

From our 2014  
special series on

THE FUTURE  
OF FOOD

by the editors of  
National  
Geographic

# NATIONAL GEOGRAPHIC

Farming is the world's  
largest endeavor. Only 55% of  
global crops go to nourish people.

A fourth of the world's people regularly eat  
insects. 48 million Americans rely on food  
assistance. Rice is Earth's most important food  
crop. 65% of Africa's labor force works in agriculture.

# FOOD

Nearly 100% of all biofuels come from food crops.  
Half of all food waste in the U.K. comes from  
private homes. We consume more farmed  
fish than beef. One in eight people—  
805 million worldwide—goes  
to bed hungry every  
night.





# Carrier Throughout the Cold Chain

FROM FARM TO FORK



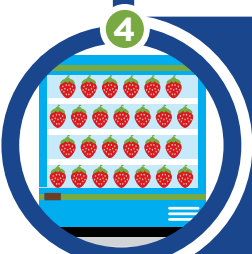
**1** Perishable cargo is loaded in containers refrigerated by Carrier's NaturaLINE™ unit, which can reduce the carbon footprint of container refrigeration by as much as 35% using natural refrigerant. On any given day, Carrier refrigerated containers move \$6 billion worth of perishable goods across oceans.



**2** Food is transported by road to supermarkets in Carrier refrigerated trucks and trailers using E-Drive™ all-electric technology, enabling fuel, noise, and emission reductions.



**3** Throughout the journey, temperatures are monitored by Sensitech to help maintain freshness, quality, and food safety.



**4** Food is displayed in refrigerated cases using Carrier's pioneering CO2OLtec™ natural refrigerant system, which has led to a reduction of greenhouse gas emissions equal to removing nearly 70,000 passenger cars from European roads.



# How will we feed a growing planet?

EFFECTIVELY MANAGING THE FOOD SUPPLY COLD CHAIN WILL AVOID WASTE, FEED MORE PEOPLE, AND PROTECT NATURAL RESOURCES.

At Carrier, we believe that greening the “cold chain”—the refrigerated delivery system—is a solution to reducing world hunger. From farm to fork, our product innovations at every stage of food transportation and display help reduce waste, increase food quality, and lower energy use. An effective cold chain will extend food supplies and help feed our growing population, which is projected to increase to 9.6 billion by 2050. Through advances in technology and collaboration with experts, Carrier intends to play a leading role in helping to keep food safer and more secure, allowing more people to be fed more sustainably.

To learn more, go to [carrier.com](http://carrier.com).

**1 BILLION**  
underfed people—and 2 billion tons of food waste.



If food waste was a country, it would be the **THIRD LARGEST** emitter of greenhouse gases in the world, after China and the United States.



**70%**  
of the world's accessible fresh water is used for agriculture.







**Gary E. Knell**  
President and CEO of  
National Geographic

We've been thinking a lot about food lately at National Geographic. This fall the National Geographic Channel presents the series *Eat: The Story of Food*. Our food blog, The Plate ([theplate.nationalgeographic.com](http://theplate.nationalgeographic.com)), hosts a variety of voices. We've delved into data by partnering with the UN Food and Agriculture Organization, conferring with experts to make visualizations of their statistics. Meanwhile the magazine has spent the year covering ways of feeding the planet. It's all part of an on-going conversation with readers about global issues. In recent years we've also run a series of stories on fresh water and another on challenges posed by the planet's growing population.

In this edited compilation you'll find the depth and breadth of *National Geographic's* food stories. Our coverage is available as an app through iTunes and will be free to download until November 15. We invite you to take a taste.

## Inside

### 4 A Five-Step Plan to Feed the World

It doesn't have to be industrial farms versus small, organic ones. There's another way. *By Jonathan Foley*  
*Photographs by George Steinmetz and Jim Richardson*

**26 BY THE NUMBERS** The farmers market boom

### 28 The Next Breadbasket

Why big corporations are grabbing up land on the planet's hungriest continent. *By Joel K. Bourne, Jr.*  
*Photographs by Robin Hammond*

**48 BY THE NUMBERS** Female farmers

### 50 The New Face of Hunger

Millions of working Americans don't know where their next meal is coming from. *By Tracie McMillan*  
*Photographs by Kitra Cahana, Stephanie Sinclair, and Amy Toensing*

**70 BY THE NUMBERS** Food waste

### 72 The Evolution of Diet

Some experts say modern humans should eat from a Stone Age menu. What's on it may surprise you. *By Ann Gibbons*  
*Photographs by Matthieu Paley*

**92 BY THE NUMBERS** Biological control agents

### 94 The Next Green Revolution

Modern supercrops will be a big help. But agriculture can't be fixed by biotech alone. *By Tim Folger*  
*Photographs by Craig Cutler*

National Geographic thanks **The Rockefeller Foundation** for its generous support of the series.

This compilation was made possible by advertising support from **United Technologies, Land O'Lakes, Cargill, and Bayer CropScience.**

To download the digital version, go to:  
[natgeofoodapp.com](http://natgeofoodapp.com)

**LAND O'LAKES, INC.**



Land O'Lakes, Inc. is a farmer-owned food and agriculture cooperative with global reach. From farm to market, with innovative ideas and strategic partnerships, we're committed to focusing on solutions that increase productivity and sustainability around the food we eat.

**1 BILLION PEOPLE** go to bed hungry each day.

**9.6 BILLION PEOPLE** will live on the planet in 2050.

**50 YEARS** In the next 50 years, the global demand for food will exceed that of the last 500 years.

**BUT TODAY...**

**145 MORE PEOPLE** are fed per farmer compared to **83 YEARS AGO.**

We can get **MORE FOOD** from **FEWER RESOURCES.**

Collaboration, innovation, and technology will give us the tools to feed our **GROWING POPULATION.**

Go to [foodchallenge.landolakesinc.com](http://foodchallenge.landolakesinc.com) to follow the conversation.

Where will we  
find enough food  
for 9 billion?

*It doesn't have to be industrial  
farms versus small, organic ones.  
There's another way.*

## A Five-Step Plan to **Feed the World**

*By Jonathan Foley*

*Photographs by George Steinmetz and Jim Richardson*





On the Vulgamore farm near Scott City, Kansas, each combine can harvest up to 25 acres of wheat an hour—as well as real-time data on crop yields. Most of the food Americans eat is now produced on such large-scale, mechanized farms, which grow row after row of a single crop, allowing farmers to cover more ground with less labor.

GEORGE STEINMETZ





At Granja Mantiqueira in Brazil eight million hens lay 5.4 million eggs a day. Conveyor belts whisk the eggs to a packaging facility. Demand for meat has tripled in the developing world in four decades, while egg consumption has increased sevenfold, driving a huge expansion of large-scale animal operations.

GEORGE STEINMETZ



On the Bassetti farm near Greenfield, California, workers harvest celery to be shipped to retail outlets in the U.S. and Asia. Dubbed “America’s salad bowl,” the Salinas Valley relies on groundwater for irrigation, which could be at risk if the current drought continues.

GEORGE STEINMETZ







*When we think about threats to the environment, we tend to picture cars and smokestacks, not dinner. But the truth is, our need for food poses one of the biggest dangers to the planet.*

Agriculture is among the greatest contributors to global warming, emitting more greenhouse gases than all our cars, trucks, trains, and airplanes combined—largely from methane released by cattle and rice farms, nitrous oxide from fertilized fields, and carbon dioxide from the cutting of rain forests to grow crops or raise livestock. Farming is the thirstiest user of our precious water supplies and a major polluter, as runoff from fertilizers and manure disrupts fragile lakes, rivers, and coastal ecosystems across the globe. Agriculture also accelerates the loss of biodiversity. As we've cleared areas of grassland and forest for farms, we've lost crucial habitat, making agriculture a major driver of wildlife extinction.

The environmental challenges posed by agriculture are huge, and they'll only become more

pressing as we try to meet the growing need for food worldwide. We'll likely have two billion more mouths to feed by mid-century—more than nine billion people. But sheer population growth isn't the only reason we'll need more food. The spread of prosperity across the world, especially in China and India, is driving an increased demand for meat, eggs, and dairy, boosting pressure to grow more corn and soybeans to feed more cattle, pigs, and chickens. If these trends continue, the double whammy of population growth and richer diets will require us to roughly double the amount of crops we grow by 2050.

Unfortunately the debate over how to address the global food challenge has become polarized, pitting conventional agriculture and global commerce against local food systems and organic

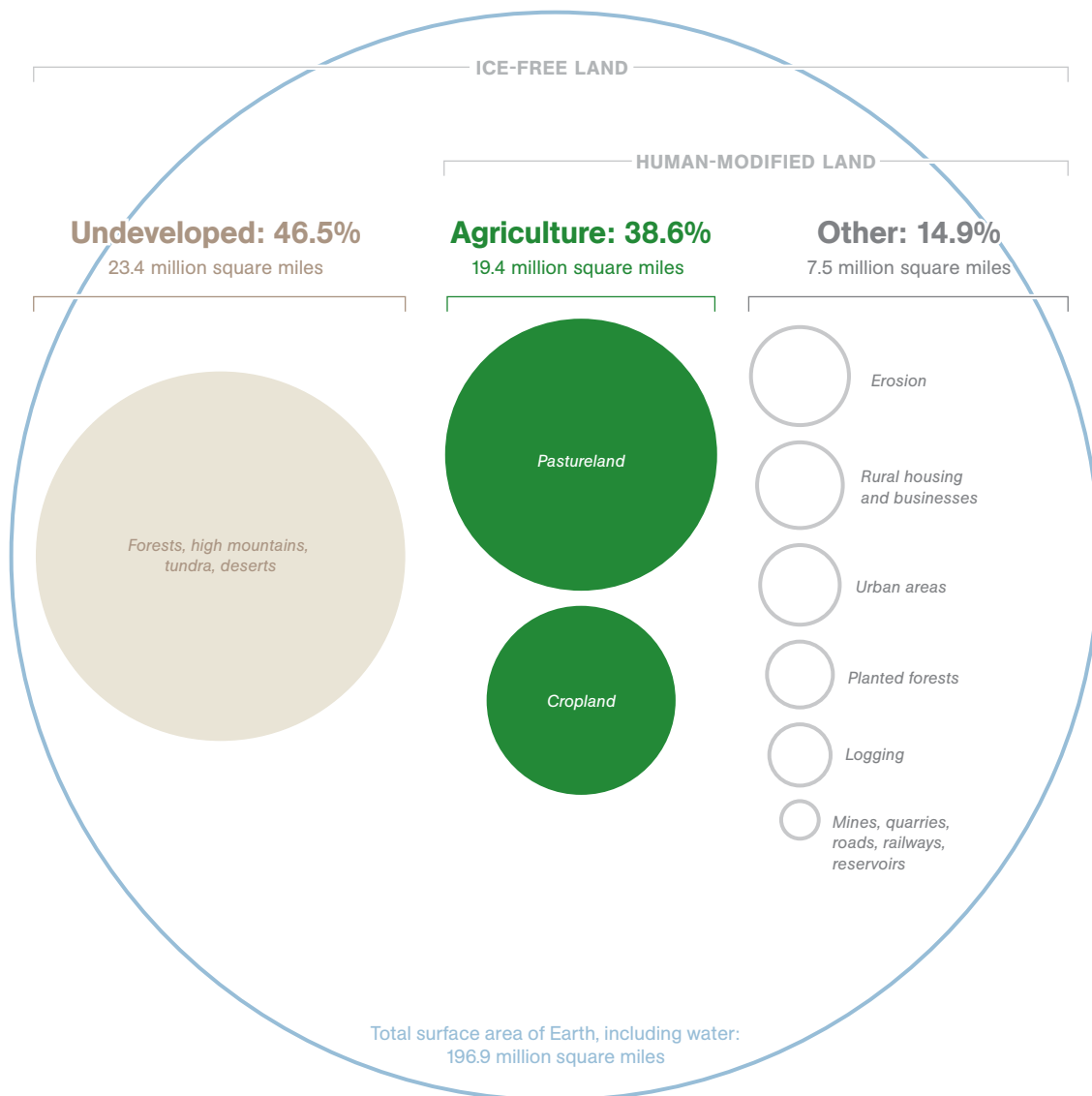
High in the Peruvian Andes, Estela Córdor grows five different varieties of potatoes to sell in the market, along with a yellow tuber called *mashua* that she cooks for her family. Small farmers like Córdor grow much of the food for people in the developing world.

JIM RICHARDSON



## Agriculture's Footprint

Farming of both livestock and crops is the largest human endeavor on Earth, using more than 38 percent of ice-free land. Our next largest impact: erosion caused by agriculture, building, logging, and mining.



ALL GRAPHICS AND MAP BY VIRGINIA W. MASON AND JASON TREAT, NGM STAFF. SOURCE: ROGER LEB. HOOKE, UNIVERSITY OF MAINE

farms. The arguments can be fierce, and like our politics, we seem to be getting more divided rather than finding common ground. Those who favor conventional agriculture talk about how modern mechanization, irrigation, fertilizers, and improved genetics can increase yields to help meet demand. And they're right. Meanwhile proponents of local and organic farms counter that the world's small farmers could increase yields plenty—and help themselves out of poverty—by adopting techniques that improve fertility without synthetic fertilizers and pesticides. They're right too.

But it needn't be an either-or proposition. Both approaches offer badly needed solutions; neither one alone gets us there. We would be wise to explore all of the good ideas, whether from organic and local farms or high-tech and conventional farms, and blend the best of both.

I was fortunate to lead a team of scientists who confronted this simple question: How can the world double the availability of food while simultaneously cutting the environmental harm caused by agriculture? After analyzing reams of data on agriculture and the environment, we proposed five steps that could solve the world's food dilemma.

### STEP ONE Freeze agriculture's footprint

For most of history, whenever we've needed to produce more food, we've simply cut down forests or plowed grasslands to make more farms. We've already cleared an area roughly the size of South America to grow crops. To raise livestock, we've taken over even more land, an area roughly the size of Africa. Agriculture's footprint has caused the loss of whole ecosystems around the globe, including the prairies of North America and the Atlantic forest of Brazil, and tropical forests continue to be cleared at

*Jonathan Foley is executive director of the California Academy of Sciences. Jim Richardson's portraits of farmers are the latest in his body of work documenting agriculture. George Steinmetz's big-picture approach reveals the landscapes of industrial food.*

alarming rates. But we can no longer afford to increase food production through agricultural expansion. Trading tropical forest for farmland is one of the most destructive things we do to the environment, and it is rarely done to benefit the 850 million people in the world who are still hungry. Most of the land cleared for agriculture in the tropics does not contribute much to the world's food security but is instead used to produce cattle, soybeans for livestock, timber, and palm oil. Avoiding further deforestation must be a top priority.

### STEP TWO Grow more on farms we've got

Starting in the 1960s, the green revolution increased yields in Asia and Latin America using better crop varieties and more fertilizer, irrigation, and machines—but with major environmental costs. The world can now turn its attention to increasing yields on less productive farmlands—especially in Africa, Latin America, and eastern Europe—where there are “yield gaps” between current production levels and those possible with improved farming practices. Using high-tech, precision farming systems, as well as approaches borrowed from organic farming, we could boost yields in these places several times over.

### STEP THREE Use resources more efficiently

We already have ways to achieve high yields while also dramatically reducing the environmental impacts of conventional farming. The green revolution relied on the intensive—and unsustainable—use of water and fossil-fuel-based chemicals. But commercial farming has started to make huge strides, finding innovative ways to better target the application of fertilizers and pesticides by using computerized tractors equipped with advanced sensors and GPS. Many growers apply customized blends of fertilizer tailored to their exact soil conditions, which helps minimize the runoff of chemicals into nearby waterways.

Organic farming can also greatly reduce the use of water and chemicals—by incorporating cover crops, mulches, and compost to improve soil quality, conserve water, and build up nutrients. Many farmers have also gotten smarter





**Mali**

Bassama Camara, Siby



**Ukraine**

Olexandra Salo, Hlynske



**Bangladesh**

Anwara Begum, Sajjali



**United States**

George Naylor, Iowa



**United States**

Chris Covelli, Wisconsin



**Ukraine**

Valentin Tarasov, Starovyshnevetske



**Indonesia**

Pak Kompiang, Bali



**United States**

Sally Gran, Iowa





## A World Demanding More

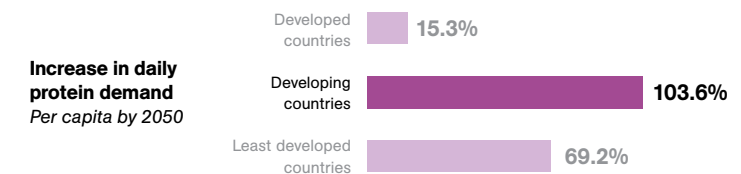
By 2050 the world's population will likely increase by about **35 percent**.



To feed that population, crop production will need to **double**.



Why? Production will have to far outpace population growth as the developing world grows prosperous enough to eat more meat.



SOURCE: DAVID TILMAN, UNIVERSITY OF MINNESOTA

about water, replacing inefficient irrigation systems with more precise methods, like subsurface drip irrigation. Advances in both conventional and organic farming can give us more “crop per drop” from our water and nutrients.

