FOOD SECURITY

Tackling the Current Crisis and Building Future Resilience

Citi GPS: Global Perspectives & Solutions

November 2022

Jason Channell
Global Head of Sustainable Finance
Citi Global Insights

+44-20-7986-8661 | jason.channell@citi.com

Elizabeth Curmi
Global Thematic Analyst
Citi Global Insights

+44-20-7986-6818 | elizabeth.curmi@citi.com

Aakash Doshi
Head of North America Commodity Strategy
Citi Research

+1-212-723-3872 | aakash.doshi@citi.com

Emma Hampton
EMEA Public Sector Group
Citi

+44 20 7986 7716 | emma.hampton@citi.com

Julie Monaco
Global Head for Public Sector, Corporate and Investment Banking
Citi

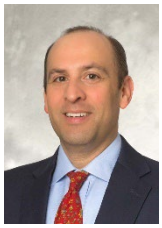
+1-212-816-5340 | julie.monaco@citi.com

Georgi Yordanov
Head of Public Sector Emerging Europe
Citi

+44-20-7986-8471 | georgi.yordanov@citi.com

Ying Qin
Global Thematic Analyst
Citi Global Insights

+44-20-7986-8325 | ying.qin@citi.com



Adam Bergman
Clean Energy Transition, Citi

+1 917-597-0763 | adam.bergman@citi.com

John Finnigan
Head of Development Organizations, Public Sector Group
Citi

+1-212-816-6166 | john.finnigan@citi.com

Dustin Oliver Ling
Global Public Sector Banking
Citi

+1-212-816-9187 | lingd@citi.com

Harlin Singh
Global Head of Sustainable Investing
Citi Private Bank

+1-212-559-8837 | harlin.singh@citi.com

FOOD SECURITY

Tackling the Current Crisis and Building Future Resilience

Kathleen Boyle, CFA
Managing Editor, Citi GPS

Around the globe, nearly a third of us worry about where our next meal is coming from, and one in ten of us suffer from hunger or malnutrition. How is that possible in a modern society? While we are having high-level debates about the possible dystopian effects on society from advanced technology, artificial intelligence, and quantum computing, we seem to be missing a simple and embarrassing truth — we have failed in our moral responsibility to ensure no one goes hungry.

It is easy to write off our current situation by pointing to a slew of one-off events that came together to create a "perfect storm" — droughts, armed conflict, skyrocketing inflation, supply chain issues. But even accounting for this tumultuous year, nearly a billion people around the world, some far away and some literally next door, have gone without food and experienced hunger for at least one day in 2022.

Food insecurity has serious social and geopolitical implications and throughout history has been a driver of civil unrest and migration. It also carries a hefty price tag — the UN's Food and Agriculture Organization estimates the costs of malnutrition to the global economy to be as high as $3.5 trillion per year. And while finding a solution will also be costly, the economic benefits to society could reach $10.5 trillion per year.

In the report that follows, we first look at what is driving the recent increase in food insecurity and find that although the Russia-Ukraine conflict fanned the flames of the crisis, it was not the sole cause. Environmental factors such as more frequent extreme weather events are making crop production more volatile and increasing the vulnerability of the agriculture sector. Higher energy prices have raised the cost of food production. Rising inflation has forced families to make trade-offs between food and other monthly expenses. And conflict in general has caused disruptions to supply chains and transportation hubs.

Although some of these issues will fix themselves in 2023, there is a scenario where higher-than-normal agriculture prices persist with continued high fertilizer prices. The recent increase in protectionist trade policies, including export bans, is also exacerbating the problem.

So how do we fix this? How do we ensure we are making out best effort to reduce the number of hungry people? The proposed solutions can be bucketed into four categories: social, technological, economic/financial, and governmental. Society can make small changes to eliminate food waste or shifting to a more plant-based diet, which would increase the amount of available food. Technological innovation in alternative proteins and indoor farming as well as automation and robotics can help in ensure food self-sufficiency for regions reliant on imports and improve the food ecosystem.

Financing vehicles such as blended finance and hedging facilities can help facilitate investment in infrastructure. And government is needed to help push the agenda forward with targeted policy and regulation as well as provide humanitarian aid and sustained investment in global agriculture.

Big problems take big solutions and big efforts.

COMBATING GLOBAL FOOD INSECURITY

NO ROOM FOR COMPLACENCY

Global food insecurity is a problem of paramount importance. Nearly 1 in 3 people globally are experiencing moderate or severe food insecurity, where food quality or quantity is reduced, while 770 million are suffering from some form of malnutrition. Despite progress in the early 2000s, hunger has been on the rise since 2015, and has even accelerated in recent years.

Food Insecurity

~30% of global population is moderately or severely food insecure

11.7% of the world is severely food insecure

Malnutrition

1/10 people globally are undernourished

8% of the world projected to face hunger in 2030

85% in sub-Saharan Africa and **70%** in South Asia cannot afford a healthy diet

Population Growth to Worsen the Crisis

Up to 2bn more people will need to be fed by 2050

Bulk of **population growth** occurring in **food insecure** regions

A PERFECT STORM

A perfect storm of conflict, environmental, and social, political and economic shifts is worsening global food insecurity. The Russia-Ukraine conflict highlighted the risk of depending on too few countries for food and on physical chokepoints for the transport of key commodities. While some effects may be alleviated in 2023, food prices may remain elevated for some time, even if further inflation looks less likely.

Conflict

Russia-Ukraine is critical global breadbasket: 25% of world's total food exports

Black Sea corridor is a supply chokepoint

Other conflicts: Ethiopia, South Sudan, Yemen

Environmental

Increasing crop volatility

More frequent extreme weather events

Reduced nutritional quality of staple cereals

Lack of rain/drought

Social, Political or Economic Shifts

High energy and fertilizer prices

Currency devaluation in highly indebted emerging markets

Food inflation squeezing family budgets

Export bans driving up food prices

GLOBAL IMPLICATIONS

While this is, first and foremost, an immediate human tragedy, the economic and social/geopolitical implications of food insecurity have material macroeconomic impacts. Disruptions in food production have employment consequences while the economic impact from malnutrition could be as high as $3.5 trillion per year. In particular, history suggests high food prices can lead to civil unrest and displacement, e.g., the Arab Spring in 2011.

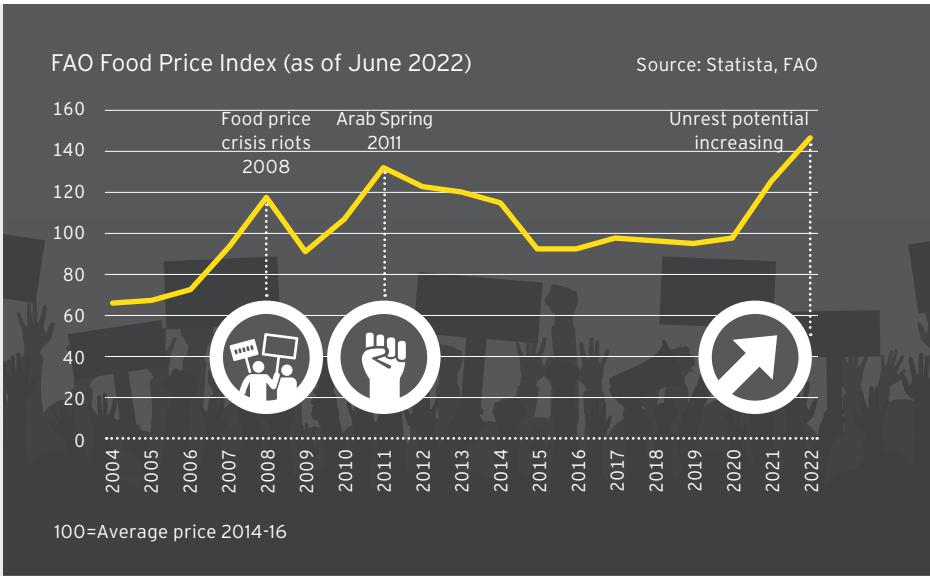
Economic

Agriculture represents **>25%** of GDP and employs nearly **60%** of the workforce in low-income countries

Cost of addressing malnutrition by 2030: **$39bn-$50bn/yr**

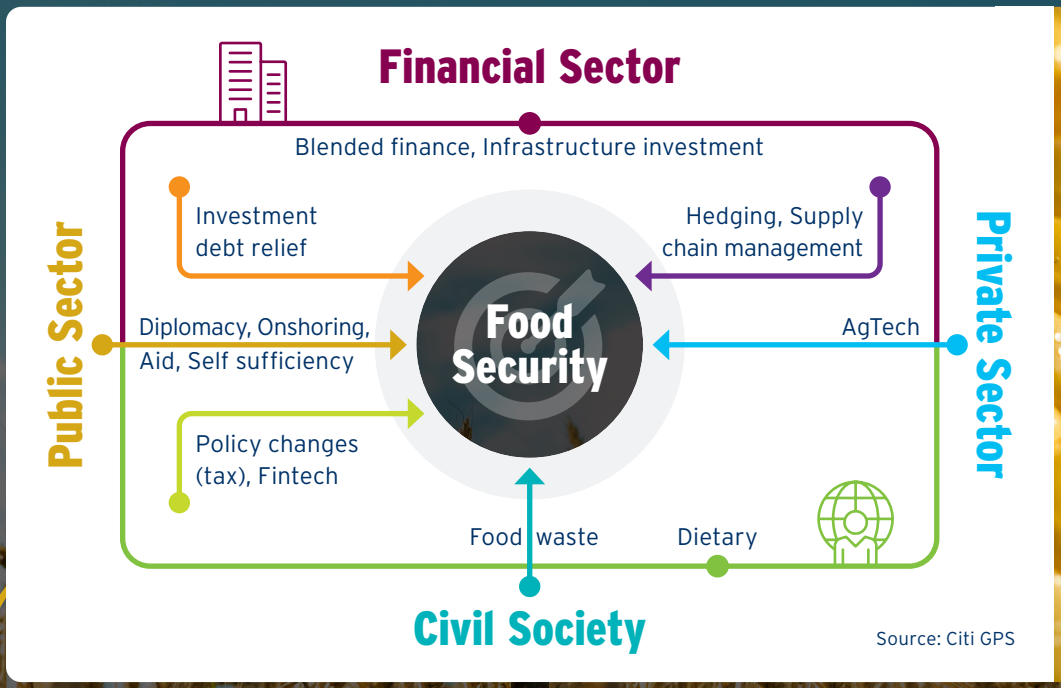
Economic gain to society to investing in nutrition: **$5.7tn/yr by 2030** and **$10.5tn/yr by 2050**

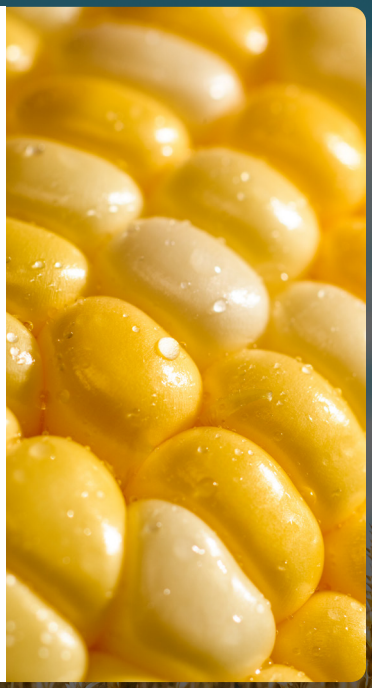
Social and Geopolitical



POTENTIAL SOLUTIONS

Although imperfect, we propose an integrated approach to ease food insecurity, hunger, and malnutrition in the short-medium term, and aim to eradicate it in the longer term. Key actors – the public, private, and financial sectors, as well as civil society – all play a role in tackling these challenges.





Contents

Summary

Hunger, food insecurity, and malnutrition are not new concepts; they have been with us through history, and have often presaged remarkable social, economic, and political upheaval — from the drought-driven famines that brought about the demise of the first kingdom in Egypt in the 22nd century BC; through the food riots that inspired Shakespeare's Coriolanus; to the Irish potato famine; and the more recent Arab Spring, for which food prices were also a catalyst.

The overwhelming issue is of course the appalling human suffering that results, which is often borne by the poorest in society, not gender-balanced, and most damaging to society's most vulnerable, namely children and the elderly. Having enough food to eat is a basic human right, and trumps almost every other concern or aspect of poverty in its significance. John Steinbeck sums up this primacy well in the novel *Grapes of Wrath*:

"*How can you frighten a man whose hunger is not only in his own cramped stomach, but in the wretched bellies of his children? You can't scare him — he has known a fear beyond every other.*"

Sadly though, food security, hunger, and malnutrition are not issues that are confined to the pages of history or literature. First and foremost, it is important to define these three terms, as they are separate but related. For this report, we follow the classification provided by the FAO:

- **Food Security:** When all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.
- **Hunger:** An uncomfortable or painful physical sensation caused by insufficient consumption of dietary energy; hunger may be referred to as undernourishment. When a person is severely food insecure, they have likely experienced hunger.
- **Malnutrition:** An abnormal physiological condition caused by inadequate, unbalanced, or excessive intake of macronutrients and/or micronutrients. It includes undernutrition, overweight, and obesity.

As we shall see in this report, even in this day and age food insecurity is still a problem that affects far too many people around the world — in fact, close to a third of all of us on this planet. Around the world, 2.3 billion people are experiencing moderate or severe food insecurity, where food quality or quantity is reduced. Within that figure close to a billion people — some 12% of the population — are suffering from severe food insecurity, where people have "run out of food, and have gone an entire day without eating at times in the last year." Food insecurity also has an impact on malnutrition as when individuals do eat, they might choose what is most readily available or cheapest, instead of the most nutritious option. Globally, 21 million infants come into this world with low birthweight, 150 million children under the age of five experience stunting (failing to reach their growth potential), and 50 million suffer from wasting (being too thin for their height). Around the world, 770 million people — one in ten of us — suffers from some form of malnutrition.

So, this is a widespread phenomenon that does not just affect a few people. It is, however, concentrated and focused among the poorest in society; in sub-Saharan Africa and South Asia, 70%-80% of the population cannot afford a healthy diet.

While the number of people experiencing hunger fell for many years in the early 2000s, it has been on the increase since 2018, and has accelerated in recent years, reaching 768 million people in 2021. Moreover, there is little room for complacency as we contemplate how we will feed an extra 1.8 billion people by 2050, with the bulk of growth coming from regions that are already experiencing the worst effects of food insecurity, hunger, and malnutrition.

So how, in 2022, can we still live in world where close to a third of us are worried where our next meal is coming from? Food insecurity is typically caused by three main factors: environmental disasters; conflict; and social, political, or economic shifts. In 2022 we find ourselves in a perfect storm as the world recovers from the COVID-19 pandemic, with poor harvests from some regions, export bans, food stockpiling, surging energy costs, rising global inflation, and high debt levels in a rising rate cycle — all exacerbated by the Russia-Ukraine conflict and the loss of those critical breadbaskets, as well as impacts on fertilizer production and availability.

While some of these factors may be alleviated going into 2023, their effects will take time to work through, and it is easy to envisage a scenario (as we examine in this report) where food prices remain elevated for some time, even if further inflation looks less likely.

The implications of the current situation are profound, beyond the obvious human suffering. Agriculture represents more than a quarter of GDP and employs close to 60% of the workforce in low-income countries. Hence the economic repercussions of agricultural disruptions are profound, especially as these are likely to get worse with the increasing frequency and severity of climate-related disruptions.

In terms of economic implications, the Food and Agriculture Organization (FAO) of the United Nations (UN) estimates the costs of malnutrition could be as high as $3.5 trillion per year. While “fixing” this will not be cheap, with some estimates of between $39 billion and $50 billion per year, this pales into insignificance compared with the avoided costs. Ending malnutrition would also bring economic benefits to society of up to $10.5 trillion per year, the obvious human benefits aside.

Food insecurity also has important social and geopolitical ramifications; it has been a key driver of civil unrest and migration throughout history and remains so today. Governments are reacting with a variety of measures, from export bans to price caps and stockpiling, many of which are exacerbating an already serious situation. Add to this the effects of general inflation, rising rates, and currency devaluation on highly indebted emerging markets, and we have a veritable powder keg for geopolitical instability.

While the situation is undoubtedly serious, it is not all doom and gloom. In this report, we examine potential solutions to alleviate current food insecurity and to try to prevent or lessen the severity of future occurrences. We split these solutions into four categories: social, technological, governmental, and financial/economic.

- **Social solutions**, such as reducing food waste, are obvious and can have a dramatic impact — we waste up to a third of food produced every year, with an estimated cost of $1.25 trillion annually, while a third of us go hungry. Dietary changes can also have a material impact; we currently use 77% of agricultural land for livestock, yet this only provides 17% of food calorific supply for consumption.

- **In technology**, the rise of agriculture technology ("AgTech") offers enormous potential, from vertical and indoor farming to digital agriculture, alternative proteins, precision fermentation, robotics and automation, animal AgTech, and agri-biotech.
- **At a public sector level**, governments can play their part through diplomacy; policies to enhance food self-sufficiency; and taxation and incentives to promote healthier diets and to maximize efficiency of available agricultural resources such as land, water, and fertilizer.
- **Financial/economic solutions** such as aid; investment in agriculture, food systems, and infrastructure; and innovative forms of financing such as debt relief, blended finance, and hedging offer further reasons for hope.

Having examined these solutions, we focus on who is best placed to tackle what, from the public sector through the financial industry, to the private sector and civil society itself.

We face many challenges in today's world, but as Steinbeck noted, few signify as much as having access to food. It is no accident that "Zero Hunger" is the second of the UN Sustainable Development Goals (SDGs) — behind only SDG 1 — No Poverty, of which hunger is itself a key factor. We are faced with a challenge of the most fundamental nature to us as human beings — a third of us are worried about where the next meal is coming from, and one in ten of us is suffering from hunger or malnutrition. John F. Kennedy said in 1963, "For the first time in the history of the world we do know how to produce enough food now to feed every man, woman, and child in the world. We have the ability, we have the means, and we have the capacity to eliminate hunger from the face of the earth in our lifetime. We only need the will." With all the resources at our disposal, let us not find we are still saying the same things in another 60 years.

Introduction

Defining Food Insecurity

If we are to attempt to eliminate food insecurity, hunger, and malnutrition, we first need to understand what it is, where it is, the extent of it, and what causes it. To do that we need to define it. The FAO tells us that:

A person is food insecure when they lack regular access to enough safe and nutritious food for normal growth and development and an active and healthy life.[1]

The FAO also goes on to tell us that food insecurity can be caused by either a lack of food or a lack of resources to obtain food, and that it has different levels of severity, as captured by the Food Insecurity Experience Scale (FIES).

Figure 1. Food Insecurity Based on the FIES: What Does it Mean?

Source: FAO

What Causes Food Insecurity?

Food insecurity can be driven by numerous factors, but there are typically three main culprits:

1. Environmental disasters, from floods to droughts, as well as pestilence, parasites, diseases, etc.
2. Conflict.
3. Political, social, or economic shifts.

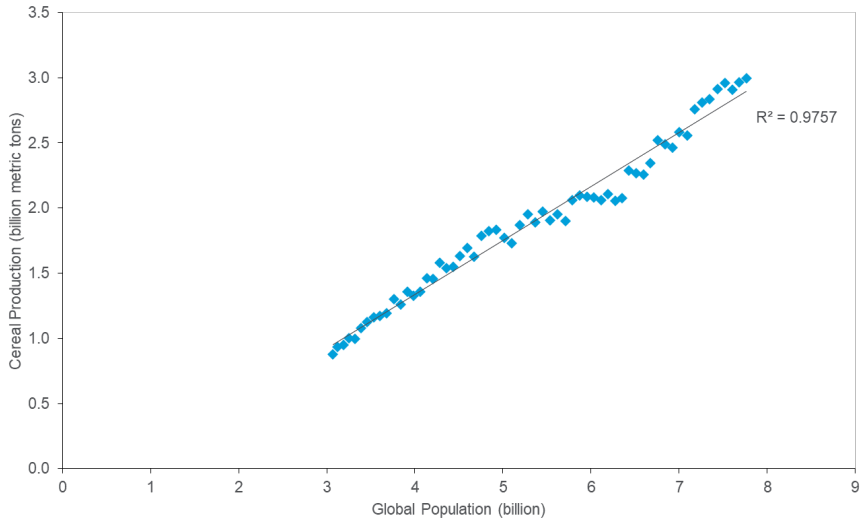
[1] The full definition of food security from the FAO considers it "*A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Based on this definition, four food security dimensions can be identified: food availability, economic and physical access to food, food utilization and stability over time. The concept of food security is evolving to recognize the centrality of agency and sustainability.*"

While the first two might seem self-explanatory, the third can be no less serious. Examples are rife throughout history of political and economic shifts driving famines, such a China's Great Leap Forward (the Second Five-Year Plan in the late 1950s and early 1960s) where a program of rural industrialization and farming quotas drove widespread food shortages, which some estimates suggest led to the death of tens of millions; or the fall of the Soviet Union and the resulting impact on nations such as North Korea.

The Extent of Food Insecurity

Throughout history, despite the predictions of the British economist Thomas Malthus (whose views we should not write off completely), food production has managed to track population growth remarkably closely.

Figure 2. Correlation Between Global Population and Cereal Production



Source: World Bank Open Data, FAOSTAT, Citi GPS

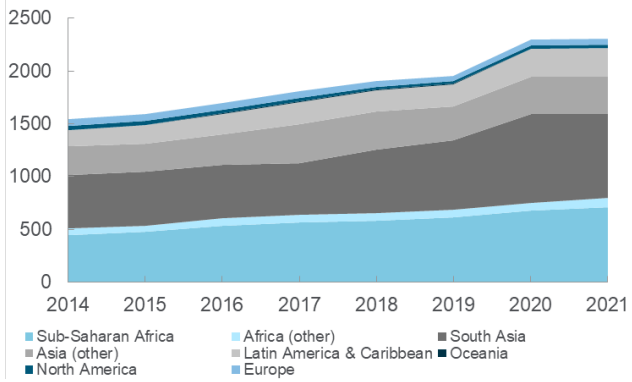
As Figure 2 shows, cereal production has tracked population growth very closely, with an R2 of 98% (where 100% is a perfect correlation). Since the 1960s, the global population has exploded from 3 billion to close to 8 billion while global cereal production has tripled.

But while this might imply we have everything in hand, the reality is rather more disappointing. As noted earlier, food insecurity is not just about hunger, but about a lack of security over where the next meal is coming from, how it is going to be paid for, and how nourishing it will be (if indeed it materializes at all).

Moderate or severe food insecurity, as defined by the FAO (reducing food quantities or quality, or skipping meals or entire days, respectively), has risen markedly since the FAO started to collect data in 2014, with more than 2.3 billion people currently suffering. Pause for one moment and consider that figure — that is around 30% of the global population, or nearly 1 in 3 of us on this planet. Look at the person to your left and to your right — if it is not you, one of them (globally) is experiencing moderate or severe food insecurity.

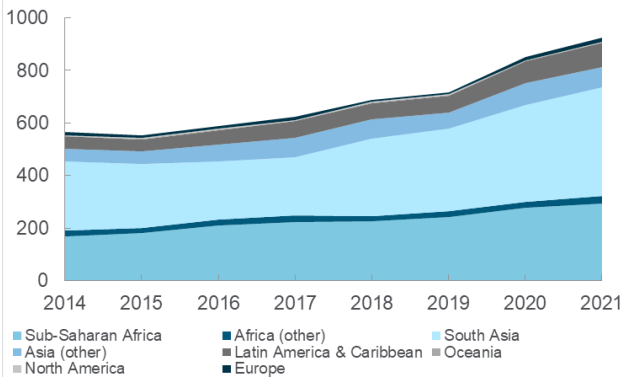
Also notable is the significant growth in the number of people affected by food insecurity from 2019 to 2020 — an increase of almost 342 million people in just one year.

Figure 3. Number of Moderately or Severely Food Insecure People (Annual Value, Millions)



Source: FAO, IFAD, UNIFEF, WFP, WHO (2022) The Stats of Food Security and Nutrition in the World 2022, Citi GPS

Figure 4. Number of Severely Food Insecure People (Annual Value, Millions)

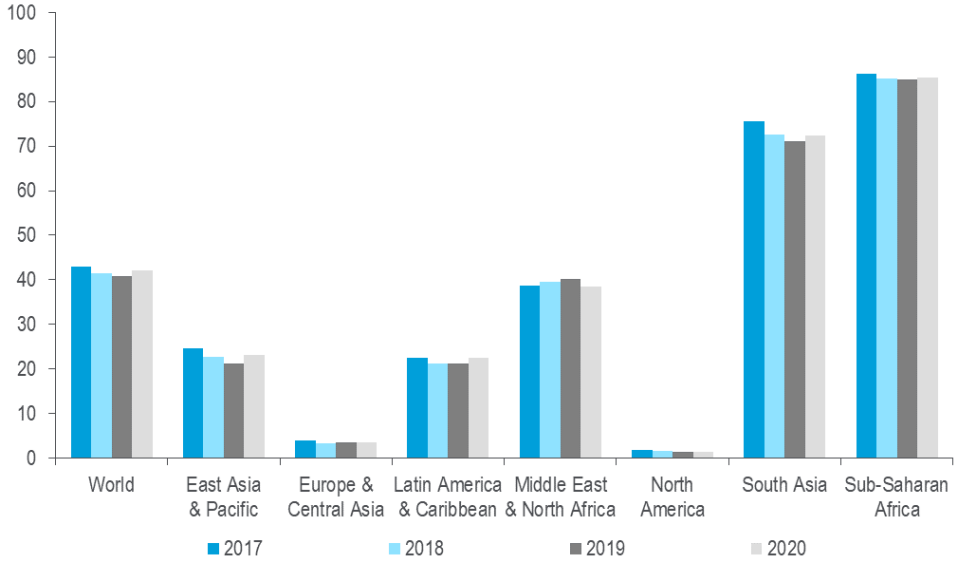


Source: FAO, IFAD, UNIFEF, WFP, WHO (2022) The Stats of Food Security and Nutrition in the World 2022, Citi GPS

While the amalgamated figures remained flat in 2021, severe food insecurity, as shown in Figure 4, rose sharply in 2021, with 923.7 million people, or 11.7% of the global population, facing severe food insecurity. Between 2014 and 2021, the number of severely food insecure people increased by about 64%. So, in this modern day and age, more than 1 in 10 of us has "run out of food and has gone an entire day without eating at times in the last year."

Looking at these figures in terms of proportions of populations gives some stark results.

