, the projected rate of improvement is similar, falling short of the regional average.

In Guatemala, the new framework projects a 43-percent decline in the number of food-insecure people. Though impressive, this improvement lags the average rate in the LAC due to Guatemala's slower per capita income growth and faster population growth. Guatemala's food supply—and food available for consumption—relies equally on domestic production and imports. Though agricultural production growth is projected to outpace population growth, current assumptions for import capacity lead to declining import growth. As a result, food insecurity is projected to worsen in Guatemala under the supply-oriented model.

Guatemala exemplifies the strengths and weaknesses of both modeling approaches. While the supply-oriented approach explicitly recognizes that food consumed must be available, either through domestic production or imports, the projections of these variables closely mirror historic trends and do not account for potential budget reallocations in response to unexpected events or changing demand. This lack of flexibility tends to underestimate future food supply and overestimate projected food insecurity in many countries.

On the other hand, the new demand-oriented approach is, at this point, not explicitly linked with domestic food supply. This implies that countries are able to freely import food to fulfill domestic demand. This framework does not account for changing trade regimes that can affect the relationship between the world and domestic price.[2]

Just as deterioration in food security is projected to be greatest in Sub-Saharan Africa (SSA) under the supply-oriented model, the region's gains are projected to be slowest under the new model. SSA is the most food-insecure region in the world according to both modeling frameworks. While the region accounts for 26 percent of the population of the 76 study countries, it accounts for an estimated 45 percent of the number of food-insecure people in 2016 in the demand-oriented framework (and 53 percent in the supply-oriented model). Under the new demand-oriented framework, the number of food-insecure people is projected to fall by 36 percent and the share of population that is food insecure falls from 29 percent in 2016 to 15 percent in 2026.

While regional GDP is expected to grow just above 5 percent a year, the SSA region's population is expected to grow much more quickly than the rest of the world, at roughly 2.5 percent per year. This population growth is slow enough to lead to an increase in per capita income, which leads to improved food security indicators for most countries in the demand-oriented model. Only Eritrea, Sudan, Togo, Congo, and Chad have decreasing per capita income projections; in Eritrea and Sudan, this leads to higher shares of food-insecure population in 2026 (and worse levels of all food security indicators). In Togo, Congo, and Chad, the declines in per capita income are projected to be more modest and—combined with falling projected food prices—the share of food-insecure people is projected to fall, though the absolute number is projected to rise in the demand-oriented framework.

This deterioration of food security is more common in the supply-oriented framework, where 19 of 36 countries in Sub-Saharan Africa are projected to see worsening in at least one food security indicator, including 3 countries that were considered food secure in 2016. In several of these countries, the number of deciles that are food insecure is stable over time, as food availability (production plus imports) grows as fast as population. However, a constant share of population that is food insecure, coupled with population growth means more SSA people fall below the food security threshold in absolute terms.

Table S1-1

**Share of population food insecure**

| | Asia | | LAC | | SSA | | North Africa | |
|---|---|---|---|---|---|---|---|---|
| | Demand-oriented | Supply-oriented | Demand-oriented | Supply-oriented | Demand-oriented | Supply-oriented | Demand-oriented | Supply-oriented |
| | *Percent* | | | | | | | |
| 2016 | 13.2 | 7.2 | 14.6 | 21.3 | 29.4 | 24.5 | 2.1 | 0 |
| 2026 | 2.5 | 8.5 | 6.4 | 13 | 14.9 | 27.6 | 0.6 | 0 |

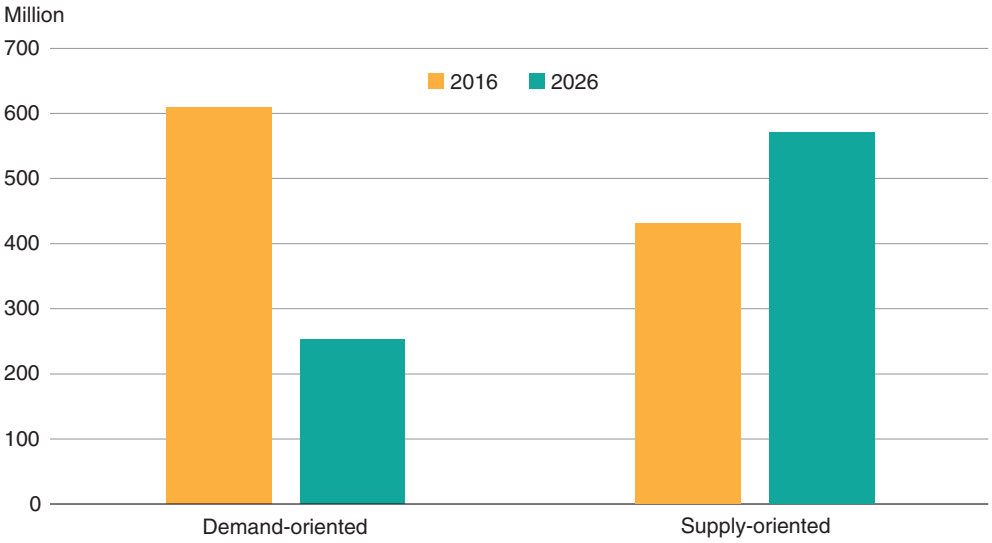
LAC = Latin America and the Caribbean, SSA = Sub-Saharan Africa.

Source: USDA, Economic Research Service.

[2]A model with integrated demand and supply sides would likely result in food insecurity projections that fall between the often pessimistic outlook of the supply-oriented approach and the optimistic outlook of the demand-oriented projections driven by assmumed income growth and price declines.