### STEP FOUR *Shift diets*

It would be far easier to feed nine billion people by 2050 if more of the crops we grew ended up in human stomachs. Today only 55 percent of the world's crop calories feed people directly; the rest are fed to livestock (about 36 percent) or turned into biofuels and industrial products (roughly

9 percent). Though many of us consume meat, dairy, and eggs from animals raised on feedlots, only a fraction of the calories in feed given to livestock make their way into the meat and milk that we consume. For every 100 calories of grain we feed animals, we get only about 40 new calories of milk, 22 calories of eggs, 12 of chicken, 10 of pork, or 3 of beef. Finding more efficient ways to grow meat and shifting to less meat-intensive diets—even just switching from grain-fed beef to meats like chicken, pork, or pasture-raised beef—could free up substantial amounts of food across the world. Because people in developing

Frank Reese raises and sells historic breeds of turkeys and other poultry on his farm in Lindsborg, Kansas. He ships thousands of the free-range heritage turkeys each Thanksgiving.

JIM RICHARDSON

countries are unlikely to eat less meat in the near future, given their newfound prosperity, we can first focus on countries that already have meat-rich diets. Curtailing the use of food crops for biofuels could also go a long way toward enhancing food availability.

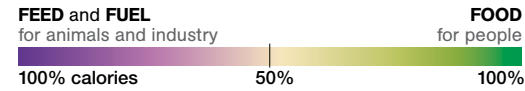
**STEP FIVE Reduce waste**

An estimated 25 percent of the world's food calories and up to 50 percent of total food weight are lost or wasted before they can be consumed. In rich countries most of that waste occurs in homes, restaurants, or supermarkets. In poor countries food is often lost between the farmer and the market, due to unreliable storage and transportation. Consumers in the developed world could reduce waste by taking such simple steps as serving smaller portions, eating leftovers, and encouraging cafeterias, restaurants, and supermarkets to develop waste-reducing measures. Of all of the options for boosting food availability, tackling waste would be one of the most effective.

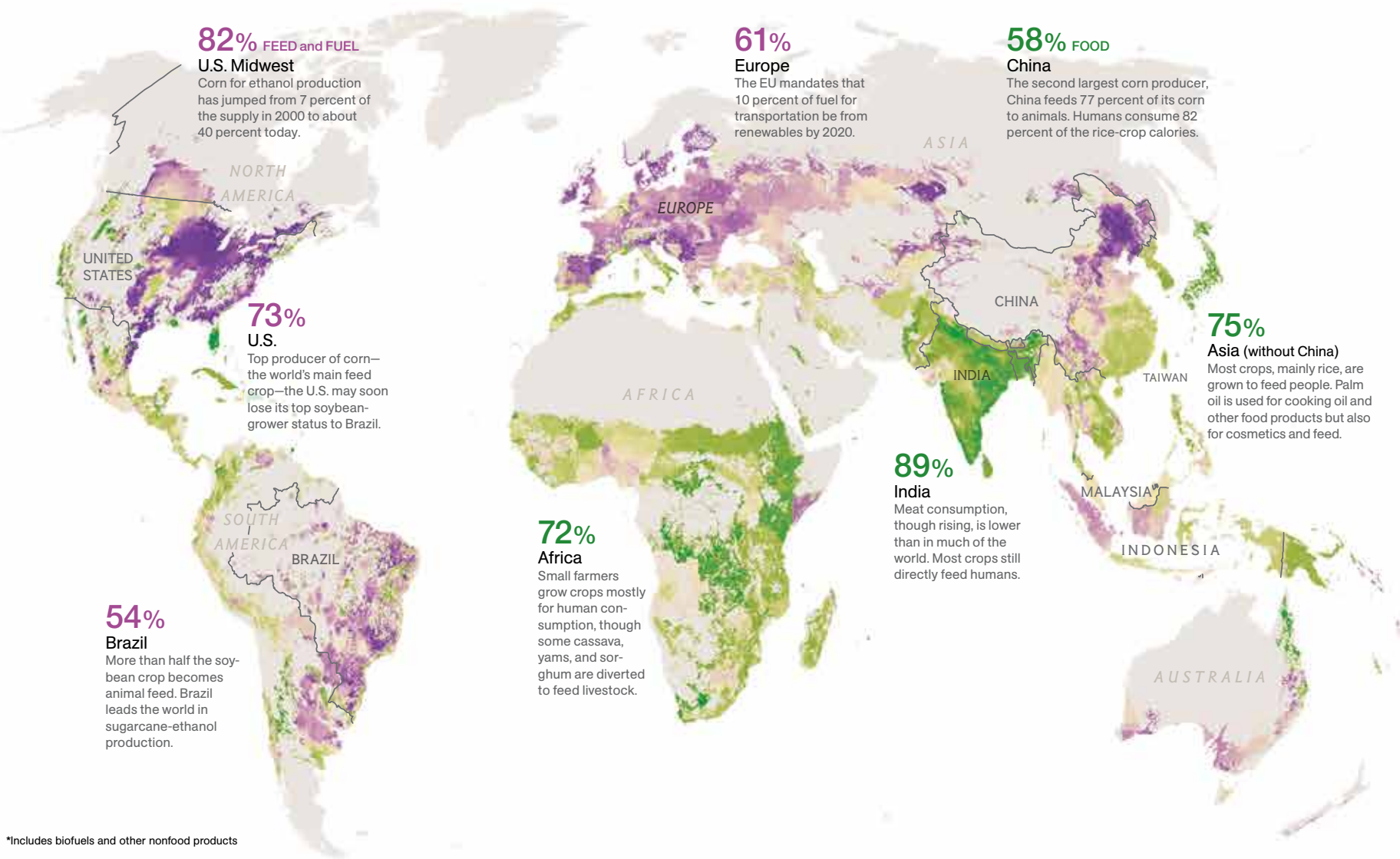
TAKEN TOGETHER, these five steps could more than double the world's food supplies and dramatically cut the environmental impact of agriculture worldwide. But it won't be easy. These solutions require a big shift in thinking. For most of our history we have been blinded by the overzealous imperative of more, more, more in agriculture—clearing more land, growing more crops, using more resources. We need to find a balance between producing more food and sustaining the planet for future generations.

This is a pivotal moment when we face unprecedented challenges to food security and the preservation of our global environment. **The good news is that we already know what we have to do; we just need to figure out how to do it. Addressing our global food challenges demands that all of us become more thoughtful about the food we put on our plates.** We need to make connections between our food and the farmers who grow it, and between our food and the land, watersheds, and climate that sustain us. As we steer our grocery carts down the aisles of our supermarkets, the choices we make will help decide the future. □

**Where the calories are produced**



**How global crop calories are used**



\*Includes biofuels and other nonfood products

SOURCE: GLOBAL LANDSCAPES INITIATIVE, INSTITUTE ON THE ENVIRONMENT, UNIVERSITY OF MINNESOTA

**Food Versus Feed and Fuel**

Percentages on the map show whether most of the calories in a region's crops go directly to human consumption (green) or go to animal feed and biofuels (purple). Only 55 percent of the world's food-crop calories directly nourish people. We get another 4 percent indirectly by eating meat, dairy, or eggs from animals raised on feed.



Only the Brazil nut trees—protected by national law—were left standing after farmers cleared this parcel of Amazon rain forest to grow corn. Despite progress in slowing deforestation, this northern state of Pará saw a worrying 37 percent spike over the past year.

GEORGE STEINMETZ





# This world can *thrive*

Today, one in nine people is undernourished. And by 2050, the population will rise to more than 9 billion. Ensuring that all people are well nourished isn't a choice—it's a collective responsibility and our company's purpose.

Together with businesses, governments and community partners, Cargill is providing access to safe, affordable, nutritious food: training farmers to produce more, moving food to the places where it's needed most, and forging powerful partnerships to help end hunger.

Because when people are well nourished, they can *thrive*.

[cargill.com/natgeo](http://cargill.com/natgeo)

A partnership between Cargill and CARE has helped 100,000 people in eight countries, including these children in the Kutch district of India's Gujarat state. The six-year initiative promotes economic opportunities for rural families while enhancing educational and nutritional support for children.

**Cargill**<sup>®</sup>

**thrive**<sup>™</sup>



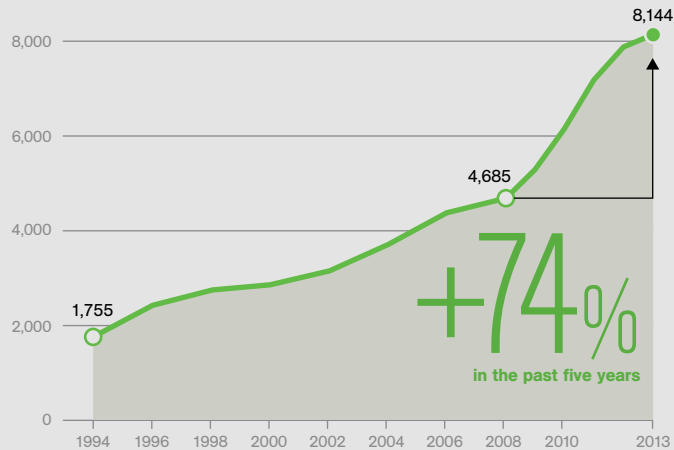
# Food for the City

The local-food movement is blossoming, with farmers markets springing up all over the United States. Demand for fresh produce and a desire to invest in local economies are driving this growth. Consumers show increased interest in "food transparency"—what the USDA's Arthur Neal defines as the "full story behind how our food is produced." Improved marketing, he says, using tools like social media and electronic forms of payment, is also contributing to the boom. —Kelsey Nowakowski

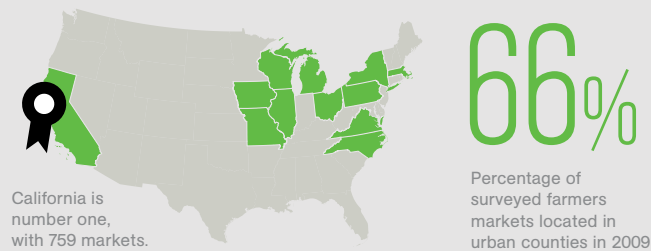
## THE FARMERS MARKET BOOM

### FARMERS MARKETS IN THE U.S.

The number of markets has skyrocketed in ten years, with the fastest growth rates seen in the western United States. Winter farmers markets are up by nearly 60 percent since 2010.

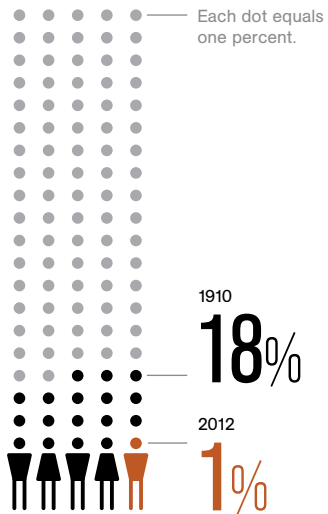


### TWELVE STATES ACCOUNT FOR HALF OF ALL MARKETS.



## FARMERS IN THE U.S.

### PERCENTAGE OF THE U.S. WORKFORCE WHO ARE FARMERS



Mechanization has improved farm efficiency, allowing more people to pursue nonfarm occupations.

### AVERAGE AGE

**58**

Of the 2.1 million farmers, 120,000 are younger than 35.

### AGE IN AGRICULTURE

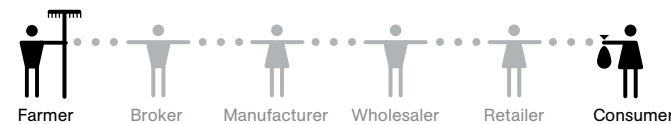
For every farmer under 35, the U.S. has seven farmers over 65. Experts say the local-food movement is inspiring more young people to farm.



## FARM ECONOMICS

### CUTTING OUT THE MIDDLEMAN

Purchasing food from farmers markets helps shorten long price chains, leaving more money for farmers.



### SMALL AND MEDIUM FARMS WITH LOCAL FOOD SALES (\$0-249,999 in sales)

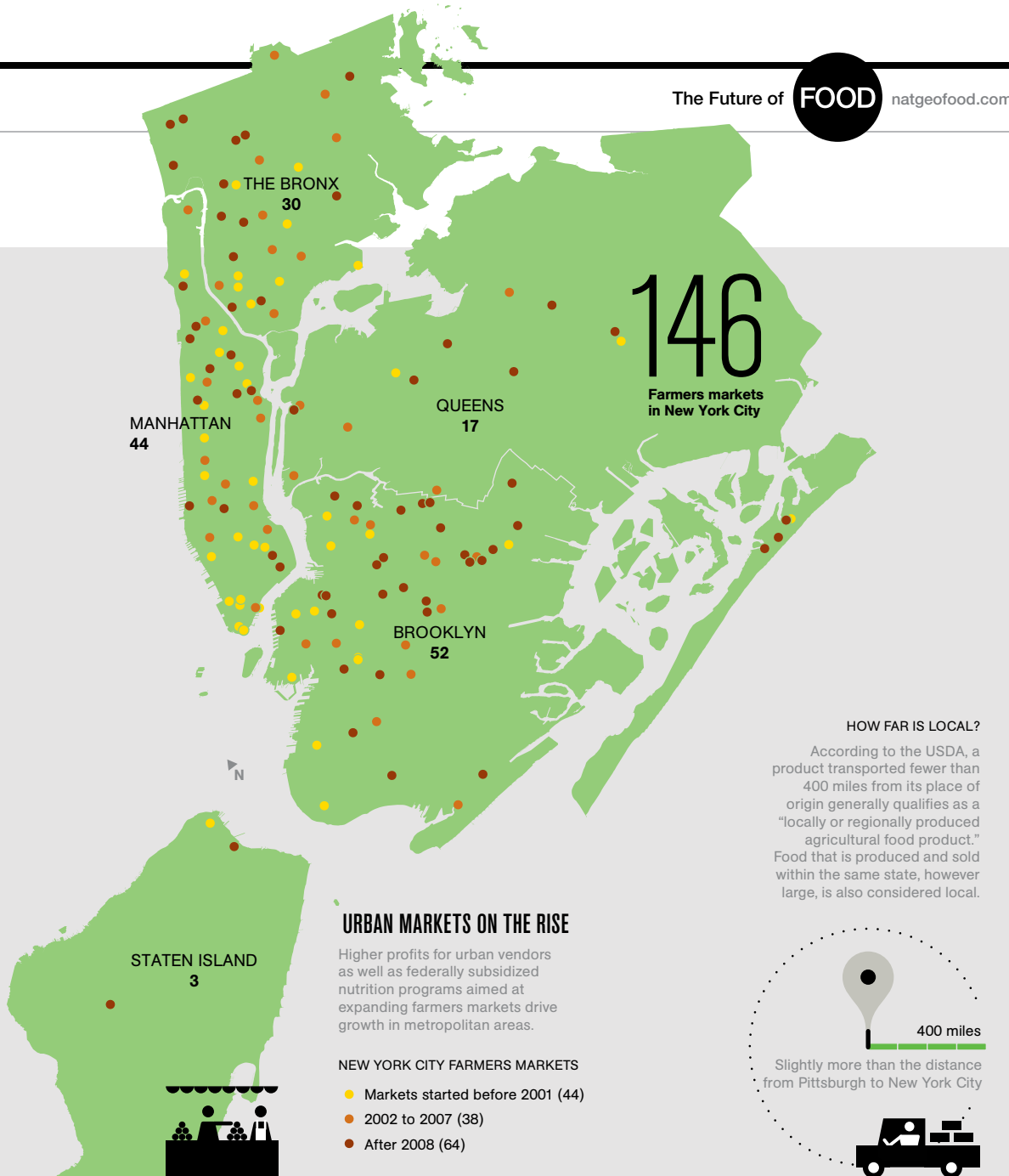


## URBAN MARKETS ON THE RISE

Higher profits for urban vendors as well as federally subsidized nutrition programs aimed at expanding farmers markets drive growth in metropolitan areas.

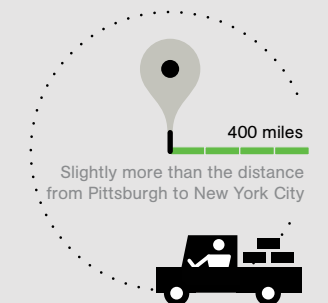
### NEW YORK CITY FARMERS MARKETS

- Markets started before 2001 (44)
- 2002 to 2007 (38)
- After 2008 (64)



### HOW FAR IS LOCAL?

According to the USDA, a product transported fewer than 400 miles from its place of origin generally qualifies as a "locally or regionally produced agricultural food product." Food that is produced and sold within the same state, however large, is also considered local.





Can Africa's  
fertile farmland feed  
the planet?

*Why big corporations are  
grabbing up land on the planet's  
hungriest continent.*

# The Next Breadbasket

*By Joel K. Bourne, Jr.*

*Photographs by Robin Hammond*





Sugarcane hawkers await customers on the Nacala railway in northern Mozambique, where Brazil and Japan hope to turn 35 million acres of small farms over to industrial-scale soybean production. The country has leased roughly 7 percent of its arable land—among the highest rates in Africa.