Figure 5. State of Nutrition in the World – Share of Population that Cannot Afford a Healthy Diet

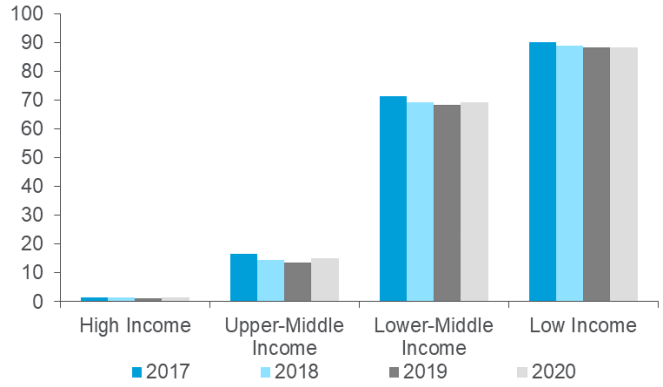


Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022., Citi GPS

More than 3 billion people could not afford a healthy diet in 2020. As Figure 5 shows, 85% of the population in sub-Saharan Africa cannot afford a healthy diet, with figures in South Asia at 70%. So much for the person either side of us — this is 3 or 4 people out of every 5 in these regions.

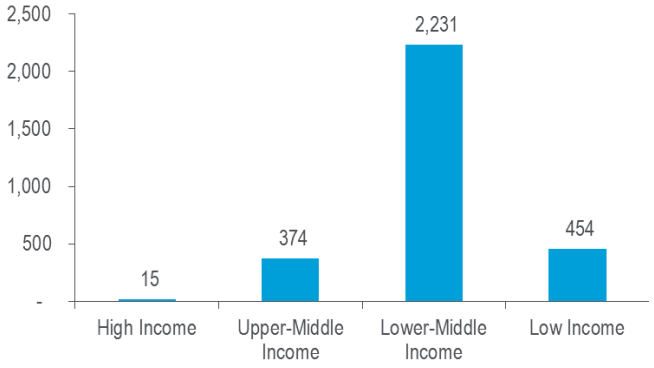
Food affordability is also an issue that, somewhat inevitably, affects the poorest in society the most.

Figure 6. Share of Population Who Cannot Afford a Healthy Diet (%)



Source: World Bank Open Data, FAO, Citi GPS

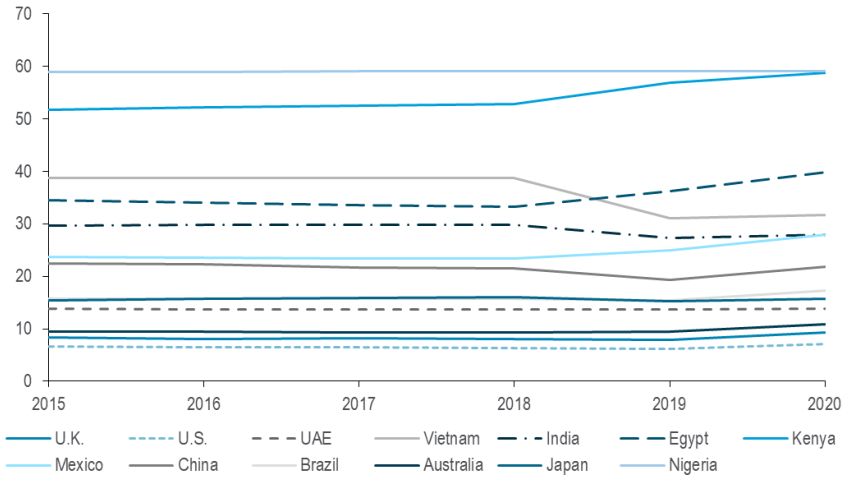
Figure 7. Population Who Cannot Afford a Healthy Diet (2020, Millions)



Source: World Bank Open Data, FAO, Citi GPS

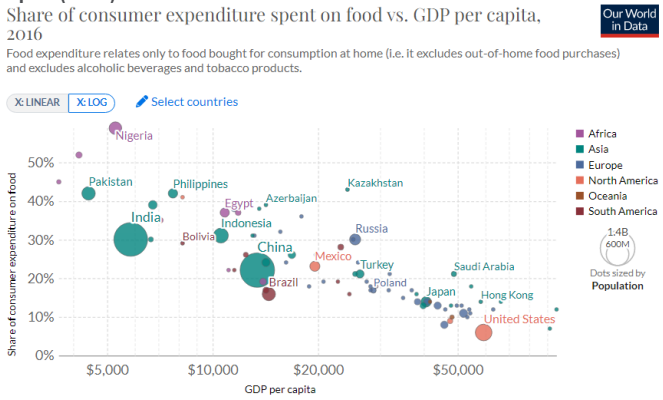
In some countries, such as Nigeria and Kenya as shown in Figure 8, close to 60% of consumer expenditure is on food and non-alcoholic drinks. Consider, as we do later in this report, the impact on these families from the rampant food inflation currently hitting much of the world. How will these families afford to eat?

Figure 8. Percent of Consumer Expenditures Spent on Food and Nonalcoholic Beverages (%)



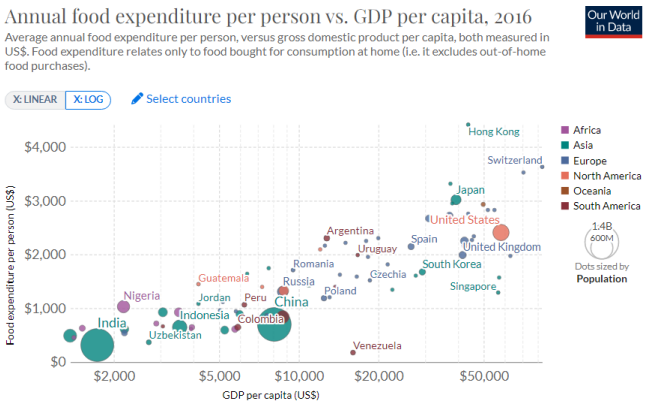
Source: USDA, Citi GPS

Figure 9. Share of Consumer Expenditure Spent on Food vs. GDP per Capita (2016)



Source: Our World in Data, Citi GPS

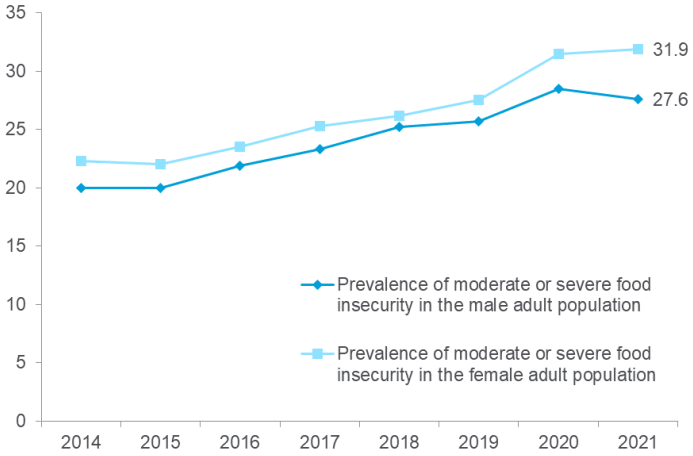
Figure 10. Annual Food Expenditure per Person vs. GDP per Capita (2016)



Source: Our World in Data, Citi GPS

There is also an important gender distinction beneath these figures with 31.9% of women experiencing moderate or severe food insecurity versus 27.6% of men. Disappointingly, this gap is widening.

Figure 11. Prevalence of Moderate or Severe Food Insecurity by Gender (%)

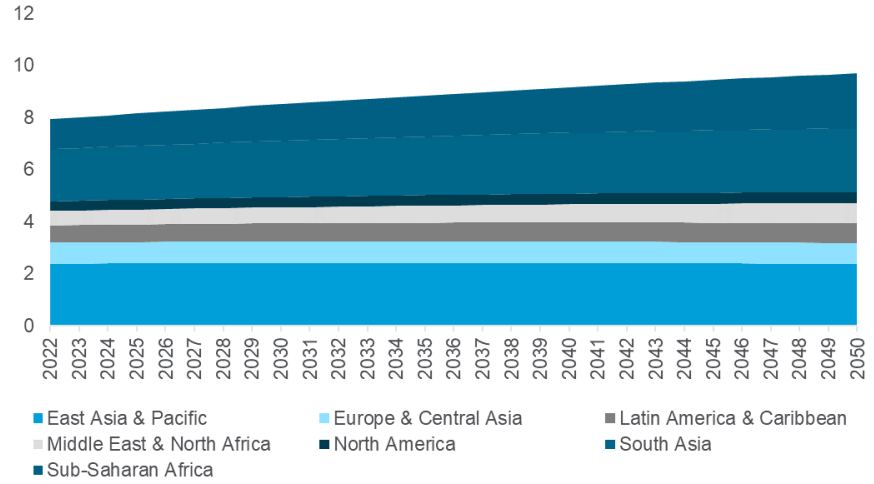


Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022, Citi GPS

As we can see, food insecurity affects the poorest in society and affects women more than men. Research has also shown that it disproportionately affects children and the elderly.

The current situation highlights a global problem that is far from impacting only a small minority of the poorest in society — this is a global phenomenon affecting almost 1 in 3 of us. Nor should we be complacent for the future. As Figure 12 highlights, the greatest concentration of food insecurity is in sub-Saharan Africa (709.4 million people) and South Asia (796.8 million people). Looking at global population projections by region, this problem will likely become even more acute unless it is tackled soon.

Figure 12. Population Forecast by Continent (Billions)



Source: UN, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022, Online Edition, Citi GPS

According to the UN, the global population is expected to reach 9.7 billion in 2050 and 10.4 billion in 2100.[2] Over the next few decades, the regional population distribution will look very different to today as population growth rates are expected to vary by region. Between 2022 and 2050, sub-Saharan Africa is projected to account for more than half of the growth of the world's population, almost doubling its population from 1.1 billion to 2.1 billion. The population of South Asia is also expected to grow significantly from 2 billion in 2022 to 2.5 billion in 2050. If we cannot feed 7.9 billion people now, and that issue focuses heavily on certain regions, how can we possibly expect to manage it with another 1.8 billion people, with most of that growth coming in regions currently experiencing the worst deprivations?

Add on to this the potentially devastating impacts of increased frequency and severity of extreme weather caused by climate change, as well as the impact on crop yields, and we have a crisis waiting to turn into a catastrophe.

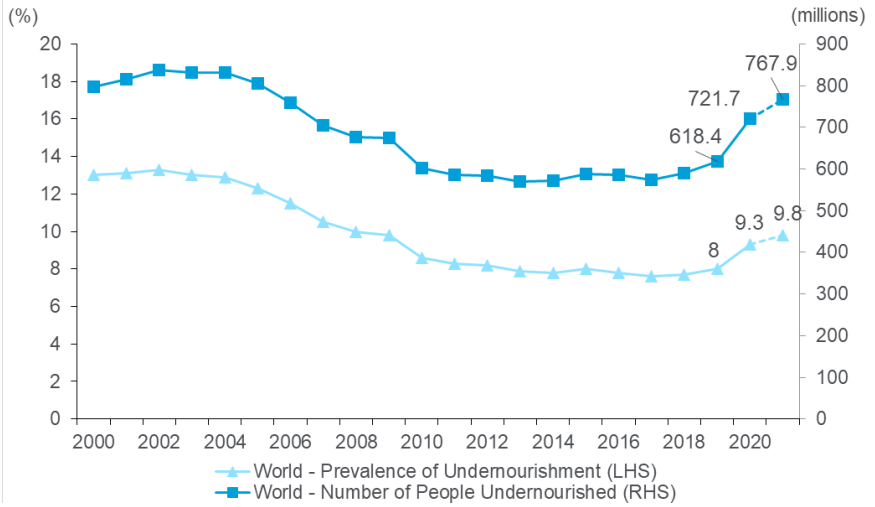
Hunger (Undernourishment)

According to the FAO, those who experience severe food insecurity have run out of food and may be referred to as the "hungry." The FAO considers hunger as "an uncomfortable or painful physical sensation caused by insufficient consumption of dietary energy." Hunger may also be referred to as undernourishment.

While these figures are less widespread than food insecurity, their arguably more serious nature still affects an extraordinary proportion of the global population. In recent years, the situation has again worsened materially.

[2] UN Department of Economic and Social Affairs, *World Population Prospects 2022: Summary of Results*, July 2022.

Figure 13. Global Population Undernourishment



Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022, Citi GPS

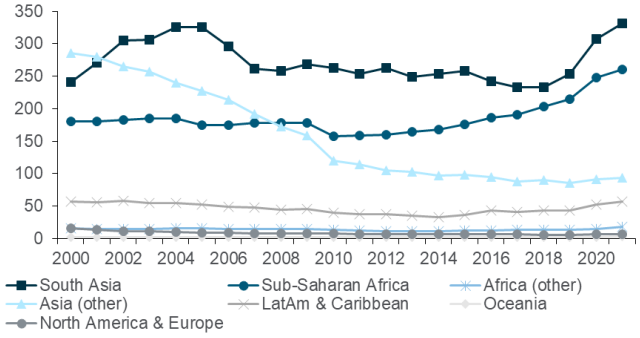
Global hunger was on a downward trajectory in the 10 years from 2005 to 2015. Over the same period, the number of people going to bed hungry each night fell by nearly 30% from around 805 million down to 590 million people as a result of proactive policies and intervention.[3] By contrast, the proportion of the global population going hungry has been rising since 2015, with the rise most acute in countries affected by conflict and climate-related disasters. As of 2021, the progress previously made has been fully reversed, with 770 million people going to bed hungry — close to the levels seen in 2005.[4]

As Figure 13 shows, while undernourishment fell from the early 2000s to around 600 million people, it has risen dramatically since 2019, with around 150 million more people being pushed into food undernourishment since the outbreak of the COVID-19 pandemic. Shockingly, this means that 10% of the world's population is still undernourished. The increase in hunger has been most severe in emerging markets. As of 2021, hunger impacted 425 million in Asia, 278 million in Africa, and 56.6 million in Latin America and the Caribbean. What is perhaps most striking is that 8% of the world's population is still projected to face hunger in 2030 — the same projection that was made in 2015.[5]

Understanding where this is occurring and where the increases are happening is also informative.

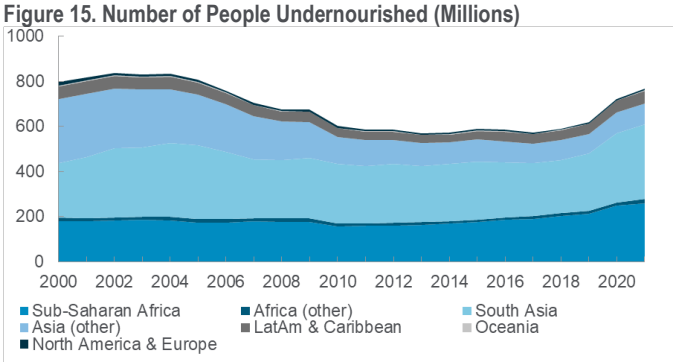
[3] Center for Strategic & International Studies, "USAID Administrator Power on the State of Global Food Security and Nutrition," transcript, July 18, 2022.
[4] UN, "State of Food Security and Nutrition in the World 2022," YouTube, August 2022.
[5] UN, "State of Food Security and Nutrition in the World 2022," YouTube, August 2022.

Figure 14. Undernourishment by Region (Millions)



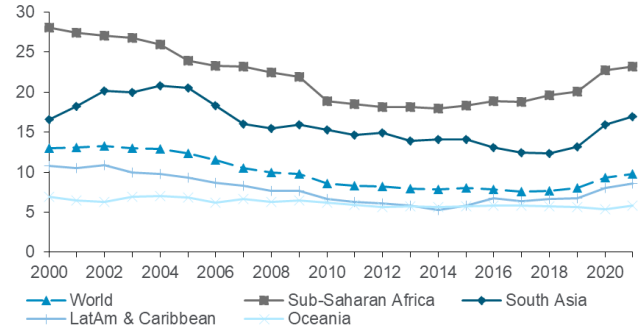
Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022, Citi GPS

Figure 15. Number of People Undernourished (Millions)



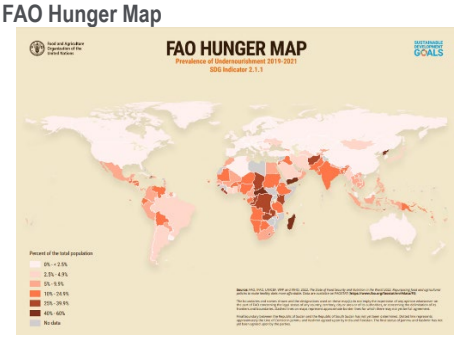
Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022, Citi GPS

Figure 16. Prevalence of Undernourishment by Region (%)



Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022, Citi GPS

Figure 17. FAO Hunger Map



Source: FAO, Citi GPS

Perhaps unsurprisingly, hunger is relatively uncommon in the developed world (though its mere existence reflects significantly on inequality); it remains heavily focused in South Asia and sub-Saharan Africa. The FAO's Hunger Map (Figure 17) demonstrates the concentration of these effects.

Malnutrition

Malnutrition includes undernutrition as well as overweight and obesity and is defined by the FAO as "an abnormal physiological condition caused by inadequate, unbalanced, or excessive intake of macronutrients and/or micronutrients." It manifests itself in many different ways, with the UN's SDG 2 — Zero Hunger having seven global nutrition indicators:

- Low birthweight.
- Exclusive breastfeeding (infants <6 months).
- Stunting (under 5 years).
- Wasting (under 5 years).
- Overweight (under 5 years).
- Anemia (women aged 15 to 49 years).
- Obesity (adults).

Figure 18. State of Nutrition in the World

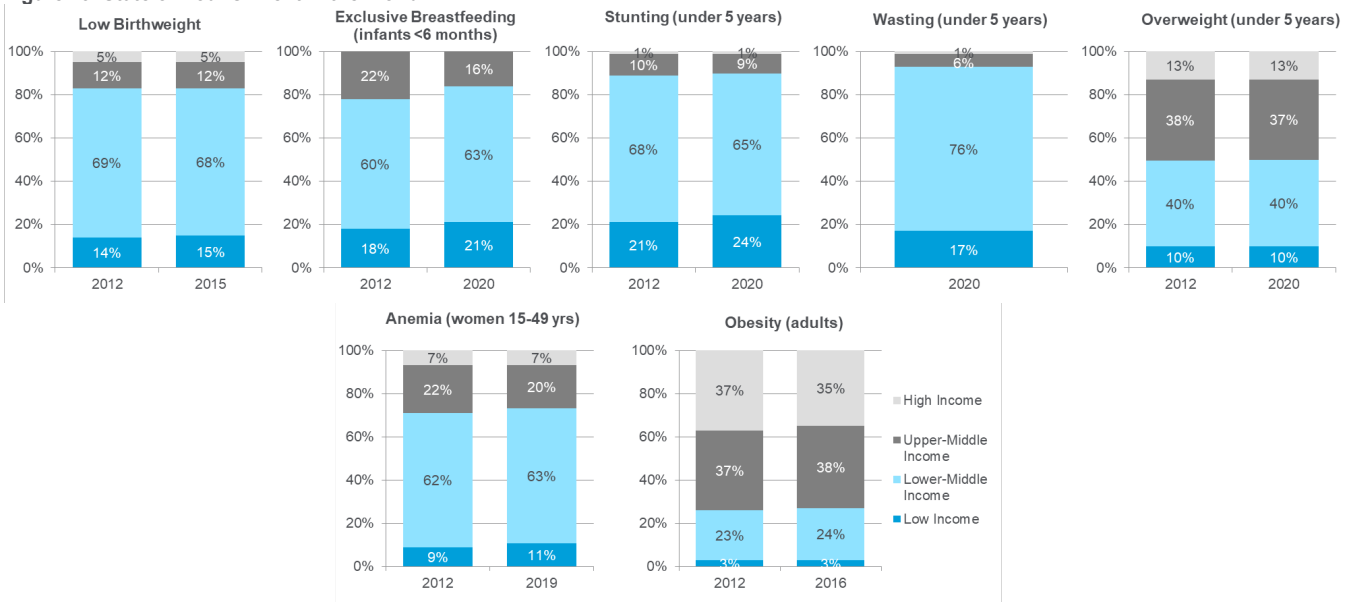
Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022, Citi GPS

This snapshot again conjures some shocking mental images — 20 million infants with low birthweight, 150 million stunted children under age five and nearly 50 million wasting, and close to 600 million women with anemia. The inequality is again stark — while much of the world's population goes hungry, close to 10% of the world's population is obese (700 million adults), with 40 million children under the age of five also overweight.

Unsurprisingly, the obesity levels are highest in high and upper-middle income brackets, while indicators of malnutrition are exclusively among the poorest elements of society. However, the WHO warns that being overweight and obese is now on the rise in low and lower-middle income countries, especially in urban areas.[6]

[6] WHO, "Obesity and Overweight," June 9, 2021.

Figure 19. State of Nourishment in the World



Source: FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022., Citi GPS

So while globalization might have done a lot to reduce levels of inequality, the figures above show that we still have much to do.

There is also little room for complacency or optimism unless we act. Projections from the FAO suggest that nearly 670 million people will still be facing undernourishment and malnutrition in 2030. As mentioned, this is approximately 8% of the world's population — a figure that is unchanged since 2015, when the 2030 UN SDG Agenda was launched. This implies a disappointing lack of progress for the issue that is the second the SDGs, "Zero Hunger." The FAO also notes there are 78 million more undernourished people in 2030 compared to a scenario in which the pandemic had not occurred. The regional disparities are also forecast to persist with Africa continuing to bear the heaviest burden, with 311 million people projected to be still facing hunger in 2030, compared to 299 million in a scenario without COVID-19. In context, that is not far short of the entire population of the United States.

Acute Food Insecurity

Another measurement of food insecurity worth mentioning is the Acute Food Insecurity scale used by the Global Network Against Food Crises in their annual global reports on food crises. The latest 2022 update paints an equally bleak picture. Acute food insecurity is defined in five stages by the Integrated Food Security Phase Classification (IPC) and the Cadre Harmonisé (CH), with Phase 5 — Catastrophe/Famine — at the highest severity level per Figure 20 below.

Figure 20. IPC/CH Acute Food Insecurity Phase Description and Response Objectives

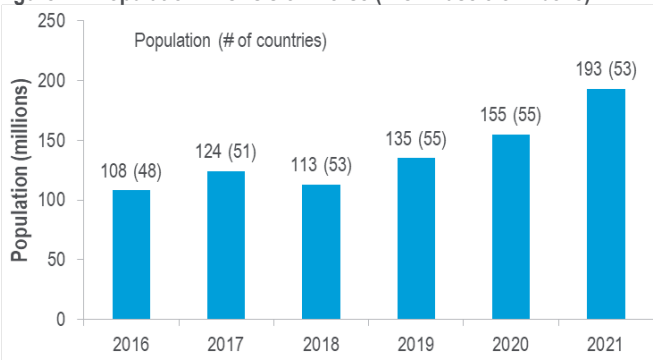
Phase	Phase description and priority response objectives
Phase 1 None/Minimal	Households are able to meet essential food and non-food needs without engaging in atypical and unsustainable strategies to access food and income. Action required to build resilience and for disaster risk reduction.
Phase 2 Stressed	Households have minimally adequate food consumption but are unable to afford some essential non-food expenditures without engaging in stress-coping strategies. Action required for disaster risk reduction and to protect livelihoods.
Phase 3 Crisis	Households either: • Have food consumption gaps that are reflected by high or above-usual acute malnutrition; or • Are marginally able to meet minimum food needs but only by depleting essential livelihood assets or through crisis-coping strategies. URGENT ACTION required to protect livelihoods and reduce food consumption gaps.
Phase 4 Emergency	Households either: • Have large food consumption gaps which are reflected in very high acute malnutrition and excess mortality; or • Are able to mitigate large food consumption gaps but only by employing emergency livelihood strategies and asset liquidation. URGENT ACTION required to save lives and livelihoods.
Phase 5 Catastrophe/ Famine	Households have an extreme lack of food and/or other basic needs even after full employment of coping strategies. Starvation, death, destitution and extremely critical acute malnutrition levels are evident. (For Famine classification, area needs to have extreme critical levels of acute malnutrition and mortality).[2] URGENT ACTION required to revert/prevent widespread death and total collapse of livelihoods.

Note: A Famine classification requires evidence on food security, nutrition, and mortality at or above IPC Phase 5 thresholds. If there is insufficient data for Famine classification but the available information indicates that Famine is likely occurring or will occur, then the famine classification is called "Famine Likely." It is important to note that Famine and Famine Likely are equally severe.

Source: Citi GPS, Global Network Against Food Crises (2022): 2022 Global Report on Food Crises

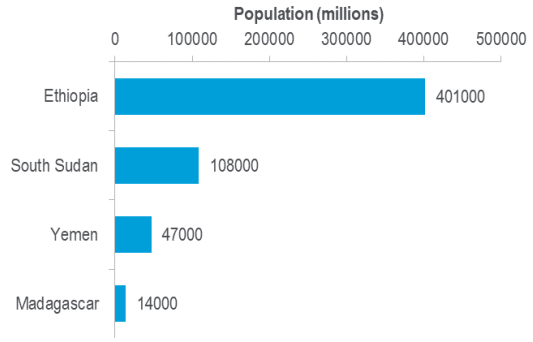
Almost 200 million people in 53 countries were in Crisis or worse (IPC/CH Phase 3 or above) in 2021, with 35 countries identified as being in major food crises. The number of people experiencing Crisis — with consumption gaps, high/above-usual acute malnutrition, and essential livelihood assets depleted alongside other crisis-coping strategies — has nearly doubled from 2016 to 2021 (Figure 21). This figure represents 40 million more people than in 2020, with the majority of those coming from just eight countries, as shown in Figure 23.