Figure S1-1

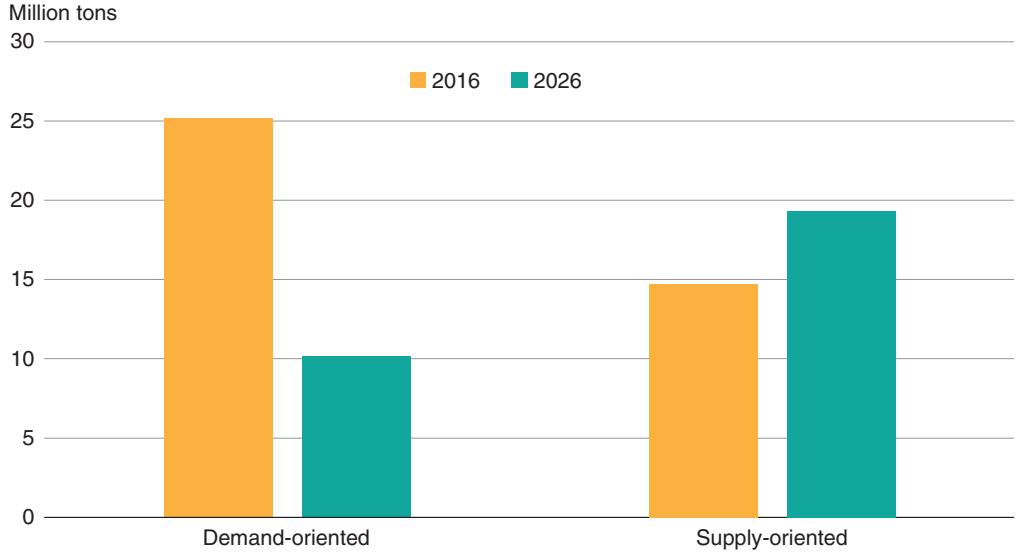
**Number of food-insecure people in the 76 study countries is projected to rise in supply-oriented model but decline in new demand-oriented model**




Source: USDA, Economic Research Service.

Figure S1-2

**Depth of food insecurity (distribution gap) improves in demand-oriented model while deteriorating in supply-oriented model**




Source: USDA, Economic Research Service.

## Implied Additional Supply Required

The demand-oriented model projects food demand based on exogenously projected world food prices. Implicitly, this assumes that a country is able to produce or import food to meet demand. In this section, we link the demand-oriented approach and one aspect of the supply-oriented approach. We compare projected food consumption/demand from the demand-oriented model to projected food production from the supply-oriented model.

When projected demand exceeds projected food production, the difference is referred to as the implied additional supply required (IASR); this is the amount of food necessary to meet demand. This demand may or may not be sufficient to meet nutritional targets. Projections are based on given income and price change expectations as well as fixed policy regimes over the projection period. The difference between projected food production and demand must not be interpreted as "projected imports" because demand projections are not explicitly linked to food supply projections to create a closed system. This means that there is no equilibrium price that could induce supply to increase or demand to decrease. Future model improvements will aim to address this shortcoming.

For the 76 countries, the IASR is estimated to total 154 million tons, grain equivalent, in 2016, which is equal to roughly 15 percent of estimated consumption. The IASR total is close to the countries' actual imports of roughly 145 million tons in recent years and is projected to more than double by 2026—reaching 329 million tons. The greatest jump comes from the Asia region, where the number is projected to rise more than threefold. While IASR increases across countries, this jump is largely attributable to India where the IASR is forecast to grow from 6.7 million tons in 2016 to nearly 19 million tons in 2026. Production is projected to barely outpace population growth, but demand—spurred by the assumption that lower world food prices are transmitted to local food markets and the projection that GDP more than doubles—is projected to grow nearly 5 percent per year. Vietnam's IASR is projected to grow tenfold, reaching about 10 million tons in 2026 due to increases in both food and feed demand.

Sub-Saharan Africa's IASR is projected to more than double, rising from 35 million tons in 2016 to nearly 72 million tons in 2026. Nigeria is currently the region's largest importer and its IASR is projected to nearly double, approaching 25 million tons in 2026. Per capita grain output is projected to decline in Nigeria, while per capita demand increases roughly 2 percent per year—driven by strong per capita income growth of 2.4 percent per year and falling food prices.

Table S1-2

**Grain imports and implied additional supply required (IASR)**

| | Grain imports, 2014-15 average | Supply-oriented model import capacity, 2016 | IASR, 2016 | Supply-oriented model import capacity, 2026 | IASR, 2026 |
|---|---|---|---|---|---|
| | | | *------million tons------* | | |
| 76-country total | 144.7 | 150.0 | 153.8 | 176.7 | 329.2 |
| Asia | 50.5 | 51.9 | 59.2 | 61.8 | 164.6 |
| SSA | 33.1 | 34.9 | 33.9 | 41.4 | 71.8 |
| LAC | 19.6 | 19.8 | 18.8 | 23.3 | 26.2 |
| NA | 41.5 | 43.3 | 41.8 | 50.2 | 66.5 |

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

Projected import capacity in the supply-oriented model is a function of historical imports, production, prices, and export earnings, implicitly assuming that countries will stay within their means when deciding on the quantity of food to import. In reality, countries display more flexibility when confronted with demand for food. The measure of import capacity is therefore likely to understate the true extent of a country's food imports while the new demand-oriented model gives us a better picture of future food demand.

Latin America and the Caribbean's IASR is projected to grow 40 percent, the slowest growth in supply gap among the regions in this study. This is partly due to the region's sluggish population growth of 1 percent per year over the next decade.

The North Africa region's IASR is projected to increase roughly 60 percent by 2026, led by Egypt, where grain output has stagnated over the last decade. Projections call for a continuation of that trend, and imports will likely be needed to satisfy growing demand.

## Conclusions

This special article compares the two ERS food security assessment frameworks. The new demand-oriented modeling framework has two principal strengths. First, estimates of food security can now be measured at levels below and within a decile due to the continuous nature of the framework, thereby allowing for a more precise measure of international food insecurity. This results in larger food insecurity estimates in some countries compared to the earlier supply-oriented results for 2016.

Second, the new, demand-oriented model better captures the effect of changes in domestic and international prices on food security. Given projections for strong income growth in most study countries and slightly lower food prices, food security projections from the demand-oriented approach are highly optimistic. The supply-oriented approach yields more varied results, ranging from improvements for roughly a dozen countries to maintenance of food security in nearly half the countries to worsening food security in the remainder.

When comparing the results from the new framework and the supply-oriented model, several differences come to light. The demand-oriented model predicts higher levels of food insecurity in 2016. However, under the new demand-oriented framework, population growth is not as large a driver of food insecurity as it is in the supply-oriented framework, and projections of income growth and falling food prices lead to improved food security in 2026. The new framework is more flexible, incorporates more information, and provides policymakers with more refined estimates of the food-insecure population.