Though some corporate farms have pushed small growers off their land, Bananalândia, a 3,500-acre enterprise near Maputo, has improved life for the locals. The company provides jobs for 2,800 workers and has built roads, schools, and power lines. It's also helped convert Mozambique into a banana exporter.



*She never saw the big tractor coming. First it plowed up her banana trees. Then her corn. Then her beans, sweet potatoes, cassava. Within a few, dusty minutes the one-acre plot near Xai-Xai, Mozambique, which had fed Flora Chirime and her five children for years, was consumed by a Chinese corporation building a 50,000-acre farm, a green-and-brown checkerboard of fields covering a broad stretch of the Limpopo River Delta.*

“No one even talked to me,” the 45-year-old Chirime says, her voice rising with anger. “Just one day I found the tractor in my field plowing up everything. No one who lost their *machamba* has been compensated!” Local civil society groups say thousands lost their land and livelihoods to the Wanbao Africa Agricultural Development Company—all with the blessing of the Mozambican government, which has a history of neglecting local farmers’ rights to land in favor of large investments. Those who managed to get jobs on the giant farm are working seven days a week with no overtime pay. A spokesman for Wanbao denied such allegations and stressed that it’s training local farmers to grow rice.

Chirime’s situation is hardly unique. She’s just one character in the biggest story in global agriculture: the unlikely quest to turn sub-Saharan Africa, historically one of the hungriest places on

the planet, into a major new breadbasket for the world. Since 2007 the near-record prices of corn, soybeans, wheat, and rice have set off a global land rush by corporate investors eager to lease or buy land in countries where acreage is cheap, governments are amenable, and property rights often ignored. Most land deals have occurred in Africa, one of the few regions on the planet that still have millions of acres of fallow land and plentiful water available for irrigation. It also has the largest “yield gap” on Earth: Although corn, wheat, and rice farmers in the U.S., China, and eurozone countries produce about three tons of grain per acre, farmers in sub-Saharan Africa average half a ton—roughly the same yield Roman farmers achieved on their wheat fields in a good year during the rule of Caesar. Despite several attempts, the green revolution’s mix of fertilizers, irrigation, and high-yield seeds—which



## Mozambique

Fatima Alex

“I’m not happy. I’m angry,” says Alex, who lost her small plot near Xai-Xai to a Chinese rice plantation. “That farm gave us food to eat. Now I have nothing.”

more than doubled global grain production between 1960 and 2000—never blossomed in Africa, thanks to the poor infrastructure, limited markets, weak governance, and fratricidal civil wars that wracked the postcolonial continent.

Many of those hurdles are now falling. Sub-Saharan Africa’s economic growth has hummed along at about 5 percent a year for the past decade, besting that of the U.S. and the European Union. National debts are declining, and peaceful elections are being held with increasing

frequency. More than one in three sub-Saharan Africans now own cell phones and use them for mobile banking, to run small businesses, or send money to relatives in rural areas. After 25 years of virtually no investment in African agriculture, the World Bank and donor countries have stepped up. The continent is emerging as a laboratory for testing new approaches to boosting food production. If sub-Saharan African farmers can raise their yields to even two tons of grain per acre using existing technology—a fourfold

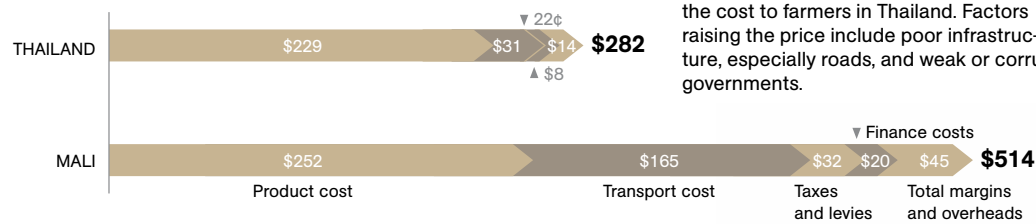


# Africa's Food Challenge

Decades ago the green revolution increased crop yields in India and other developing countries using fertilizer, irrigation, and improved seeds. But it never took root in Africa, where yields have barely risen since the 1960s. Less than 5 percent of arable land in sub-Saharan Africa is irrigated. As the continent rapidly urbanizes, an already stressed food system will lose farmers and add a staggering number of consumers. But with modern farming techniques and programs to help farmers afford them, this potential breadbasket could not only feed itself but also export a surplus.

## The High Cost of Fertilizer

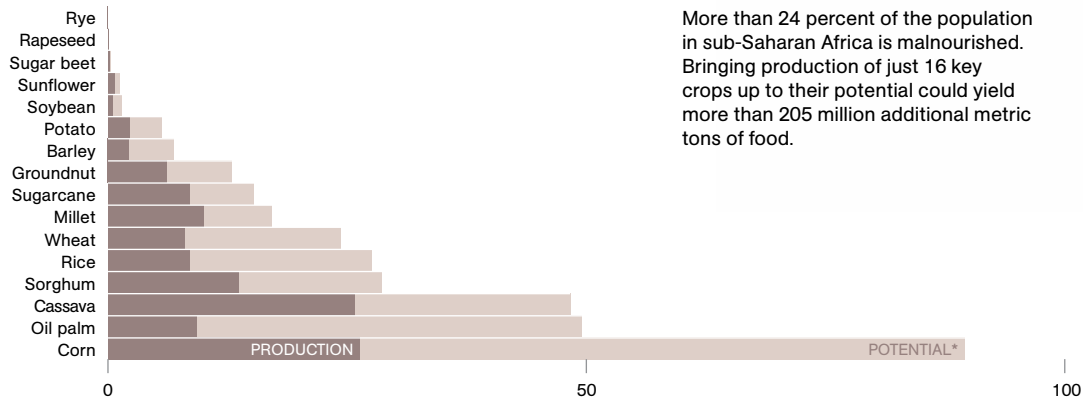
Fertilizer prices U.S. dollars per metric ton



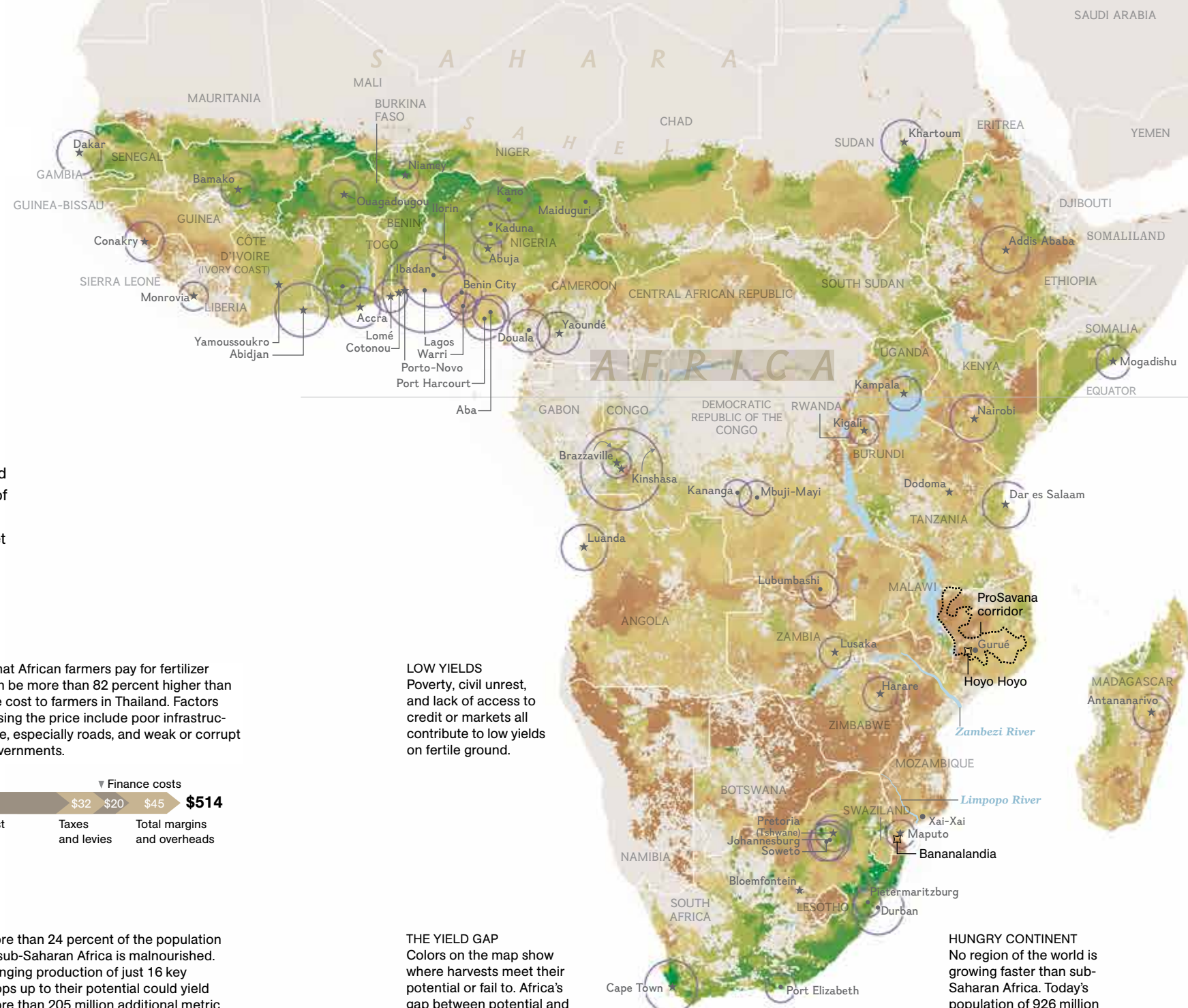
What African farmers pay for fertilizer can be more than 82 percent higher than the cost to farmers in Thailand. Factors raising the price include poor infrastructure, especially roads, and weak or corrupt governments.

## Boosting the Harvest

Africa's key crops dry weight, million metric tons



More than 24 percent of the population in sub-Saharan Africa is malnourished. Bringing production of just 16 key crops up to their potential could yield more than 205 million additional metric tons of food.



**LOW YIELDS**  
Poverty, civil unrest, and lack of access to credit or markets all contribute to low yields on fertile ground.

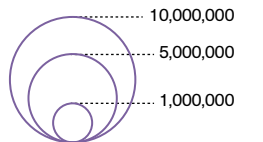
**THE YIELD GAP**  
Colors on the map show where harvests meet their potential or fail to. Africa's gap between potential and yield is the world's largest.

### Where yields could improve



**HUNGRY CONTINENT**  
No region of the world is growing faster than sub-Saharan Africa. Today's population of 926 million may hit 2.2 billion by 2050.

### Urban population over one million





increase and still a tall order—some experts believe they could not only better feed themselves but actually export food, earning much needed cash and helping to feed the world as well.

It's an optimistic vision, for sure. Thailand currently exports more agricultural products than all sub-Saharan countries combined, and the specter of climate change threatens to hammer Africa's yields. But the thorniest question is, Who will do the farming in Africa's future? Will it be poor farmers like Chirime working one-acre plots, who make up roughly 70 percent of the continent's labor force? Or will it be giant corporations like Wanbao, operating industrial farms modeled on those of the American Midwest?

Humanitarian groups that deal with global hunger and peasants' rights call corporate land deals neocolonialism and agri-imperialism. Yet veterans of agricultural development say the massive infusion of private cash, infrastructure, and technology that such deals may bring to poor rural areas could be a catalyst for desperately needed development—if big projects and small farmers can work together. The key, says USAID's Gregory Myers, is protecting the land rights of the people. "This could significantly reduce global poverty, and that could be the story of the century."

"IF YOU WROTE A LETTER to God and asked him for the best soil and climate conditions for farming, this is what he'd send you," says Miguel Bosch, an Argentine agronomist who manages Hoyo Hoyo, a nearly 25,000-acre corporate soybean farm in northern Mozambique. "It is a paradise for growers. I've spent many years farming in Brazil and Argentina and have never seen such soil."

Fertile land, skyrocketing demand for soybeans and rice, and a government willing to cut big land deals have put the former Portuguese colony at the center of the land rush sweeping the continent. In 2013 the nation was the third poorest on the planet, with almost half its children under

---

*Contributing writer Joel Bourne reported on the global food crisis in 2009. Robin Hammond covered Zimbabwe in our May 2013 issue.*

five stunted by malnutrition. Recent discoveries of world-class coal and natural gas deposits in the north as well as other mining and forestry concessions are slowly changing its fortunes. The rush to tap these hydrocarbons has ignited Mozambique's economy, which grew by an estimated 7 percent in 2013. Massive infrastructure projects are springing up, many financed largely by loans from nations eager to curry favor with political leaders and get in on the action. Japan is building roads and bridges. Portuguese companies are building ports and rail lines. China has already built a new airport, the parliament building, the national soccer stadium, and even the new presidential palace overlooking the broad bay in the capital, Maputo. In 2013 President Armando Guebuza spent a week visiting the new Chinese president with a ten-billion-dollar wish list of new construction projects in hand.

Little of that bounty has trickled down to the nation's 24 million citizens, more than half of whom still live on less than \$1.25 a day. A return to civil unrest is the only thing that could upset the river of cash flowing into Mozambique. After riots over food prices broke out in Maputo in 2010, President Guebuza fired his agriculture minister and replaced him with Interior Minister José Pacheco, an agronomist, who has continued courting investors at conferences around the world. Of its 89 million acres of arable land, the government deems almost 85 percent "unutilized." Since 2004 some six million acres have been leased to both foreign and domestic investors for everything from forestry products to biofuels to sugarcane, roughly 7 percent of the country's arable land—among the highest rates in Africa.

Signing a deal with a ministry official in a swank Maputo hotel is the easy part. Getting a massive corporate farm up and running and turning a profit in the midst of often hostile neighbors is something else entirely. Hoyo Hoyo, located in the nation's prime soybean-growing region of Gurué, was supposed to be a shining example of the new African agriculture. Instead it became the poster child for how such deals can go wrong. In 2009 Mozambican officials leased



This land outside Maputo provides a snapshot of Africa's agricultural choices: Will its food be produced on giant, leveled plantations like Bananalândia (at left) or on small farms, called *machambas*? "It must be a mix of big ag and small," says Dries Gouws, the sprawling banana farm's founder.

the nearly 25,000 acres of an abandoned state farm to a Portuguese company with ties to the government. But local villagers had been growing food for their families there for years. When the Portuguese managers came in, they met with village leaders and promised them double the amount of land to farm elsewhere as well as a school, a clinic, and new wells.

Few of those promises were kept. The school and clinic were never built, though the company did buy an ambulance to take the sick to a hospital in Gurué, an hour's ride away. Only about 40 men got low-paying jobs as watchmen on

the farm, while hundreds were displaced. Those who did receive acreage have found it to be far from home, swampy, and overgrown. Custódio Alberto is one of them. I meet the 52-year-old farmer at a threshing party just outside the Hoyo Hoyo boundary, where two dozen men from the local Roman Catholic church are beating piles of soybeans with wooden clubs. An equal number of women are winnowing the chaff with handwoven baskets. The seven-acre plot, for the moment still controlled by the church, is next to Hoyo Hoyo's wide-open fields, which stretch toward the green mountains in the distance.





A Chinese chicken farmer haggles with his customers in Lusaka, Zambia. Like many foreign-owned food operations in Africa, his company doesn't ship its chickens back home but sells them to locals and the country's 20,000 Chinese. Overall Africa is home to some two million Chinese.



“For us as small farmers, the production of this soy guarantees the family income, even enough for us to send our children to college so they can become engineers or even doctors,” Alberto says. “Fields are fundamental for us. No fields, no life.”

The displaced villagers, who survived 16 years of war, are poor but far from powerless. Soon after the Portuguese got the lease to Hoyo Hoyo, which means “welcome” in the local language, the farm began having trouble with its equipment. John Deere tractors imported from the United States mysteriously failed to start. I ask a farmer working nearby what the problem was.

“I don’t know how it happens,” he said with a knowing smile. “Maybe African magic.”

THE CONFLICT OVER Hoyo Hoyo pales in comparison with what’s coming down the road. In 2009 the government signed an agreement with Brazil and Japan to develop an agricultural megaproject dubbed ProSavana, which would make almost 35 million acres of northern Mozambique available for industrial-scale soybean production, possibly the largest such land deal ever reported. The plan is inspired by a Japanese-Brazilian project that transformed Brazil’s *cerrado* grasslands into one of the largest soy-exporting regions in the world, with the bulk of its yield going to feed Europe’s and China’s livestock. The North Carolina-size corridor would be dotted here and there with modern, 25,000-acre farms run by Brazilian agribusinesses and with technical centers to educate local farmers on how to boost yields of cassava, beans, vegetables, as well as soy—or so the initial vision went. But when a group of Brazilian farmers toured the region in 2013, they had a rude awakening.

“They saw good lands, but everywhere was a community,” says Anacleto Saint Mart, who works with farmers in the region for the U.S. nonprofit TechnoServe. “They were seeing a reality very different from what they were told in Brazil.” Development experts who’ve pored over maps of the area say most of it is already leased for mining or logging, is protected as wildlife reserves, or is already being cultivated by local farmers. Only about 2.2 million acres are currently unutilized,

and those are the worst lands for farming.