Figure 21. Population in Crisis or Worse (IPC Phase 3 or Above)



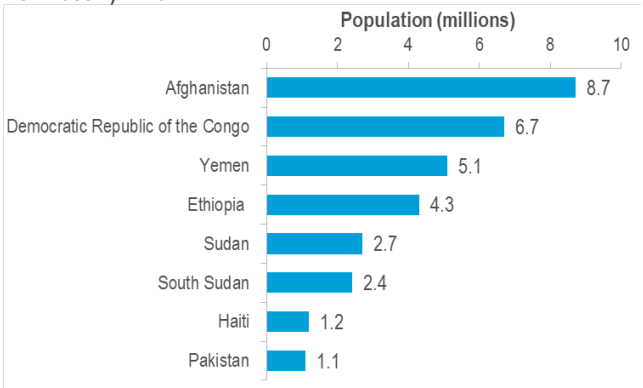
Source: Global Network Against Food Crises (2022), Citi GPS

Figure 22. Number of People in Catastrophe (IPC Phase 5) in 2021



Source: Global Network Against Food Crises (2022), Citi GPS

Figure 23. Eight Countries had Over 1 Million People in Emergence (IPC Phase 4) in 2021



Source: Global Network Against Food Crises (2022), Citi GPS

At even more acute levels of food insecurity, eight countries have more than a million people each in Emergency (Phase 4), with very high acute malnutrition and excess mortality, and where emergency livelihood strategies and asset liquidation are realities of life. Meanwhile, more than half a million people were in Catastrophe/Famine (Phase 5) in 2021 (Figure 22), facing starvation, death, severe acute malnutrition, and destitution.

Summary

This overview of food insecurity, hunger, and malnutrition hopefully provides a brief insight into a problem that is all too common around the world, of paramount importance, and only going to get worse over time due to population growth and the increasing impacts of factors such as climate change.

In this report we start by looking at the factors that are currently driving increasing food insecurity — the so-called perfect storm of environmental; conflict; and social, political, and economic shifts, before trying to assess how these factors might play out over the next couple of years. We then look at the implications of food insecurity beyond the obvious human ones, such as the geopolitical and economic implications. These highlight that we should not see fixing the problem as a "cost" — the avoided costs and economic benefits of fixing it far outweigh any costs, even before we consider the alleviation of human suffering. Finally, we examine potential solutions for food insecurity, such as social, financial, and governmental, as well as formulating a proposed playbook of who is best placed to tackle which aspects. This is a problem we cannot afford to ignore, either as a society on moral grounds, or if we value the economic and geopolitical future of our world.

The Current "Perfect Storm" in Food Security

Although there were undoubtedly many before it, the first documented example of famine occurred over 4,000 years ago. So how is it possible, with all of our technical know-how, that we are in a situation in 2022 where 2.3 billion people, or 30% of the population, are still suffering from food insecurity and hunger?

The *2022 Global Report on Food Crises*, published by the Global Network Against Food Crises, pinpoints the same three culprits highlighted earlier, namely environmental and economic crises, exacerbated by the conflict in Russia-Ukraine. The crises have exposed the interconnected nature and fragility of global food systems, with poverty and inequality as underlying causes. The report also highlights that these issues are not standalone, and that feedback loops mean that they are often "mutually reinforcing."

In terms of numbers, the report highlights the following:[7]

1. Conflict primarily contributed to 139 million people in 24 countries facing acute food insecurity in 2021, up from 99 million in 23 countries in 2020.

2. Weather extremes placed over 23 million people in eight countries into acute food insecurity in 2021, up from 15.7 million in 15 countries in 2020.

3. Over 30 million people in 21 countries faced acute food insecurity due to economic shocks in 2021, though this was down from over 40 million people in 17 countries in 2020, mainly due to the fallout from the COVID-19 pandemic.

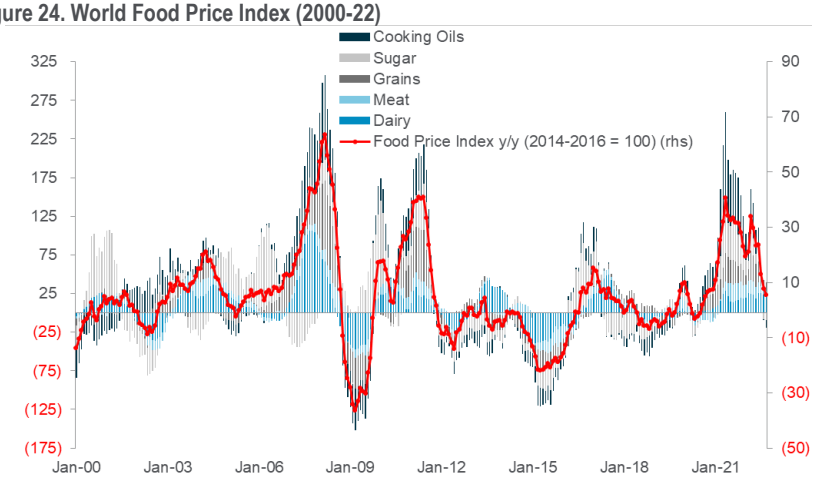
In this chapter, we examine the key drivers behind the recent increase in food insecurity in order to understand how we might alleviate their impacts and prevent, or lessen, their reoccurrence in the future.

Causes of Recent Increases in Food Insecurity

While it is tempting to simplistically lay the blame for the increase in global food insecurity firmly at the feet of the Russia-Ukraine conflict, in reality many other factors have been at play. A synchronous recovery in global growth after the COVID-19 shock; a multi-year spike in Chinese grain and oilseed imports in 2021; a strong La Niña weather cycle, which adversely impacted the Brazilian corn and sugar harvests; the build-out of renewable diesel and biofuel capacity that uses agriculture feedstock; and surging energy costs were all major factors driving agriculture commodities higher prior to the conflict in the Black Sea, as shown in Figure 24. To be clear though, the Russia-Ukraine war has added fuel to the fire, complicating crop market rebalancing efforts that likely would have materialized at some point in 2022.

[7] Key drivers of acute food insecurity based on the IPC/CH classification of Crisis or worse (Phase 3 or above).

Figure 24. World Food Price Index (2000-22)



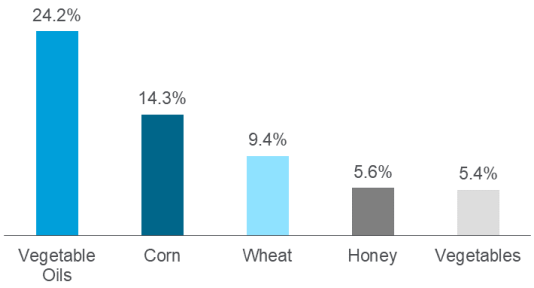
Source: Citi GPS, UN

The Russia-Ukraine Conflict

To understand why the situation in Russia-Ukraine is having such dramatic impacts on food insecurity, we must first understand the extraordinary significance of these countries in terms of food production. Combined wheat exports from Russia and Ukraine accounted for 25% of the world's total food exports before the invasion, making them a critical global breadbasket. Overall, Ukraine's food exports provide the calories to feed 400 million people across the globe.[8]

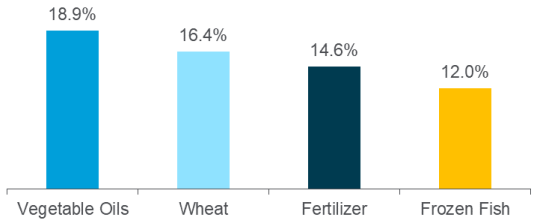
For some food-importing nations the situation is even more extreme: Russia and Ukraine contribute about half the cereals imported by Lebanon and Tunisia, while for Libya and Egypt the figure is even higher at two-thirds of total imports. The war is disrupting these supplies because Ukraine has mined its waters to deter an assault, and Russia is blockading the port of Odesa.

Figure 25. Share of Global Exports from Ukraine (2019)



Source: Citi GPS

Figure 26. Share of Global Exports from Russia (2019)



Source: Citi GPS

A July 2022 agreement between Russia, Ukraine, Turkey, and the UN to restart food exports from Ukraine's Black Sea ports has helped to contain food prices. Wheat prices dropped by 14.5% between June and July 2022, encouraged by the prospect of more than 20 million metric tons of grain locked in Ukrainian silos being exported.

[8] *The Economist*, "The Coming Food Catastrophe," May 19, 2022.

However, the agreement got off to a precarious start as Russia immediately attacked the Port of Odesa, and there have been some complications along the way, dimming optimism for the agreement's success.[9]

As we examine in the next chapter, the impact of the war on global agricultural markets is expected to continue at least through 2023, regardless of whether the war remains ongoing. In Ukraine, farmers have nowhere to store their 2022 harvest, which may lead to perishing of the grains. Meanwhile, Russia is expected to face shortages in the seed and pesticide supplies it usually buys from the European Union.[10]

However, while it might be tempting the lay the current food crisis firmly at the feet of the Russia-Ukraine situation, and while it is undoubtedly putting global food systems under strain, the reality is much more complex, with multiple factors at work. Moreover, one could argue that the conflict is taking attention and resources away from the other factors, such as climate change/environmental impacts, energy, and general inflation.

Other examples of conflict

The *2022 Global Report on Food Crises* found that conflict was the key driver in three of the four countries in the most severe IPC/CH acute food security phase (5 – Catastrophe/Famine) — Ethiopia, South Sudan, and Yemen. The impacts of conflict include disruptions to food production, livelihoods, and markets as well as displacement and economic crisis. Since the start of the civil war in Northern Ethiopia in November 2020, more than 10 million people have required humanitarian food assistance. The majority of the population in the affected regions of Tigray, Amhara, and Afar are subsistence farmers and the conflict has substantially impacted crop production and livelihoods where fields have been abandoned, seeds and equipment have been stolen or destroyed, livestock killed, and crops pillaged and burned.[11] Years of civil war in South Sudan have driven people from their homes and disrupted livelihoods, trade, and markets. Conflict prevented farmers from growing crops, leading to country-wide food shortages and the UN Security Council declaring in 2014 that South Sudan's food crisis was "the worst in the world." The World Food Programme (WFP) continues to have a South Sudan emergency appeal highlighting that 75% of the population is facing severe food insecurity.[12] The situation in Yemen, where an ongoing civil war since 2014 has devasted the country, is also severe. A joint statement from FAO, United Nations Children's Fund (UNICEF), and WFP in March 2022 stressed that conflict remains the primary underlying driver of hunger in Yemen, and that the war in Ukraine is likely to drive food prices up further given that the country depends almost entirely on food imports, with 30% of wheat imports from Ukraine.[13] As is often the case during times of crises, women and children are the worst affected by conflict and its impacts. According to the WFP, malnutrition rates among women and children in Yemen are among the highest in the world, with 2.2 million children under 5 years of age needing treatment for acute malnutrition.[14]

---

[9] Eddy Wax, "The World Food Crisis Is About to Get Worse," *Politico*, August 15, 2022.
[10] *The Economist*, "The Coming Food Catastrophe," May 19, 2022.
[11] GEOGLAM, *Northern Ethiopia: Conflict and Food Insecurity,* September 2022.
[12] World Food Programme, "South Sudan Emergency," accessed November 1, 2022.
[13] FAO, UNICEF, and World Food Programme, "Yemen: Acute Hunger at Unprecedented Levels as Funding Dries Up," March 14, 2022.
[14] World Food Programme, "Yemen Emergency," accessed November 1, 2022.

Environmental

The challenge of ensuring food security has first and foremost been intensified by the agriculture sector's extreme vulnerability to climate change. With a changing climate, crop volatility is expected to increase, expanding the likelihood of years with unusually low global production as well as those with bumper (ample) yields. Even years with bumper crops are not all positive as bumper yields could negatively affect food prices, putting downward pressure on the incomes of farmers.

The negative impacts of climate change are already occurring in many forms, including increasing temperatures, weather variability, shifting agroecosystem boundaries, invasive crops and pests, and more frequent extreme weather events. Climate change is reducing crop yields, lessening the nutritional quality of major staple cereals, and lowering livestock productivity. Substantial investments in adaptation will therefore be necessary to maintain current yields and achieve production and food quality increases to meet demand.

China, the world's largest wheat producer, has said that after rain delayed planting in 2021, the crop in 2022 may be its worst ever. Similarly in India, the world's second largest producer, temperatures have reached extreme highs, further reducing yields. Moreover, a lack of rain threatens to sap yields in other breadbaskets, from America's wheat belt to the Beauce region of France. The trend continues in the Horn of Africa, which is being devastated by its worst drought in four decades.[15] On the other end of the extreme weather spectrum, flooding can also have disastrous consequences for food security by destroying crops and grain stores across large areas, and damaging infrastructure and equipment as well as agricultural land. A recent 2022 study found that flooding could affect food security for over 5.6 million people across Africa, with impacts both immediately after the event and months after.[16]

Lower-income economies and populations are likely to continue to face the biggest impacts since they often depend on outdoor work, such as in agriculture, or rely on natural capital, both of which are vulnerable to a changing climate. And with less financial means to adapt, emerging markets could be left far more exposed. Countries across the world are expected to lose working hours due to rising heat and humidity levels. In the richest countries (based on GDP per capita), the share of annual daylight working hours lost could be 1 to 3 percentage points higher in 2050 compared to today, whereas in the poorest countries, the share lost could reach 5 to 10 percentage points higher.[17]

[15] *The Economist*, "The Coming Food Catastrophe," May 19, 2022.
[16] Connor Reed et al., "The Impact of Flooding on Food Security Across Africa," *Proceedings of the National Academy of Sciences*, Vol. 119, No. 43, October 2022.
[17] Mekala Krishnan and Jonathan R. Woetzel, "Climate Change Hits the Poor the Hardest. Here's How to Protect Them," McKinsey, November 16, 2020.

Social, Political or Economic Shifts

Fertilizer Crisis

Russia, the world's largest exporter of fertilizer, began to restrict its supply of fertilizer to global markets in November 2021, which, combined with the 2021 EU sanctions on 20% of Belarusian potash (potassium fertilizer) exports, contributed to a near tripling of fertilizer prices.[18] After the start of the war in early 2022, Russian fertilizer producers reduced their exports by 40% and the EU implemented further restrictions on all potash products from Belarus due to its involvement in the Ukraine invasion.[19] Given that fertilizer can account for a significant share of the variable cost of crop production (e.g., about 33% for corn), such a spike in fertilizer prices makes it more expensive to grow food.

With higher fertilizer prices, farmers can only afford a suboptimal amount of fertilizer, meaning they produce less crops, which result in smaller harvests and a decrease in future income. Worse still is the timing: At a time when enhanced crop yields are critical to alleviating heightened food insecurity, farmers in Africa in particular, are cutting back on fertilizer, which could result in a 20% shortfall in harvests worth approximately $11 billion.[20] The underuse of fertilizers is not just a short-term problem. The reduction of their use casts a shadow on future harvests as fertilizers remain in the soil, so underapplication will constrain yields and put upward pressure on prices for years to come.

The impact is exacerbated in emerging markets, whose access to capital is more constrained with a less prevalent forward market. This is in comparison to developed markets, which have greater market depth, meaning that farmers can sell products forward in a wider variety of produce. Therefore, the farmers receive an income at a time when they need it most in order to buy the required fertilizer and other input products to ensure their crops experience optimal conditions to maximize yields.

Nitrogen is a key component in fertilizer and as governmental environmental policy constrains fertilizer application, there could be a significant impact on biodiversity and ecosystems. The EU's Seventh Environment Action Programme (7th EAP) has called for better and more sustainable management of the nutrient cycle. It has also called for improvements in the efficiency of the use of fertilizers in order to reduce the excessive nutrient losses that affect soil, air, and water quality and have a negative impact on ecosystems as well as the potential to cause problems for human health. As a result, EU countries, for example, are required to cut their use of chemical fertilizer by at least 20% over the next ten years.

One UN official warned that the crisis is "enormous" and threatens to prolong the hunger emergency if farmers across the globe spread less of the yield-boosting chemicals to save their bottom lines. The price of fertilizer was already high before Russia invaded Ukraine, but with more than one-fifth of all fertilizer exports restricted and the industry dependent on natural gas, which has also skyrocketed in price since the war, fertilizer prices have risen even further.

---

[18] European Parliament, "At a Glance: Russia's War on Ukraine: Sanctions Targeting Belarus," PDF, accessed October 11, 2022.
[19] *Tass Russian News Agency*, "Russia's Fertilizer Exports Fell by 40% in April," June 16, 2022; European Parliament, "At a Glance: Russia's War on Ukraine: Sanctions Targeting Belarus," PDF, accessed October 11, 2022.
[20] Center for Strategic & International Studies, "USAID Administrator Power on the State of Global Food Security and Nutrition," transcript, July 18, 2022.

Energy Crisis

This leads us swiftly onto the impact of the energy crisis. Aside from gas being the main cost component in the fertilizer production chain, gas is also a key determinant in a household's cost of living, whether this is directly through energy or fuel prices or indirectly through increased costs of goods as producers push higher production and transport costs onto consumers. According to Jerome Powell, Chair of the Federal Reserve, every $10 increase in the price of a barrel of oil generally results in an increase in inflation of 20 basis points.[21] With oil prices up by a peak of $50 from January to June 2022, by this measure, energy prices alone have driven inflation up by close to 100 basis points.

Rising Inflation

According to the World Bank, between May and September 2022, high inflation (above 5%) has been seen in 88.9% of low-income countries, 91.1% of lower-middle-income countries and 96% of upper-middle income countries, with many experiencing double-digit inflation.[22] High inflation increases the cost of other products such as meats, fresh produce, and dairy, which heightens the trade-off families have to make between food and other rising costs. For families facing this trade-off, inflation can increase food insecurity and limit the adequacy of current food programs in place. As always, these impacts are being felt hardest by the poorest households, many of which are still recovering from COVID-19's economic or lockdown-related effects in terms of employment, income, and finances.

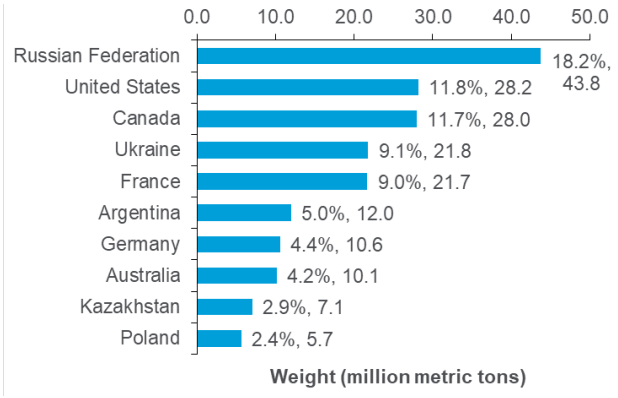
A special UN task force estimates that over 60 countries have difficulty affording agricultural imports.[23] The impact of the "perfect storm" that has hit the global food system poses a critical risk to decades of progress in the fight against hunger and food insecurity. This perfect storm, which combines the mounting impacts of climate change, rising inflation, and the effects of COVID-19 — which has driven public debt levels to record highs — faced even more pressure from the impact of Russia's invasion of Ukraine. The FAO reports that the impacts of the war in Ukraine could cause the number of people undernourished to increase by 13 million in 2022 and 19 million more in 2023.[24]

Above all else, the final nail in the coffin of this perfect storm is that the world remains too dependent on too few countries for its food, with less than 10 countries accounting for 90% of global exports of key commodities.[25] This means that when one of these 10 breadbaskets has a bad year for crop yields or experiences an unforeseen geopolitical event, we witness a severe supply side contraction, driving prices up and hitting low-income earners the hardest.

[21] Ibid.
[22] World Bank, "Food Security Update," accessed October 21, 2022.
[23] Eddy Wax, "More Than 60 Countries Struggling to Afford Food Imports, Says Leaked UN Email," *Politico*, August 15, 2022.
[24] FAO, IFAD, UNICEF, WFP, and WHO, *The State of Food Security and Nutrition in the World 2022*, July 2022.
[25] The Economist, "The Global Food Crisis, Explained," YouTube, August 2022.

Figure 27. Top Exporters in 2020

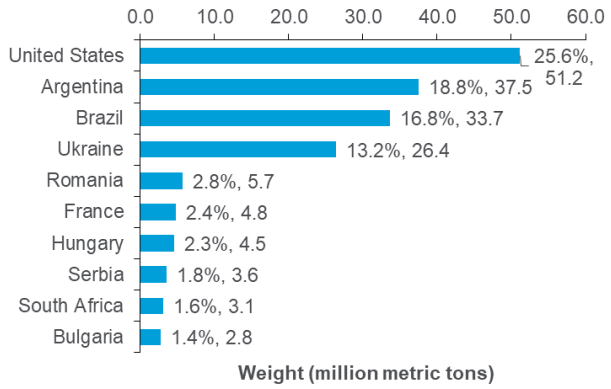
Wheat



Source: Chatham House Resource Trade Database, Citi GPS

Figure 28. Top Exporters in 2020

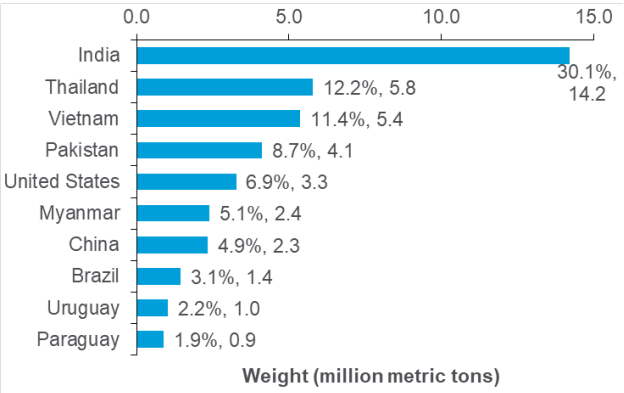
Maize



Source: Chatham House Resource Trade Database, Citi GPS

Figure 29. Top Exporters in 2020

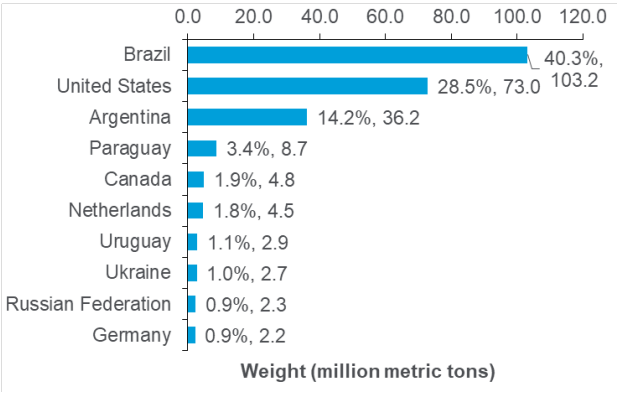
Rice



Source: Chatham House Resource Trade Database, Citi GPS

Figure 30. Top Exporters in 2020

Soybean



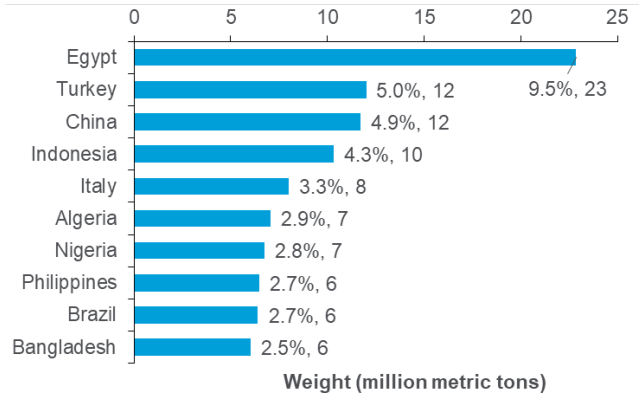
Source: Chatham House Resource Trade Database, Citi GPS

Figure 27 through Figure 30 show the incredible importance of Russia and Ukraine in terms of wheat production, representing close to 30% of the global market. Indeed, the top five producers are responsible for around 60% of the global wheat market. For maize, the top four producers are responsible for around three-quarters of the global market, with Ukraine again among them. For rice, India represents 30% of global trade volumes, while China is responsible for 40% of global soybean trade volumes.

It is also informative to look at the size and focus of imports by country, as shown in the following charts for the same commodities.

Figure 31. Top Importers 2020

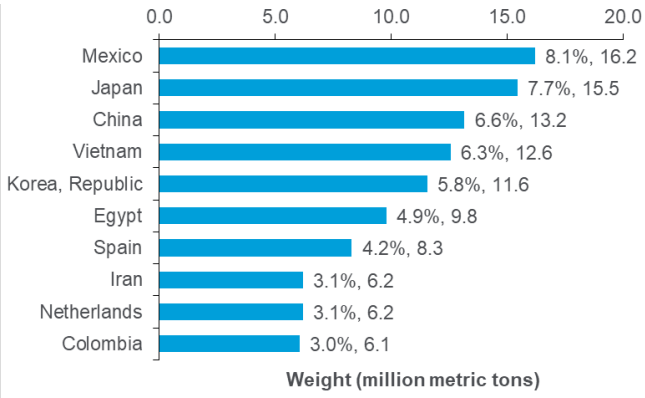
Wheat



Source: Chatham House Resource Trade Database, Citi GPS

Figure 32. Top Importers 2020

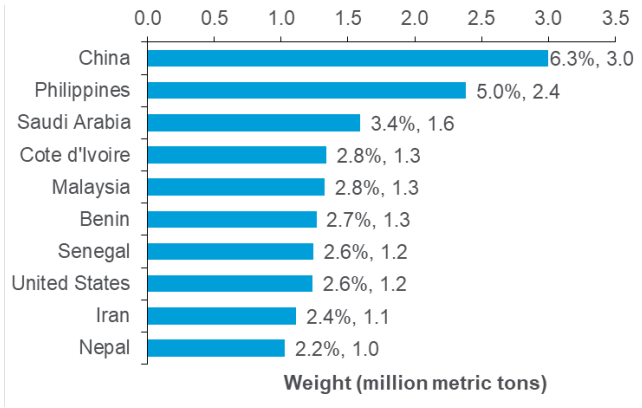
Maize



Source: Chatham House Resource Trade Database, Citi GPS

Figure 33. Top Importers 2020

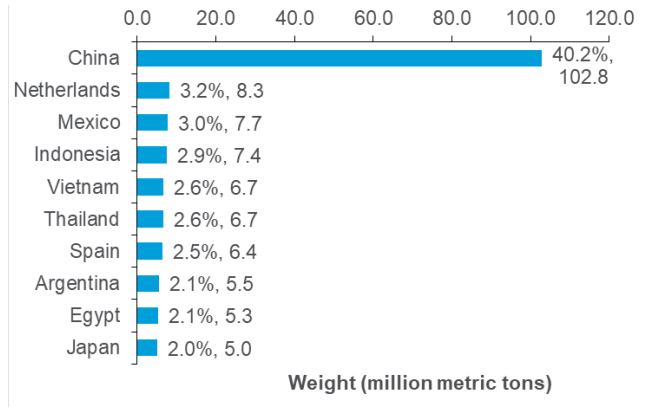
Rice



Source: Citi GPS, Chatham House Resource Trade Database

Figure 34. Top Importers 2020

Soybean



Source: Chatham House Resource Trade Database, Citi GPS

Of these charts, the wheat chart is perhaps the most informative — it highlights the extreme dependency of countries such as Egypt on food imports, with these imports, as we have seen, coming from just a few key exporters. Disruption to any one of these markets, let alone the aforementioned perfect storm across many, can have dramatic effects not just on the availability of the product, but also on commodity prices. Again, it is often the poorest countries that are most exposed and least able to afford these increased prices or to adapt to the situation with substitutes.