# Food Security Assessment: 2016-26, Supply-Oriented Model

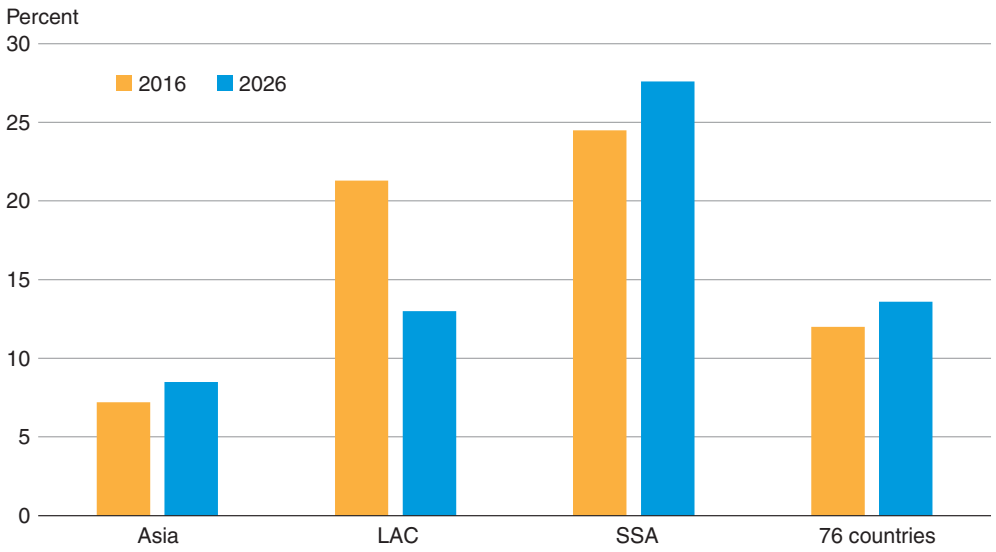
The supply-oriented USDA-ERS International Food Security Assessment (IFSA) model, created in 1995, provides an estimate of food security by projecting production and commercial import capacity for each study country. The resulting supply estimate, which is assumed to be equal to consumption, is then compared to a nutritional target in order to measure food security (see Appendix 2 for methodology). The number of food-insecure people is defined here as those who consume less than the nutritional target of roughly 2,100 calories per person per day.[3]

In many of the study countries, consumption in the lower income deciles falls significantly below a country's average (per capita) consumption. The distribution gap measures the food needed to raise consumption in each food-deficit income decile to the nutritional target. This is a measure of the intensity of food insecurity, or the extent to which consumption falls below the nutritional target.

Over the next decade, food security in the 76 study countries is projected to deteriorate at the aggregate level. The share of the population that is food insecure is projected to rise to 13.6 percent by 2026. The number of food-insecure people is projected to reach 570 million, a rise of 32 percent, with population growth accounting for about half of this increase. This is virtually the same increase as that projected for the distribution gap, suggesting no change in the intensity of food insecurity through 2026, although there is wide variation among countries.

Figure 6

**Share of population food insecure rising, except for LAC**




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

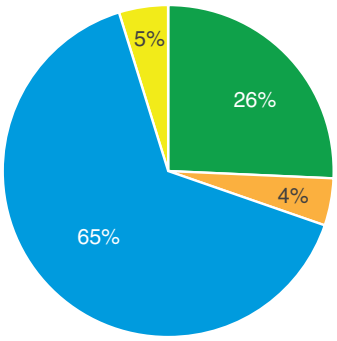
[3]The target of 2,100 calories was chosen as an approximation for food security. A truly adequate dietary energy intake target is based on sex, age, body mass, and physical activity level. Not all people who consume less than 2,100 calories per day are food insecure, as there may be food-insecure people consuming more than 2,100 calories per day.

***Sub-Saharan Africa*** is the most food-insecure region in the world. While the region (comprised in this study of 39 countries) accounts for about a quarter of the total population of the 76 countries, it is estimated to account for over half of the number of food-insecure people in 2016. Nearly 25 percent of the region's population is estimated to be food insecure in 2016. That being said, the region's greatest food insecurity is concentrated in only a handful of countries, including Central African Republic, the Democratic Republic of Congo, Burundi, Eritrea, Somalia, Lesotho, and Chad. Most of these countries are characterized by civil unrest and/or the lack of resources for productive agricultural sectors or ample commercial food imports. The most food-secure countries are in West Africa, including Benin, Côte d'Ivoire, Ghana, Guinea, Mauritania, Mali, Niger, Nigeria, Senegal, and Sierra Leone. In well over half of the West African countries, grain output outpaced population growth over the last decade, thereby improving food security. In Guinea, Liberia, Mali, and Sierra Leone, per capita grain output increased 3 percent or more per year.

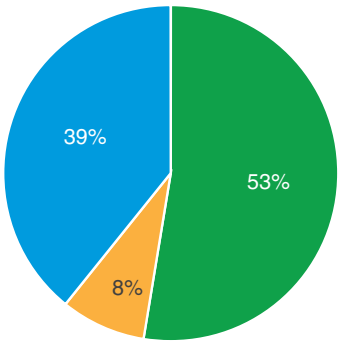
Food security in many SSA countries has vastly improved from a decade ago, supported by strong growth in grain output. Grains account for over half of the diet in most of these countries, and more than 80 percent of grain supplies are produced domestically. Therefore, performance of the grain sector is an important component of the food security equation. SSA grain production increased 4.2 percent per year since 2000. As a result, the share of the population that is food insecure fell from 47 percent in

Figure 7

**SSA accounts for one-quarter of the population of the 76 countries. . .**




**. . .but more than half of the food-insecure people**


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

2000 to less than 25 percent in 2016. Moreover, in 22 of the region's 39 countries, 80 percent or more of the population is estimated to be food secure in 2016. These model results are based on 2016 production and do not reflect recent El Niño effects. Therefore, the actual food security situation in the SSA region may be slightly worse than supply-oriented model results indicate.