“When you look at ProSavana, who is winning?” asks Devlin Kuyek of GRAIN, the nonprofit that first focused the world’s attention on corporate investments in farmland. “The land is currently worked by small farmers, and [yet] the government is placing it in the hands of corporations. I’m sure there are some companies with good intentions. But they’re still profiting from low wages and low land prices. Industrial agriculture will just lead to more exploitation.”

With the right policies, small farmers can be extremely productive, Kuyek says, pointing to the rice farmers of Vietnam or the small dairy farmers in Kenya, who supply more than 70 percent of the nation’s milk. Simply providing women—who make up the majority of African farmers—the same access to land, credit, and fertilizer as men could boost food production by as much as 30 percent. The government of Mozambique doesn’t see it that way. Though food production by small farmers has improved over the past few years, 37 percent of the population is undernourished, and the country’s southern region is plagued by droughts and floods. Despite its mineral wealth, Mozambique remains one of the hungriest nations in the world. The government thinks bigger farms are the answer.

“I look at ProSavana along with the Zambezi Valley region as the food store of the country,” says Raimundo Matule, the national director of economics at the Ministry of Agriculture. “I don’t envision huge farms like in Brazil, but more medium-size producers of three to ten hectares [7 to 25 acres]. The Brazilians have knowledge, technology, and equipment that we can adapt and transfer to medium-size farms. If ProSavana doesn’t contribute to better food security, then it will not have government support.”

A FEW MILES down a washboard dirt road from Hoyo Hoyo, a soybean farm run by a retired schoolteacher is an example of a productive middle path. Armando Afonso Catxava began growing vegetables in his spare time on a small plot of land and over the years has cobbled together about 64 acres. He now grows soybeans



## Ethiopia

Greda Telila

On his five-acre farm Telila grows stalks of sorghum. A subsistence farmer whose land is prone to flooding, he struggles to feed his 12 children.

as an “outgrower” under contract with a new company called African Century Agriculture, which provides him with seeds and mechanical weeding. In return he sells his soybeans to the company at an agreed-on price, minus the cost of the services provided. So far both have profited from the arrangement.

“I think middle-size farms are the secret,” Catxava says. “Big farms take too much area, and there is nowhere for people to live. If everybody had five hectares [12 acres] of soy, they would

make money and not lose their land.” Outgrower arrangements have been successful with poultry and high-value crops like tobacco and even organic baby corn grown for export to Europe. Now Mozambique’s farmers are starting to raise soybeans for feed to supply the booming chicken industry.

Rachel Grobbelaar is a tall, tough Zimbabwean who left a good job in London’s financial district to run African Century, which works with more than 900 outgrowers—a mix of smallholders



and medium-size growers—on nearly 2,500 acres. Farmers each get seven visits a season from the company's extension agents, who teach them the basics of conservation agriculture and the use of inexpensive seed treatments, instead of expensive fertilizer, to boost yields.

"I was visiting one of our small farmers up on the mountain yesterday, and he grew 2.4 tons per hectare [one ton per acre]," Grobelaar says, referring to last year's harvest—more than double the average yield. "He couldn't believe it. He made 37,000 meticaïs [about \$1,200] profit. That's a lot. I'm very supportive of the outgrower model in Africa. Commercial farms may give them a job, but it takes away their land and typically pays them bare-minimum salaries. I honestly believe we can increase production this way."

When done right, larger-scale farms can benefit locals too. Dries Gouws, a former surgeon in Zambia, planted 30 acres of banana trees on a bankrupt citrus farm outside of Maputo 14 years ago. He slowly grew the operation into what he now calls Banalandia. At 3,500 acres, it's the largest banana farm in Mozambique and one of the nation's largest employers, with 2,800 year-round workers. During that time Gouws's farm helped turn Mozambique from a banana importer into a banana exporter. As the farm grew, Gouws paved roads, built a school and a clinic, dug wells, and ran 34 miles of electrical lines that not only power his irrigation but also supply the surrounding villages where his employees live. His lowest paid workers make 10 percent more than minimum wage; his tractor drivers and plantation managers make more than double that.

Gouws believes in a mix of big and little farms, with small farmers raising cattle and tending plots of land as a safety net and source of pride, and big farms like his bringing in roads, power, and infrastructure that the government does not provide. Big farms supply employment for some; other people make it on their own. The key to corporate farms winning over local communities, he says, is simple: Keep your word.

"I built this power line for the village," Gouws says, as we follow a wire along a red-dirt path

toward a cluster of huts amid the banana fields. "I've never been asked to do it or expected to do it. But at some point, not to get too philosophical about it, we want to make the world a better place, don't we? It can't just be about the money."

Yet make no mistake, money—not some noble idea of feeding the world—is driving the land rush in Africa. A recent conference for agricultural investors in New York drew some 800 financial leaders from around the globe who manage nearly three trillion dollars in investments. These included giant pension funds, life insurance companies, hedge funds, private equity funds, and sovereign-wealth funds, which currently have about 5 percent of their combined assets allocated to investments in agriculture. That number is expected to triple over the next decade. Such a massive infusion of private cash, technology, and infrastructure is exactly what global agriculture needs, according to FAO experts, who estimate we'll need to invest \$83 billion a year in agriculture in developing countries to feed two billion more people by 2050.

The key is leveraging that investment to yield benefits for all, ensuring secure land rights, thriving markets, and increased productivity on all farms, big and small. "If we could do that, we'd have a triple win," says Darryl Vhugen, a lawyer with Landesa, a Seattle-based nonprofit that helps poor farmers in developing countries defend their land rights. "Investors benefit, local communities benefit, and nations benefit from jobs, infrastructure, food security. That's gold."

ON A LONG ROAD in the heart of the proposed ProSavana project, I stop at a mud-brick hut to talk with Costa Ernesto, a 35-year-old farmer, and his wife, Cecilia Luis. They have never heard of ProSavana. They are simply trying to feed their family on two and a half acres of corn, and selling bamboo poles for thatched roofs on the side. Their five children range in age from six months to 11 years. The eldest, a shy girl named Esvalta, is pounding corn with a wooden pestle as tall as she is, just as her mother and grandmother and great-grandmother did before her.



## Rwanda

Marie Mukarukaka

"Before, I grew only food for my family, and it would last two weeks," says Mukarukaka. After receiving a seed and fertilizer loan from the One Acre Fund, she has boosted her yields and is now raising livestock too.

My guide, who has worked in agricultural development for 20 years, says the children and parents appear to be stunted from malnutrition. I ask Ernesto if he has grown enough corn to eat that year. "Yes," he says proudly. After some prodding, Cecilia adds: "When we keep ahead of weeding, we produce enough for the whole year."

Two other men walk up during the conversation, and I ask if they would give up their small farms for a job on a big farm. Given their ragged clothing, their swollen bellies, their sod houses,

their obvious poverty, the question seems almost unfair. Yes, they say, without the slightest hesitation.

"I have been praying that something like this would happen," the oldest of the three men replies. "Because I really need a job."

Whether Mozambique's future farmers will look more like industrial farmers in Iowa or the small but productive rice farmers of Vietnam remains to be seen. But all sides agree on one thing: The status quo is unacceptable. □



Sheep and goats are herded aboard a ship bound for Saudi Arabia at the Somaliland port of Berbera, a key port for Arab traders since the second century. Saudi Arabia imports 80 percent of its food, with meat consumption projected to rise this decade—good news for Somaliland's nomadic herders.



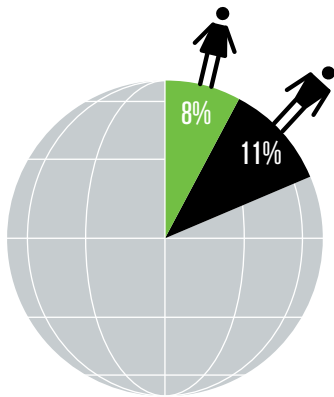


**Female Farmers** Women are just as good at farming as men, says the UN Food and Agriculture Organization. But with less access to resources, they get much lower yields. By 2050 the global population is expected to grow by 2.3 billion people; food demand could rise 60 percent. Closing the gender gap in farming would not only fight hunger but also provide “positive secondary effects,” says Anna Fälth of UN Women. “Empowered women have healthier and better educated children.” —Kelsey Nowakowski

WOMEN IN AGRICULTURE

**564 million**

Female farmers are 8 percent of the world's population, men 11 percent.



**The Problem**

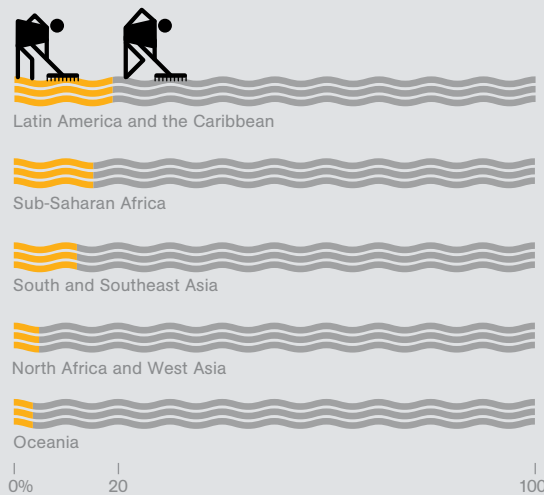
The yield gap between men and women averages 20 to 30 percent, for several reasons.



LANDHOLDERS

PERCENTAGE OF LANDHOLDERS BY GENDER

In developing countries only 10 to 20 percent of landholders are women.



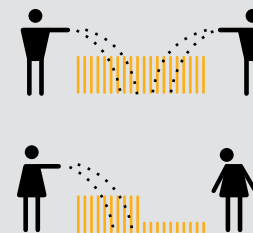
FINANCES

**NO CREDIT**

In most countries the share of women with small farms who have access to credit is 5 to 10 percentage points lower than for men.

TECHNOLOGY

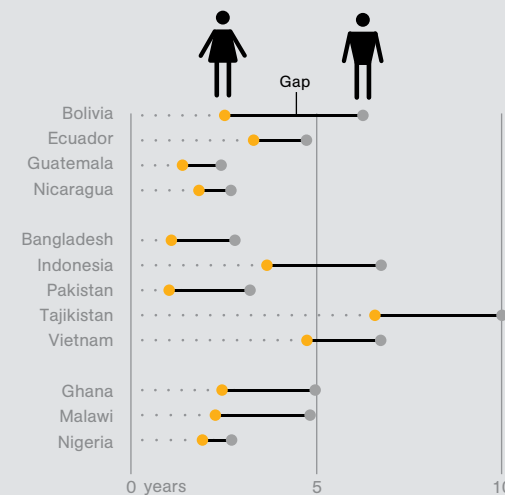
USE OF FERTILIZERS



Less access to credit makes it harder for women to buy fertilizer.

EDUCATION

AVERAGE YEARS OF EDUCATION OF HOUSEHOLD HEAD



Women have less access to education, especially in rural areas. The education gap is largest in Asia and sub-Saharan Africa.

LIVESTOCK

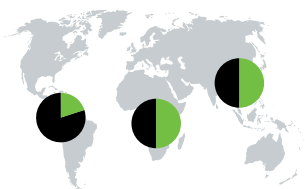
OWNED BY WOMEN

Women are less likely to own large farm animals, leaving them with smaller livestock and small-scale dairy projects.

**POULTRY, EGGS, AND DAIRY**

**43%**

OF THE AGRICULTURAL LABOR FORCE IN DEVELOPING COUNTRIES IS FEMALE.

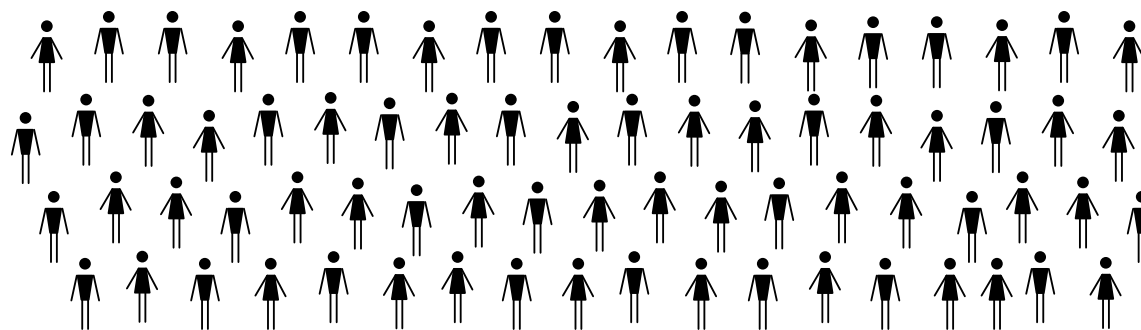


Women are 20 percent of the force in Latin America, nearly 50 percent in East Asia and sub-Saharan Africa.

**The Solution**

Closing the gender gap could increase yields in developing countries by up to 4 percent. This could reduce the number of undernourished people by 130 million, or 15 percent.

**870 million** UNDERNOURISHED POPULATION OF THE WORLD  
Each figure= ten million people



Closing the gender gap could feed

**130 million**



OR the populations of CHAD, ETHIOPIA, BURUNDI, ERITREA, ZAMBIA, HAITI

These countries have some of the highest rates of undernourishment.



Why are people  
malnourished in the  
richest country  
on Earth?

*Millions of working Americans  
don't know where their next meal  
is coming from.*

# *The* **New Face of Hunger**

By *Tracie McMillan*

Photographs by *Kitra Cahana,*  
*Stephanie Sinclair,* and *Amy Toensing*





Kristin Hahn and her grandmother, Janet Groven, visit a weekly soup kitchen in Charles City, Iowa. "By the end of the month we have nothing," says Groven, who also depends on a food pantry to feed her family. Of America's 48 million "food insecure"—the modern term for the hungry—more than half are white, and more than half live outside cities.

AMY TOENSING





New York City's Bronx borough is crammed with fast-food restaurants but has few grocery stores, earning it a reputation as a food desert. Home to America's poorest congressional district, the Bronx has a hunger rate of 37 percent, the highest in the city.

STEPHANIE SINCLAIR



*On a gold-gray morning in Mitchell County, Iowa, Christina Dreier sends her son, Keagan, to school without breakfast. He is three years old, barrel-chested, and stubborn, and usually refuses to eat the free meal he qualifies for at preschool. Faced with a dwindling pantry, Dreier has decided to try some tough love: If she sends Keagan to school hungry, maybe he'll eat the free breakfast, which will leave more food at home for lunch.*

Dreier knows her gambit might backfire, and it does. Keagan ignores the school breakfast on offer and is so hungry by lunchtime that Dreier picks through the dregs of her freezer in hopes of filling him and his little sister up. She shakes the last seven chicken nuggets onto a battered baking sheet, adds the remnants of a bag of Tater Tots and a couple of hot dogs from the fridge, and slides it all into the oven. She's gone through most of the food she got last week from a local food pantry; her own lunch will be the bits of potato left on the kids' plates. "I eat lunch if there's enough," she says. "But the kids are the most important. They have to eat first."

The fear of being unable to feed her children hangs over Dreier's days. She and her husband, Jim, pit one bill against the next—the phone against the rent against the heat against the gas—trying always

to set aside money to make up for what they can't get from the food pantry or with their food stamps, issued by the Supplemental Nutrition Assistance Program (SNAP). Congressional cuts to SNAP last fall of five billion dollars pared her benefits from \$205 to \$172 a month.

On this particular afternoon Dreier is worried about the family van, which is on the brink of repossession. She and Jim need to open a new bank account so they can make automatic payments instead of scrambling to pay in cash. But that will happen only if Jim finishes work early. It's peak harvest time, and he often works until eight at night, applying pesticides on commercial farms for \$14 an hour. Running the errand would mean forgoing overtime pay that could go for groceries.

It's the same every month, Dreier says. Bills



Keagan and Cheyenne Dreier have the toys and trappings of a middle-class life, but their parents rely on donated foods—typically processed—to feed them. "It's not like we can eat all healthy," says mom Christina. With junk food plentiful and often cheap, hunger and obesity are now parallel problems.

go unpaid because, when push comes to shove, food wins out. "We have to eat, you know," she says, only the slightest hint of resignation in her voice. "We can't starve."

CHANCES ARE GOOD that if you picture what hunger looks like, you don't summon an image of someone like Christina Dreier: white, married, clothed, and housed, even a bit overweight. The image of hunger in America today differs markedly from Depression-era images of the gaunt-

faced unemployed scavenging for food on urban streets. "This is not your grandmother's hunger," says Janet Poppendieck, a sociologist at the City University of New York. "Today more working people and their families are hungry because wages have declined."

In the United States more than half of hungry households are white, and two-thirds of those with children have at least one working adult—typically in a full-time job. With this new image comes a new lexicon: In 2006 the U.S. government replaced "hunger" with the term "food insecure" to describe any household where, sometime during the previous year, people didn't have enough food to eat. By whatever name, the number of people going hungry has grown dramatically in the U.S., increasing to 48 million by 2012—a fivefold jump since the late



1960s, including an increase of 57 percent since the late 1990s. Privately run programs like food pantries and soup kitchens have mushroomed too. In 1980 there were a few hundred emergency food programs across the country; today there are 50,000. Finding food has become a central worry for millions of Americans. One in six reports running out of food at least once a year. In many European countries, by contrast, the number is closer to one in 20.