This is highlighted well in the following table, which shows the trade balance of different regions in the world by commodity.

Figure 35. Trade Balance in 2020 by Region and Agricultural Commodities (Net Exports, Million Metric Tons)

		Asia	Africa	LatAm	Europe	N. America	Oceania
Cereals	Wheat	-78.5	-49.7	-9.1	71.5	48.5	19.7
	Maize	-52.6	-20.9	33.6	12.3	63.5	0.0
	Rice	19.3	-17.1	-0.7	-1.9	1.4	-0.7
	Other Coarse Grains	-30.0	-3.9	1.6	20.1	8.9	7.9
Oilseeds	Soybean	-120.1	-5.7	89.1	-15.7	62.5	0.0
	Other Oilseeds	-8.7	-0.2	-0.7	-2.3	10.0	2.6
	Protein Meals	-27.0	-4.1	39.5	-17.6	13.1	-3.0
	Vegetable Oils	5.8	-9.9	7.0	-2.1	0.2	0.6
Sugar		-17.9	-9.7	34.5	-3.1	-4.0	3.1
Meats		-16.5	-2.4	6.2	5.0	7.5	2.4
Eggs		0.0	0.0	0.0	0.1	0.9	0.0
Dairy and Dairy Products		-5.0	-1.1	-0.3	3.0	1.2	3.0
Fish and Fish Products		0.7	-0.9	4.4	-0.9	-3.7	0.2
Roots and Tubers		-3.1	-0.1	-0.3	-0.7	-0.1	-0.1
Pulses		-7.2	-0.4	-0.4	-0.3	7.7	1.9
Total Trade Balance		-390.2 Importer	-126.2 Importer	204.3 Exporter	67.4 Exporter	217.7 Exporter	37.6 Exporter

Volume of net exports (million metric tons)
Import 0-40 41-80 81+
Export 0-40 41-80 81+

Source: OECD Agriculture Statistics, Citi GPS

Figure 35 paints a clear picture — it is those poorest regions of the world, such as parts of Asia and Africa, that are the most extreme importers of agricultural commodities. Richer parts of the world tend to be larger exporters, which, by inference, implies a greater level of self-sufficiency. To take this last comment further, we look at production versus consumption, as shown in Figure 36, to see a similar but clearer picture.

Figure 36. Self-Sufficiency Calculation (Production Over Consumption)

		Asia	Africa	LatAm	Europe	N. America	Oceania
Cereals	Wheat	0.85	0.33	0.75	1.39	2.11	3.42
	Maize	0.78	0.82	1.19	1.08	1.17	0.91
	Rice	1.04	0.60	0.96	0.61	1.35	0.35
	Other Coarse Grains	0.66	0.94	1.09	1.23	1.46	2.53
Oilseeds	Soybean	0.22	0.34	1.84	0.39	1.80	1.22
	Other Oilseeds	0.85	0.98	0.85	0.96	1.53	3.38
	Protein Meals	0.85	0.72	1.89	0.73	1.29	0.24
	Vegetable Oils	1.05	0.47	1.33	0.93	1.02	1.74
Sugar		0.79	0.56	2.29	0.83	0.67	3.24
Meats		0.89	0.88	1.13	1.09	1.16	1.64
Eggs		1.00	0.99	1.00	1.00	1.14	1.00
Dairy and Dairy Products		1.00	0.94	1.32	0.96	0.64	1.15
Fish and Fish Products		0.97	1.00	0.98	0.97	0.98	0.94
Roots and Tubers		0.85	0.98	1.03	0.97	3.45	3.25
Pulses							

Source: OECD Agriculture Statistics, Citi GPS

As before, it is the poorer parts of the world that are least self-sufficient, while richer parts of the world are either largely self-sufficient or close to it. Moreover, as we saw earlier, food represents a far smaller share of household expenditure in developed markets; hence, these markets are better placed to cope with disruptions, handle inflation, and source alternatives.

We should also point out, however, that the production versus consumption argument is not always the be-all and end-all. Many studies find that Africa, for example, actually produces more than enough food to feed itself, but it lacks the infrastructure to transport agricultural produce from producing to consuming regions and possesses insufficient storage and refrigeration facilities. This raises the question, when it comes to solutions, of whether we should be investing in infrastructure and systems rather than just trying to produce yet more food.

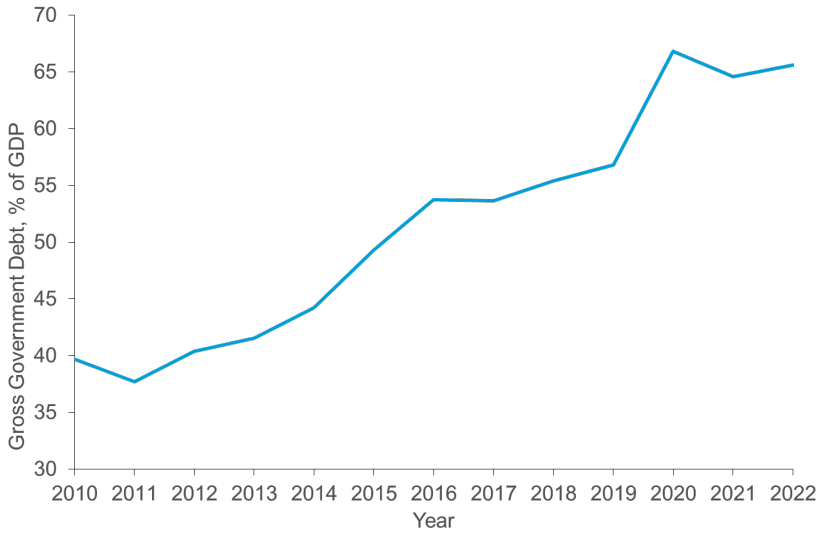
National Indebtedness

To make matters worse, debt levels across low-income countries stand at the highest levels in decades, reducing their capacity to respond to the current food crisis. Squeezed by the high cost of food and energy, while still bearing the legacy costs of COVID-19, the combination of heavy debt burdens, slowing global growth, and tightening financial conditions on top of the current food crisis will be more than some governments can handle. Some of the poorest economies, which have been less able to borrow in relatively safe ways (such as in their own currencies) and face unsustainable debt levels due to the pandemic, are most at risk.

The IMF highlighted this in its most recent Financial Stability Report (October 2022), noting that "*Many frontier markets, however, are facing a loss of market access and a high probability of sovereign default*," going on to note that it judged more than half of all low-income countries either to already be in debt distress, or to have a high probability of entering it.[26]

In its most recent release of its debt sustainability assessments (DSAs) for low-income countries eligible for assistance under the Poverty Reduction and Growth Trust (PRGT), the IMF recently noted that 28 low-income countries (LIC's) were at high risk of default, with nine already in debt distress.[27] The growth in debt levels for these most at risk countries has ballooned in recent years.

Figure 37. Gross Government Debt as a % of GDP for 36 of the 37 Countries Noted Most Recently by the IMF as Being at High Risk or, or Already in, Debt Distress



Note: Period after which estimates start vary by country from 2018 to 2021, but is generally 2020. Data not available for Republic of Congo.

Source: International Monetary Fund, World Economic Outlook Database, April 2022, Citi GPS

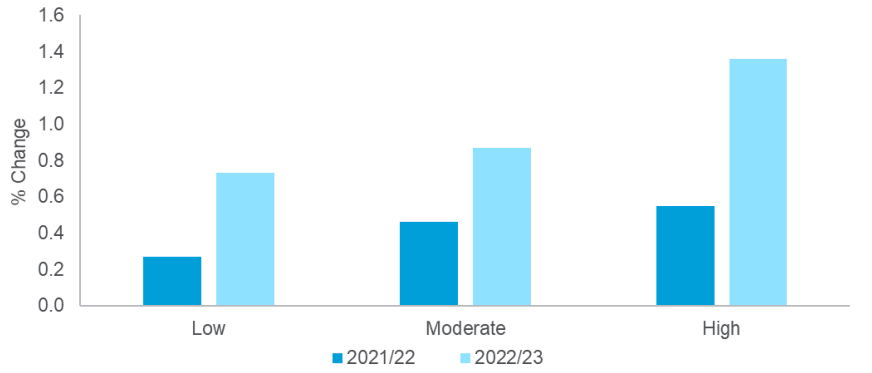
[26] International Monetary Fund, *Global Financial Stability Report: Navigating the High-Inflation Environment*, October 2022.

[27] IMF, "List of LIC DSAs for PRGT-Eligible Countries," PDF, Accessed November 1, 2022.

Further charts from the aforementioned IMF Global Financial Stability Report also show that the ratio of interest to revenue costs for frontier markets has risen from just over 4% in 2010 to more than 13% in 2022.[28] To add to this, the IMF highlights that, "*Over 40 percent of frontier bonds maturing through 2025 are trading at distressed spreads (above 1,000 basis points), and close to 80 percent are trading at spreads of more than 700 basis points*." Moreover, the accompanying charts in the IMF report highlight how frontier sovereign issuance has plummeted in 2022, down 75% for the year to September.

Research from the World Bank shows that food import bills are growing fastest for poor countries that are already in debt distress or at high risk of it.

Figure 38. Change on Net Import Bill for Wheat, Maize & Rice (% of 2020 GDP) for Countries in Low, Moderate & High Risk of Debt Distress



Source: World Bank (2022) For poor countries already facing debt distress, a food crisis looms, Citi GPS

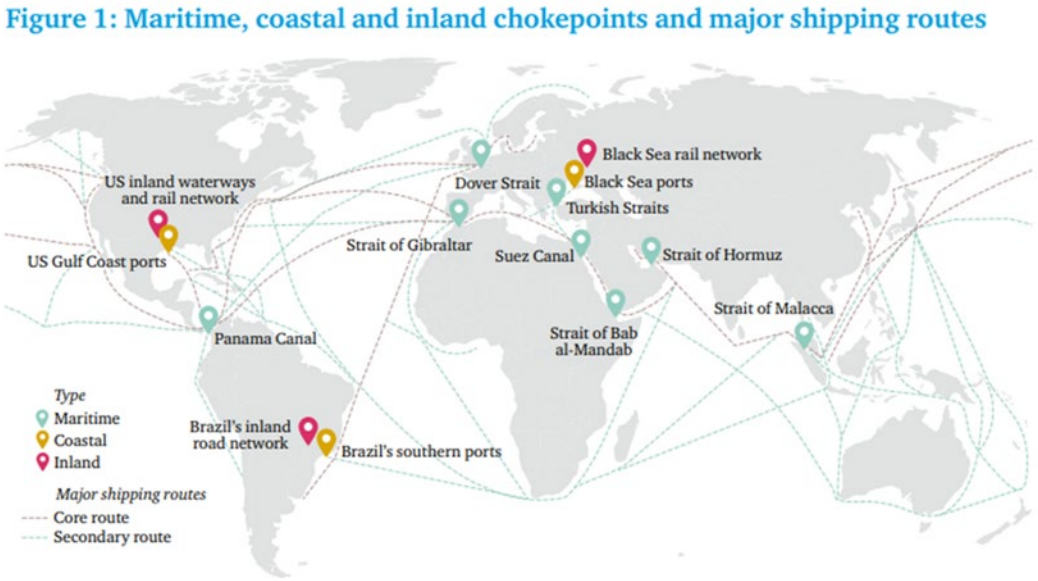
Crucially, many of the countries suffering most acutely from the rise in food insecurity are also struggling with high debt levels, increasing interest cost burdens, and maturing debt profiles, all against a backdrop of a global economic slowdown and a rising rate environment. This will make issuing new debt (or rolling over expiring debt) to fund measures to offset the crisis difficult and expensive — if not impossible — for these countries.

Physical Chokepoints

The Russia-Ukraine situation highlights not just the dependence on certain countries in terms of production, but also the exposure to physical chokepoints in the transportation of agricultural commodities. In a 2017 report, Chatham House identified 14 key sea, costal, and land-based locations upon which the global commodities trade is heavily dependent. The loss of any of these from either conflict, environmental, economic, or political issues could have severe ramifications for global food security.

[28] International Monetary Fund, *Global Financial Stability Report: Navigating the High-Inflation Environment*, October 2022.

Figure 39. Maritime, Coastal, and Inland Chokepoints and Major Shipping Routes



Source: Bailey, R., & Wellesley, L. (2017). Chokepoints and vulnerabilities in global food trade. London, UK: Chatham House., Citi GPS

As the Chatham House report points out, the poorest countries, such as those in North Africa, East Africa and the Horn of Africa, have the highest levels of import dependency and are most exposed to any breakdown in key supply corridors. That said, other high-income countries with food import necessities are also exposed, such as countries in the Middle East, as well as Japan and South Korea.

The dependence on these key chokepoints for specific commodities is highlighted well in the following table.

Figure 40. Agricultural Imports: Chokepoint Dependence, 2018-20

	Panama Canal	Dover Strait	Strait of Gibraltar	Turkish Straits	Suez Canal	Strait of Bab-al-Mandab	Strait of Hormuz	Strait of Malacca
World imports: Cereals	9.5%	3.2%	10.7%	16.7%	14.6%	13.6%	6.4%	13.5%
World imports: Soybeans	17.0%	4.4%	10.5%	3.4%	4.5%	4.2%	2.3%	33.5%
World imports: Fertilizers	7.2%	6.8%	17.6%	11.8%	14.5%	14.4%	8.5%	15.7%

Source: King, R. (2022). Exploring the cascading impacts from climate shocks to chokepoints in global food trade. London, UK: Chatham House, Citi GPS

Summary

As this chapter has hopefully highlighted, food insecurity is not all about the Russia-Ukraine conflict, although that is significant. Other factors, such as environmental disasters like floods, droughts, and heatwaves; economic and political issues such as rising energy prices and general inflation; and a rising rate cycle that is impacting the economic security of the poorest nations, have all combined to create a perfect storm for global food insecurity.

As we discussed earlier, while many of these factors may recede over time, there is no room for complacency, with extreme weather events expected to become both more severe and more frequent against a backdrop of rapidly growing global populations. Moreover, population growth will be centered around areas that are already suffering from the highest levels of food insecurity and have the least economic clout to alleviate the situation or protect their populations from these effects, either at a personal or a national level.

So, what of the future? In the next chapter, we examine, without making explicit predictions, what the outlook for global food security looks like and how some of the many factors examined in this chapter may play out over coming years.

The Future: The Outlook for 2023 and Beyond

Though staple crop prices have declined in the second half of 2022 versus the record nominal peaks observed in March-May 2022, food inflation remains elevated, and there are a plethora of uncertainties with respect to balancing agricultural supply and demand into 2023. While we find it plausible that the 2023-24 marketing cycle could be disinflationary and potentially even deflationary for agriculture commodities — especially considering the first half of 2023 base effects and Citi's crude oil outlook — the era of mostly "low prices and low volatility" realized for the more than half-decade period from 2014 to early 2020 is unlikely to rapidly re-emerge. So average food prices are likely to stay high, even if the rate of inflation eases or reverses into and during 2023. Indeed, agriculture commodity markets may require more embedded price premiums given ongoing geopolitical and supply tail risks, exacerbated by uncertainty surrounding key inputs. A real decline in food prices may also incur hefty economic costs, especially if it coincides with a global recession. This could remain a pain point for low-income consumers, especially those in frontier economies. Food security is a key policy conundrum across developed and emerging markets, as the world confronts the worst such crisis in at least a decade.

In this context, our agricultural commodities analysts present three scenarios for staple grains and oilseed prices in 2023:

- **Scenario #1 (60% probability):** Higher-than-normal agriculture prices persist — albeit below the peaks of the first half of 2022 — managed by U.S. and Brazilian exports, some ongoing improvements in Ukraine trade flows, a record Russian staple cereal harvest, and demand rationing. We assume normal weather and flat year-over-year production in Ukraine. Fertilizer prices remain high but on a deflationary trend along with energy, as tight balances slowly loosen.
- **Scenario #2 (30% probability):** A structural bull cycle occurs with higher sequential prices through 2023 and potentially fresh nominal price peaks. Fertilizer and ammonia capacity stays shut-in and puts upward pressure on the cost curve and downward pressure on harvest productivity. The Black Sea trade corridor deal negotiated by Turkey and the UN with Russia-Ukraine breaks down. Adverse weather hinders yields and harvests in the 2022-23 Southern Hemisphere row crop season. Ukraine production trends even lower.
- **Scenario #3 (10% probability):** Staple agriculture prices collapse to the "low price/low volatility" regime of 2015-19. There is an immediate resolution and normalization of Russia and Ukraine relations and export flows, fertilizer markets shift to a large surplus in 2023, and ideal weather conditions prompt record yields across the Northern and Southern Hemisphere. The Black Sea region realizes record 2023-24 harvests and global growth slows down sufficiently to crimp demand growth.

Figure 41. Staple Grain Price Point Levels Under Various Scenarios

	6-9 Month Levels							
	September-2022		Scenario #1		Scenario #2		Scenario #3	
	$/bu	$/metric ton	$/bu	$/metric ton	$/bu	$/metric ton	$/bu	$/metric ton
Corn	$6.80	$265	$6.00	$236	$8.25	$325	$3.85	$152
Soybeans	$14.75	$542	$13.00	$478	$18.00	$661	$9.75	$358
Wheat	$8.75	$322	$7.25	$266	$12.00	$441	$4.75	$175

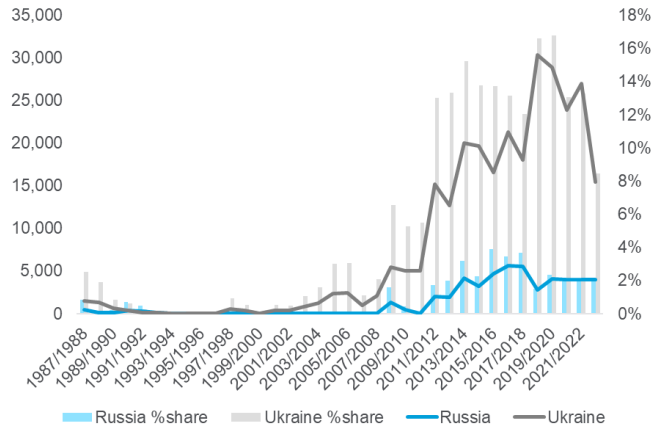
Source: Citi GPS

Why do Russia and Ukraine matter for food security? As we have seen, Russia and Ukraine represent the largest world wheat export bloc with share of around 28%, with Russia at about 18% of global wheat trade flow. Ukraine is also the fourth leading global exporter of corn (after the U.S., Brazil, and Argentina), and each economy represents an approximately 15% share of barley exports, for a combined 30% of global trade for the minor feed grain. The two economies are also key edible oil producers and exporters (e.g., sunflower and rapeseed). The closest recent analogy we have to the current situation is Russia's self-imposed wheat export ban in the summer of 2010, which was lifted in third quarter of 2011. From July 2010 to May 2011, wheat prices doubled, peaking around $9 per bushel (bu), then selling off approximately 25% in June 2011 right before the ban was lifted. In 2022, wheat prices reached as high as $14/bu in 1H'22 (approximately $550 to $600/metric ton) and were still trading at $8-$9/bu in September-October 2022. Current cash premiums for corn are higher than CBOT (Chicago Board of Trade) futures trading. This, in our view, points to concerns about supply.

Figure 42. Russia and Ukraine Wheat Exports (000t) and World Trade Share (%)

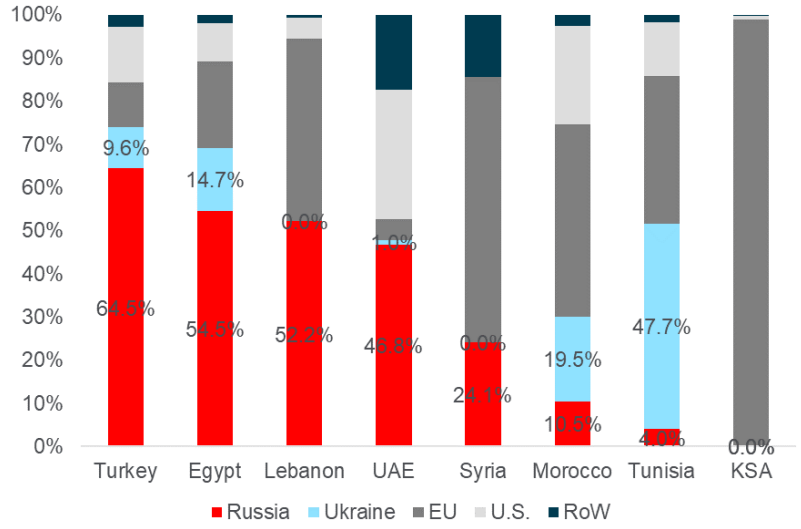
Source: USDA, Citi GPS

Figure 43. Russia and Ukraine Corn Exports (000t) and World Trade Share (%)



Source: USDA, Citi GPS

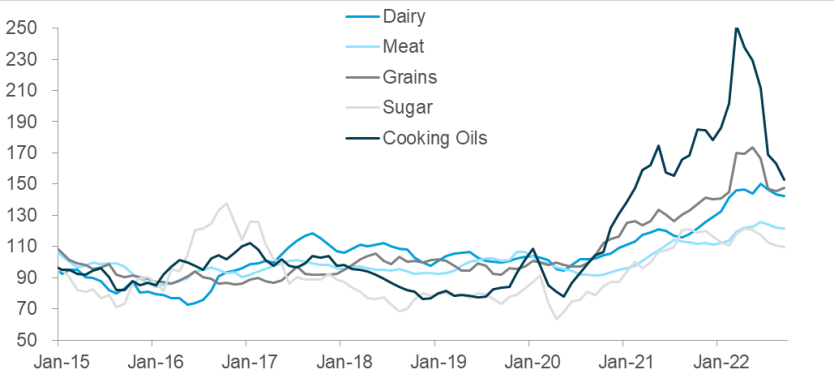
Figure 44. MENA Region Exposure to Grain Imports by Origin (% of Total Trade Demand)



Source: OECD, Citi GPS

On the one hand, 2022-23 is less dire than 2010-11 for Black Sea agriculture trade, as the causes of supply tightness are different. A decade ago, the ban on Russian wheat exports and the plunge in Ukraine crop export share was a function of physical harvest shortfalls. The Black Sea region quite literally did not have a grain harvest to sell. In 2022, logistical issues and military conflict that closed off Ukrainian ports (where 85%-90% of the country's food is typically exported) and impacted its new-crop harvest, though the country holds large carryover stocks. In the case of Russia, its deep-sea ports have long been open for business, but expensive freight, insurance, and some self-sanctioning has limited export flows until recently. However, Russia has a record staple cereal harvest, and we can expect trade to normalize to Middle East and North Africa (MENA) and South and East Asian consumers, particularly for wheat, over the coming months. As such, to some extent, geopolitical solutions and a shift in political and economic behavior can help get supply to market. Indeed, Ukrainian exports have started to tick substantially higher in recent months as its ports have slowly re-opened, and the humanitarian trade corridor emerged at the start of the Northern Hemisphere summer, weighing on crop prices in the second half of 2022 from the highs of the first half of 2022 (see Figure 45).