Sub-Saharan Africa's food security situation is forecast to deteriorate in the next decade as the share of population that is food insecure is projected to rise nearly 3 percent to 27.6 percent in 2026. The growth in the number of food-insecure people, 43 percent, is projected to exceed the growth in the distribution gap, 35 percent, meaning food insecurity in the region will spread rather than become more intense. Countries where food security is projected to worsen most include Ethiopia, Tanzania, Uganda, Madagascar, Mozambique, and Burkina Faso. Except for Uganda, these countries will not be among the most food-insecure in the region. Per capita consumption in the lowest income groups in these countries is not far below the nutritional target. For example, in Ethiopia and Tanzania, consumption in the lowest (10 percent) income decile is projected at 93 percent of the target. Most of these countries have among the highest population growth rates in the world, making increases in per capita consumption difficult. Uganda has the highest projected annual population growth in the group, averaging 3.2 percent through 2026; Burkina Faso's growth is 3 percent and Ethiopia's is 2.8 percent.

Despite worsening food security at the aggregate level, 80 percent or more of the population is projected to be food secure in 23 of the region's 39 countries by 2026. The greatest concentration of relatively food-secure countries is, again, in West Africa. Countries projected to grow more food secure are spread throughout SSA and include Kenya, Lesotho, Zambia, Zimbabwe, Chad, and Namibia. For all but Zambia, these countries are characterized by very low population growth or a significant slowdown in the rate. In Zambia, grain output grew more than 10 percent annually during the last decade. While such growth is unlikely to continue, it will exceed population growth, resulting in higher per capita food supplies.

After North Africa, ***Asia*** is the most food-secure region and food security is estimated to improve in 2016 as the number of food-insecure people falls nearly 19 percent (from 2015) to roughly 170 million. The Asia region is estimated to account for nearly two-thirds of the total population of the 76 countries, but only 39 percent of food-insecure people. An estimated 7.2 percent of the region's population is food insecure in 2016. In 19 of the 22 countries, more than 80 percent of the population is considered food secure, due to per capita gains in grain output. Although growth in grain output, at 2.6 percent per year since 2000, falls well short of SSA gains, it exceeds Asia's population growth of less than 1.5 percent per year. The region relies on domestic production for a larger share of grain supplies, more than 90 percent, than any other region in the study. The most food-insecure countries in the region are Yemen and North Korea, both of which suffer from poor governance and instability.

Over the long term, Asia's food security situation is projected to deteriorate as the share of the region's population that is food insecure rises to 8.5 percent by 2026. The number of food-insecure people jumps 30 percent, roughly the same as the increase in the distribution gap, meaning no change in the intensity of food insecurity. The deterioration in food security can be attributed to just two countries—Afghanistan and the Philippines.

In Afghanistan, the share of food-insecure people is projected to rise from 10 percent in 2016 (a historical low) to 30 percent in 2026. Timely and abundant rains contributed to a bumper wheat crop in 2015, which followed an above-average crop in 2014. Therefore, current food supplies are relatively high and food security in 2016 was much better than the historical norm. Over the longer term, however, per capita consumption is expected to decline, albeit slowly. While grain output gains

are projected to slightly outpace population growth, Afghanistan's growth in commercial imports, which account for about a quarter of the country's grain supplies, is likely to be constrained by limited foreign exchange. Still, per capita consumption does not fall far below the nutritional target, indicating a low intensity of food insecurity.

In the Philippines, the share of the population that is food insecure rises from less than 10 percent in 2016 to 20 percent in 2026. As in Afghanistan, production growth is projected to exceed population growth, but import growth is projected to fall short. However, per capita consumption in the lowest income decile is projected at 96 percent of the nutritional target in 2026, meaning that food insecurity is not severe.

The ***Latin America and Caribbean*** region is projected to continue its trend of improving food security as the number of food-insecure people is expected to fall 20 percent from 2015 to 2016. The share of population food insecure is estimated to fall from 27 to 21.3 percent. The most food-insecure country in the region is Haiti, where 80 percent of the population is estimated to be food insecure in 2016, followed by Ecuador at 50 percent. This does mark an improvement from earlier years in both countries as population growth slows and grain production improves, particularly in Ecuador.

Over the longer term, improvement in the region's food security is expected to continue as the share of population that is food insecure falls to 13 percent by 2026. The greatest improvements are projected for Bolivia (from 40 to 10 percent), Ecuador (from 50 to 10 percent), and Honduras (from 40 to 10 percent). In all three cases, despite relatively slow production growth, per capita consumption is expected to rise due to a steady deceleration of population growth. In Bolivia and Honduras, population growth is projected to average roughly 1.5 percent per year through 2026, while in Ecuador it is expected to be even lower, 1.2 percent.

***North Africa*** is the most food secure of the regions included in the study. Per capita intake in the four countries—Algeria, Egypt, Morocco, and Tunisia—averages about 3,400 calories per day, which is comparable to the European Union. High consumption levels are largely a result of food subsidy programs which, in recent years, have undergone cuts and revisions. While all NA countries are considered food secure at the aggregate level, we recognize that our supply-oriented analysis does not capture food insecurity that likely exists among the lowest income populations within these countries.

## References

United Nations, Food and Agriculture Organization. *Crop Prospects and Food Situation*. No. 2, October 2015.

United Nations, Food and Agriculture Organization. FAOSTAT database.