To witness hunger in America today is to enter a twilight zone where refrigerators are so frequently bare of all but mustard and ketchup that it provokes no remark, inspires no embarrassment. Here dinners are cooked using

between food that's filling but not nutritious and may actually contribute to obesity." For many of the hungry in America, the extra pounds that result from a poor diet are collateral damage—an unintended side effect of hunger itself.

AS THE FACE OF HUNGER has changed, so has its address. The town of Spring, Texas, is where ranchland meets Houston's sprawl, a suburb of curving streets and shade trees and privacy fences. The suburbs are the home of the American dream, but they are also a place where poverty is on the rise. As urban housing has gotten more expensive, the working poor have been pushed out. Today hunger in the suburbs is

## It can be tempting to ask families receiving food assistance, If you're really hungry, then how can you be overweight? For many of the hungry in America, it's an unintended side effect of hunger itself.

macaroni-and-cheese mixes and other processed ingredients from food pantries, and fresh fruits and vegetables are eaten only in the first days after the SNAP payment arrives. Here you'll meet hungry farmhands and retired schoolteachers, hungry families who are in the U.S. without papers and hungry families whose histories stretch back to the *Mayflower*. Here pocketing food from work and skipping meals to make food stretch are so common that such practices barely register as a way of coping with hunger and are simply a way of life.

It can be tempting to ask families receiving food assistance, If you're really hungry, then how can you be—as many of them are—overweight? The answer is “this paradox that hunger and obesity are two sides of the same coin,” says Melissa Boteach, vice president of the Poverty and Prosperity Program of the Center for American Progress, “people making trade-offs

growing faster than in cities, having more than doubled since 2007.

Yet in the suburbs America's hungry don't look the part either. They drive cars, which are a necessity, not a luxury, here. Cheap clothes and toys can be found at yard sales and thrift shops, making a middle-class appearance affordable. Consumer electronics can be bought on installment plans, so the hungry rarely lack phones or televisions. Of all the suburbs in the country, northwest Houston is one of the best places to see how people live on what might be called a minimum-wage diet: It has one of the highest percentages of households receiving SNAP assistance where at least one family member holds down a job. The Jefferson sisters, Meme and Kai, live here in a four-bedroom, two-car-garage, two-bath home with Kai's boyfriend, Frank, and an extended family that includes their invalid mother, their five sons, a daughter-in-law,

and five grandchildren. The house has a rickety desktop computer in the living room and a television in most rooms, but only two actual beds; nearly everyone sleeps on mattresses or piles of blankets spread out on the floor.

Though all three adults work full-time, their income is not enough to keep the family consistently fed without assistance. The root problem is the lack of jobs that pay wages a family can live on, so food assistance has become the government's—and society's—way to supplement low wages. The Jeffersons receive \$125 in food stamps each month, and a charity brings in meals for their bedridden matriarch.

Like most of the new American hungry, the Jeffersons face not a total absence of food but the gnawing fear that the next meal can't be counted on. When Meme shows me the family's food supply, the refrigerator holds takeout boxes and beverages but little fresh food. Two cupboards are stocked with a smattering of canned beans and sauces. A pair of freezers in the garage each contain a single layer of food, enough to fill bellies for just a few days. Meme says she took the children aside a few months earlier to tell them they were eating too much and wasting food besides. “I told them if they keep wasting, we have to go live on the corner, beg for money, or something.”

Jacqueline Christian is another Houston mother who has a full-time job, drives a comfortable sedan, and wears flattering clothes. Her older son, 15-year-old Ja'Zarrian, sports bright orange Air Jordans. There's little clue to the family's hardship until you learn that their clothes come mostly from discount stores, that Ja'Zarrian mowed lawns for a summer to get the sneakers, that they're living in a homeless shelter, and that despite receiving \$325 in monthly food stamps, Christian worries about not having enough food “about half of the year.”

Christian works as a home health aide, earning \$7.75 an hour at a job that requires her to crisscross Houston's sprawl to see her clients. Her schedule, as much as her wages, influences what she eats. To save time she often relies on premade food from grocery stores. “You can't go all the way home and cook,” she says.

On a day that includes running a dozen errands and charming her payday loan officer into giving her an extra day, Christian picks up Ja'Zarrian and her seven-year-old, Jeremiah, after school. As the sun drops in the sky, Jeremiah begins complaining that he's hungry. The neon glow of a Hartz Chicken Buffet appears up the road, and he starts in: Can't we just get some gizzards, please?

Christian pulls into the drive-through and orders a combo of fried gizzards and okra for \$8.11. It takes three declined credit cards and an emergency loan from her mother, who lives nearby, before she can pay for it. When the food finally arrives, filling the car with the smell of hot grease, there's a collective sense of relief. On the drive back to the shelter the boys eat until the gizzards are gone, and then drift off to sleep.

Christian says she knows she can't afford to eat out and that fast food isn't a healthy meal. But she'd felt too stressed—by time, by Jeremiah's insistence, by how little money she has—not to give in. “Maybe I can't justify that to someone who wasn't here to see, you know?” she says. “But I couldn't let them down and not get the food.”

OF COURSE IT IS POSSIBLE to eat well cheaply in America, but it takes resources and know-how that many low-income Americans don't have. Kyera Reams of Osage, Iowa, puts an incredible amount of energy into feeding her family of six a healthy diet, with the help of staples from food banks and \$650 in monthly SNAP benefits. A stay-at-home mom with a high school education, Reams has taught herself how to can fresh produce and forage for wild ginger and cranberries. When she learned that SNAP benefits could be used to buy vegetable plants, she dug two gardens in her yard. She has learned about wild mushrooms so she can safely pick ones that aren't poisonous and has lobbied the local library to stock field guides to edible wild plants.

---

*Tracie McMillan is the author of The American Way of Eating. Photographers Kitra Cahana, Stephanie Sinclair, and Amy Toensing are known for their intimate, sensitive portraits of people.*





Dinner can be a haphazard affair for the White family. Parents Rebecca and Bob struggle to feed five children—and pay all their bills—on the \$2,000-a-month salary Bob earns at the nearby Winnebago plant. Nearly 60 percent of food-insecure U.S. households have at least one working family member.

AMY TOENSING





A young father braves the highways of sprawling Spring, Texas, north of Houston, to reach a homeless shelter and a free meal. The suburbs have become a new home for the hungry. The rates of poverty and of food stamp use are so high that advocates and legislators coined the phrase “the SUV poor.”

KITRA CAHANA



## Hunger in America

# Looking for a Decent Meal

“We wouldn’t eat healthy at all if we lived off the food-bank food,” Reams says. Many foods commonly donated to—or bought by—food pantries are high in salt, sugar, and fat. She estimates her family could live for three months on the nutritious foods she’s saved up. The Reamses have food security, in other words, because Kyera makes procuring food her full-time job, along with caring for her husband, whose disability payments provide their only income.

But most of the working poor don’t have the time or know-how required to eat well on little. Often working multiple jobs and night shifts, they tend to eat on the run. Healthful food can be hard to find in so-called food deserts—communities with few or no full-service groceries. Jackie Christian didn’t resort to feeding her sons fried gizzards because it was affordable but because it was easy. Given the dramatic increase in cheap fast foods and processed foods, when the hungry have money to eat, they often go for what’s convenient, just as better-off families do.

IT’S A CRUEL IRONY that people in rural Iowa can be malnourished amid forests of cornstalks running to the horizon. Iowa dirt is some of the richest in the nation, even bringing out the poet in agronomists, who describe it as “black gold.” In 2007 Iowa’s fields produced roughly one-sixth of all corn and soybeans grown in the U.S., churning out billions of bushels.

These are the very crops that end up on Christina Dreier’s kitchen table in the form of hot dogs made of corn-raised beef, Mountain Dew sweetened with corn syrup, and chicken nuggets fried in soybean oil. They’re also the foods that the U.S. government supports the most. In 2012 it spent roughly \$11 billion to subsidize and insure commodity crops like corn and soy, with Iowa among the states receiving the highest subsidies. The government spends much less to bolster the production of the fruits and vegetables its own nutrition guidelines say should make up half the food on our plates. In 2011 it spent only \$1.6 billion to subsidize and insure “specialty crops”—the bureaucratic term for fruits and vegetables.

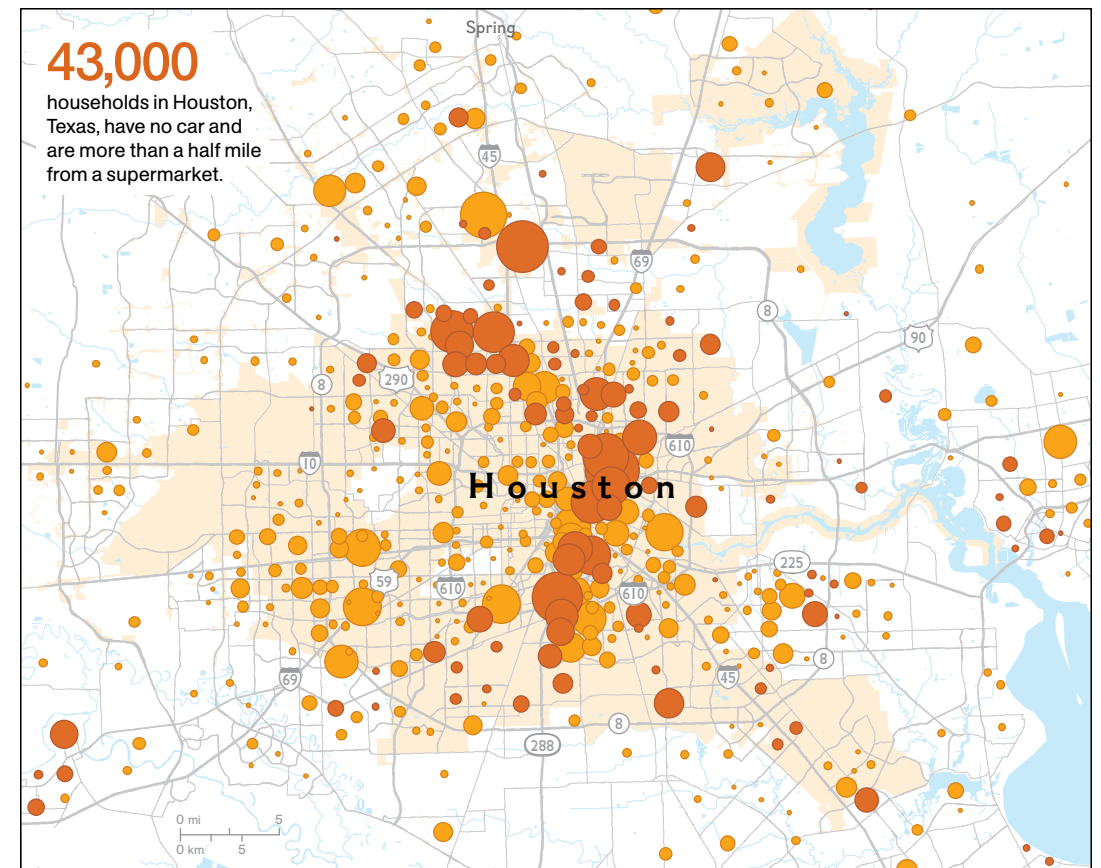
Those priorities are reflected at the grocery store, where the price of fresh food has risen steadily while the cost of sugary treats like soda has dropped. Since the early 1980s the real cost of fruits and vegetables has increased by 24 percent. Meanwhile the cost of nonalcoholic beverages—primarily sodas, most sweetened with corn syrup—has dropped by 27 percent.

“We’ve created a system that’s geared toward keeping overall food prices low but does little to support healthy, high-quality food,” says global food expert Raj Patel. “The problem can’t be fixed by merely telling people to eat their fruits and vegetables, because at heart this is a problem about wages, about poverty.”

When Christina Dreier’s cupboards start to get bare, she tries to persuade her kids to skip snack time. “But sometimes they eat saltine crackers, because we get that from the food bank,” she said, sighing. “It ain’t healthy for them, but I’m not going to tell them they can’t eat if they’re hungry.”

The Dreiers have not given up on trying to eat well. Like the Reamses, they’ve sown patches of vegetables and a stretch of sweet corn in the large green yard carved out of the cornfields behind their house. But when the garden is done for the year, Christina fights a battle every time she goes to the supermarket or the food bank. In both places healthy foods are nearly out of reach. When the food stamps come in, she splurges on her monthly supply of produce, including a bag of organic grapes and a bag of apples. “They love fruit,” she says with obvious pride. But most of her food dollars go to the meat, eggs, and milk that the food bank doesn’t provide; with noodles and sauce from the food pantry, a spaghetti dinner costs her only the \$3.88 required to buy hamburger for the sauce.

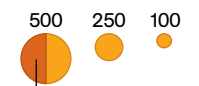
What she has, Christina says, is a kitchen with nearly enough food most of the time. It’s just those dicey moments, after a new bill arrives or she needs gas to drive the kids to town, that make it hard. “We’re not starved around here,” she says one morning as she mixes up powdered milk for her daughter. “But some days, we do go a little hungry.” □



### Stranded in a Food Desert

Tens of thousands of people in Houston and in other parts of the U.S. live in what’s called a food desert: Their homes are more than half a mile from a supermarket, and they don’t own a car, because of poverty, illness, or age. Public transportation may not fill the gap. How do they get nutritious food? Small neighborhood markets or fast-food restaurants may be within walking distance but may not accept food vouchers. And if they do, they may charge more and offer fewer nutritious options than supermarkets.

Households lacking a car and located more than half a mile from a supermarket



Dark orange: Households in neighborhoods with the greatest poverty

City of Houston



# Help for the Hungry

More than 48 million Americans rely on what used to be called food stamps, now SNAP: the Supplemental Nutrition Assistance Program. In 2013 benefits totaled \$75 billion, but payments to most households dropped; the average monthly benefit was \$133.07 a person, less than \$1.50 a meal. SNAP recipients typically run through their monthly allotment in three weeks, then turn to food pantries. Who qualifies for SNAP? Households with gross incomes no more than 130 percent of the poverty rate. For a family of four that qualifying point is \$31,005 a year.\*

\*QUALIFYING INCOMES IN ALASKA AND HAWAII ARE HIGHER THAN IN THE CONTIGUOUS U.S.

**17.6 million** households in the U.S. don't have adequate resources to meet their basic food needs.

**72%** of SNAP recipients are children, disabled adults, or the elderly.

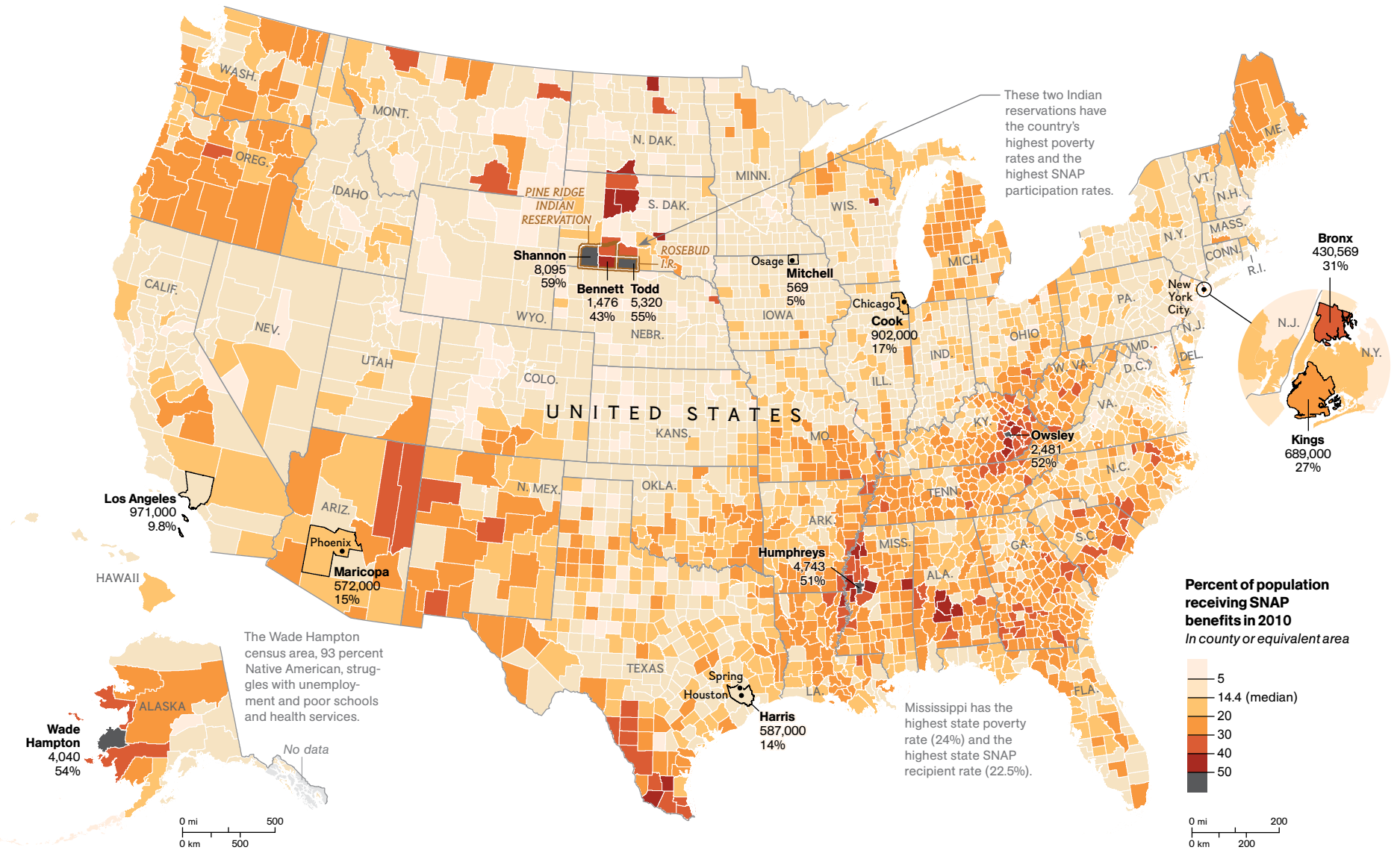
### Counties with the highest SNAP participation in 2010

Recipients, in thousands

1 Los Angeles, CA	971
2 Cook, IL	902
3 Kings, NY	689
4 Harris, TX	587
5 Maricopa, AZ	572

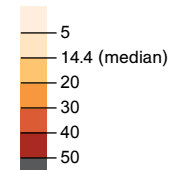
Percent of county population

1 Shannon, SD	59
2 Todd, SD	55
3 Wade Hampton, AK	54
4 Owsley, KY	52
5 Humphreys, MS	51



The Wade Hampton census area, 93 percent Native American, struggles with unemployment and poor schools and health services.