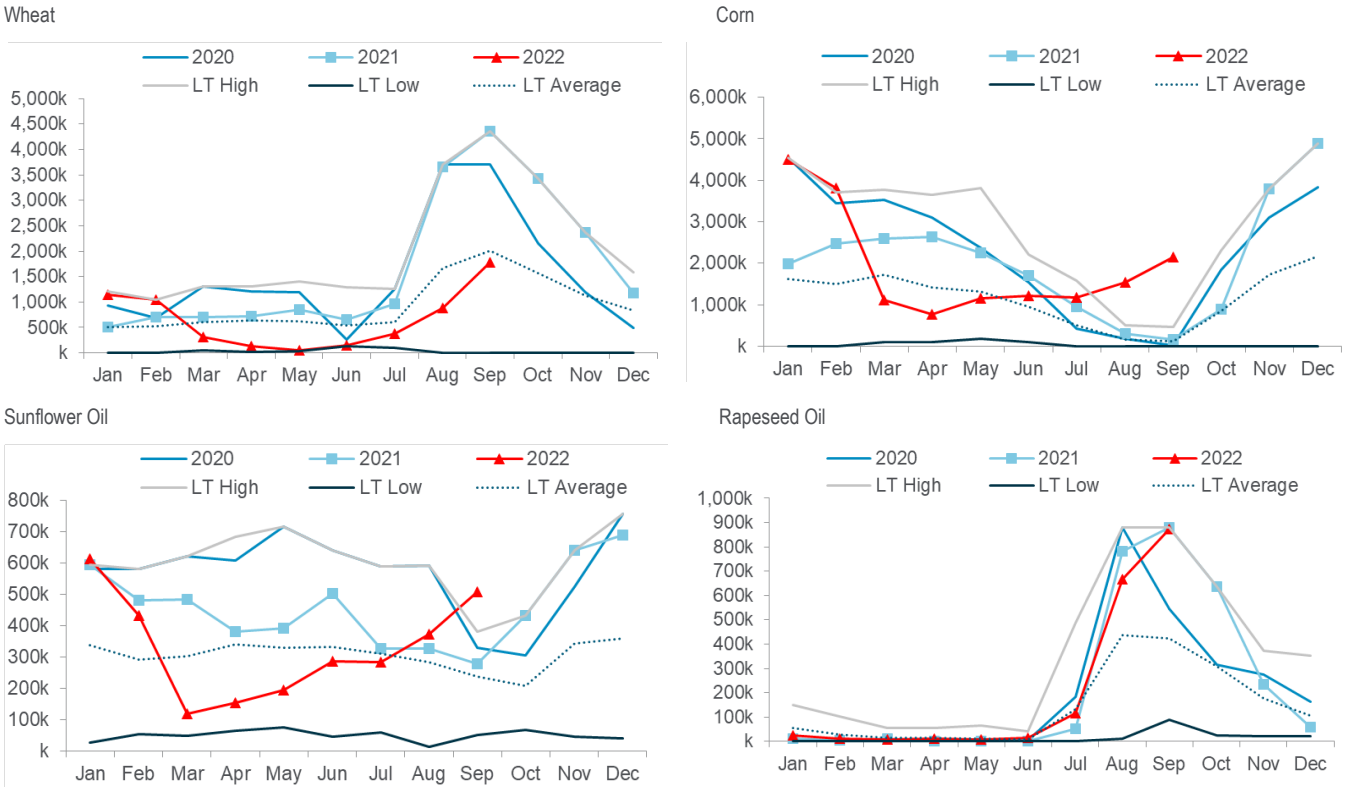
Figure 45. Global Food Prices Start to Come Off, Especially Edible Oils, Starting Late in the 1H 2022 as Recession Fears Grip Economies and Black Sea Trade Flows Start to Rebound



Source: UN, Citi GPS

On the other hand, though, what makes 2022-23 also different from 2010-11 is the EU gas/power crisis and persistently elevated fertilizer prices, which are down from the record levels of the second quarter of 2022 but starting to tick up again and remain up substantially versus 2021 and normal historical levels. Any closure of the export corridor or structural tightness (loss availability) of fertilizer inputs in 2023 is also a fat tail risk that could extend the high price cycle. This is because Ukrainian production is more than likely to be well below the pre-war trend for at least the next twelve months. As such, while some trade flows are on the mend, the risk of food insecurity is not fully extinguished

Figure 46. Ukraine Monthly Export Seasonality (Wheat, Corn, Sunflower Oil, Rapeseed Oil)

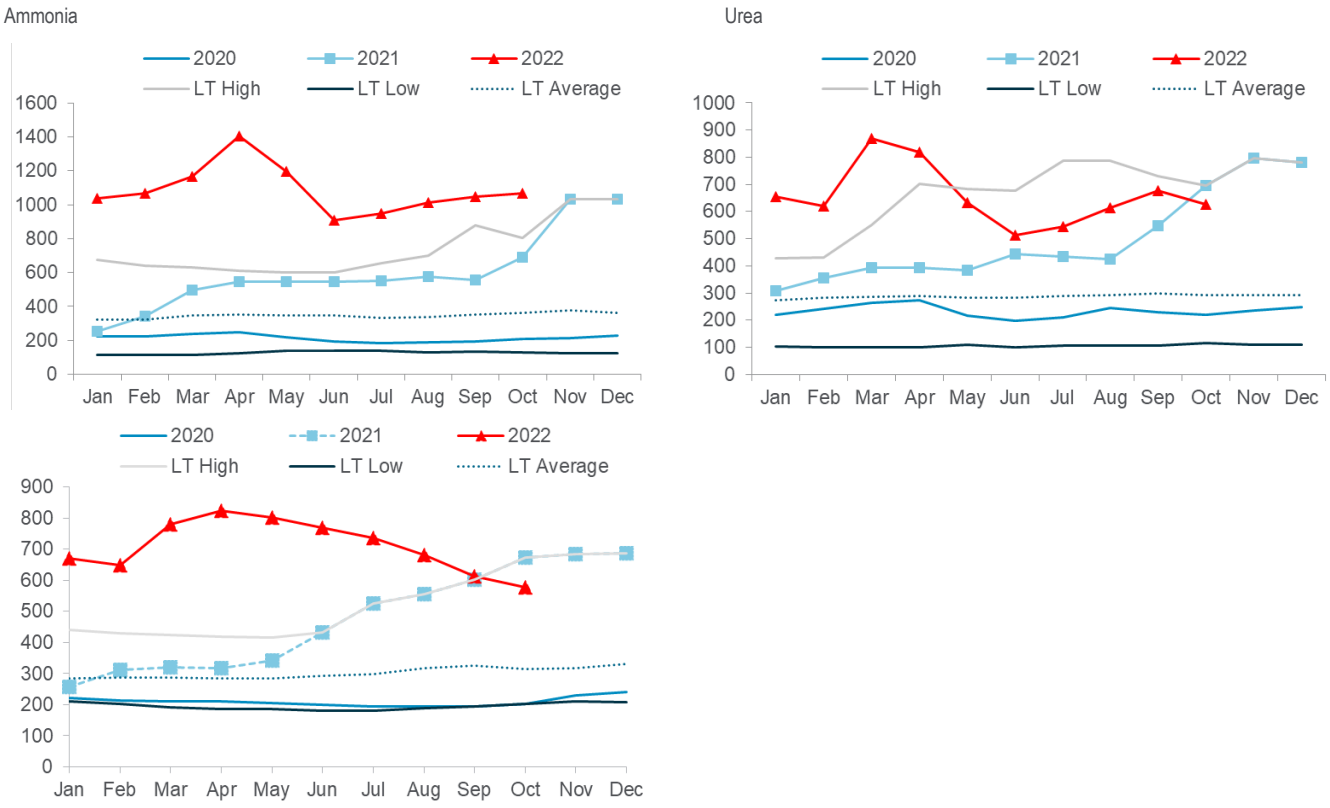


Source: UkrAgroConsult, Citi GPS

High fertilizer costs and input availability are significant bullish risks for 2023-24 crop production growth, with crop nutrient values soaring since early 2021. Although fertilizer prices are down from record levels in the first half of 2022, nitrogen-based fertilizers have been rallying again since June. Prices for ammonia, the key chemical intermediary used in all nitrogen-based fertilizers (and a by-product of natural gas), though down approximately 25% versus April, are up 75%-80% year-over-year north of $1,000/short ton (st) on the U.S. Gulf Coast. Shut-in capacity in Europe, due to record power/gas prices, has kept markets tight. The region has lost about half of its ammonia capacity and approximately 33% of its nitrogen fertilizer production as plants continue to shut down. Phosphorus and potassium-based fertilizers, on the other hand, are trending a bit lower since reaching a peak in March-April of 2022 but still remain historically elevated. About 33% of corn variable costs are attributable to fertilizer, and that figure is approximately 15% for soybeans and wheat. Given the spike in chemical/fertilizer prices in 2022, this represents some 40% of corn and wheat variable costs and 20%-25% of soybean expenses (beans produce their own nitrogen).

High fertilizer prices boost the "cost curve" for grains and could also curtail farmer input. High feedstock prices might even reduce fertilizer availability outright, though Northern Hemisphere producers are still several months away from sourcing 2023-24 supplies.

Figure 47. U.S. Gulf Coast Ammonia, Urea, and Potash Fertilizer Prices ($/short ton)



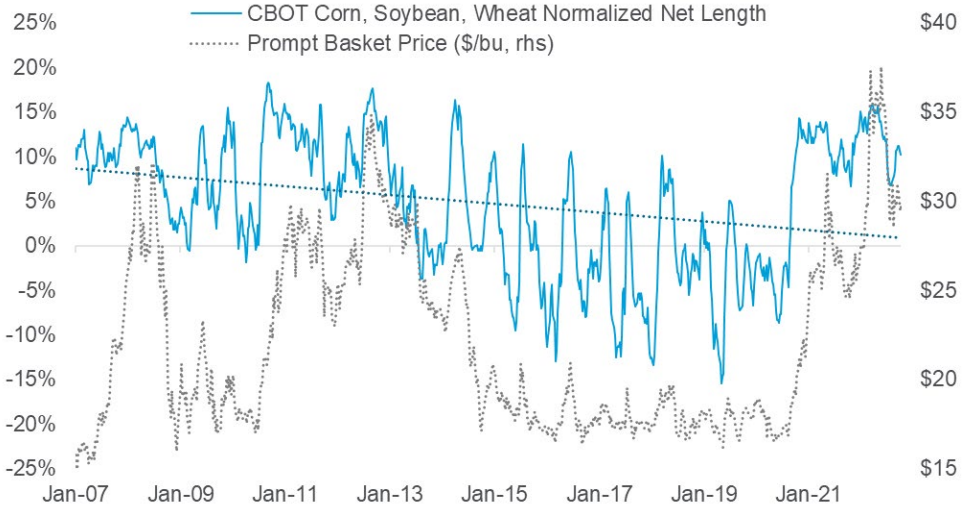
Source: Green Markets, Citi GPS

Recent statements from Russia, the largest fertilizer exporter in the world, provide mixed signals for the agricultural chemical ("agri-chem") markets. Statements from Russian authorities suggest the opening up of the humanitarian trade corridor, which is lifting Ukraine's agricultural shipments, could boost Russian mineral fertilizer exports, which were down approximately 7.2% year-over-year in the first half of 2022 to 17 million metric tons (MMt) but are targeted to be flat versus 2021 for all of 2022. Per Russian Deputy Prime Minister of Industry and Trade Denis Manturov, who provided the fertilizer volume data for the first half of 2022 and policy statements to the information services provider Interfax, Russian fertilizer sales will require "ongoing work," but the objective is to "maintain stable supply," which implies improving exports into end-2022. However, other statements from the Russian Foreign Ministry, stating that around 8 MMt of Russian fertilizers and raw materials remain blocked at trans-shipment terminals due to Western sanctions as of August 27th, suggest that Russian fertilizer might face several hurdles before reaching the international market. To be sure, some of the sequential declines in potash (potassium) fertilizer prices, where Russia and Belarus have outsized trade, point to a normalization of exports. But, like the gas situation with Europe, these can turn off quickly, and bottlenecks remain in the transport market, a tail risk to monitor.

China, the second largest fertilizer exporter in the world after Russia, also plays an important role in the current crisis. Against the backdrop of rising crude and natural gas prices in 2021, China started imposing a series of restrictions on fertilizer exports in order to cap the soaring domestic prices and support the country's grain production, which exacerbated the global supply shortage and contributed to a surge in prices in the international market. In July 2021, the National Development and Reform Commission of China (NDRC) ordered a few major fertilizer companies to pause exporting. Later in the year, China imposed export restrictions on phosphate, resulting in the shuttering of six major Chinese fertilizer manufacturers. The restriction was recently extended as an export quota of 3.16 MMt for the second half of 2022, down 40% from 5.5 MMt for the same period in 2021. To be sure, China customs reported total fertilizer exports were down more than 40% year-over-year in the first seven months of 2022. It is very likely that China extends the quota again in 2023 in order to ensure domestic supply and reduce emissions. From a longer-term perspective, the "fertilizer reduction and efficiency" initiative, introduced in 2015, suggests that production and exports may not reach the 2021 peak level even after the current crisis is over. This will put key importers of fertilizers from China, such as India and Pakistan, at risk.

On the other hand, local consultants suggest that Brazil, the leading Southern Hemisphere grower, has secured fertilizer shipments and could reap a record row crop harvest in the first half of 2023 of approximately 125 MMt corn and 150 MMt beans (putting downward pressure on U.S. export demand). Indeed, monoammonium phosphate (MAP) and diammonium phosphate (DAP) prices collapsed in Brazil and India in August 2022 (to the mid-$800s/metric ton CFR), with import data in Brazil showing volumes up 4% year-over-year this January-July.[29] Undoubtedly, the evolution of gas and energy prices will influence staple crop prices through the transport and fertilizer channel. A deflationary path for energy markets into 2023 should underpin a more bearish environment for corn, soybean, wheat, and broader agriculture markets. However, the recent rebound in crude oil and the spike in global gas and EU power prices have been a tailwind for market risk premiums, staving off the sell-off and driving a long speculative positioning rebound, especially on the corn side.

Figure 48. Managed Money Normalized Net Length, Prompt CBOT Basket Price (2007-Sept 2022) — Corn, Soybeans, Wheat



Source: CFTC, CME, Citi GPS

[29] CFR = with cost and freight.

When agriculture markets are "tight" — meaning either a loss in supply/trade or a shift out in aggregate demand — risk premiums can stay elevated for longer, exacerbating the risk of food insecurity (e.g., 2006-08 or 2011-12). At the moment, world grain stocks-to-use ratios are tight, but not as binding as what governments dealt with at the peak of the 2011-12 food shock. In part, that has to do with the growth of Brazil output and trade, a sharp build in global inventories from 2017-19, better risk management from MENA importers, and robust U.S. yields realizing mostly healthy crop yields between 2016-20. However, if we strip out China inventories from global stockpiles and assume they are not as readily available, then staple cereal balances remain about as tight as 2011-12.

Figure 49. World Stocks-to-Use Ratios for Corn and Wheat

Source: USDA, Citi GPS

Food inflation has two main components: food-at-home Consumer Price Index (CPI) and food-away-from-home CPI. The focus on (staple) crop prices and the availability and costs of them in the grocery aisle is more a food-at-home inflation phenomenon; this is the majority of food CPI but not by as wide a margin as one might imagine, at least in developed markets. Food-away-from-home inflation has a lot of other factors influencing it, though both CPI measures tend to be positively correlated and underpin overall food inflation. On the away-from-home and restaurant side, much depends on labor costs, non-food expenses or margin pressures (e.g., rents/real estate costs, capital equipment, etc.), and the broader consumer economy from meal demand (which in last few years has been skewed by the COVID-19 pandemic). However, crop prices should feed through — especially for key cereals like corn, wheat, and soybeans — as they are not only consumed foodstuffs, but are feedstock for meat/animal feed, dairy, cooking oils, processed/packaged goods, and so forth. So, the direction of staple cereal prices should help underpin broader food inflation (or disinflation) over time, especially in the food-at-home area. The fertilizer side is very closely linked to energy and especially natural gas, which is a direct feedstock for ammonia production. Diesel and propane are also relevant to agricultural costs of production. So, if energy deflates, that can help food deflate in time. But higher energy prices, if sticky, can exacerbate food insecurity.

While the peak in food prices may have plausibly been realized in 2022, historically elevated consumer costs are still likely to persist in 2023, and low supplies remain a tail risk for economies. This is most evident in the high price and tight supply of fertilizer inputs. But ongoing Ukraine production shortfalls could also be a structural issue in 2023-24 the longer the military war persists. While Ukraine's high carryover stocks of grains and vegetable oils that were shut out of trade through most of 1H'22 slowly make their way back to export markets, what will be the future of its harvests? Will Ukraine go from an over 40 MMt corn and 30 MMt wheat per year producer to levels 25%-50% lower? Will there be adequate foundational seed and a return of its farmer population, which is mostly Dutch and German continental Europeans that have helped increase productivity in recent years?

These unknowns are tails in the market, even as the short-term export flow has helped calm markets after the 1H'22 shock. Of course, Russia itself has a record staple crop harvest, and does not seem incentivized to cut off trade to its emerging market buying-base. But what about fertilizer shipments that go to Europe? This leaves the bias for higher prices, even if absolute levels trend lower. For food CPI, that may be beneficial, as even if prices stay high but do not rise, the impact will not be on increasing inflation. However, as a real cost for consumers and food security, the harm can continue — especially as Russia launches its own disinformation campaigns domestically about the "causes" of food insecurity and inflation. Only time will tell, but as before, and with longer term upward population drivers and likely increased frequency and severity of weather-related and environmental impacts from climate change, there is little room for complacency regarding this critical issue for the global population.

The Implications of Global Food Insecurity

Economic and Employment Implications

While food insecurity is, first and foremost, an immediate human tragedy, there are countless knock-on human effects, such as the impacts of child malnutrition on later life, health, and the ability to work. Food insecurity, hunger, and malnutrition are also key elements of multi-dimensional poverty and an important factor in inequality.[30]

The economic impacts of the causes of food insecurity at a macro level can also be stark. While any of the three key drivers (environmental disasters, conflict, or social/political/economic factors) that we examined earlier can obviously have a dramatic impact on economies, the follow on economic and social effects from food insecurity can exacerbate these issues.

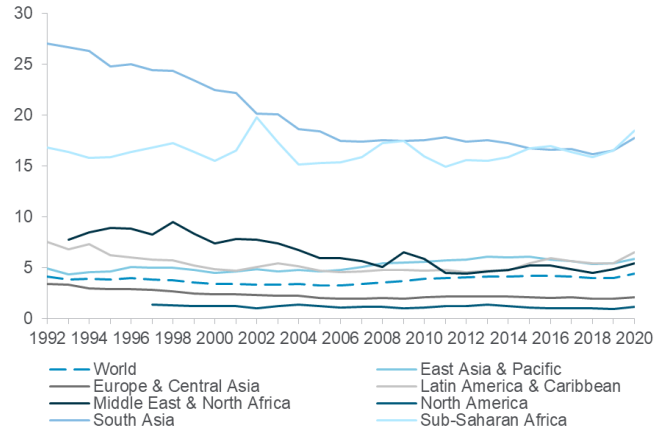
As Figure 50shows, for some regions of the world — again, typically the poorest — agriculture still represents a material element of GDP, at around 18% in Sub-Saharan Africa and South Asia. This compares to a global average of 4.4%. Splitting this further, in high-income countries, agriculture represented just 1.3% of GDP, whereas for low-income countries it represented 26.8% of GDP.

Hence, anything that impacts agricultural production can have not just a sustenance impact on the population concerned, but also a material macro-economic impact. This, of course, has severe ramifications for the ability of any government to deal with whatever crisis has driven food insecurity to increase, be it flood, drought, war, or politics.

Within a time series of these figures, it is also interesting that agriculture represents an increasing share of GDP across almost all regions since 2018, though this may have more to do with the relative resilience of agriculture in the face of the economic slowdowns caused by the COVID-19 pandemic.

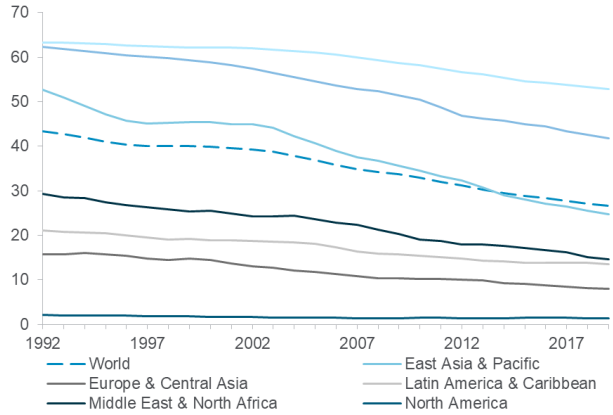
At an individual level, the share of employment in agriculture also highlights this "double-whammy" effect when food production is disrupted.

Figure 50. Agriculture, Forestry, and Fishing Value Added (% of GDP)



Source: World Bank Open Data, Citi GPS

Figure 51. Employment in Agriculture (% of Total Employment)



Source: World Bank Open Data, Citi GPS

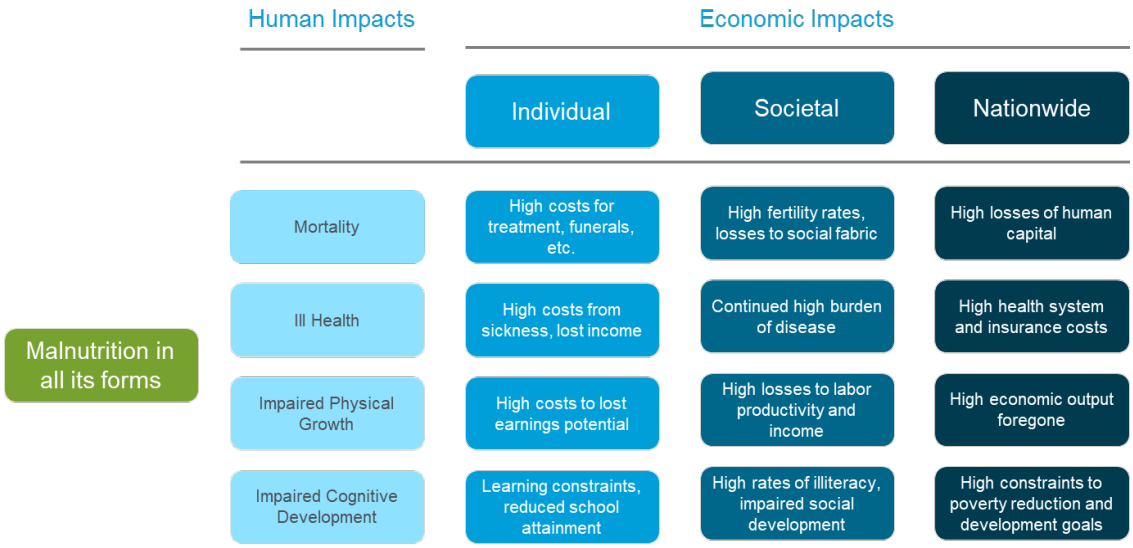
[30] See the Citi GPS report *Eliminating Poverty: The Importance of a Multidimensional Approach in Tackling SDG 1*.

As Figure 51 shows (2019 data), in sub-Saharan Africa, over half the population (52.9%) works in agriculture, with South Asia not far behind (41.9%). Once again, splitting countries by income level shows that just 3.1% of the population worked in agriculture in 2019 in high-income countries, whereas for low-income countries the figure was 59.5%. Globally, almost a billion people (928 million) worked in agriculture.

The Costs of Hunger and Malnutrition

One widely cited statistic from the UN FAO is that the estimated impact of malnutrition on the global economy could be as high as $3.5 trillion per year — or close to $500 for every individual on the planet.

Figure 52. Conceptual Framework for Understanding the Economic Impact of Malnutrition in All Its Forms



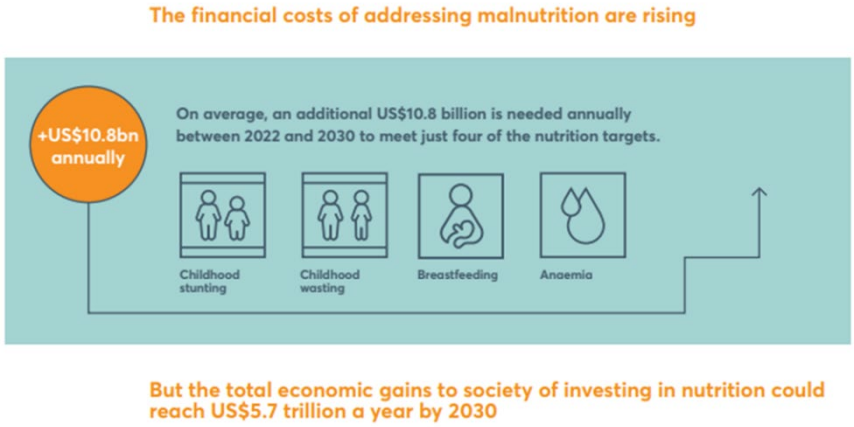
Source: Global Panel. 2016. The Cost of Malnutrition. Why Policy Action Is Urgent. London, UK: Global Panel on Agriculture and Food Systems for Nutrition, Citi GPS

Costs to Fix Malnutrition

The 2021 Global Nutrition Report, a multi-stakeholder initiative, found that the financial costs of addressing poor diets and malnutrition have risen (partly due to the impacts of COVID-19) while resources are dwindling; however, the costs of inaction are far greater. The cost to address four nutrition targets (stunting, wasting, maternal anemia, and breastfeeding) is an additional $10.8 billion per year for 2022-30, while previous estimates for 2016-25 were for an additional spend of $7 billion per year. The cost of meeting wider nutrition-specific and nutrition-sensitive needs under SDG 2 targets by 2030 is much higher, at approximately $39 billion to $50 billion annually.

However, beyond the obvious human benefits, we should not see “fixing” hunger and malnutrition as a cost — the total economic gains to society of investing in nutrition are estimated to be as high as $5.7 trillion per year by 2030, rising to $10.5 trillion a year by 2050, as shown in Figure 53.

Figure 53. The Financial Cost of Addressing Malnutrition Is Rising



Source: 2021 Global Nutrition Report

Geopolitical Implications

Record-high food prices have triggered a global crisis that will drive millions more into extreme poverty, magnifying hunger and malnutrition, while threatening to erase hard-won gains in development. The war in Ukraine, supply chain disruptions, and the continued economic fallout of the COVID-19 pandemic are reversing years of development gains and pushing food prices to all-time highs.[31]

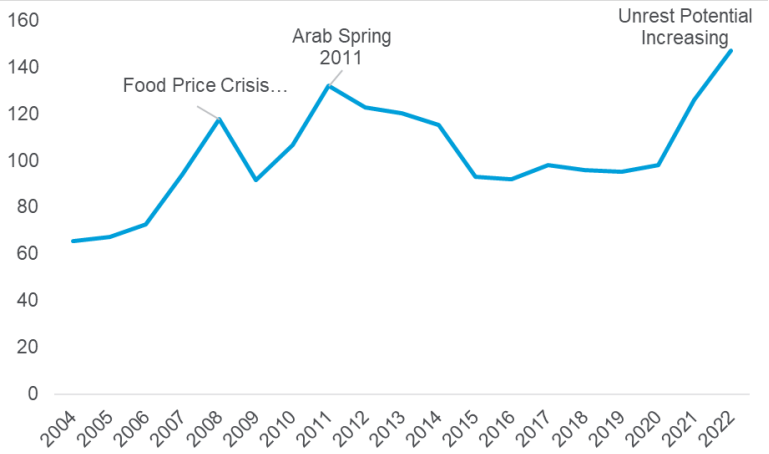
Emerging markets are more vulnerable to a food crisis, illustrated by the average consumer households in these markets spending 25% of their budget on food compared to developed markets spending only 14.8%.[32] In sub-Saharan Africa, average budget spending on food is well above the average of emerging markets, at around 40%. Russia's invasion exacerbates a situation that is already dire, and as a result, 40 million additional people may be pushed into extreme poverty.[33]

Civil Unrest and Global Displacement

In the past, similar surges in the price of food have led to social unrest. Examples include the bread riots in Egypt in 1970 and 1977 and the Arab Spring in 2011, when populations in North Africa and the Middle East, cornered by oppressive regimes and feeling the additional squeeze on their livelihoods due to high prices, rose and toppled their regimes. The current level of food prices is even surpassing the peaks observed in 2008 and 2011, when food and other prices rose dramatically, causing unrest in several African countries as well as in Bangladesh, Haiti, Indonesia, and Yemen.

[31] World Bank, "Food Security Update," accessed October 21, 2022.
[32] Eurostat, "Household Expenditure: Change in the EU Member States," January 17, 2022.
[33] *The Economist*, "The Coming Food Catastrophe," May 19, 2022.

Figure 54. FAO Food Price Index



Source: FAO Food Price Index, Citi GPS

Recent examples include Lebanon, where food prices quadrupled in December 2020 compared to December of the previous year; this contributed to street protests and roadblocks in several major cities. Similarly, in February 2021, Sudan declared a state of emergency in several states following violent protests against increasing food prices.

The effects of the food crisis could reverberate across borders, destabilizing societies and causing conflict — and as a consequence, pushing more people to migrate. This occurred in 2015 when a lack of funds at the World Food Programme to feed Syrian refugees helped drive a massive refugee crisis in Europe.[34] Another example was seen in Egypt, where the Arab Spring pushed approximately 1 million citizens to irregularly immigrate into Europe.