Table 2

**Supply-oriented model projections of food insecurity, 2016 and 2026**

| | Population | | Population food insecure | | Share of population food insecure | | Distribution gap* (total) | | Distribution gap* (per capita) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 |
| | *Million* | | *Million* | | *Percent* | | *1,000 MT* | | *kg* | |
| **Total** | **3,599.8** | **4,171.0** | **431.3** | **570.3** | **12.0** | **13.6** | **14,657** | **19,293** | **4.1** | **4.6** |
| **Asia** | **2,333.2** | **2,609.5** | **169.2** | **222.2** | **7.2** | **8.5** | **1,488** | **1,933** | **0.6** | **0.7** |
| Afghanistan | 33.3 | 42.0 | 3.3 | 12.6 | 10 | 30 | 17 | 94 | 0.5 | 2.2 |
| Armenia | 3.1 | 2.9 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Azerbaijan | 9.9 | 10.6 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Bangladesh | 171.7 | 200.5 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Cambodia | 16.0 | 18.2 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Georgia | 4.9 | 4.9 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| India | 1,266.9 | 1,409.4 | 126.7 | 140.9 | 10 | 10 | 701 | 736 | 0.6 | 0.5 |
| Indonesia | 258.3 | 278.5 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Korea, DPR | 25.1 | 26.3 | 12.6 | 10.5 | 50 | 40 | 174 | 115 | 6.9 | 4.4 |
| Kyrgyzstan | 5.7 | 6.3 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Laos | 7.0 | 8.1 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Moldova | 3.5 | 3.1 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Mongolia | 3.0 | 3.3 | 0.3 | 0.0 | 10 | 0 | 0 | - | 0.1 | - |
| Nepal | 32.1 | 37.1 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Pakistan | 202.0 | 231.3 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Philippines | 102.6 | 119.1 | 0.0 | 26.2 | 0 | 20 | - | 185 | - | 1.6 |
| Sri Lanka | 22.2 | 23.7 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Tajikistan | 8.3 | 9.6 | 1.7 | 1.9 | 20 | 20 | 12 | 16 | 1.4 | 1.7 |
| Turkmenistan | 5.3 | 5.8 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Uzbekistan | 29.5 | 32.1 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Viet Nam | 95.3 | 103.1 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Yemen | 27.4 | 33.4 | 24.7 | 30.1 | 90 | 90 | 584 | 788 | 21.3 | 23.6 |
| **LAC** | **165.0** | **183.1** | **35.1** | **23.9** | **21.3** | **13.0** | **606** | **425** | **3.7** | **2.3** |
| Bolivia | 11.0 | 12.6 | 4.4 | 1.3 | 40 | 10 | 95 | 43 | 8.6 | 3.4 |
| Colombia | 47.2 | 51.6 | 4.7 | 5.2 | 10 | 10 | 14 | 38 | 0.3 | 0.7 |
| Dominican Republic | 10.6 | 11.8 | 1.1 | 0.0 | 10 | 0 | 2 | - | 0.1 | - |
| Ecuador | 16.1 | 18.0 | 8.0 | 1.8 | 50 | 10 | 114 | 19 | 7.1 | 1.0 |
| El Salvador | 6.2 | 6.3 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Guatemala | 15.2 | 17.8 | 4.6 | 7.1 | 30 | 40 | 79 | 121 | 5.2 | 6.8 |
| Haiti | 10.2 | 11.4 | 8.2 | 6.8 | 80 | 60 | 228 | 172 | 22.3 | 15.1 |
| Honduras | 8.9 | 10.3 | 3.6 | 1.0 | 40 | 10 | 73 | 31 | 8.3 | 3.0 |
| Jamaica | 3.0 | 3.2 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Nicaragua | 6.0 | 6.5 | 0.6 | 0.7 | 10 | 10 | 1 | 1 | 0.1 | 0.2 |
| Peru | 30.7 | 33.5 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| **North Africa** | **175.1** | **200.2** | **0.0** | **0.0** | **0.0** | **0.0** | **-** | **-** | **-** | **-** |
| Algeria | 40.3 | 46.3 | 0.0 | 0.0 | 0.0 | 0.0 | - | - | - | - |
| Egypt | 90.1 | 105.2 | 0.0 | 0.0 | 0.0 | 0.0 | - | - | - | - |
| Morocco | 33.7 | 36.8 | 0.0 | 0.0 | 0.0 | 0.0 | - | - | - | - |
| Tunisia | 11.1 | 11.9 | 0.0 | 0.0 | 0.0 | 0.0 | - | - | - | - |

Continued—

Table 2

**Supply-oriented model projections of food insecurity, 2016 and 2026—continued**

| | Population | | Population food insecure | | Share of population food insecure | | Distribution gap* (total) | | Distribution gap* (per capita) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 | 2016 | 2026 |
| | *Million* | | *Million* | | *Percent* | | *1,000 MT* | | *kg* | |
| **SSA** | **926.5** | **1,178.2** | **227.0** | **324.2** | **24.5** | **27.6** | **12,564** | **16,935** | **13.6** | **14.4** |
| Angola | 20.2 | 26.3 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Benin | 10.7 | 13.9 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Burkina Faso | 19.5 | 26.1 | 0.0 | 5.2 | 0 | 20 | - | 22 | - | 0.8 |
| Burundi | 11.1 | 15.3 | 11.1 | 15.3 | 100 | 100 | 978 | 1,642 | 88.2 | 107.6 |
| Cabo Verde | 0.6 | 0.6 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Cameroon | 24.4 | 31.3 | 0.0 | 3.1 | 0 | 10 | - | 21 | - | 0.7 |
| Central African Republic | 5.5 | 6.8 | 5.5 | 6.8 | 100 | 100 | 304 | 457 | 55.2 | 67.5 |
| Chad | 11.9 | 14.2 | 10.7 | 7.1 | 90 | 50 | 252 | 93 | 21.3 | 6.6 |
| Congo | 4.9 | 6.1 | 1.5 | 1.8 | 30 | 30 | 18 | 19 | 3.6 | 3.2 |
| Congo, DR | 81.3 | 101.1 | 81.3 | 101.1 | 100 | 100 | 8,533 | 10,864 | 104.9 | 107.4 |
| Côte d'Ivoire | 23.7 | 28.1 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Eritrea | 6.7 | 8.1 | 6.7 | 8.1 | 100 | 100 | 674 | 751 | 101.0 | 92.3 |
| Ethiopia | 102.4 | 134.7 | 10.2 | 40.4 | 10 | 30 | 27 | 313 | 0.3 | 2.3 |
| Gambia | 2.0 | 2.4 | 0.4 | 0.5 | 20 | 20 | 4 | 6 | 1.8 | 2.7 |
| Ghana | 26.9 | 33.3 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Guinea | 12.1 | 15.6 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Guinea-Bissau | 1.8 | 2.1 | 0.4 | 0.4 | 20 | 20 | 4 | 2 | 2.0 | 1.2 |
| Kenya | 46.8 | 53.8 | 14.0 | 10.8 | 30 | 20 | 198 | 140 | 4.2 | 2.6 |
| Lesotho | 2.0 | 2.0 | 1.8 | 1.2 | 90 | 60 | 61 | 30 | 31.4 | 15.4 |
| Liberia | 4.3 | 5.4 | 0.4 | 1.1 | 10 | 20 | 2 | 14 | 0.6 | 2.6 |
| Madagascar | 24.4 | 30.8 | 7.3 | 12.3 | 30 | 40 | 84 | 163 | 3.4 | 5.3 |
| Malawi | 18.6 | 25.8 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Mali | 17.5 | 23.1 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Mauritania | 3.7 | 4.5 | 0.0 | 0.5 | 0 | 10 | - | 0 | - | 0.0 |
| Mozambique | 25.9 | 33.1 | 7.8 | 13.2 | 30 | 40 | 113 | 216 | 4.4 | 6.5 |
| Namibia | 2.2 | 2.3 | 0.9 | 0.5 | 40 | 20 | 16 | 7 | 7.0 | 3.0 |
| Niger | 18.6 | 25.4 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Nigeria | 186.1 | 236.0 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Rwanda | 13.0 | 16.4 | 6.5 | 8.2 | 50 | 50 | 89 | 114 | 6.9 | 6.9 |
| Senegal | 14.3 | 18.0 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Sierra Leone | 6.0 | 7.7 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Somalia | 10.8 | 13.6 | 10.8 | 13.6 | 100 | 100 | 387 | 765 | 35.8 | 56.2 |
| Sudan | 36.7 | 43.5 | 0.0 | 0.0 | 0 | 0 | - | - | - | - |
| Swaziland | 1.5 | 1.6 | 1.2 | 1.3 | 80 | 80 | 23 | 25 | 16.0 | 15.6 |
| Tanzania | 52.5 | 68.7 | 5.2 | 13.7 | 10 | 20 | 27 | 149 | 0.5 | 2.2 |
| Togo | 7.8 | 10.0 | 1.6 | 2.0 | 20 | 20 | 10 | 25 | 1.3 | 2.5 |
| Uganda | 38.3 | 52.2 | 19.2 | 36.5 | 50 | 70 | 239 | 687 | 6.2 | 13.2 |
| Zambia | 15.5 | 20.7 | 12.4 | 12.4 | 80 | 60 | 311 | 281 | 20.1 | 13.6 |
| Zimbabwe | 14.5 | 17.7 | 10.2 | 7.1 | 70 | 40 | 209 | 129 | 14.4 | 7.3 |