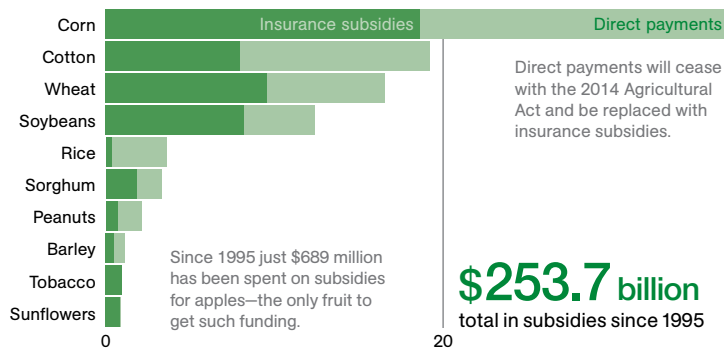
Percent of population receiving SNAP benefits in 2010  
In county or equivalent area



# Crops taxpayers support with subsidies

Top ten farm subsidies by crop  
1995–2012, in billions of dollars

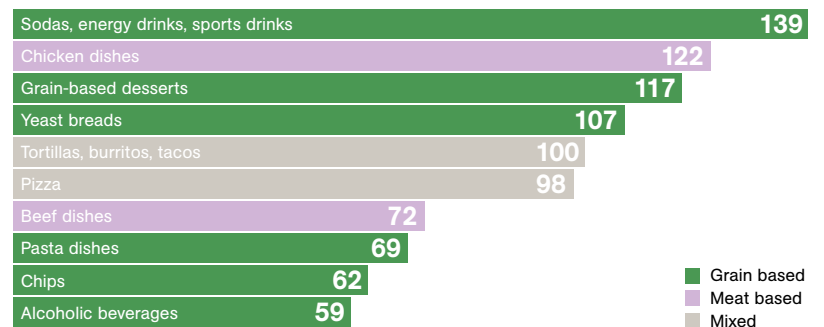
Federal crop subsidies began in the 1920s, when a quarter of the U.S. population worked on farms. The funds were meant to buffer losses from fluctuating harvests and natural disasters. Today most subsidies go to a few staple crops, produced mainly by large agricultural companies and cooperatives.



# How subsidized crops affect diet

Top ten sources of calories for low-income individuals  
Age two and older, per person per day

Subsidized corn is used for biofuel, corn syrup, and, mixed with soybeans, chicken feed. Subsidies reduce crop prices but also support the abundance of processed foods, which are more affordable but less nutritious. Across income brackets, processed foods make up a large part of the American diet.





# Shared Solutions



Food security is one of the biggest challenges facing the planet today. Bayer CropScience realizes they can't do it alone, and they need to grow the next generation of agricultural innovators who will help feed an estimated 9.6 billion people in 2050. "Farmers constantly experience new challenges that threaten food security worldwide," says Liam Condon, CEO of Bayer CropScience. "This drives the need for continual innovation and collaboration to ensure that the world has enough to eat." As a leading crop science company, with global stakeholders and partners, Bayer's holistic approach will help plant the seeds for a future in which everyone gets enough to eat.

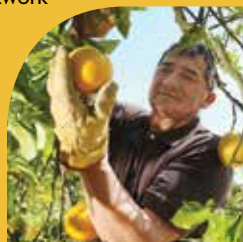
## FOR A HEALTHY WORLD



Science For A Better Life

### INNOVATION TO FEED THE WORLD

Population growth, changing eating habits, urbanization, diseases, and weather all impact the food supply chain. Research and development, new products, more efficient processes, and an expanded network of partnerships in the food chain help Bayer CropScience keep pace with increasing demand.



THE ORANGE MARKET HAS SUFFERED THE LOSS OF MORE THAN **\$4.5 BILLION** SINCE 2005



**Challenge:** Citrus greening by the Asian Citrus Psyllid insect is ravaging Florida's orange groves.

**Bayer CropScience Solution:** Provide growers with an integrated pest management approach, including crop protection products, monitoring tools, training in Brazil and California, and research.

**90%** OF GLOBAL RICE PRODUCTION IS CULTIVATED AND PRODUCED IN ASIA

**Challenge:** High salinity in soil challenges rice growers in Asia.

**Bayer CropScience Solution:** Create new hybrid variety that's salinity tolerant for greater productivity on coastlines and river deltas.

**29%** OF PRIMARY SCHOOL CHILDREN IN THE U.K. THINK THAT CHEESE COMES FROM PLANTS

**Challenge:** Children are increasingly alienated from agriculture and the demand for healthy food and efficient farming is rising.

**Bayer CropScience Solution:** Introduce an Agricultural Education Program, which includes hands-on learning programs, agricultural scholarships, and a Youth Ag-Summit.

**86%** OF U.S. CONSUMERS ARE AT LEAST SOMEWHAT CONCERNED WITH MODERN FARMING AND AGRICULTURAL FOOD PRODUCTION PRACTICES

**Challenge:** Demonstrate the benefits of modern agriculture that make food more available and affordable.

**Bayer CropScience Solution:** Launch the Farming's Future Dialogues, an open online discussion on the benefits modern agriculture brings to society.



Bayer CropScience's Agricultural Education Program is reaching out to the next generation of scientists, growers, and thought leaders with initiatives like a global youth conference in Canberra, Australia,

in 2015, now accepting applications at [YouthAgSummit.com](http://YouthAgSummit.com). Also core to its mission is collaboration with science, business, policymakers, and consumers through open, transparent dialogue. To facilitate this, Bayer has created multiple forums, educational centers, and platforms.

### YOUTH EDUCATION AND ENGAGING STAKEHOLDERS



#### Feeding future billions could be our biggest challenge yet.

Ensuring enough healthy food for everyone is a big job. Today, one in eight people doesn't have enough to eat. By 2050, it's estimated there will be two billion more people to feed. Bayer CropScience is committed to engaging tomorrow's thought leaders – with initiatives like the 2015 Youth Ag-Summit, agricultural scholarships and hands-on learning programs at our labs and farms – because innovating and working together is the only way we'll sustainably intensify agriculture. We've rolled up our sleeves to take on the challenge of feeding a hungry planet. And you can help.

Get involved today. Visit [cropscience.bayer.com](http://cropscience.bayer.com)

Sources: IRI; University of Florida; British Nutrition Foundation; Omnibus survey of more than 1,000 U.S. people, July 2014.





## Waste Not

How much food never makes it from the market to your mouth? According to a recent U.S. Department of Agriculture report on food loss, quite a lot. In 2010, 21 percent of food at the consumer level went uneaten. USDA defines food loss as “the amount of edible food, postharvest, that is available for human consumption but is not consumed.” It includes half-eaten pasta left at a café, scraps from food preparation, and sour milk a family pours down the drain. “It’s lost in bits and pieces along the way,” says scientist Dana Gunders. That means, she says, that small changes by consumers will add up. —Lindsay N. Smith

## 1,160 LBS.

is the annual average food loss for a U.S. family of four.

A year’s worth of uneaten food, represented here in the Waldt family’s New Jersey home, was later donated to a nonprofit.

### A YEAR OF FOOD LOSS ACCOUNTS FOR

**2.5%**

of U.S. energy consumption.

**>25%**

of all fresh water used for agriculture in the United States.

**300 MILLION**

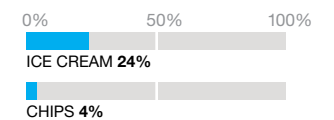
barrels of oil.

**\$115 BILLION**

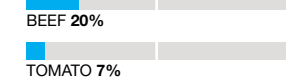
dollars lost.

### PERCENTAGE OF FOOD LEFT UNCONSUMED

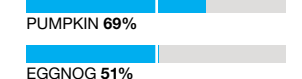
**SNACKS** Freezer burn, a likely cause of wasted ice cream, may look unappealing but doesn’t make the food unsafe.



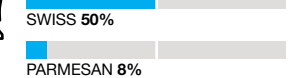
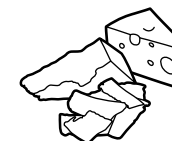
**DINNER** In 2010 U.S. consumers spent more than \$900 million on tomatoes that went uneaten.



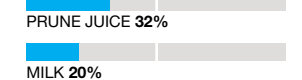
**HOLIDAY** Pumpkins are often wasted, likely because many are carved and not consumed.



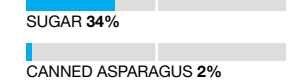
**CHEESE** Soft cheeses often spoil in weeks; hard cheeses tend to keep for months.



**BEVERAGES** Date labels, originally meant to indicate freshness, can mislead consumers into discarding edible food.



**PANTRY** The USDA’s sugar data includes both separate portions and sugar in premade foods.





Could eating like  
our ancestors make  
us healthier?

*Some experts say modern humans  
should eat from a Stone Age menu.  
What's on it may surprise you.*

# *The* Evolution of Diet

By *Ann Gibbons*

Photographs by *Matthieu Paley*





ESCARGOTS, SARDINES, AND FAVA BEANS, CRETE



NAAN IN SALTY YAK-MILK TEA, AFGHANISTAN



FRIED GERANIUM LEAVES, CRETE



BOILED CRAB, MALAYSIA



DRIED-APRICOT SOUP, PAKISTAN



BOILED PLANTAINS, BOLIVIA



STEWED-SEAWEED SALAD, MALAYSIA



BULGUR, BOILED EGGS, AND PARSLEY, TAJIKISTAN



GRILLED TUNA, MALAYSIA



COOKED POTATOES, TOMATOES, AND FAVA BEANS IN OLIVE OIL, CRETE



RICE WITH MELTED YAK BUTTER, AFGHANISTAN



FRIED FISH WITH TAMARIND, MALAYSIA



*It's suppertime in the Amazon of lowland Bolivia, and Ana Cuata Maito is stirring a porridge of plantains and sweet manioc over a fire smoldering on the dirt floor of her thatched hut, listening for the voice of her husband as he returns from the forest with his scrawny hunting dog.*

With an infant girl nursing at her breast and a seven-year-old boy tugging at her sleeve, she looks spent when she tells me that she hopes her husband, Deonicio Nate, will bring home meat tonight. “The children are sad when there is no meat,” Maito says through an interpreter, as she swats away mosquitoes.

Nate left before dawn on this day in January with his rifle and machete to get an early start on the two-hour trek to the old-growth forest. There he silently scanned the canopy for brown capuchin monkeys and raccoonlike coatis, while his dog sniffed the ground for the scent of pig-like peccaries or reddish brown capybaras. If he was lucky, Nate would spot one of the biggest packets of meat in the forest—tapirs, with long, prehensile snouts that rummage for buds and shoots among the damp ferns.

This evening, however, Nate emerges from the forest with no meat. At 39, he's an energetic guy who doesn't seem easily defeated—when he isn't hunting or fishing or weaving palm fronds into roof panels, he's in the woods carving a new canoe

from a log. But when he finally sits down to eat his porridge from a metal bowl, he complains that it's hard to get enough meat for his family: two wives (not uncommon in the tribe) and 12 children. Loggers are scaring away the animals. He can't fish on the river because a storm washed away his canoe.

The story is similar for each of the families I visit in Anachere, a community of about 90 members of the ancient Tsimane Indian tribe. It's the rainy season, when it's hardest to hunt or fish. More than 15,000 Tsimane live in about a hundred villages along two rivers in the Amazon Basin near the main market town of San Borja, 225 miles from La Paz. But Anachere is a two-day trip from San Borja by motorized dugout canoe, so the Tsimane living there still get most of their food from the forest, the river, or their gardens.

I'm traveling with Asher Rosinger, a doctoral candidate who's part of a team, co-led by biological anthropologist William Leonard of Northwestern University, studying the Tsimane to document what a rain forest diet looks like. They're particularly interested in how the

José Mayer Cunay, 78, looks for plantains ready to be picked near his *chaco*, a half-acre agricultural plot that the Tsimane elder and his son Felipe Mayer Lero created in the Bolivian Amazon using slash-and-burn techniques. Four generations of the family eat the fruit, corn, and other crops grown here, but the foods they prize most must be pursued: fish, fowl, and game.



**The Tsimane of Bolivia** get most of their food from the river, the forest, or fields and gardens carved out of the forest.



Indians' health changes as they move away from their traditional diet and active lifestyle and begin trading forest goods for sugar, salt, rice, oil, and increasingly, dried meat and canned sardines. This is not a purely academic inquiry. What anthropologists are learning about the diets of indigenous peoples like the Tsimane could inform what the rest of us should eat.

Rosinger introduces me to a villager named José Mayer Cunay, 78, who, with his son Felipe Mayer Lero, 39, has planted a lush garden by the river over the past 30 years. José leads us down a trail past trees laden with golden papayas and mangoes, clusters of green plantains, and orbs of grapefruit that dangle from branches

we choose to eat in the coming decades will have dramatic ramifications for the planet. Simply put, a diet that revolves around meat and dairy, a way of eating that's on the rise throughout the developing world, will take a greater toll on the world's resources than one that revolves around unrefined grains, nuts, fruits, and vegetables.

Until agriculture was developed around 10,000 years ago, all humans got their food by hunting, gathering, and fishing. As farming emerged, nomadic hunter-gatherers gradually were pushed off prime farmland, and eventually they became limited to the forests of the Amazon, the arid grasslands of Africa, the remote islands of Southeast Asia, and the tundra

## A diet that revolves around meat and dairy will take a greater toll on the world's resources than one based on unrefined grains, nuts, fruits, and vegetables.

like earrings. Vibrant red "lobster claw" heliconia flowers and wild ginger grow like weeds among stalks of corn and sugarcane. "José's family has more fruit than anyone," says Rosinger.

Yet in the family's open-air shelter Felipe's wife, Catalina, is preparing the same bland porridge as other households. When I ask if the food in the garden can tide them over when there's little meat, Felipe shakes his head. "It's not enough to live on," he says. "I need to hunt and fish. My body doesn't want to eat just these plants."