Case Study: Egypt's Food Crisis and Political Unrest

Egypt has been of the countries hardest hit by the current food crisis, as it is the largest global importer of wheat (spending $5.2 billion in 2020) and is largely dependent on Russia and Ukraine for its wheat, relying on the two countries combined for 80% of wheat imports in 2021. The Russian invasion of Ukraine has therefore had a massive effect on the Egyptian economy and food security, where the price of wheat has increased 44%.[35]

In a country where political discontent often follows spikes in food prices, the potential for bread shortages is among the most urgent security challenges the Egyptian state has faced since the 2013 coup that installed President Abdel Fattah Al Sisi in power.[36] As a result, the government has implemented measures including new wheat supplies from Paraguay and India, directing the country's farmers to harvest wheat earlier than usual in 2022 and capping prices on certain products.

Since Russia's invasion of Ukraine, governments from Turkey to Indonesia, and Somalia to Lebanon, have scrambled to find new supplies and cope with rising prices. However, the stakes are especially high for Egypt, the most populous country in the Middle East, where the economy was in a precarious position before the war started.[37] With a third of the 103 million Egyptians living below the official poverty line, the price of bread is crucial to maintaining social and political balance. With the current global food crisis, this balance could well be toppled, and the main slogan of the protesters during the 2011 revolution, "bread, freedom, and social justice," could be soon heard once again.

[34] World Food Programme, "A Global Food Crisis: 2022: A Year of Unprecedented Hunger," accessed October 17, 2022

[35] The Borgen Project, "Ukraine's Invasion and the Food Crisis in Egypt," May 14, 2022.

[36] Chao Deng and Amira El-Fekki, "Egypt's Bread Crisis Awakens Old Fears of Political Unrest," *Wall Street Journal*, May 23, 2022.

[37] Ibid.

Government Responses

Export Bans

Due to a steep increase in food prices, countries are resorting to wide-ranging protectionist trade policies. At least 23 countries have declared a total of 33 export bans, restricting 10% of globally traded calories combined. The imposition of export bans on food further squeeze supply in world markets, driving up prices in an already high inflation era impacted by pandemic-induced supply chain bottlenecks. Recent examples include Argentina banning exports on soybean meal and oil; Egypt and India banning exports of wheat; and Malaysia barring the export of chickens, reducing the poultry supply of Singapore by one-third.[38] Low-income households are the most vulnerable amid the implementation of these recent export bans, as food costs take up a larger share of their income.[39]

Indonesia's Brief Palm Oil Ban

Indonesia — the leading producer of palm oil, accounting for almost two-thirds of global palm oil exports — implemented an export ban in late April 2022. The effects of the ban were especially strong in heavily populated countries relying on vegetable oil for cooking, such as Bangladesh, Egypt, India, and Pakistan.[40] The ban further pushed up global food prices and spilled over into other industries as 50% of packaged goods contain palm oil, raising the price of items like toothpaste and detergent. In addition, Indonesia's trade position deteriorated, as it received fewer export dollars while imported goods became increasingly costly. Indeed, the Indonesian rupiah dropped to an eight-month low after the announcement of the ban.

Although Indonesia aimed to protect its most vulnerable citizens, the ban likely had the opposite effect as the devalued rupiah increased the cost of imports and further increased prices.[41] As a result of these adverse consequences, the government lifted their ban on exports only three weeks later. Since then, the government has implemented rules under the Domestic Market Obligation (DMO) to keep producing palm oil. However, exports have only picked up slowly, with suppliers blaming the DMO rules for the slow export rate. The timeline and results of Indonesia's export ban provide a strong example that bans can have the opposite of their intended effect, with economies still struggling to return to normal trade volumes.

Price Ceilings and Subsidies: Lessons from Tunisia's Bread Price Ceiling

Other economic mechanisms regularly used by governments are price ceilings and subsidies imposed on selected goods and services to provide a buffer against shocks. A recent example can be seen in Tunisia, which imposed a price ceiling on bread during mid-2022. The country used subsidies to fill the price gap between the fixed price consumers had to pay and the amount producers would receive under normal market conditions. However, the rising wheat prices have left Tunisia needing to add more than $1.5 billion to their subsidy bill, which caused Fitch Ratings to downgrade Tunisia to CCC (substantial credit risk). This, in turn, has made it more costly and difficult for the country to raise money in capital markets.[42]

---

[38] Alex Capri, *After Ukraine: The New Geopolitics of Food Security*, Hinrich Foundation, June 2022.

[39] Trinh Nguyen, "Why Indonesia's Palm Oil Export Ban Could Backfire," Carnegie Endowment for International Peace, April 28, 2022.

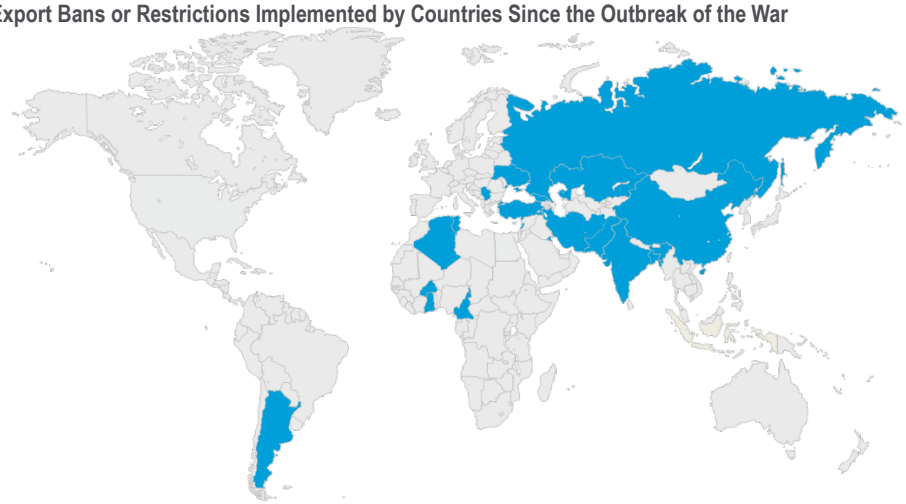
[40] Steffi Hamann, "The Impact of Indonesia's Ban on Palm Oil Exports Reverberated Across the Globe," *The Conversation*, May 14, 2022.

[41] Trinh Nguyen, "Why Indonesia's Palm Oil Export Ban Could Backfire," Carnegie Endowment for International Peace, April 28, 2022.

[42] David J. Lynch, "Tunisia Among Countries Seeing Major Economic Consequences from War in Ukraine," *Washington Post*, April 14, 2022.

Tunisian farmers were further impacted when the state found it difficult to pay the subsidies and instructed farmers to sell their grain to them for a lower price. As a result, farmers were unwilling to produce more grain due to extremely low marginal gains. According to a farm manager in Tunisia, "The earth in this country is good. There is plenty of spare land. If they could earn a market rate for their wheat, they would plant more of it. But they receive less than a fifth of the world price, so they don't." The Tunisian government's response is an example of the potential negative impact of government subsidies, which can become expensive while also constraining incentives to produce and lowering supply.[43]

Figure 55. Significant Export Bans or Restrictions Implemented by Countries Since the Outbreak of the War



Source: International Food Policy Research Institute, Citi GPS

Protectionism and Food Security: China's Rapid Stockpiling of Wheat and Corn

Government measures not only include economic policies such as export bans or price ceilings and subsidies, but also national protection of goods and commodities. China is stockpiling key food commodities, for example, and by 2023, the U.S. Department of Agriculture estimates that China will have accumulated 65% of the world's corn and 53% of its wheat.[44]

The rationale for stockpiling is that, even though China is home to 20% of the global population, it only has about 7% of the world's arable land. In addition, the square footage of China's arable land shrank by nearly six percentage points between 2010 and 2060, amid urbanization and widespread pollution of soil and water. As a result, China has been relying more heavily on imports, making it one of the world's largest wheat importers and the largest corn, barley, and oilseed importer. Most importantly, China consumes nearly 120 million tons of soybeans a year and imports about 62% of all the soybeans traded internationally.[45]

[43] *The Economist*, "Costly Food and Energy Are Fostering Global Unrest," June 23, 2022.
[44] N.S. Lyons, "Why Is China so Obsessed With Food Security?," *The Upheaval*, September 1, 2022; Betsy Joles and Cissy Zhou, "Farming Out: China's Overseas Food Security Quest," *Nikkei Asia*, August 31, 2022.
[45] N.S. Lyons, "Why Is China so Obsessed With Food Security?," *The Upheaval*, September 1, 2022; *Reuters*, "China's Total Arable Land Shrinks Nearly 6% from 2009-2019 – Survey," August 27, 2021.

The level of dependence on imports, at least in part, drives China's protectionism, and the situation is not expected to improve anytime soon. As President Xi Jinping noted in March 2022, "the international situation is complicated and severe." He also said, "In the future, the demand for food will continue to increase, and the balance between supply and demand will become tighter and tighter." This is why, China "cannot rely solely on the international market to solve" its food security challenges any longer.[46]

Impact of Currency Devaluation for Highly Indebted Emerging Markets

The Federal Reserve's rising rate environment and therefore the strengthening of the U.S. dollar are causing investors to fly to safety and flee from emerging markets. In addition, the current food crisis is exacerbating the currency devaluation in many net-importing countries, as more foreign currency is needed to purchase imports and, as a result, making imports relatively more expensive.

In the case of war-torn Yemen, the civil war has caused the currency to diverge, and in part of the country controlled by the government, the exchange rate fell to 1,100 YER per $1 in June 2022 (an unofficial rate but one that is used by money exchangers).[47] The devaluation has made basic necessities such as food unaffordable for ordinary households as they grapple with higher food prices due to costlier imports in a country that imports the vast majority (90%) of its food. As a result, the lowest-income households and the vulnerable have been most affected. This is evidenced by Yemen having the highest levels of malnutrition on record for children under the age of five.[48]

Currency devaluation is further aggravated in countries with high foreign currency debt, as their foreign denominated debt has risen drastically relative to the declining value of their local currency. As of July 15th, four governments had already defaulted (Lebanon, Sri Lanka, Suriname, and Zambia), with around a dozen other countries on the brink of default or distress. Furthermore, according to the IMF, approximately 60% of low-income countries are at or near distressed debt levels.[49]

Debt-distressed countries will need to pay billions in debt-service payments on their public and publicly guaranteed external debt, creating a further challenge for them to tackle the food crisis. In this dire scenario, implementation of fiscal policies and help from abroad including emergency aid to countries at risk; targeted, cost-effective cash transfers to the most vulnerable households; and debt restructuring and debt relief to countries with unsustainable debt burdens will be crucial in alleviating the debt crisis.

---

[46] N.S. Lyons, "Why Is China so Obsessed With Food Security?," *The Upheaval*, September 1, 2022; Keith Bradsher, "War and Weather Sent Food Prices Soaring. Now, China's Harvest Is Uncertain," *New York Times*, May 11, 2022.

[47] Khalid Al-Karimi, "Yemeni Currency Devaluation Persists, Despite New Leadership," *Aljazeera*, June 28, 2022.

[48] International Rescue Committee, "Yemen Currency Devalues to Historic Lows, Exacerbating Hunger Needs, Warns IRC," July 21, 2021.

[49] Andrea Shalal and David Lawder, "IMF Fiscal Chief Underscores Need for 'Orderly Debt Restructuring,'" *Reuters*, October 12, 2022.

Solutions

As we have hopefully demonstrated, food insecurity is not a small problem affecting a few people in the poorest parts of the world — this is an issue that affects billions around the world, and with the perfect storm of environmental, economic, political, and conflict issues seen in recent years, it is a problem tragically on the increase. Furthermore, unless we act now, population growth's upward pressure on the already-stretched systems in the most food-insecure parts of the world is likely to make the situation even worse.

So how do we go about tackling a challenge that seems overwhelming in its scale and complexity? Sadly, there is no easy fix. That said, there are things we can do that can both alleviate the problem in the short to medium term and begin to solve it for the future, as well as prevent the increases of recent years from reoccurring. We have split these solutions into four brackets, namely social solutions, technological solutions (encompassing the new and exciting area of AgTech), economic/financial solutions, and government solutions.

Social Solutions

Food waste

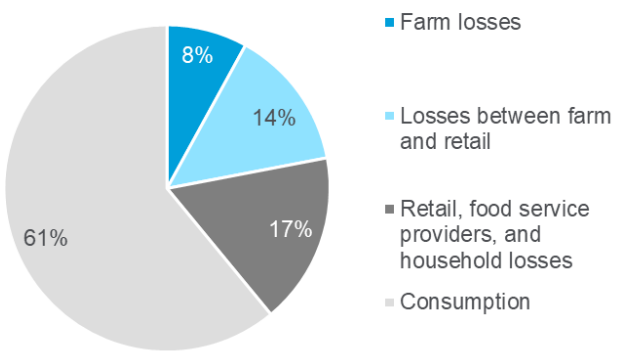
Perhaps the most shocking statistic regarding food insecurity is that with close to a third of the world's population experiencing moderate or severe food insecurity, and with close to 800 million people undernourished, we either lose or waste an estimated one-third of all food produced and more than 2 billion metric tons of food produced each year never gets consumed.[50] So we waste a third of our food, and a third of us go hungry — this should theoretically be relatively easy math.

Food waste and loss occurs at every stage of the global food system, from the initial farming phase through manufacturing/processing, retailing, and consumption. UN Sustainable Development Goal (SDG) 12 seeks to "ensure sustainable consumption and production patterns." Target 3 under this goal specifically calls for cutting in half per capita global food waste at the retail and consumption level and reducing food losses across the food supply chain. The Champions 12.3 SDG progress report estimates that 8% of the food produced today is lost on the farm; 14% is lost between the farm and the retail sector; and 17% of the world's food is wasted at retail, food service providers, and in households.[51]

[50] Food loss differs from food waste and largely takes place during the earlier stages of the food supply chain, and it may be the unintended consequence of food processes or the result of inefficient systems and infrastructure. Food waste typically takes place at the retail and consumer end of the value chain and could be due to negligence or active choices to throw away food that is still fit for human consumption.

[51] Brian Lipinski, *SDG Target 12.3 on Food Loss and Waste: 2021 Progress Report*, Champions 12.3, September 2021.

Figure 56. Food Loss and Waste



Source: Champions 12.3 (2022) Target 12.3 on Food loss and waste: 2022 Progress report, Citi GPS

Beyond the human impacts, reducing food waste would have dramatic environmental and economic benefits. If we considered food waste as a country, it would be the third-largest greenhouse gas emitter, the second-largest country by land mass (it needs a land area bigger than China), and the largest consumer of surface and groundwater.[52]

According to the Food and Land Use Coalition, the direct economic loss associated with food loss and waste is a staggering $1.25 trillion.[53] For every $1 a company invests in reducing food loss and waste, they save an estimated $14 in operating costs, and savings to consumers could be even greater.[54] Reducing food waste is a win-win opportunity, as it saves money for farmers, companies, and households; lowers emissions; and reduces the use of resources such as land, water, and fertilizers. Most importantly, though, it can also improve food security and malnutrition — wasting less means feeding more people.

So given the obvious benefits, why have we not yet cracked the challenge of food waste? The situation is complex, but there are a number of solutions and initiatives that can help tackle the issue:

- First, we need more data and information. The adage “you can’t improve what you don’t measure” applies to food waste and we need a better understanding of exactly where, what, and why food waste and loss is occurring along the value chain. There are a number of studies looking to improve this information.
- Tackling food loss, which occurs largely upstream in production and processing and in developing countries, includes investment in better infrastructure and equipment as well as training to improve handling, processing, and storage practices.

[52] FAO, *Food Wastage Footprint: Impacts on Natural Resources: Summary Report*, September 2013.
[53] The Food and Land Use Coalition, *Growing Better: Ten Critical Transitions to Transform Food and Land Use*, September 2019.
[54] Craig Hanson and Peter Mitchell, *The Business Case for Reducing Food Loss and Waste*, Champions 12.3, March 2017.

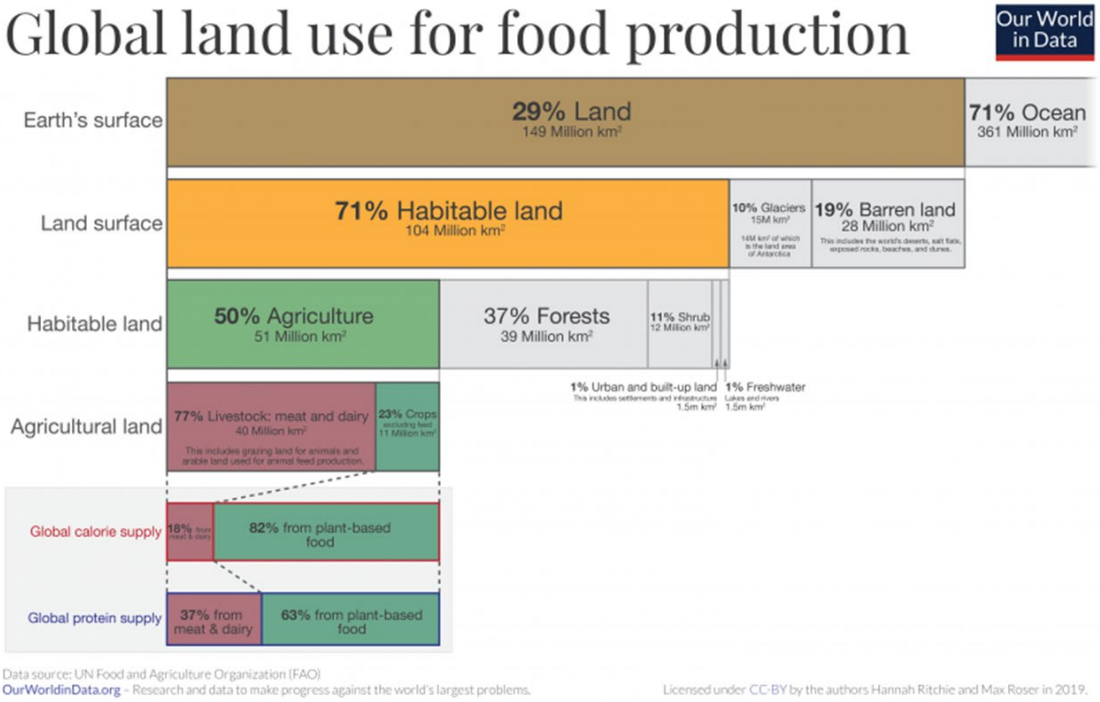
- Tackling food waste downstream at retailers and consumers requires a number of different solutions, including:
  - Improving cold storage facilities in many developing countries. For example, an estimated 45% of post-harvest food spoils in Nigeria due to a lack of affordable cold storage.[55]
  - Scaling up of innovations such as shelf-life extensions (which we discuss in more detail further in the report).
  - Changing selection standards from both retailers and consumers that overemphasize appearance. For example, more than a third of farmed fruit and vegetables are discarded every year across Europe due to cosmetic imperfections.[56]
  - Improving food labeling, as use-by-date labels are currently only a simple estimation of how long a product will last. Many people dispose of perfectly good food based on these dates. There are now calls to remove use-by dates for certain products, and in 2022 one food retailer became the first U.K. supermarket to scrap the use-by date for most of its milk.
  - Improving planning by consumers and enabling consumers to buy what they need (for example, selling fruit and vegetables by weight or volume).

Dietary changes

The second social solution is having a greater awareness of what we eat, and the implications of those choices. Without wishing in any way to demonize meat, as Figure 57 shows, half of the habitable land on earth is used for agriculture — but 77% of that land is used for the raising of livestock (some 40 million km^2), through a combination of grazing land and land use for animal feed production for livestock, yet this produces only 17% of the calories that we consume. Figures on protein are less extreme to be sure, with meat and dairy providing 33%, but the intensity of land use is still striking. The 11 million km^2 of land used for crop production provides 83% of global caloric supply and 67% of food protein supply.[57]

[55] Benson Kibiti and Heniz Strubenhoff, "How Off-Grid Cold Storage Systems Can Help Farmers Reduce Post-Harvest Losses," Brookings, October 16, 2019.
[56] Stephen D. Porter et al., "Avoidable Food Losses and Associated Production-Phase Greenhouse Gas Emissions Arising From Application of Cosmetic Standards to Fresh Fruit and Vegetables in Europe and the U.K.," Journal of Cleaner Production, Volume 201, August 2018.
[57] Hannah Ritchie, "Half of the World's Habitable Land Is Used for Agriculture," Our World in Data, November 11, 2019.

Figure 57. Land Area Used for Food Production



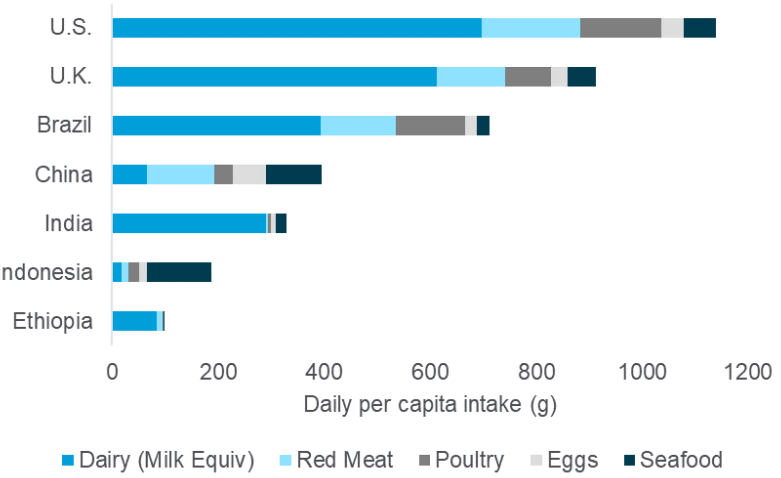
Source: Our World in Data

On average, the agriculture system produces 23.7 million metric tons of food daily, and the total daily value of agriculture production is an estimated $7 billion.[58] Cereals, roots, tubers, fruits, and vegetables account for 82% of daily production. While meat makes up only 5% (1.1 million metric tons) of production, 36% of the crop calories produced go straight to animal feed.[59] To put it simply, not only are we using the vast majority of agricultural land for livestock, much of the crops we do produce are also used to feed that livestock.

While we are not, of course, advocating that everyone moves to a completely plant-based diet overnight, if we are serious about tackling the challenge of food insecurity, reduced consumption of meat and dairy could potentially help to alleviate the situation. This is clearly a bigger issue for the developed world, where diets tend to include greater proportions of meat and dairy, as shown in Figure 58 below.

[58] FAO, *Building a Common Vision for Sustainable Food and Agriculture: Principles and Approaches*, 2014.
[59] Emily S. Cassidy et al., "Redefining agricultural yields: From Tonnes to People Nourished Per Hectare," *Environmental Research Letters*, Volume 8, No. 3, 2013.

Figure 58. Daily Per Capita Food Intake for Select Countries



Source: Our World in Data, Citi GPS

As before, this problem is only likely to get worse. Meat consumption is rising across the globe, particularly in developing countries as people acquire more wealth. Global consumption of meat proteins over the next decade is expected to increase by 14% in 2030 compared to the period from 2018-20, driven primarily by population growth and income.

The World Resources Institute estimates a 56% food gap between crop calories produced in 2010 and the crop calories needed in 2050. Accordingly, it is important that we use the food we do produce to meet these calorific demands in the most efficient way possible.

So how might we go about changing diets — something that is a deeply personal choice and often rooted in tradition and cultural preferences? The answer comes from potential changes at a personal/consumer level, an industrial level, and a governmental level.

Consumers

Consumers have significant influence over the direction of the global food system. They express their preferences through their purchases and help shape the decisions food manufacturers and retailers make. Their influence is growing, as they consider what to buy, why they buy it, and where they purchase their goods. Consumers are increasingly demanding to know and understand what ingredients are going into their food products as well as where their products are sourced from. Sustainability concerns are growing among consumers, which is why we are seeing many companies move towards better labeling and sourcing of their products. Consumers can demand food that is healthier, more nutritious, and more sustainable. As above, consumers can also change their diet to one that is less meat intensive — this does not necessarily mean becoming vegan or vegetarian but moving to a diet that consists of more fruit, vegetables, nuts, and healthy oils. We are already seeing evidence of this happening. For example, manufacturers have responded to skyrocketing demand for plant-based products in many countries — from milks to yogurts, ice cream, and meat.

Private sector

The private sector will of course adapt to consumer demand, but it is, no pun intended, a chicken-and-egg situation. If food manufacturers and retailers devote more attention (as is indeed happening) to producing meat-free alternatives and providing greater choice (and more information) at a retail level, this can go hand in hand with consumer-driven change. As we have seen in developed markets, consumers are typically willing to pay slightly more for sustainable products — and hence are also open to consumer education and awareness — which can be driven by the food industry and can help re-tilt diets, without necessarily impacting the important bottom line for the private sector. The investment community is also helping to drive change at a corporate level, given the dramatic rise in environmental, social, and governance (ESG) and sustainable investing, and the impact, both positive and negative, of those investments.

Government/public sector

Many governments are contemplating adding a tax on meat to encourage consumers to move towards a more plant-based diet and help cover the environmental costs resulting from livestock production. Politicians in Germany have proposed raising the VAT (value-added tax) for meat products from 7% to 19%. Standard VAT rate in Germany is 19%, but most foods including meat benefit from a reduced VAT rate of 7%. The European Union had a discussion on introducing a meat tax. Meanwhile, the government of New Zealand proposed to bring meat and dairy farms into its emissions trading system by 2025; this is still being discussed with the relevant parties. Introducing any tax — especially a sin tax such as this — is controversial, as politicians are not keen to tell people what they should be eating. It does happen though; for example, a sugar tax was introduced in the U.K. on sweetened drinks.

On the one hand, the Institute for New Economic Thinking finds that meat is significantly underpriced when the relevant externalities are taken into account. It states that consumption taxes on meat can help mitigate the negative environmental effects of meat production and could lead to a substantial decrease in emissions.[60] On the other hand, a Lee et al. (2021) study estimates that a meat tax would cost the U.K. $310 million per year, and could do more harm than good.[61] The authors state it will be more beneficial to look at which areas are best suited for cattle and sheep farms, and which areas should be turned into other uses, such as cereal production or even agroforestry. According to the TAAP (True Animal Protein Price) Coalition, consumers in Europe are more open to the idea of a meat tax, if the tax revenues are used to reduce VAT on fruit and vegetables. Reducing the prices of fruit and vegetables is a good idea, as many of these perishable products are expensive compared to other off-the-shelf products.