*Measured in grain equivalent.

Source: USDA, Economic Research Service.

# Appendix 1—New Demand-Oriented Model: Definitions and Methodology

The new IFSA model used in this report projects food consumption (food demand), food access, and food gaps in 76 low- and middle-income countries through 2026. The food security of a country is evaluated based on the gap between projected domestic food consumption (food demand) and a nutritional target—set at 2,100 calories per capita per day—necessary to sustain life at a moderate level of activity. The model projections of food demand are expressed in grain equivalent based on the commodities' caloric content to allow aggregation across food groups; this grain equivalent is easily expressed in kilograms or calories.[1]

The simulation framework used for projecting food demand is based on partial equilibrium models for each country in the assessment. The methodology is introduced in Beghin et al. (2015a); Beghin et al. (2015b), and Beghin et al. (forthcoming) provide more detail on price transmission and food security projections.

Each country model is comprised of a price-independent generalized logarithmic (PIGLOG) demand system for each of the four food groups (major grains, minor grains, root crops, and other food), which is calibrated on a 3-year average of prices and incomes, observed consumption levels and a measure of inequality, and elasticities estimated by Muhammad et al. (2011). Demand projections are based on projected prices and incomes; the model implicitly assumes the preferences represented by the demand system, as well as the income distribution embedded in the calibration and projection, are constant over time.

## Structural Framework for Estimating and Projecting Aggregate Food Demand

*Demand system definition and calibration*

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

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

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 into average per capita market demand (Muellbauer, 1975). The average demand for food group i is:

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

The latter is a function of average per capita income and Theil's (1967) entropy measure of income inequality $z$.

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

We also define average expenditure share for good category *i* as:

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

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

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

The own-price elasticity of the average demand is

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

All consumers in different deciles have similar underlying preferences over good *i* as embodied in parameters $\alpha_{i0}$, $a_{i1}$, $b_{i0}$, $b_{i1}$; and their respective consumptions vary because their respective incomes vary.

With a system of three linear equations (equations 3, 4, and 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 $a_{io}$ as a function of the free parameter. Once these three parameters are recovered, parameters $\tilde{a}_{i0}, \tilde{a}_{i1}, \hat{b}_{i0}$, and $\tilde{b}_{i1}$ and , along with income $x^h$ and price $p_i$, are used to generate the consumption level of good *i* for each decile specified in equation (1). In this initial calibration, the quality of any good *i* is assumed constant across deciles.

For each country, we calibrate a demand system for each of the four food groups. We determine the major grain (which varies across country) based on caloric share in the diet. The minor grains food group contains all other grains; the prices for the food group are weighted by its components' caloric share.

For the food prices that we do not observe in the calibration stage, we create a synthetic domestic price, $p_i^{dom,syn}$ that is linked to the world price $p_i^{world}$. The parameter θ is the price transmission slope, which we assume is 0.7.[2] The parameter $trc_{int}$ represents international transportation and marketing costs (e.g., CIF/FOB), which we assume are 10 percent of total commodity value, and $trc_{dom}$ are domestic trade costs, which we assume are $20 per ton in real terms.

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

[2]We choose a slope of 0.7 in light of Minot's (2011) finding that staple food prices in Sub-Saharan Africa rose by about three-quarters of the increase in world prices in 2007-08.

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:

$$p_i^{dom} = \theta^* p_i^{world} + \widehat{intercept}. \quad (7)$$

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

***Projection of Food Demand and Quality Scaling***

Consistent with real-world observation, we assume that the quality of good *i* increases with income and that its price also increases with quality. This quality is represented by a scaling factor $\mu(x)$ that, when normalized appropriately over all deciles, is equal to 1. The scaling factor scales quality and prices such that the product of quality-adjusted quantity consumed and prices (or the expenditure share) remains constant. The detailed procedure is explained in Beghin et al. (2015b).