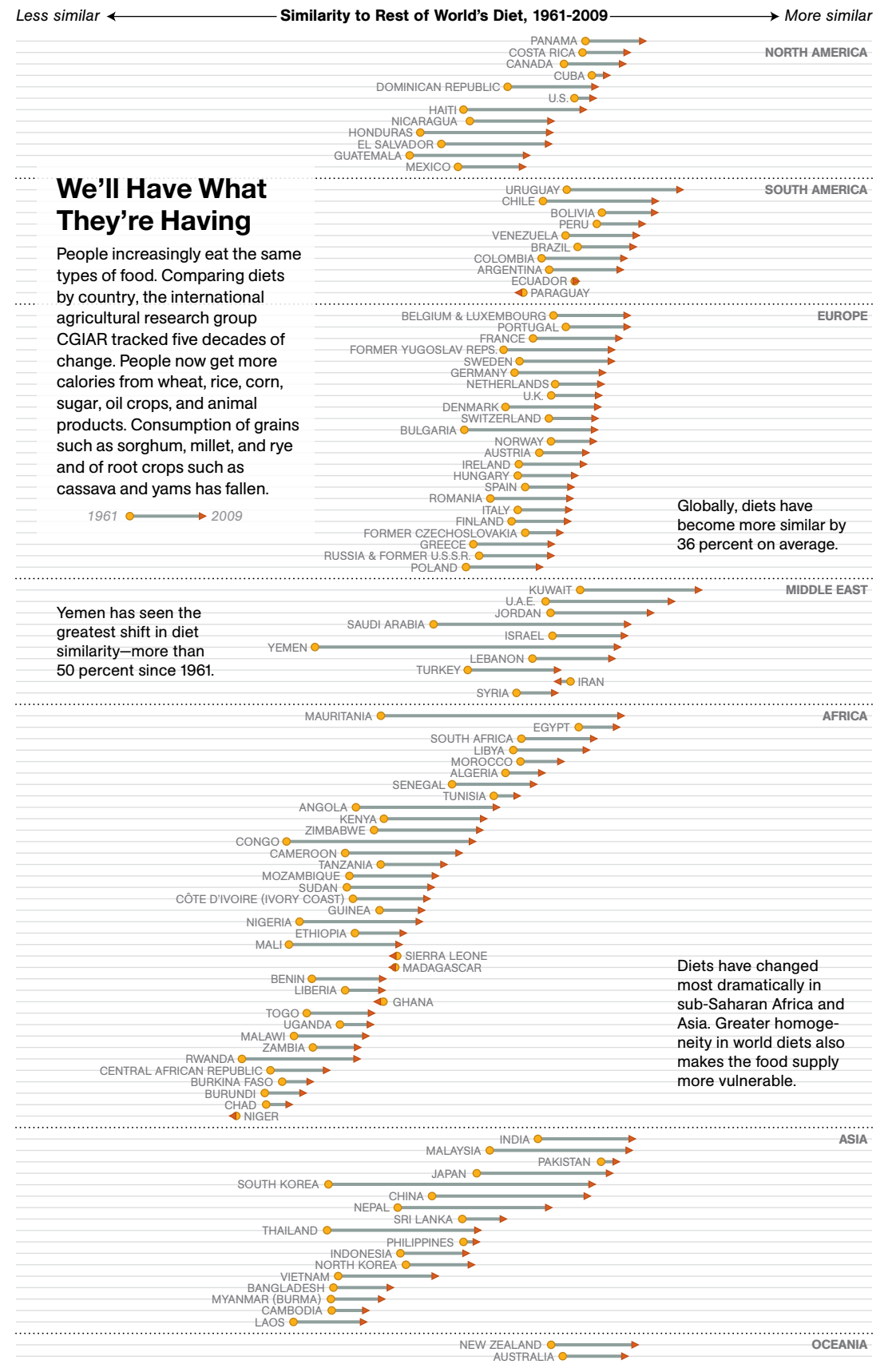
AS WE LOOK TO 2050, when we'll need to feed two billion more people, the question of which diet is best has taken on new urgency. The foods

*Ann Gibbons is the author of The First Human: The Race to Discover Our Earliest Ancestors. Matthieu Paley photographed Afghanistan's Kyrgyz for our February 2013 issue.*

of the Arctic. Today only a few scattered tribes of hunter-gatherers remain on the planet.

That's why scientists are intensifying efforts to learn what they can about an ancient diet and way of life before they disappear. "Hunter-gatherers are not living fossils," says Alyssa Crittenden, a nutritional anthropologist at the University of Nevada, Las Vegas, who studies the diet of Tanzania's Hadza people, some of the last true hunter-gatherers. "That being said, we have a small handful of foraging populations that remain on the planet. We are running out of time. If we want to glean any information on what a nomadic, foraging lifestyle looks like, we need to capture their diet now."

So far studies of foragers like the Tsimane, Arctic Inuit, and Hadza have found that these peoples traditionally didn't develop high blood pressure, atherosclerosis, or cardiovascular disease. "A lot of people believe there is a discordance between what we eat today and what



Only countries with populations greater than three million shown. Some country names reflect those used in 1961.

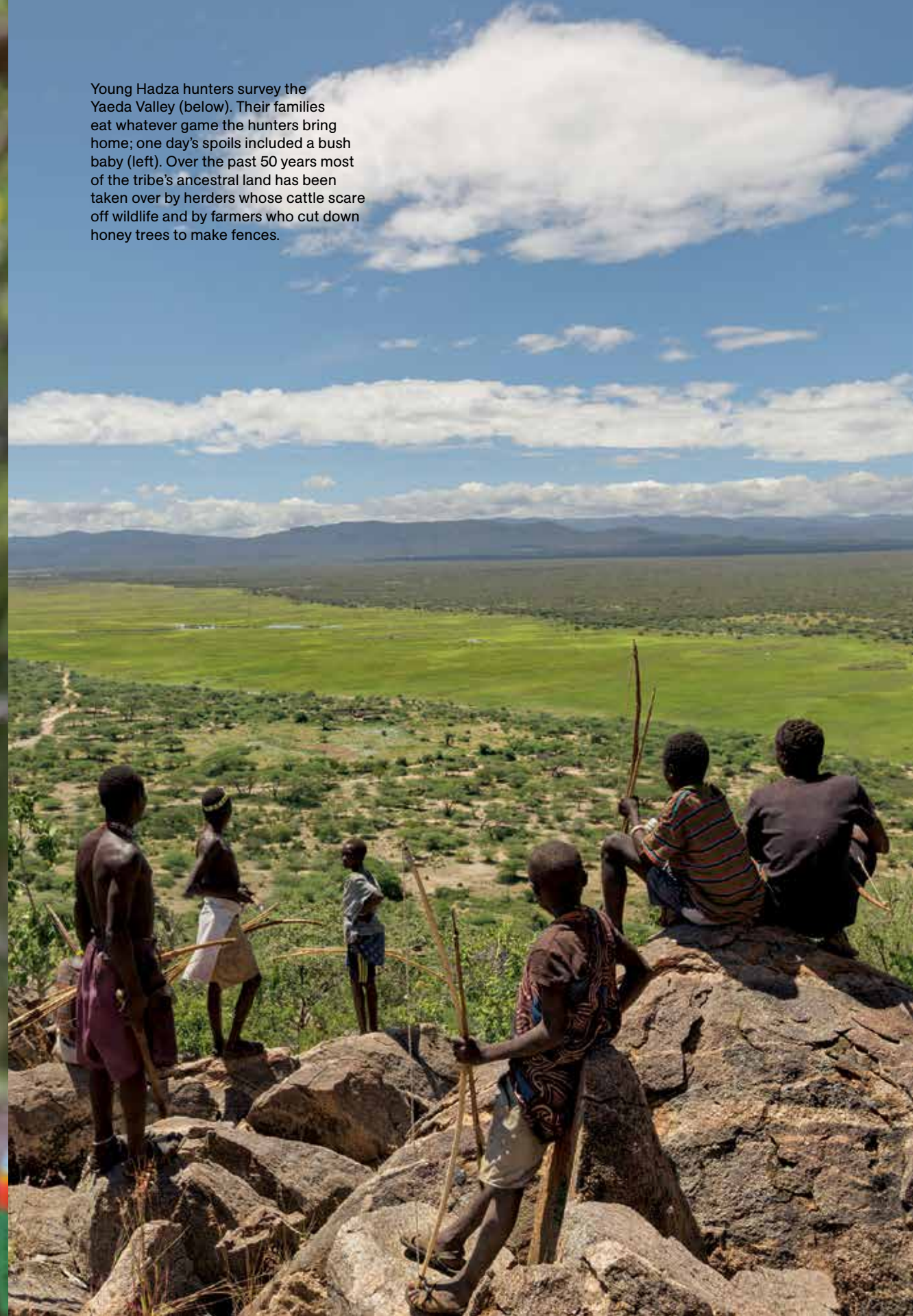
JASON TREAT, NGM STAFF. SOURCE: COLIN KHOURY, CGIAR



**The Hadza of Tanzania** are the world's last full-time hunter-gatherers. They live on what they find: game, honey, and plants, including tubers, berries, and baobab fruit.



Young Hadza hunters survey the Yaeda Valley (below). Their families eat whatever game the hunters bring home; one day's spoils included a bush baby (left). Over the past 50 years most of the tribe's ancestral land has been taken over by herders whose cattle scare off wildlife and by farmers who cut down honey trees to make fences.





our ancestors evolved to eat,” says paleoanthropologist Peter Ungar of the University of Arkansas. The notion that we’re trapped in Stone Age bodies in a fast-food world is driving the current craze for Paleolithic diets. The popularity of these so-called caveman or Stone Age diets is based on the idea that modern humans evolved to eat the way hunter-gatherers did during the Paleolithic—the period from about 2.6 million years ago to the start of the agricultural revolution—and that our genes haven’t had enough time to adapt to farmed foods.

A Stone Age diet “is the one and only diet that ideally fits our genetic makeup,” writes Loren Cordain, an evolutionary nutritionist

more complicated. The popular embrace of a Paleo diet, Ungar and others point out, is based on a stew of misconceptions.

MEAT HAS PLAYED a starring role in the evolution of the human diet. Raymond Dart, who in 1924 discovered the first fossil of a human ancestor in Africa, popularized the image of our early ancestors hunting meat to survive on the African savanna. Writing in the 1950s, he described those humans as “carnivorous creatures, that seized living quarries by violence, battered them to death...slaking their ravenous thirst with the hot blood of victims and greedily devouring livid writhing flesh.”

## The popularity of so-called Stone Age diets is based on the idea that modern humans evolved to eat the way hunter-gatherers did during the Paleolithic period.

at Colorado State University, in his book *The Paleo Diet: Lose Weight and Get Healthy by Eating the Foods You Were Designed to Eat*. After studying the diets of living hunter-gatherers and concluding that 73 percent of these societies derived more than half their calories from meat, Cordain came up with his own Paleo prescription: Eat plenty of lean meat and fish but not dairy products, beans, or cereal grains—foods introduced into our diet after the invention of cooking and agriculture. Paleo-diet advocates like Cordain say that if we stick to the foods our hunter-gatherer ancestors once ate, we can avoid the diseases of civilization, such as heart disease, high blood pressure, diabetes, cancer, even acne.

That sounds appealing. But is it true that we all evolved to eat a meat-centric diet? Both paleontologists studying the fossils of our ancestors and anthropologists documenting the diets of indigenous people today say the picture is a bit

Eating meat is thought by some scientists to have been crucial to the evolution of our ancestors’ larger brains about two million years ago. By starting to eat calorie-dense meat and marrow instead of the low-quality plant diet of apes, our direct ancestor, *Homo erectus*, took in enough extra energy at each meal to help fuel a bigger brain. Digesting a higher quality diet and less bulky plant fiber would have allowed these humans to have much smaller guts. The energy freed up as a result of smaller guts could be used by the greedy brain, according to Leslie Aiello, who first proposed the idea with paleoanthropologist Peter Wheeler. The brain requires 20 percent of a human’s energy when resting; by comparison, an ape’s brain requires only 8 percent. This means that from the time of *H. erectus*, the human body has depended on a diet of energy-dense food—especially meat.

Fast-forward a couple of million years to

when the human diet took another major turn with the invention of agriculture. The domestication of grains such as sorghum, barley, wheat, corn, and rice created a plentiful and predictable food supply, allowing farmers’ wives to bear babies in rapid succession—one every 2.5 years instead of one every 3.5 years for hunter-gatherers. A population explosion followed; before long, farmers outnumbered foragers.

Over the past decade anthropologists have struggled to answer key questions about this transition. Was agriculture a clear step forward for human health? Or in leaving behind our hunter-gatherer ways to grow crops and raise livestock, did we give up a healthier diet and stronger bodies in exchange for food security?

When biological anthropologist Clark Spencer Larsen of Ohio State University describes the dawn of agriculture, it’s a grim picture. As the earliest farmers became dependent on crops, their diets became far less nutritionally diverse than hunter-gatherers’ diets. Eating the same domesticated grain every day gave early farmers cavities and periodontal disease rarely found in hunter-gatherers, says Larsen. When farmers began domesticating animals, those cattle, sheep, and goats became sources of milk and meat but also of parasites and new infectious diseases. Farmers suffered from iron deficiency and developmental delays, and they shrank in stature.

Despite boosting population numbers, the lifestyle and diet of farmers were clearly not as healthy as the lifestyle and diet of hunter-gatherers. That farmers produced more babies, Larsen says, is simply evidence that “you don’t have to be disease free to have children.”

THE REAL PALEOLITHIC DIET, though, wasn’t all meat and marrow. It’s true that hunter-gatherers around the world crave meat more than any other food and usually get around 30 percent of their annual calories from animals. But most also endure lean times when they eat less than a handful of meat each week. New studies suggest that more than a reliance on meat in ancient human diets fueled the brain’s expansion.

Year-round observations confirm that hunter-

gatherers often have dismal success as hunters. The Hadza and Kung bushmen of Africa, for example, fail to get meat more than half the time when they venture forth with bows and arrows. This suggests it was even harder for our ancestors who didn’t have these weapons. “Everybody thinks you wander out into the savanna and there are antelopes everywhere, just waiting for you to bonk them on the head,” says paleoanthropologist Alison Brooks of George Washington University, an expert on the Dobe Kung of Botswana. No one eats meat all that often, except in the Arctic, where Inuit and other groups traditionally got as much as 99 percent of their calories from seals, narwhals, and fish.

So how do hunter-gatherers get energy when there’s no meat? It turns out that “man the hunter” is backed up by “woman the forager,” who, with some help from children, provides more calories during difficult times. When meat, fruit, or honey is scarce, foragers depend on “fallback foods,” says Brooks. The Hadza get almost 70 percent of their calories from plants. The Kung traditionally rely on tubers and mongongo nuts, the Aka and Baka Pygmies of the Congo River Basin on yams, the Tsimane and Yanomami Indians of the Amazon on plantains and manioc, the Australian Aboriginals on nut grass and water chestnuts.

“There’s been a consistent story about hunting defining us and that meat made us human,” says Amanda Henry, a paleobiologist at the Max Planck Institute for Evolutionary Anthropology in Leipzig. “Frankly, I think that misses half of the story. They want meat, sure. But what they actually live on is plant foods.” What’s more, she found starch granules from plants on fossil teeth and stone tools, which suggests humans may have been eating grains, as well as tubers, for at least 100,000 years—long enough to have evolved the ability to tolerate them.

The notion that we stopped evolving in the Paleolithic period simply isn’t true. Our teeth, jaws, and faces have gotten smaller, and our DNA has changed since the invention of agriculture. “Are humans still evolving? Yes!” says geneticist Sarah Tishkoff of the University of Pennsylvania.

One striking piece of evidence is lactose tolerance. All humans digest mother’s milk as infants,





**The Bajau of Malaysia** fish and dive for almost everything they eat. Some live in houses on the beach or on stilts; others have no homes but their boats.

Her face dusted in *bedak sejuk*, a cooling powder made of rice and pandan leaves, Alpaidda paddles out to visit friends in stilt houses. The teen and her family belong to the tribal group known as the Sea Bajau because they live year-round on their *lepa-lepas*, handmade houseboats.





**Greenland's Inuit** survived for generations eating almost nothing but meat in a landscape too harsh for most plants. Today markets offer more variety, but a taste for meat persists.



An Inuit girl feeds her brother (left) a bit of liver from a seal their father has just caught. What's not eaten right away will stay frozen in outdoor sheds; one family's "freezer" (above) holds the meat, ribs, and jaw of a killer whale and the foreflipper of a bearded seal.





Ayeem Khan wears boots borrowed from her father and the red veil of an unmarried Kyrgyz girl, to be traded for a white one when she weds. Twice a day she milks the family's yaks; some milk curd will be dried for use in winter, when yaks give less.

**The Kyrgyz of the Pamir Mountains** in northern Afghanistan live at a high altitude where no crops grow. Survival depends on the animals that they milk, butcher, and barter.



but until cattle began being domesticated 10,000 years ago, weaned children no longer needed to digest milk. As a result, they stopped making the enzyme lactase, which breaks down the lactose into simple sugars. After humans began herding cattle, it became tremendously advantageous to digest milk, and lactose tolerance evolved independently among cattle herders in Europe, the Middle East, and Africa. Groups not dependent on cattle, such as the Chinese and Thai, the Pima Indians of the American Southwest, and the Bantu of West Africa, remain lactose intolerant.

Humans also vary in their ability to extract sugars from starchy foods as they chew them, depending on how many copies of a certain gene

living. Diabetes was virtually unknown, for instance, among the Maya of Central America until the 1950s. As they've switched to a Western diet high in sugars, the rate of diabetes has skyrocketed. Siberian nomads such as the Evenk reindeer herders and the Yakut ate diets heavy in meat, yet they had almost no heart disease until after the fall of the Soviet Union, when many settled in towns and began eating market foods. Today about half the Yakut living in villages are overweight, and almost a third have hypertension, says Leonard. And Tsimane people who eat market foods are more prone to diabetes than those who still rely on hunting and gathering.

For those of us whose ancestors were adapted

## The real hallmark of being human isn't our taste for meat but our ability to adapt to many habitats and to create many healthy diets.

they inherit. Populations that traditionally ate more starchy foods, such as the Hadza, have more copies of the gene than the Yakut meat-eaters of Siberia, and their saliva helps break down starches before the food reaches their stomachs.