Governments can do other things to encourage consumers to reduce their meat consumption, such as promote “meatless Mondays” and invest in better public health campaigns. Given today’s inflationary food price environment, it is hard to see how any government would increase taxes on food products now; however, this could change in the future.

[60] Franziska Funke et al., “Is Meat Too Cheap? Towards Optimal Meat Taxation,” *Review of Environmental Economics and Policy*, Vol. 16, No. 2, January 2022.
[61] M.R.F Lee et al., “Nutrient Provision Capacity of Alternative Livestock Farming Systems per Area of Arable Farmland Required,” *Scientific Reports*, Volume 11, 2021.

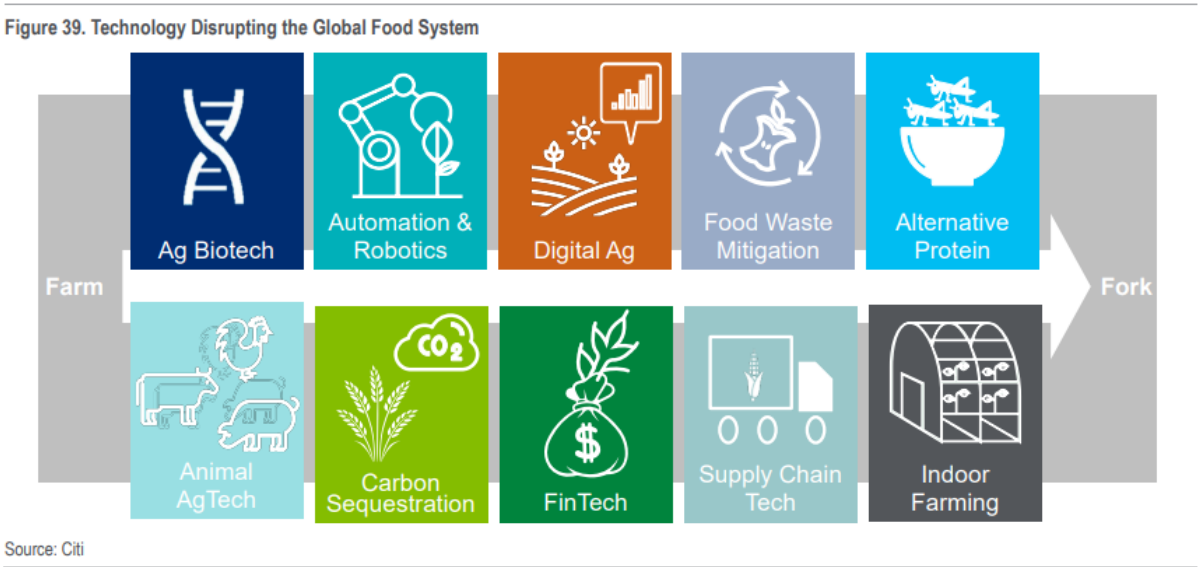
The downsides of switching diets

As always, there is no such thing as a "free lunch," and there are negative implications to consider too in changing global diets. The meat and dairy industry is complex, involving hundreds of companies from farmers, to meat processing facilities, distributors, retailers, and consumers. According to the FAO, livestock contributes 40% of the global value of agriculture output and supports the livelihoods and food and nutritional security of almost 1.3 billion people. Globally, 500 million pastoralists rely on livestock herding for food, income, and as a store for wealth in times of need. It is important that for a just transition to happen in the global food system, these people are included in the process of re-tilting our diets and reducing emissions from this sector. With so many of the world's poorest people working in agriculture, and agriculture being typically a larger part of less developed economies as we saw earlier, any proposed switching of diets must be done in such a way that it does not harm the very people that it is trying to help.

Technological Solutions – The Rise of AgTech

The world is at a tipping point. Two of the largest challenges facing humanity — climate change and food security — are becoming more intertwined, making the need for technology and other innovations to tackle these problems more essential than ever. Technology has always enabled agriculture to evolve, but for most of history, the goal has been yield improvement. Climate change, combined with food security issues, have caused a rethink of the role of agriculture, and once again, technology is offering hope.

Figure 59. Technology Disrupting and Evolving the Global Food System



Source: Citi GPS

This is not the first time that food security has been in the news — as some might remember, in the second half of the 20th century, there were growing concerns about the ability to feed a rapidly growing global population. This led to the emergence of Nathan Borlaug who, along with other agronomists and plant scientists, successfully increased crop yields, doubling global food output from 1960 to 2000. Many titled this the "Green Revolution" and Nathan Borlaug received a Nobel Peace Prize in 1970 for his role in fighting global hunger.

Innovations in agriculture during the past century include the Haber-Bosch process of producing synthetic fixed nitrogen (chemical fertilizers); equipment mechanization; crop protection and hybrid seeds; and, more recently, the use of biotechnology through the development of genetically modified (GMO) seeds, which have been hugely successful in driving up yields in key agricultural crops. Despite all the progress made, we have not solved food insecurity. Furthermore, although Nathan Borlaug's "Green Revolution" increased crop yields in both developing and developed countries alike, it has become apparent that this type of "industrial agriculture" has been the cause of significant environmental damage to soil, ground water, lakes, rivers, streams and oceans. The challenge we face today is how we feed approximately 10 billion people in 2050, roughly 23% more than today's population, while using fewer, rather than more, resources, such as chemical crop inputs (e.g., fertilizers and pesticides), energy, land, and water. In 2007, Megan Clark, the head of Australia's national science agency, the Commonwealth Scientific and Industrial Research Organization, noted that the world will have to produce more food in the next 50 years than we have in the thousands of years since civilization began. Luckily, we are seeing the emergence of new technology that, if adopted by the agriculture sector, has the chance to feed the world's population, without destroying our planet.

Although there is a growing focus on sustainability globally, countries threatened with food insecurity are unlikely to implement policies that focus on sustainability, unless the solutions to solve the food crisis happen to be more sustainable. Whereas political leaders in developed countries without food security concerns might prefer to push more sustainable food initiatives, those running countries where food insecurity is very real must make finding ways to feed their population the top priority. With the recent fall of Sri Lanka's government and the Arab Spring, which occurred a decade ago, still in the minds of political leaders, feeding people will be their key concern, rather than lower emissions.

Technology has changed the way we live our lives and impacted all sectors of the economy, including AgTech and FoodTech, where we are beginning to see the emergence of innovations that can have a sustained impact on reducing food insecurity as well as providing food self-sufficiency. The decision by some countries to ban exports of key agricultural products is forcing those countries, which are net food importers, to look for ways to grow more agricultural products domestically. Food self-sufficiency also is likely to drive the increased adoption of sustainable technologies, including alternative proteins and indoor farming, which can be utilized in countries with climates not suitable to growing produce or raising animals outdoors. Additionally, automation and robotics, digital agriculture, and food waste mitigation are solutions that all countries will be able to use to make their food systems more efficient, improve food security, and reduce their impact on climate change.

So, which technologies look the most promising? Alternative proteins (whether cultivated or fermented as well as insect-, mycelium-, and plant-based) have generated significant consumer interest, leading to billions of dollars in investment over the last few years. Whereas much of the initial growth in the sector was driven by plant-based protein (think burgers and breakfast sausage made from soy, yellow pea, and other traditional row crops), other protein types are beginning to catch the eye of consumers and investors. Of the different technologies emerging, the one with the biggest opportunity to be a direct replacement for traditional animal protein is cultivated meat, which is grown from a small amount of cells, harvested from a living animal. These cells are fed nutrients like amino acids, vitamins, glucose, and inorganic salts. Then, the cells are grown into meat at a rapid rate using a bioreactor.

From start to finish this process takes about 14 days to create cultured chicken, which is much faster than raising a traditional broiler chicken, which takes between six and 10 weeks from chick to slaughter. The advantages of cultivated protein make it a tremendous investment opportunity in the long term. It is likely to be many years before companies using this technology will achieve the unit economics or scale needed to take meaningful market share from conventional animal protein.

One technology that seems to be getting closer to competing with animal proteins is precision fermentation. Consumers of beer and wine will be familiar with fermentation using yeast to create alcohol. Precision fermentation is a little bit different, as it uses specific fungi to generate specialized organic molecules, including specific proteins, enzymes, or fats, depending on the precise strain of fungus or bacteria. Precision fermentation typically requires the use of genetically engineered microorganisms, which have had the code of the desired protein's DNA inserted, in order to create very large quantities of a single critical molecule of protein. Products made through precision fermentation can not only create stand-alone proteins, but can also combine with plant-based and other proteins, like egg whites, cheese, or infant formula, to improve the taste and texture. More companies are bringing products to market using precision fermentation; these products are benefiting from taste and texture improvements over traditional plant-based proteins.

Fungus can help with alternative meats in another, completely different way. Many fungi grow long threads called mycelia that are a bit like a plant's roots. These threads are made up of linear proteins. Mycelium can be grown in indoor farms to create products that have linear proteins, and hence, exhibit a texture that is much more like traditional meat than extruded pea- or soy-protein, which is how most plant-based proteins are made. Equally importantly, unlike pea or soy isolates, the key inputs in plant-based proteins, mycelium does not have a particular taste, which means it is relatively easy to create a desired flavor. Products derived from fungus are poised for strong growth in the coming years.

Insect-based protein is another technology that has tremendous potential, although more likely in non-human consumption areas. In this process, insects are used to convert organic waste (bio-waste) into protein and compost. The process typically has insect larvae feed on a substrate of organic waste, including animal feces, waste from row crop production, and slaughterhouse waste. The insects are harvested within two weeks and processed into oils or meals with a high protein content. The protein is very rich and has a good balance of amino acids. The residue is organic fertilizer, which has become even more valuable recently, since chemical fertilizers are more expensive and harder to purchase. Fertilizer is another key to optimizing food production, so procuring more sustainable fertilizers is becoming even more essential, not only for food security, but also for reducing carbon emissions. There are many different types of insects with the potential to be used to create protein, but the two with the most interest are black soldier flies and mealworms. Insects are among the most effective convertors of waste and other by-products into protein, using less land and water. The negative of insect protein is that many consumers, especially in the developed world, cannot bring themselves to eat bugs, which is why most of what is produced goes to animal feed, aquaculture, and pet food.

After experiencing tremendous growth in 2020 and 2021, sales of plant-based proteins have slowed as the novelty has worn off. Furthermore, many consumers have soured on plant-based proteins, unconvinced about the health benefits and nutritional value of these products and lingering concerns about taste and texture. In the meantime, investment into next-generation alternative proteins, including cultivated proteins and fermentation-, insect-, and mycelium-based proteins, has increased rapidly, as more countries see this as a route to make up gaps in protein demand and potentially even become an option for protein self-sufficiency. Next-generation alternative proteins are generating increasing interest from both food security and climate-change perspectives. By using animal cells, fungus, insects, mycelia, sugar, and waste streams as key product inputs, they reduce the need for chemicals, energy, land, and water to grow row crops like soy or peas as the first step in developing proteins. Additionally, since production occurs inside large factories, the risk of growing crops outdoors under increasingly volatile climate conditions is mitigated. With protein consumption continuing to rise, and many countries without the ability to raise enough animals domestically to meet demand, viable alternative protein options like these will be a key to reducing food insecurity.

There are a number of issues still to overcome, including whether consumers are willing to eat proteins grown in labs from animal cells and fungi, let alone insects; whether governments will move quickly enough with regulatory approval to foster these new technologies; and whether established industry stalwarts will overpower the newcomers through strong lobbying efforts and deep pockets to fight any changes in a sector with over $1 trillion in annual sales.

Another technology that tackles both food insecurity and climate change is indoor farming. In the developed world, many consumers are choosing indoor grown produce because they regard it as more sustainable, due to its lack of use of fungicides and pesticides, its smaller land footprint, its reduced water usage, and its ability to be grown closer to the consumer, making it fresher and more “farm-to-table.” For a number of developing countries with worries about having to import food, indoor farming is the best option as a source of year-round produce. Growing food closer to end-consumers also helps to reduce the environmental impact of the global “cold chain,” which is used to move perishable items around the world.

There are two types of indoor farms: greenhouses, which use sunlight as at least part of their energy source; and vertical farms, which use artificial light, typically light-emitting diodes (LEDs), and no sunlight. Greenhouses are a well-established technology, having been used for growing crops indoors for over 150 years. Modern greenhouses have the latest technologies, including automation, data analytics, energy efficient heating, ventilation, and air conditioning (HVAC) and lighting systems. Thus, coupled with economies of scale, these new greenhouses have the potential to become cost-competitive with organic produce, to achieve profitability. Vertical farms have mostly proliferated as a result of the rapidly declining prices of LED lights. Seed companies are developing genetics to take advantage of optimized growing conditions, including the replacement of sunshine with more reliable and predictable LED lights. Such controlled indoor environments provide significant advantages compared to the outdoor field, which is subject to the whims of Mother Nature.

Figure 60. Greenhouse

Source: Total Energy Group

Figure 61. Vertical Farm

Source: Fluence Bioengineering

The challenge of indoor farming is that the countries that would benefit most are in regions close to the equator, where building facilities that can operate at the optimal temperature can be challenging and costly. Additionally, running an indoor farm can be energy-intensive and expensive in countries where energy costs are high and the electricity grid is not always reliable.

Restorative aquaculture is another area of potential, where rivers and seas that have been heavily polluted by runoff from agriculture, shipping, and mining can be substantially improved by growing food in the form of bivalves (i.e., aquatic mollusks with a hinged shell) and seaweed. Clams, oysters, and other bivalves sequester many pollutants including heavy metals, runoff nitrogen, and phosphorous, among others. While this does not immediately sound great for consumption, bivalves have the unusual ability to sequester pollutants in their shells, while leaving their meat clean for human consumption. They are therefore are high-quality protein sources that actively improve local water conditions. Unlike expensive restoration projects, restorative aquaculture can be practiced as a business that is self-sustaining. The world is demanding more protein as populations move out of poverty, and protein from bivalve operations can help meet this demand without shifting to even more meat cultivation, with all its resource and environmental implications. The Nature Conservancy recently published an estimate that expansion of restorative aquaculture and improved wild fishery management could sustainably increase food from the ocean by between 36% and 74% by 2050.[62]

Other options in aquaculture include integrated multi-trophic aquaculture, where two or more aquatic species are farmed together (e.g., oysters, scallops, or mussels, which feed on the excretions of species of fish, with sweet sugar kelp filtering the water and native sea cucumbers sucking up heavier organic matter).

[62] The Nature Conservancy, *Foodscapes: Toward Food System Transition*, November 2021.

Food Waste

It will take years before alternative proteins and indoor farms can make a real impact on reducing food insecurity. In the meantime, food waste mitigation is, as we have seen, the easiest and most cost-effective way to tackle this problem. Food waste remains a huge issue globally as over 30%, of food grown annually — equating to $2.6 trillion — is not consumed, according to the UN's Food and Agriculture Organization (FAO). Reducing food waste is the most important path to a more sustainable agriculture system, allowing farmers to use less scarce resources (land and water) as well as polluting crop inputs (chemical fertilizer and pesticides).

Through creating a more efficient food system, food waste reduction would lead to decreased emissions as well as reduced need for cold storage infrastructure, crop inputs, farmland, transportation, and water for items grown that are never consumed. Food waste mitigation will be essential to ensuring there is enough food to feed a population projected to reach almost 10 billion people by 2050. Long term, the best tools for averting a food crisis, and the resulting political instability, are solutions that promote sustainability and efficiency.

There are plenty of technologies being developed to reduce food waste. One of the key goals is to extend the shelf life of perishable foods, typically produce and proteins. Companies are emerging that use natural substances which safely coat produce and proteins to maintain moisture and reduce oxidation, while at the same time providing a longer time frame for products to be consumed before they spoil. Other technologies use active ingredients in product packaging to reduce or prevent mold and decay; or neutralize the effects of ethylene, a hormone that many fruits and vegetables release which self-triggers continued ripening and eventually, spoilage. Other ways to reduce food waste include technologies for more effective food inventory management, and lower-tech business models like finding uses for imperfect produce and turning food waste into fertilizer and pet food.

As with other industries, including the manufacturing sector, improved production efficiency has been achieved through the use of automation and robotics, the Internet of Things (IoT) and other advanced technologies (artificial intelligence, data analytics, and machine learning). These same technologies are coming to the agriculture sector and offer tremendous opportunities to help with food security. Their implementation will be important for helping farmers, particularly in less developed countries, to improve crop yields and reduce on-farm waste. Additionally, these technologies also will play a major part in making the farm more sustainable by decreasing the amount of fuel used for farm machinery and enabling crop inputs to be used on specific problem areas rather than over entire fields.

- **Ag Biotech:** Agricultural biotech is a broad term that includes many different applications including the production of plants that are disease resistant, plants with enhanced nutrition content, and plants with improved yields with less inputs. Large agribusinesses have been working in biotech for many years; however, a number of start-up companies are now adopting and developing new capabilities in this sector. These include products that can enhance nutrient uptake in crops to improve crop health and increase yields. If scaled up globally, this technology has the possibility of significantly improving efficiencies in the food system, reducing the amount of land required and subsequently reducing emissions.

- **Automation and Robotics:** Automation and robotics includes equipment used on the farm that replaces human labor. In many countries, farm labor shortages are having a huge impact on the industry. Some applications of these innovative technologies include using artificial intelligence to help with weeding, robots that help harvest fruits and vegetables, robots that help collect visual data from farms and help farmers spot plant diseases, and aerial drones that carry sensors to monitor crops. These innovations can help reduce labor costs and make a farm more efficient by growing more food with fewer inputs.

- **Digital Agriculture:** Digital agriculture is defined as the use of new and advanced technologies to enable farmers to improve crop production. A number of technologies fall under this category, including precision agriculture, tractors equipped with GPS (Global Positioning System), and optimization platforms. Real-time and accurate ground-truth data on a farm can really help farmers optimize their inputs such as fertilizer and water use, maximize their yields, and manage farm logistics.

- **Animal AgTech:** Animal AgTech includes new solutions related to improving the sustainability of livestock production. It includes a number of different themes including smart livestock and dairy farming, precision and herd management solutions, breeding, and genetics. For example, mobile applications are being developed to integrate the operational management and analytics of cattle farming on a single platform, allowing farmers to optimize their farming practices. There are also products that can capture methane directly from livestock.

- **Fintech:** For many farmers the decision to grow certain crops, invest in new and efficient farming methods that could lead to more sustainable production, and purchase new equipment relies on their access to finance. Fintech is enabling many rural farmers to gain access not only to banking services, but also to new and innovative insurance products as well as new market opportunities.

- **Supply Chain Tech:** The supply chains of food are complex, with many different key stakeholders involved — from farmers to commodity traders, food manufacturers, retailers, and others. Sometimes a firm might not have any visibility of its supply chain and have no idea where its raw ingredients actually come from. Several new technologies are emerging — such as blockchain, supply chain analytics, and logistics platforms — that can help companies trace their supply chain, improve food safety, and generate efficiencies by reducing waste across the system.

Technology Summary

There is no bigger statement to how technology is emerging as a solution to food security than the billions of dollars being invested into alternative proteins and indoor farming. In particular, we are witnessing accelerating investment by development authorities and sovereign wealth funds, particularly from Asia and the Middle East, into companies that are able to provide food domestically in countries unable to produce outdoors.

The agriculture sector might be one of the last industries to undergo a tech revolution, but it is arguably the most important one. Demands for action to mitigate climate change are not just coming from environmentalists, but from the top-most echelons of corporations and governments. It is true that environmental sustainability has been the focus during the past few years, but politicians are now facing the real prospect of not being able to feed their citizens. With food insecurity likely to become even more pressing in 2023, society's best hopes for solving food security also happen to be technologies that are good for the planet.

Financial Solutions

Traditional Types of Financing

In order to combat the global food crisis, the world must come together to provide financing that is accessible to governments, particularly in those countries where governments are under severe debt stress. In order to support these countries, the primary types of financing available comes in three forms:

1. Aid.
2. Investment.
3. Diplomacy.

Aid

Historically, providing immediate humanitarian aid to the severely hungry and malnourished has been a key lifeline to many, particularly in times of crisis when food insecurity spikes to unprecedented levels, both in scale and severity, such as in 2021. This aid not only helps to rebuild livelihoods after a disaster, but it can also help increase food production and thus improve the quality and quantity of food available.

An example of a successful aid program is the EU's policy on humanitarian food assistance, which has been in place since 2010. Since its establishment, the EU has helped more than 100 million people lacking access to enough safe and nutritious food. Emergency food assistance and nutrition comprised one-quarter of the EU's humanitarian aid budget in 2021. With the food crisis becoming increasingly dire, this share may grow even larger in 2022.[63]

The EU provides a significant portion of its assistance through cash transfers. Conditional cash transfers are arguably the most efficient form of giving aid as they are easier to sustain in the longer run, and perhaps even grow, due to their lower cost of delivery.[64] Conditional cash transfers are targeted to lower-income households, conditional on household investments in education or health, and have well-documented impacts of improving the utilization of health and nutrition services among mothers and children. This is because sometimes adequate food is available for purchase but lack of money (especially for victims of disasters) is the problem. In such cases, the EU finds that cash transfers are more efficient and effective at reaching and benefiting the most vulnerable than shipping food across the world.

However, one could argue that an aid program such as the EU's, which increases the local supply of food, may depress prices and thus undercut the income of rural farmers in the recipient nations, discouraging local production as a result. Since the lowest-income earners are often concentrated in rural areas and operating at a smaller scale, they are often not targeted by such large-scale projects. As a result, food aid may in fact disproportionately hurt low-income earners. Similarly, aid may not always reach the people who need it most in the case where local politicians are using aid for their own means or for political gain.

[63] European Commission, "Food Assistance: Factsheet," accessed October 18, 2022.
[64] John Loeser, Berk Özler, and Patrick Premand, "What Have We Learned About Cash Transfers?," World Bank Blogs, May 10, 2021.

There is also the possibility that countries may become dependent on donor countries for aid, which would exacerbate the crisis if the aid were to run out or end. For example, the timely and effective delivery of food assistance is currently at risk due to the simultaneous and sudden increase in needs and operational costs following the war in Ukraine, which poses huge risks to countries such as Afghanistan, Sudan, and Yemen, which were the largest beneficiaries of EU-funded food assistance in 2022.[65]

Investment

An alternative type of financing comes in the form of providing sustained investment in global agriculture to help farmers boost their harvests.

A prime example of agricultural development financing came in the form of President Barack Obama's ambitious food security initiative Feed the Future, launched in 2010.[66] The initiative aimed to boost agricultural productivity in countries with potential to become agricultural powers, enabling them to better manage and even possibly help prevent the next food crisis. The U.S. invests nearly $2 billion annually toward this aim, with a significant portion of the funds funneled into long-term investments. These include R&D for seeds that can resist heat and long droughts, and partnerships with the private sector to help small-holder farmers expand their customer base beyond selling locally.[67]

Feed the Future appears to have positive results. In the 12 countries where it operates, 23 million people have been lifted out of poverty, and there has been evidence of improved nutrition and greater resilience to unpredictable events. Along with alleviating poverty and malnutrition, countries that prioritized agricultural productivity investments — such as Ethiopia, Ghana, and Bangladesh — are better placed to manage the current food crisis.[68]

(c) Diplomacy

And finally, countries undertaking concerted diplomacy — particularly countries that are more developed — can help to mobilize more resources from donors, avoid export restrictions that can exacerbate the crisis, and lessen the burden on lower-income countries.

In addition, as a result of these countries providing financing facilities that are accessible to governments — such as the provision of loans at low rates with long maturities — governments will have the flexibility to deploy the funds in the most effective way without the concern of a near-term repayment date.

---

[65] European Commission, "Food Assistance: Factsheet," accessed October 18, 2022.
[66] Feed the Future, "Who We Are," accessed October 18, 2022.
[67] Center for Strategic & International Studies, "USAID Administrator Power on the State of Global Food Security and Nutrition," transcript, July 18, 2022.
[68] Ibid.

Innovative Types of Financing

In addition to these traditional types of financing, alternative resources, such as innovative financing mechanisms, are urgently needed for agriculture, food security, and nutrition. To maximize their contribution to food security objectives, these innovative financing mechanisms should, as much as possible, be targeted towards food production and supply, as well as family farming. These include but are not limited to (a) government debt relief, (b) investment in the latest technology, (c) hedging, and (d) policy changes.

(a) Financing in the Form of Debt Relief

An alternative way to boost direct financing to low-income countries that are currently facing food insecurity includes bilateral creditors coming together to provide substantial debt relief for countries on an unprecedented scale. In order to have a significant impact, relevant creditors (including non-Paris Club countries such as China) need to provide debt relief and restructuring.[69] More than a third of the world's most debt-distressed countries are also among those most indebted to Chinese lenders. However, many indebted economies are reluctant to ask for debt relief from China, fearing a loss of access to future funding, and Chinese institutions have tended to prefer reprofiling debts to outright relief. At the same time, deteriorating relations between China and the West have reduced the scope for co-operation in handling debt problems.

(b) Investment in the Latest Technology

However, it is not just the access to the financing that is important. Countries must also consider how they prioritize their spending, with expenditure on the ever-growing AgTech sector already reaping rewards.

The adoption of drought-tolerant varieties of seeds is expected to increase productivity and yield stability, as well as reduce exposure to the increasingly prominent risk of weather variability. Drought-tolerant maize varieties reduce risk, enabling producers to undertake investments that can generate high returns but were once thought to be too risky. For example, a study carried out across 840 farm samples in Uganda found that the adoption of drought-tolerant maize varieties led to a 15% increase in yields and a 30% reduction in the likelihood of crop failure.[70] The Drought Tolerant Maize for Africa project aims to increase maize yields by at least 1 ton per hectare under moderate drought conditions in 13 sub-Saharan African countries. This would represent a 20%-30% increase over farmers' current yields. The project provides smallholder farmers access to various drought-tolerant and disease-resistant seeds and offers support and training to African seed producers.[71]

[69] Ibid.

[70] Franklin Simtowe et al., "Impacts of Drought-Tolerant Maize Varieties on Productivity, Risk, and Resource Use: Evidence from Uganda," *Land Use Policy*, Vol. 88, No. 104091, November 2019.

[71] International Maize and Wheat Improvement Center, "Drought Tolerant Maize for Africa (DTMA)," accessed October 18, 2022.