## Food Security Indicators

Inadequate access to food is the most common cause of chronic food insecurity among developing countries and is related to income level. Estimates of food gaps at the aggregate or national level fail to take into account the distribution of food consumption among different income groups.

We estimate a distribution of calorie availability by income level, summarized by a coefficient of variation of food availability. This approach is described in Beghin et al. (2015b). Using this distribution, we recover the proportion of the population that falls below the calorie target (2,100 calories per capita per day) and the average caloric intake of the food-insecure population.

The food gap can be computed by looking at the difference between the target 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 produce 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 2013 to 2015. 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, Domestic Prices (Synthetic).

Projections are based on data from the ERS International Macroeconomic Dataset and use the calibrated demand parameters and price transmission 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 (most recent available)[3]

Grain Shares – FAO Food Balance Sheet[4]

Elasticities of Price and Income – Muhammad et al. (2011)[5]

Domestic Prices (Observed) – FAO GIEWS (annual average; market depends on reporting)

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

Exchange Rates and CPIs – ERS International Macroeconomic Dataset[7]

Population – ERS International Macroeconomic Dataset[8]

World Prices – USDA Agricultural Projections to 2025[9]

Per Capita Income – generated using GDP and population from ERS International Macroeconomic Dataset[10]

Income Distribution – World Bank data bank.[11] Assumed constant at 2013-2015 (calibration) levels during the projection period.

Coefficient of Variation (CV) of Food Consumption – FAO SOFI 2015; assumed constant during the projection period.[12]

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[3]Food Balance Sheets (FBS) are from 2011 or 2013. There are no FBS for Somalia, Sudan, Eritrea, Burundi, and DR Congo. Instead, we use grain consumption levels and share of grains in total calories as reported in the FAO-GIEWS *Cereal Supply and Demand Balance for Sub-Saharan African Countries* report to generate per capita consumption for each food group.

[4]There are no FBS for Somalia, Sudan, Eritrea, Burundi, and DR Congo. We access preliminary FBS for Somalia and former Sudan for 2011 from the old FAOSTAT, which is no longer maintained. We use FBS of neighboring countries (Burundi-Rwanda; DR Congo-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 substitute 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; an average of Cambodia, Vietnam, Philippines, and Mongolia for North Korea; and Bolivia for Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, and Nicaragua.

[6]Tariffs are available for 2013-2014 only. The tariffs on rice for Sri Lanka and Indonesia, and for soy oil in Pakistan are from UNCTAD. Somalia, North Korea, and Turkmenistan do not report to WTO. Turkmenistan tariffs are from UNCTAD for 2002. Somalia tariffs are the means observed for Sub-Saharan African IFSA countries, and North Korea tariffs are the maximum observed tariffs for IFSA countries.

[7]We modeled Ecuador and El Salvador using U.S. dollars as the local currency unit; CPI growth rates are from IMF. For Somalia, we assumed a constant real exchange rate. We modeled North Korea using USD and the LCU. For Somalia, we used the average CPI growth rate for Sub-Sharan Africa; for North Korea, we used the average for Asia.

[8]Population levels and projections for Somalia and North Korea are from the U.S. Census Bureau.

[9]The world price series are: maize (U.S. Gulf #2 yellow); rice (Thai, B, fob Bangkok); sorghum (U.S. Gulf, #2 yellow); wheat (U.S. Gulf, #2 HRW); barley (EC, French, Rouen); Oats (U.S. farm); roots and tubers (cassava; tapioca, hard pellets, Rotterdam, fob); other food (represented by soy 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).

[10]Somalia and North Korea GDP are generated using 2013 levels and 2013-2014 real growth rates from the UN Data Bank.

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

[12]FAO does not calculate CV for all countries. We substitute 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.

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# Appendix 2—Supply-Oriented Model: Definitions and Methodology

The International Food Security Assessment model used in this report was developed by USDA's Economic Research Service to project food consumption, food access, and food gaps (previously called food needs) in low- and middle- income countries through 2026**.** Food is divided into three groups: grains, root crops, and a category called "other," which includes all other commodities consumed, thus covering 100 percent of food consumption. All of these commodities are expressed in grain equivalent.

Food security of a country is evaluated based on the gap between projected domestic food consumption (domestic production plus imports minus nonfood uses) and a nutritional target. We include total food aid data (cereal and noncereal food commodities) provided by the World Food Program. All food aid commodities are converted into grain equivalents based on calorie content to allow aggregation.[1]

While projection results provide a baseline for the food security situation in the countries, results depend on the specification of the model and underlying assumptions. Since the model is based on historical data, it implicitly assumes that the historical trend in key variables will continue in the future.

One food security indicator provided is the ***distribution gap***, where the objective is to let each income decile achieve the daily caloric intake standard of about 2,100 calories per capita per day. The caloric targets (based on total share of grains, root crops, and "other") used in this assessment are those necessary to sustain life at a moderate level of activity. If food availability in a given income group is lower than this target, that difference is part of the distribution gap for this country. This gap provides a measure of the intensity of food insecurity.

## Framework for projecting food consumption in the aggregate and by income group

**Projection of food availability.** The simulation framework used for projecting aggregate food availability is based on partial equilibrium recursive models of 76 low- and middle-income countries. The country models are synthetic, meaning that the parameters that are used are either cross-country estimates or are estimated by other studies. Each country model includes three commodity groups: grains, root crops and "other." The production side of the grain and root crops are divided into yield and area response. Crop area is a function of 1-year lagged returns (real price times yield) to crop production, lagged returns to substitute crops, and lagged crop area. Yield responds to input use. Commercial imports are assumed to be a function of domestic price, world commodity price, and foreign exchange availability. Food aid received by countries is assumed constant at the base level during the projection period.

Foreign exchange availability is a key determinant of commercial food imports and is the sum of the value of export earnings and net flow of credit. Foreign exchange availability is assumed to be equal to foreign exchange use, meaning that foreign exchange reserves are assumed constant during the

[1]For example: grain has 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 (1 divided by 3.5); 1 ton of vegetable oil (8 calories per gram) is equivalent to 2.29 tons of grain (8 divided by 3.5).

projection period. Countries are assumed to be price takers in the international market, meaning that world prices are exogenous in the model. However, producer prices are linked to the international market through food imports and their impact on domestic supply. The projection of consumption for the "other" commodities is based on a trend that follows the projected growth in supply of the food crops (grains plus root crops). Though simplistic, this approach improves on the previous approach where commodities such as meat and dairy products were overlooked.

Food consumption (*FC*) for grains and root crops (*c*) is defined as domestic supply (*DS*) minus nonfood use (*NF*), where *n* is a country index and *t* is a time index.

$$FC_{cnt} = DS_{cnt} - NF_{cnt}. \quad (1)$$

Nonfood use is the sum of seed use (*SD)*, feed use (*FD*), exports *(EX)*, and other uses (*OU*).

$$NF_{cnt} = SD_{cnt} + FD_{cnt} + EX_{cnt} + OU_{cnt}. \quad (2)$$

Domestic supply of a commodity group is the sum of domestic production (*PR*) plus commercial imports (*CI*), changes in stocks (*CSTK*), and food aid (*FA*).

$$DS_{cnt} = PR_{cnt} + CI_{cnt} + CSTK_{cnt} + FA_{cnt}. \quad (3)$$

Production is generally determined by the area and yield response functions:

$$PR_{cnt} = AR_{cnt} * YL_{cnt} \quad (4)$$

$$YL_{cnt} = f(LB_{cnt}, FR_{cnt}, K_{cnt}, T_{cnt}) \quad (5)$$

$$RPY_{cnt} = YL_{cnt} * DP_{cnt} \quad (6)$$

$$RNPY_{cnt} = NYL_{cnt} * NDP_{cnt} \quad (7)$$

$$AR_{cnt} = f(AR_{cnt-1}, RPY_{cnt-1}, RNPY_{cnt-1}, Z_{cnt}), \quad (8)$$

where *AR* is area, *YL* is yield, *LB* is rural labor, *FR* is fertilizer use, *K* is capital use, *T* is technology change, *DP* is real domestic price, *RPY* is yield times real price, *NDP* is real domestic substitute price, *NYL* is yield of substitute commodity, *RNPY* is yield of substitute commodity times substitute price, and *Z* represents exogenous policies.

The commercial import demand function is defined as:

$$CI_{cnt} = f(WPR_{ct}, NWPR_{ct}, FEX_{nt}, PR_{cnt}, M_{nt}), \quad (9)$$

where *WPR* is real world food price, *NWPR* is real world substitute price, *FEX* is real foreign exchange availability, and *M* is import restriction policies.

The real domestic price is defined as:

$$DP_{cnt} = f(DP_{cnt-1}, DS_{cnt}, NDS_{cnt}, GDP_{nt}, EXR_{nt}), \quad (10)$$

where *NDS* is the supply of a substitute commodity, *GDP* is real income, and *EXR* is the real exchange rate.

**Estimations/projections of food consumption by income group**. Inadequate access to food is the most important cause of chronic food insecurity among developing countries and is related to income level. Estimates of food gaps at the aggregate or national level fail to take into account the distribution of food consumption among different income groups. Lack of such data for the study countries is the key factor preventing estimates of food consumption by income group. We attempt to fill this information gap by using an indirect method of projecting calorie consumption by different income groups based on income distribution data.[2] This approach ignores the substitution of different food groups by income class. The procedure uses the income/consumption relationship to allocate the total projected amount of available food among different income deciles in each country (income distributions are assumed constant during the projection period).

Assuming that consumption increases with income but at a declining rate (semi-log functional form), the income/consumption relationship was specified as shown below:

$$C = a + b \ ln \ Y \tag{11}$$

$$C = C_o/P \tag{12}$$

$$P = P_1 + \ldots\ldots\ldots + P_i \tag{13}$$

$$Y = Y_o/P \tag{14}$$

$$i = 1 \text{ to } 10$$

where $C$ and $Y$ are known average per capita food consumption (all commodities in grain equivalent) and per capita income (all deciles), $C_o$ is total food consumption, $P$ is total population, $i$ is income deciles, $a$ is the intercept, and $b$ is the consumption income propensity. A consumption-income elasticity, $b/C$, is calculated for individual countries. The parameter $b$ was estimated based on cross-country (76 low-income countries) data for per capita calorie consumption and income. The parameter $a$ is estimated for each country based on the known data for average per capita calorie consumption and per capita income.

## Data

Historical crop production, supply and use balance, and trade data for 1990-2014—and 2015 when available—are from FAOSTAT, FAO/GIEWS and USDA as of March 2016. Food aid data are from the UN's World Food Program (WFP) for 1988-2012, and financial data are from the International Monetary Fund and World Bank. Population data are from the U.S. Census. Base-year data used for projections are the average for 2012-2014, where possible, or else the most recent 3-year average available.

***Endogenous projection variables**:*

*Production*, *area*, *yield*, *commercial imports*, *domestic producer prices*, and *food consumption*.

[2]The method is similar to that used by Shlomo Reutlinger and Marcelo Selowsky in "Malnutrition and Poverty," World Bank, 1978.

***Exogenous projection variables***:

*Population*—U.S. Census

*World price*—Data are USDA/baseline projections.

*Stocks*—FAO data; assumed constant during the projection period.

*Seed use*—FAO data; projections are based on area projections using constant base seed/area ratio.

*Food exports*—FAOSTAT data, projections are either based on the population growth rate or extrapolation of historical trends.

*Inputs*—Fertilizer and capital projections are, in general, extrapolations of historical growth data from FAO.

*Agricultural labor*—Projections are based on United Nations population projections, accounting for urbanization growth.

*Net foreign credit*—Assumed constant during the projection period.

*Value of exports*—Projections are based on World Bank (*Global Economic Prospects and the Developing Countries*, various issues), IMF (*World Economic Outlook*, various issues), or extrapolations of historical growth.

*Export deflator or terms of trade*—World Bank (*Commodity Markets--Projection of Inflation Indices for Developed Countries*).

*Income*—World Bank data for supply-oriented model, IMF data for projections.

*Income distribution*—World Bank data; income distributions are assumed constant during the projection period.