Other types of seed genetics include those that offer natural resistance to pests, resulting in reduced need for pesticides. One example of this involves breeding soybean plants that produce a protein deadly to the larvae of corn rootworm, thus reducing the need to use insecticides to control this rootworm. When considering the total cost of pesticides, which includes both the cost to the farmer directly, as well as the indirect costs the chemicals have on the human health of populations, pesticides arguably cost double the amount they yield, estimated at between €1.3 billion and €13 billion annually in the United States.[72] As a result, any seeds that are able to reduce the need for pesticides will have a significant reduction in overall cost.

Costs can further be reduced through investment in the latest technologies to help farmers waste less fertilizer. For example, in Ethiopia, satellite mapping is being used to help farmers fine-tune their fertilizer application, which has resulted in a reduction of fertilizer waste by 40%-80%, with yields growing by as much as 200%.[73] Similarly, by installing solar-powered walk-in cold-storage rooms in markets, farmers gain a method to store their produce and prevent spoilage. This reduction of food production waste is particularly beneficial in countries like Nigeria, where 40% of the country's food production is lost.

Hedging

An alternative solution to mitigate the risk from crop volatilities involves agricultural producers implementing a hedging strategy. Hedging can help to make profits more consistent by establishing either a price floor or a price ceiling. When markets are predicting a bountiful harvest, a farmer will normally expect lower profits due to the likely surplus. Instead, the farmer may want to take advantage of locking in a price above their minimum profitability threshold, to offset that expected reduction in profits and lower their expected risk of production. Just as a strong harvest can lower prices, a weak harvest can prove to be detrimental to the profits of a farm.

Not only does such a hedging strategy benefit farmers in years of lower prices and lower production, but it can also help them to budget for future years as well as cover their production costs upfront, as they know exactly what they are getting paid from every harvest. On a larger scale, for food-exporting countries, governments that have implemented a hedging program know in advance exactly what their revenues will be from the agricultural sector, which can help them to budget their expenditures accordingly.

Not only is hedging a potential strategy for food exporters, but food-importing countries can also benefit via programs such as the World Food Programme, as can agri-commodity traders. Countries that are reliant on food imports are exposed to rising food prices. A successful hedging program could help ensure they can afford to import sufficient food volumes at all prices of the commodity, while also containing import costs. Similarly, programs such as the World Food Programme could benefit from fixing their prices up front, which can help mitigate cases such as the jump in cost of the group's aid programs by 46% in 2022, compared with 2019.[74]

---

[72] Wester van Gaal, "Pesticides 'Cost Double the Amount They Yield,' Study Finds," *EUobserver*, November 30, 2021.
[73] Center for Strategic & International Studies, "USAID Administrator Power on the State of Global Food Security and Nutrition," transcript, July 18, 2022.
[74] Gabriele Steinhauser, "Inside the Worst Hunger Emergency in a Half-Century," *Wall Street Journal*, July 20, 2022.

In addition to facilitating the buying and selling of food, agri-commodity traders have over the years expanded their business to include food production, processing, and manufacturing. As such, they could benefit from a similar hedging strategy to that of food-exporting countries by fixing the revenues they receive upfront.

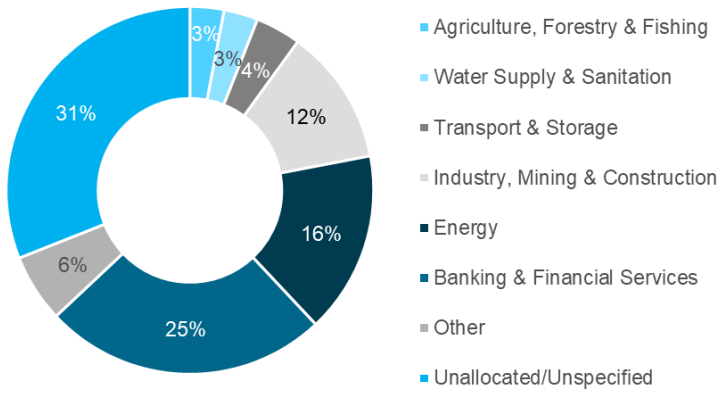
Public Private Partnerships: Blended Finance Structures

The solution to the food security crisis cannot be left to the public sector alone. Instead, a concerted effort between both the public and the private sectors is vital — for example, through the use of blended finance.

Blended finance is most often used to lower the risk of an investment. This can be done through guarantees, insurance, provision of a first-loss tranche, and offering technical assistance, for example. It can also enhance returns through incentives, interest rate subsidies, and directly topping up returns, among other things. Blended finance can also include activities such as donor-funded transaction advisory services, as well as promotion and convening, which help address the issues of high transaction costs.

Historically, blended finance has been used most at the fund level (35% of total finance) and for larger projects (median size $130 million), and disproportionately in the energy (35%) and agriculture (28%) sectors.[75] This is due in part to the higher costs of structuring a blended finance deal. However, once the structure has been developed, it can be replicated at much lower cost to mobilize private capital at scale.

Figure 62. Amounts Mobilized From the Private Sector, By Sector ($bn, 2019)



Note: Unspecified sectors are mainly a result of reporting data at aggregate level due to confidentiality constraints.
Source: Citi GPS, OECD, "Good Blended Finance Practices Can Scale Up Finance for Agri-SMEs," 2021

Blended finance can also reduce coordination and transaction costs that are common barriers to investment. Not all opportunities will meet the necessary risk-return profile that investors require. This lack of fit can be due to either a fundamentally lower return or higher risk; or to the novelty of the asset class, sector, or geography that has a high perceived risk but is otherwise investable at market rates.

[75] Convergence, *The State of Blended Finance 2021*, October 2021.

Figure 63. Benefits of Blended Finance

Source: Citi GPS

The agri-food sector presents plenty of opportunities for potential uses of blended finance, as it largely consists of small family farms and small and medium enterprises (SMEs). Blended finance can enable agricultural SMEs better access to more capital and targeted financial products to grow their businesses and their contribution towards combating food insecurity.

It is also important that blended finance programs are designed with room for the producers to experiment, innovate, and adjust, particularly in a sector such as agriculture, which is facing such rapid change as a result of climate change. Close consultation with local farmers and other target producers will enable insights into both supply and demand challenges associated with commercial finance.

Local institutions, including financial institutions, governments, and agri-food market players, are critical partners in developing and delivering blended finance solutions that can impact not only on individual transactions but also market factors underlying investment risk. Donor governments have the financial instruments to mobilize private finance for the agri-sector via their aid agencies, development finance institutions, or multilateral development banks.

Some existing case studies of successful application of blended finance in the agricultural sphere include:

Figure 64. Overview of Select Blended Finance Case Studies

Case	Country	Providers of Finance and/or Technical Assistance	Financing Structure and Instruments Used
Financing Ghanaian Agriculture Projects (FinGAP)	Ghana	USAID, Palladium	Payment by Result (PBR) Guarantees, TA
Programme for Rural Outreach of Financial Innovations and Technologies (PROFIT)	Kenya	Agricultural Finance Corporation of Kenya	Credit Lines, Guarantees, TA
Private Agriculture Sector Support (PASS)	Tanzania	DANIDA, SIDA, Tanzanian Government, Agriculture Sector Programme Support (ASPS)	Guarantees, TA
Blending Happiness, Hazelnuts and Finance in Bhutan:	Bhutan	ADB, Private Sector Window of GAFSP	Equity, Quasi-equity
Development of a Macauba-Based Silvopastoral System and Value Chain Implemented by Inocas	Brazil	IDB, Forest Investment Programme (part of the Climate Investment Fund), Althelia	Grant, Equity, TA
Social Trust Fund to incorporate vulnerable Smallholder Farmers into Paraguay's Chamomile Value Chain	Paraguay	Government of Paraguay, Fundacion Capital, Private Investors	Grants
Sustainable Landscapes Portfolio Guarantee	India	USAID, Rabobank Foundation	Guarantees
Family Farming Financing Programme (PROAF)	Mexico	Mexican Agriculture Development Bank (FIRA)	Guarantees, TA
CARD SME Bank	Philippines	Canadian International Development Agency (CIDA), CARD Bank	Debt, TA

Note: Not all providers of finance are listed.

Source: Citi GPS, OECD (2021)

The vast prevalence of small- and medium-enterprise-scale actors (often down to microfinance scale) in the food and agriculture space means that the availability of blended finance is of paramount importance, as attracting commercial capital on a standalone basis into enterprises at this scale and stage of development is likely to be extremely difficult, and in many cases, impossible. As the case studies from the above-referenced OECD report highlight, there are various mechanisms available to blend finance, from credit facilities to loans, grants, guarantees, and equity, all of which provide differing levels of flexibility and should ultimately increase the quantities of finance available. Alongside the financial, it is also important to highlight the importance of technical assistance, which can not only improve the effectiveness of the finance provided, but also serve to reduce risk.

Blended finance will not, of course be suitable for all types of projects; public or development finance will remain critical to many of these enterprises. However, blended finance provides an important potential solution to bringing commercial capital into the space by boosting the amount of capital available in the space. It can also help match risk tolerances of capital with risk profiles of projects, with the many and varied mechanisms on offer providing different situational and stage-of-development solutions. Given the dispersion of the food and agriculture sector, development finance and blended finance will remain critically important for the foreseeable future. However, blended finance will also help increase the knowledge and experience in the space for the providers of commercial capital. Hopefully, over time, this will lead to broader, deeper, and more liquid capital markets that can provide greater levels of commercial financing to this critical sector.

Geopolitical Solutions

Beyond the governmental options discussed earlier, there are other potential routes for the public sector to alleviate food insecurity and prevent or lessen the impact of any reoccurrence.

Policy Changes

Policy changes are important and needed. Even with all the innovative solutions and financing in the world, without proactive government policies to improve the availability and affordability of healthy diets, the prospect of food security is likely to be a long way off. First and foremost, more efficient use of public resources is necessary so that governments can achieve a greater impact without changing what they currently spend. This is doable by repurposing existing food and agricultural policy support to make healthy diets less costly and more affordable for everyone.

Current government support to food and agriculture often includes trade and market interventions, as well as fiscal subsidies to producers and consumers. However, these current subsidies are often market-distorting and do not reach the farmers that need them the most. As a result, it is important that governments work together to avoid export restrictions where possible, which can exacerbate the crisis. Since the outbreak of the Russia-Ukraine conflict, 24 countries have implemented such bans, restricting approximately 16% of all total calories traded globally. [76]

By contrast, free trade policies can allow countries to exploit their comparative advantages in economic activity, increasing average per capita incomes, longer-term growth rates, and capacity to fund social safety nets for lower-income earners. However, many countries abandoned those policies in favor of domestic protections in their efforts to mitigate the effects of short-run food crises. The policy challenge is therefore to resolve the tension between optimal long-run policies and short-run initiatives to address food security concerns.

1. **Support the Black Sea trade corridor:** With Ukraine holding a large, roughly 15 million metric ton (MMt) carryover stock of grains and additional vegetable oil capacity, shipping agriculture commodities to consumers will help temper price gains. This is as Russia itself has a record staple cereal harvest and bumper wheat crop and is starting to see physical trade rebound. Shut-in trade and sanctions risks were the biggest threats to global food security in the first half of 2022, but both have started to ease in the second half. This could continue in 2023 given the right political and policy will from state actors and leadership.

2. **Boost domestic production and fertilizer capacity:** Similar to calls for onshoring of energy production and manufacturing capacity, we could see a growing movement of economies pushing homegrown agriculture. While insufficient arable land, expertise, growing conditions, and climate do not make this feasible for all the major cash crops, incremental pushes could allow for more stable production and trade regimes. Farmland used to cultivate crops has been on a steady decline in the EU and growing slowly in the U.S., but we have seen massive growth in the Southern Hemisphere, especially in Brazil and sub-Saharan Africa. A policy push to allow for more incremental and dynamic production in the Northern Hemisphere (e.g., subsidies) could enhance supply and security.

[76] Center for Strategic & International Studies, "USAID Administrator Power on the State of Global Food Security and Nutrition," transcript, July 18, 2022.

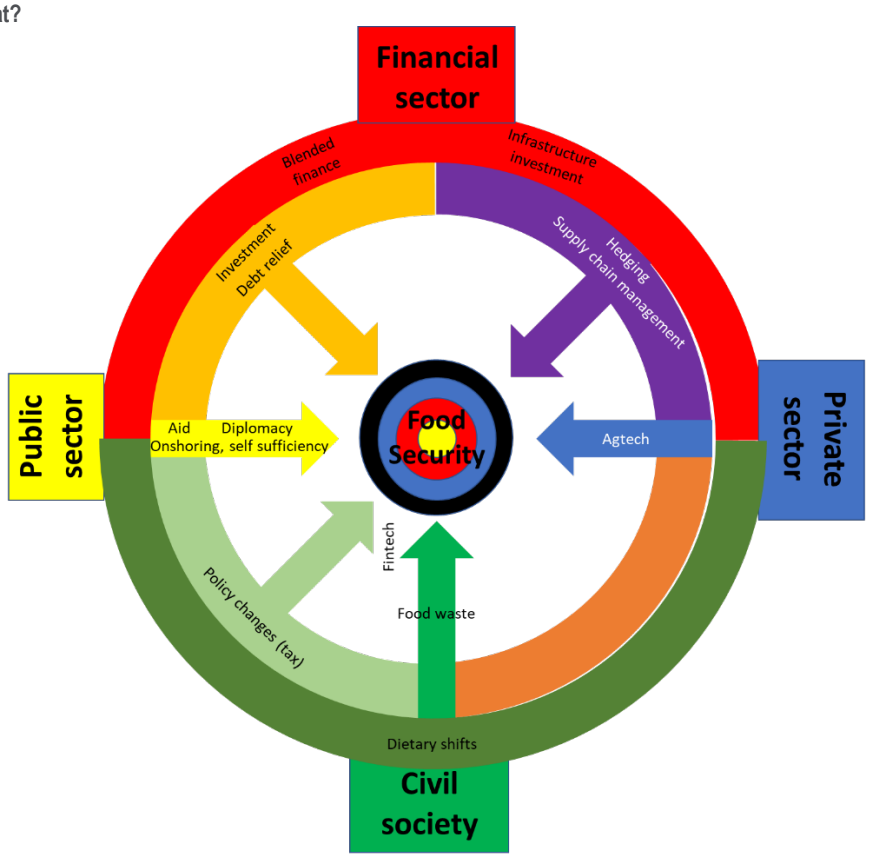
3. **China reserves:** China is the largest single holder of staple grains and cereal reserves globally. We expect its imports in in 2022-23 to slow versus 2021-22, which were lower than 2020-21. To the extent China wants to use its cereal stocks and fertilizer (especially nitrogen-based) as a geopolitical carrot, it could help consumer economies in larger deficit.

Conclusions and Recommendations – Who Does What?

Hopefully this report has highlighted that while food insecurity, hunger, and malnutrition are widespread and have primacy and immediacy versus many other pressing issues, there are many routes that we can take to alleviate the current issues, and potential solutions exist for the longer term. As we have seen, potential solutions range from the financial, through to the social and technological, as well as geopolitical opportunities.

But how do we make this happen, and which sector of society is best placed to do what? In this chapter, we attempt to construct an integrated approach to easing food insecurity, hunger, and malnutrition in the short and medium term, as well as to eradicate it for the longer term. We recognize that this is far from perfect — but we hope that this report has helped to further debate on this critical subject, and we look forward to continuing that debate with interested parties, from all sectors of society, and all around the globe.

Figure 65. Who Does What?



Source: Citi GPS

Figure 65 aims to combine all of the aforementioned proposed solutions, split by the sector(s) of society best placed to implement the changes needed. Clearly it is not perfect, but hopefully it focuses attention on how each sector of society can play its part in tackling food insecurity, hunger, and malnutrition around the world. As to-do lists go, it is about as important as it gets; our tasks are as follows:

- **Public Sector:** Focus on diplomacy, food self-sufficiency, and onshoring; enable and provide access to financing, potentially via blended finance, aid, or debt relief; and concentrate investment in infrastructure and food systems. Additionally, consider taxation and other incentives to promote healthier diets, focusing on incentives that utilize available agricultural resources most efficiently, and seek to eliminate food waste at all stages of the chain.
- **Private Sector:** Focus on food waste reduction and supply chain management and work with consumers to facilitate dietary shifts to a food system that effectively manages resources. Accelerate investment into AgTech, including vertical, indoor and digital farming; alternative proteins and precision fermentation; animal AgTech; and automation and robotics.
- **Financial Sector:** Facilitate investment in infrastructure for the public and private sector to enhance onshore production; eliminate food waste; build more efficient agricultural and food systems; provide financing vehicles such as blended finance and hedging facilities; and promote fintech across the agricultural chain.
- **Civil Society:** Focus on reducing and eliminating food waste and on dietary shifts, which can lead to more optimal usage of resources. Smaller and individual farmers should seek access to fintech solutions to improve financial inclusion, stabilize income, and maximize revenues.

Put like that, it does not look like much. It is, however, an enormous challenge that will take many years to filter through existing systems. But it is a challenge which we must embrace, not just for the sake of the 2.3 billion people who are currently hungry, malnourished, or worrying where their next meal is coming from — but for all of us, if we value the stability of our societies, and hold our humanity dear.

We started out with a *Grapes of Wrath* quote from John Steinbeck that succinctly encapsulates the primacy of food security over almost every other consideration. It therefore seems fitting to end with a quotation from his acceptance speech for the Nobel prize for literature, which he won in 1962:

"*Furthermore, the writer is delegated to declare and to celebrate man's proven capacity for greatness of heart and spirit — for gallantry in defeat, for courage, compassion and love. In the endless war against weakness and despair, these are the bright rally flags of hope and of emulation*."

The battle against food insecurity is indeed a war against weakness and despair, but as we have seen, there are many reasons for hope and much we can do. We must seize those "bright rally flags" and build a fairer, more stable, and more equitable society where no one has to go to bed hungry.

Citi Global Perspectives & Solutions (Citi GPS) is designed to help our clients navigate the global economy's most demanding challenges, identify future themes and trends, and help our clients profit in a fast-changing and interconnected world. Citi GPS accesses the best elements of our global conversation and harvests the thought leadership of a wide range of senior professionals across the firm.

All Citi GPS reports are available on our website www.citi.com/citigps

Energy Transition: Vol 1
Mixed Momentum on the Path to Net Zero
November 2022

Energy Transition: Vol 2
Building Bridges to Renew Momentum
November 2022

China's Inward Tilt
The Pursuit of Economic Self-Reliance
October 2022

Philanthropy v2.0
Reinventing Giving in Challenging Times
October 2022

Food and Climate Change
Sustainable Foods Systems for a Net Zero Future
July 2022

Home of the Future 2
PropTech – Towards a Frictionless Housing Market?
June 2022

Global Supply Chains
The Complexities Multiply
June 2022

Space
The Dawn of a New Age
May 2022

Investing for Outcomes
Why Impact Is Relevant Beyond Impact Investing
April 2022

Metaverse and Money
Decrypting the Future
March 2022

Global Art Market Disruptions
Pushing Boundaries
March 2022

Women Entrepreneurs
Catalyzing Growth, Innovation, and Equity
March 2022

Eliminating Poverty
The Importance of a Multidimensional Approach
February 2022

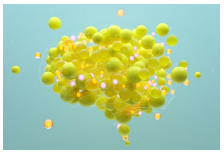
Global Supply Chains
The Complicated Road Back to "Normal"
December 2021

Philanthropy and the Global Economy
Opportunities in a World of Transition
November 2021

Education: Learning for Life
Why L&D is the Next Frontier in Global Education
November 2021

Home of the Future
Building for Net Zero
October 2021

Global Carbon Markets
Solving the Emissions Crisis Before Time Runs Out
October 2021

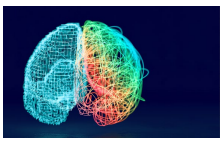


Disruptive Innovations VIII
Ten More Things to Stop and Think About
October 2021

Holistic Digital Policy
Nation States Must Lead in Building Equitable Human-Centric Digital Economies
October 2021

Biodiversity
The Ecosystem at the Heart of Business
July 2021

Natural Gas
Powering Up the Energy Transition
July 2021



Technology at Work v6.0
The Coming of the Post-Production Society
June 2021

Hard to Abate Sectors & Emissions
The Toughest Nuts to Crack
May 2021

Future of Money
Crypto, CBDCs and 21st Century Cash
April 2021

Systemic Risk
Systemic Solutions for an Interconnected World
April 2021

The Global Art Market and COVID-19
Innovating and Adapting
December 2020

Bitcoin
At the Tipping Point
March 2021

Financing a Greener Planet
Volume 1
Volume 2
February 2021

Electric Vehicle Transition
February 2021

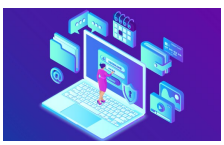
Investment Themes in 2021
January 2021

Education: Fast Forward to the Future
October 2020

The Holistic Case for Investment in Girls
October 2020

Closing the Racial Inequality Gaps
September 2020

Negative Interest Rates
Where Is the Real Limit to Cheap Money?
July 2020



ePrivacy & Data Protection
Data Privacy & its Influence on AI Ethics, Competition & Tech Evolution
July 2020

If you are visually impaired and would like to speak to a Citi representative regarding the details of the graphics in this document, please call USA 1-888-800-5008 (TTY: 711), from outside the US +1-210-677-3788

IMPORTANT DISCLOSURES

This communication has been prepared by Citigroup Global Markets Inc. and is distributed by or through its locally authorised affiliates (collectively, the "Firm") [E6GYB6412478]. This communication is not intended to constitute "research" as that term is defined by applicable regulations. Unless otherwise indicated, any reference to a research report or research recommendation is not intended to represent the whole report and is not in itself considered a recommendation or research report. The views expressed by each author herein are his/ her personal views and do not necessarily reflect the views of his/ her employer or any affiliated entity or the other authors, may differ from the views of other personnel at such entities, and may change without notice.

You should assume the following: The Firm may be the issuer of, or may trade as principal in, the financial instruments referred to in this communication or other related financial instruments. The author of this communication may have discussed the information contained herein with others within the Firm and the author and such other Firm personnel may have already acted on the basis of this information (including by trading for the Firm's proprietary accounts or communicating the information contained herein to other customers of the Firm). The Firm performs or seeks to perform investment banking and other services for the issuer of any such financial instruments. The Firm, the Firm's personnel (including those with whom the author may have consulted in the preparation of this communication), and other customers of the Firm may be long or short the financial instruments referred to herein, may have acquired such positions at prices and market conditions that are no longer available, and may have interests different or adverse to your interests.

This communication is provided for information and discussion purposes only. It does not constitute an offer or solicitation to purchase or sell any financial instruments. The information contained in this communication is based on generally available information and, although obtained from sources believed by the Firm to be reliable, its accuracy and completeness is not guaranteed. Certain personnel or business areas of the Firm may have access to or have acquired material non-public information that may have an impact (positive or negative) on the information contained herein, but that is not available to or known by the author of this communication.

The Firm shall have no liability to the user or to third parties, for the quality, accuracy, timeliness, continued availability or completeness of the data nor for any special, direct, indirect, incidental or consequential loss or damage which may be sustained because of the use of the information in this communication or otherwise arising in connection with this communication, provided that this exclusion of liability shall not exclude or limit any liability under any law or regulation applicable to the Firm that may not be excluded or restricted.

The provision of information is not based on your individual circumstances and should not be relied upon as an assessment of suitability for you of a particular product or transaction. Even if we possess information as to your objectives in relation to any transaction, series of transactions or trading strategy, this will not be deemed sufficient for any assessment of suitability for you of any transaction, series of transactions or trading strategy.

The Firm is not acting as your advisor, fiduciary or agent and is not managing your account. The information herein does not constitute investment advice and the Firm makes no recommendation as to the suitability of any of the products or transactions mentioned. Any trading or investment decisions you take are in reliance on your own analysis and judgment and/or that of your advisors and not in reliance on us. Therefore, prior to entering into any transaction, you should determine, without reliance on the Firm, the economic risks or merits, as well as the legal, tax and accounting characteristics and consequences of the transaction and that you are able to assume these risks.

Financial instruments denominated in a foreign currency are subject to exchange rate fluctuations, which may have an adverse effect on the price or value of an investment in such products. Investments in financial instruments carry significant risk, including the possible loss of the principal amount invested. Investors should obtain advice from their own tax, financial, legal and other advisors, and only make investment decisions on the basis of the investor's own objectives, experience and resources.

This communication is not intended to forecast or predict future events. Past performance is not a guarantee or indication of future results. Any prices provided herein (other than those that are identified as being historical) are indicative only and do not represent firm quotes as to either price or size. You should contact your local representative directly if you are interested in buying or selling any financial instrument, or pursuing any trading strategy, mentioned herein. No liability is accepted by the Firm for any loss (whether direct, indirect or consequential) that may arise from any use of the information contained herein or derived herefrom.

Although the Firm is affiliated with Citibank, N.A. (together with its subsidiaries and branches worldwide, "Citibank"), you should be aware that none of the other financial instruments mentioned in this communication (unless expressly stated otherwise) are (i) insured by the Federal Deposit Insurance Corporation or any other governmental authority, or (ii) deposits or other obligations of, or guaranteed by, Citibank or any other insured depository institution. This communication contains data compilations, writings and information that are proprietary to the Firm and protected under copyright and other intellectual property laws, and may not be redistributed or otherwise transmitted by you to any other person for any purpose.

IRS Circular 230 Disclosure: Citi and its employees are not in the business of providing, and do not provide, tax or legal advice to any taxpayer outside of Citi. Any statements in this Communication to tax matters were not intended or written to be used, and cannot be used or relied upon, by any taxpayer for the purpose of avoiding tax penalties. Any such taxpayer should seek advice based on the taxpayer's particular circumstances from an independent tax advisor.

NOW / NEXT

Key Insights regarding the future of Food Security

INFRASTRUCTURE

We currently waste up to one-third of good food produced annually, with an estimated cost of $1.25 trillion annually, while a third of the planet goes hungry. / Food waste must be addressed at every stage of the food chain – from the farm to retail, food providers, and households. Investment in better infrastructure and equipment as well as training to improve handling, process and storage practices will help.

INNOVATION

The agriculture and food industry has been operating in pretty much the same way for decades and embracing new technology and patterns that could disrupt the system can be difficult to embrace. / Innovations disrupting the global food system are emerging in areas such as agricultural biotech, digital agriculture, and food waste mitigation, among others.

SUSTAINABILITY

Traditional types of financing have helped smaller farmers but without a specific focus on boosting harvest. / Countries must consider how they prioritize their spending, especially in the ever-growing AgTech sector that focuses on seed genetics and fertilizer optimization.