These examples suggest a twist on "You are what you eat." More accurately, you are what your ancestors ate. There is tremendous variation in what foods humans can thrive on, depending on genetic inheritance. Traditional diets today include the vegetarian regimen of India's Jains, the meat-intensive fare of Inuit, and the fish-heavy diet of Malaysia's Bajau people. The Nochmani of the Nicobar Islands off the coast of India get by on protein from insects. "What makes us human is our ability to find a meal in virtually any environment," says the Tsimane study co-leader Leonard.

Studies suggest that indigenous groups get into trouble when they abandon their traditional diets and active lifestyles for Western

to plant-based diets—and who have desk jobs—it might be best not to eat as much meat as the Yakut. Recent studies confirm older findings that although humans have eaten red meat for two million years, heavy consumption increases atherosclerosis and cancer in most populations—and the culprit isn't just saturated fat or cholesterol. Our gut bacteria digest a nutrient in meat called L-carnitine. In one mouse study, digestion of L-carnitine boosted artery-clogging plaque. Research also has shown that the human immune system attacks a sugar in red meat that's called Neu5Gc, causing inflammation that's low level in the young but that eventually could cause cancer. "Red meat is great, if you want to live to 45," says Ajit Varki of the University of California, San Diego, lead author of the Neu5Gc study.

Many paleoanthropologists say that although advocates of the modern Paleolithic diet urge us

to stay away from unhealthy processed foods, the diet's heavy focus on meat doesn't replicate the diversity of foods that our ancestors ate—or take into account the active lifestyles that protected them from heart disease and diabetes. "What bothers a lot of paleoanthropologists is that we actually didn't have just one caveman diet," says Leslie Aiello, president of the Wenner-Gren Foundation for Anthropological Research in New York City. "The human diet goes back at least two million years. We had a lot of cavemen out there."

In other words, there is no one ideal human diet. Aiello and Leonard say the real hallmark of being human isn't our taste for meat but our ability to adapt to many habitats—and to be able to combine many different foods to create many healthy diets. Unfortunately the modern Western diet does not appear to be one of them.

THE LATEST CLUE as to why our modern diet may be making us sick comes from Harvard primatologist Richard Wrangham, who argues that the biggest revolution in the human diet came not when we started to eat meat but when we learned to cook. Our human ancestors who began cooking sometime between 1.8 million and 400,000 years ago probably had more children who thrived, Wrangham says. Pounding and heating food "predigests" it, so our guts spend less energy breaking it down, absorb more than if the food were raw, and thus extract more fuel for our brains. "Cooking produces soft, energy-rich foods," says Wrangham. Today we can't survive on raw, unprocessed food alone, he says. We have evolved to depend upon cooked food.

To test his ideas, Wrangham and his students fed raw and cooked food to rats and mice. When I visited Wrangham's lab at Harvard, his then graduate student, Rachel Carmody, opened the door of a small refrigerator to show me plastic bags filled with meat and sweet potatoes, some raw and some cooked. Mice raised on cooked foods gained 15 to 40 percent more weight than mice raised only on raw food.

If Wrangham is right, cooking not only gave early humans the energy they needed to build bigger brains but also helped them get more

calories from food so that they could gain weight. In the modern context the flip side of his hypothesis is that we may be victims of our own success. We have gotten so good at processing foods that for the first time in human evolution, many humans are getting more calories than they burn in a day. "Rough breads have given way to Twinkies, apples to apple juice," he writes. "We need to become more aware of the calorie-raising consequences of a highly processed diet."

It's this shift to processed foods, taking place all over the world, that's contributing to a rising epidemic of obesity and related diseases. If most of the world ate more local fruits and vegetables, a little meat, fish, and some whole grains (as in the highly touted Mediterranean diet), and exercised an hour a day, that would be good news for our health—and for the planet.

ON MY LAST AFTERNOON visiting the Tsimane in Anachere, one of Deonicio Nate's daughters, Albania, 13, tells us that her father and half-brother Alberto, 16, are back from hunting and that they've got something. We follow her to the cooking hut and smell the animals before we see them—three raccoonlike coatis have been laid across the fire, fur and all. As the fire sings the coatis' striped pelts, Albania and her sister, Emiliana, 12, scrape off fur until the animals' flesh is bare. Then they take the carcasses to a stream to clean and prepare them for roasting.

Nate's wives are cleaning two armadillos as well, preparing to cook them in a stew with shredded plantains. Nate sits by the fire, describing a good day's hunt. First he shot the armadillos as they napped by a stream. Then his dog spotted a pack of coatis and chased them, killing two as the rest darted up a tree. Alberto fired his shotgun but missed. He fired again and hit a coati. Three coatis and two armadillos were enough, so father and son packed up and headed home.

As family members enjoy the feast, I watch their little boy, Alfonso, who had been sick all week. He is dancing around the fire, happily chewing on a cooked piece of coati tail. Nate looks pleased. Tonight in Anachere, far from the diet debates, there is meat, and that is good. □



# A Natural Solution

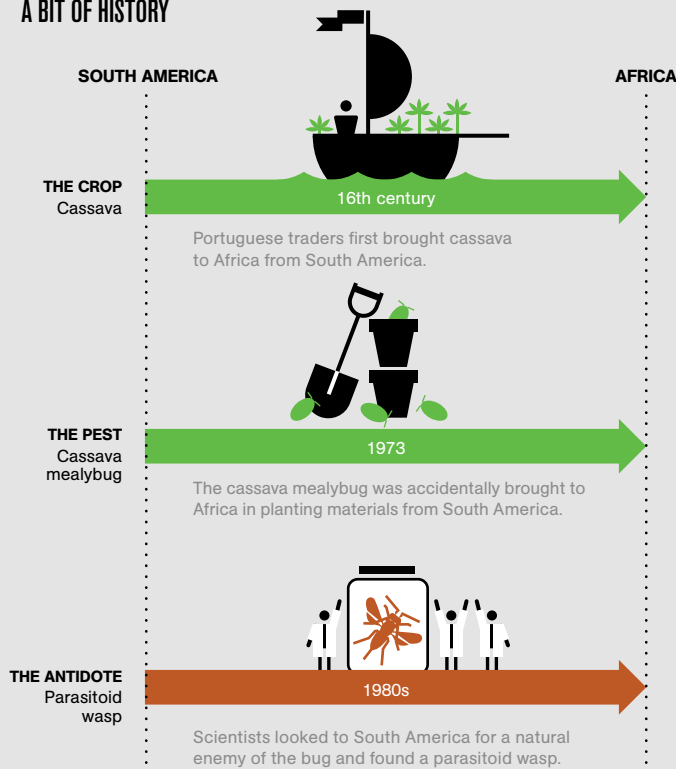
A growing number of farmers are managing agricultural pests with biopesticides and biological control agents, including natural materials such as plants, bacteria, and fungi. Predatory and parasitic insects are a form of biological control. All these methods work to keep pest levels low enough to minimize crop losses without posing a major threat to the environment.

Demand for produce free of pesticide residues is driving the increase in biopesticides, says Mark Davis of the UN Food and Agriculture Organization. Biopesticides are inherently less harmful to humans and break down more quickly than typical agrochemicals. According to Davis, some beneficial fungi even go beyond pest killing by liberating soil nutrients that promote plant growth. —Kelsey Nowakowski

## THE CASSAVA CASE

Cassava's starchy roots are a staple for millions of Africans, but cassava mealybugs ravaged the continent's crops in the 1970s and 1980s, decreasing yields by up to 80 percent. Scientists found a solution in natural pest management.

### A BIT OF HISTORY



### NATURE IN ACTION

- A** The mealybug sucks sap from cassava leaves, causing them to shrivel and clump together.
- B** The female parasitoid wasp lays its eggs in the mealybug, which remains alive as larvae develop.
- C** When the eggs hatch, emerging larvae eat the mealybug from the inside out, killing their host.
- D** As new wasps hatch, the process starts over again, gradually reducing the pest population.

### ECONOMIC BENEFIT

For every **\$1** spent on biological control, **\$150** was returned to cassava farmers

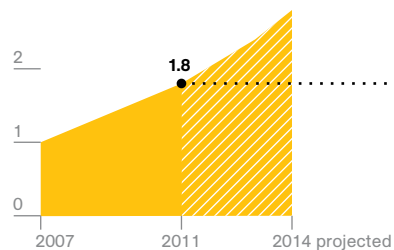
**2-4 YEARS**

AMOUNT OF TIME IT TAKES TO FULLY MANAGE MEALYBUG INFESTATION

## BIOPESTICIDE SALES

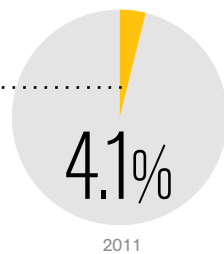
BIOPESTICIDE SALES ARE GROWING...

\$3 billion



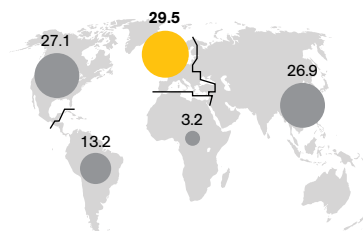
Biopesticide statistics include invertebrates.

BUT ARE STILL A SMALL PART OF THE TOTAL PESTICIDE MARKET



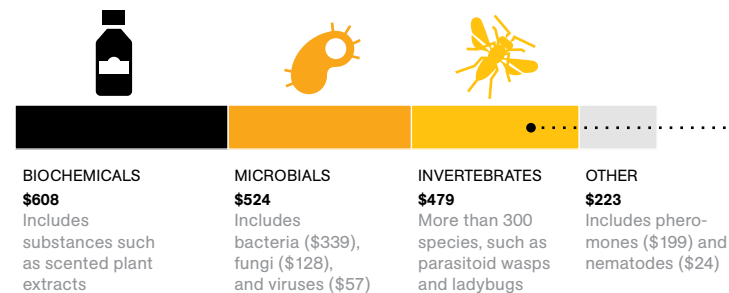
## TOP MARKETS

PERCENTAGE OF BIOPESTICIDE SALES BY REGION, 2011



## SALES BY TYPE

2011 WORLDWIDE SALES, IN MILLIONS (U.S. DOLLARS)





Science prevented  
the last food crisis. Can  
it save us again?

*Modern supercrops will be a  
big help. But agriculture can't  
be fixed by biotech alone.*

# *The* Next Green Revolution

By *Tim Folger*

Photographs by *Craig Cutler*





In a wheat seed bank at Kansas State, plant pathologist Bikram Gill holds a "genetic treasure": goat grass. About 8,000 years ago the Middle Eastern weed (enlarged above) naturally pollinated another wheat ancestor, creating a grain that went global. Gill is mimicking nature, tapping goat grass for genes to help modern wheat resist pests, heat, and cold.





Red-eyed Asian citrus psyllids, an eighth of an inch long, feast on an orange stem. The insects spread citrus greening, a bacterial scourge sweeping through Florida's citrus groves. Infected trees produce deformed, green, bitter fruit. At left, seedlings genetically altered to make defensive antibiotics may help protect a nine-billion-dollar industry.

USGS BEE INVENTORY AND MONITORING LABORATORY (RIGHT)



*Something is killing Ramadhani Juma's cassava crop. "Maybe it's too much water," he says, fingering clusters of withered yellow leaves on a six-foot-high plant. "Or too much sun." Juma works a small plot, barely more than an acre, near the town of Bagamoyo, on the Indian Ocean about 40 miles north of Dar es Salaam, Tanzania. On a rainy March morning, trailed by two of his four young sons,*

he's talking with a technician from the big city, 28-year-old Deogratius Mark of the Mikocheni Agricultural Research Institute. Mark tells Juma his problem is neither sun nor rain. The real cassava killers, far too small to see, are viruses.

Mark breaks off some wet leaves; a few whiteflies dart away. The pinhead-size flies, he explains, transmit two viruses. One ravages cassava leaves, and a second, called brown streak virus, destroys the starchy, edible root—a catastrophe that usually isn't discovered until harvest time. Juma is typical of the farmers Mark meets—most have never heard of the viral diseases. "Can you imagine how he'll feel if I tell him he has to uproot all these plants?" Mark says quietly.

Juma is wearing torn blue shorts and a faded green T-shirt with "Would you like to buy a vowel?" printed on the front. He listens carefully to Mark's diagnosis. Then he unshoulders his heavy hoe and starts digging. His oldest son, who is ten, nibbles a cassava leaf. Uncovering a cassava root, Juma splits it open with one swing of his hoe. He sighs—the creamy white flesh is streaked with brown, rotting starch.

To save enough of the crop to sell and to feed his family, Juma will have to harvest a month early. I ask how important cassava is to him.

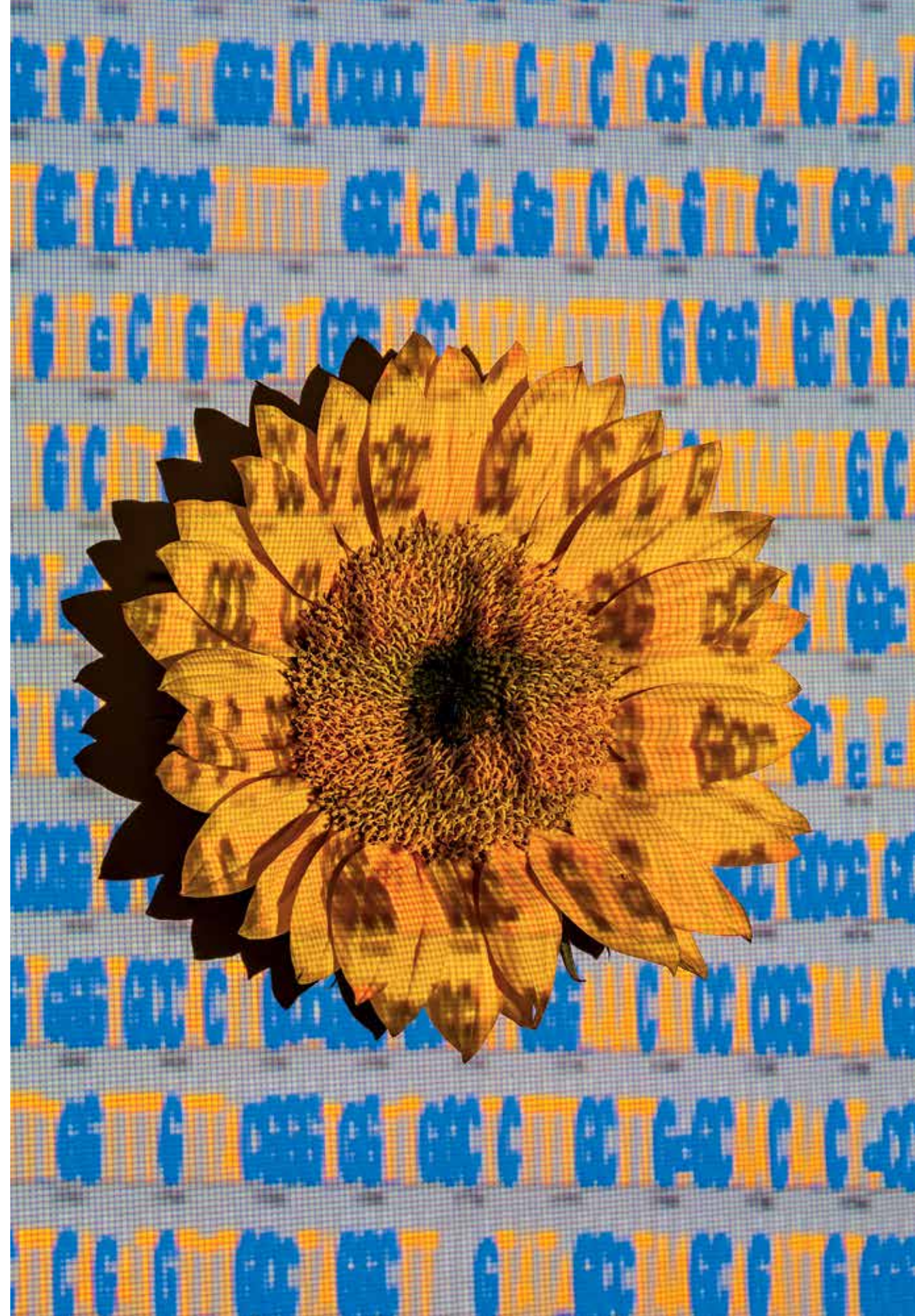
"*Mihogo ni kila kitu*," he replies in Swahili. "Cassava is everything."

Most Tanzanians are subsistence farmers. In Africa small family farms grow more than 90 percent of all crops, and cassava is a staple for more than 250 million people. It grows even in marginal soils, and it tolerates heat waves and droughts. It would be the perfect crop for 21st-century Africa—were it not for the whitefly, whose range is expanding as the climate warms. The same viruses that have invaded Juma's field have already spread throughout East Africa.

Before leaving Bagamoyo, we meet one of Juma's neighbors, Shija Kagembe. His cassava fields have fared no better. He listens silently as Mark tells him what the viruses have done. "How can you help us?" he asks.

ANSWERING THAT QUESTION will be one of the greatest challenges of this century. Climate change and population growth will make life

The genes of all living things on Earth—including the sunflower, a valuable oil crop—consist of varying sequences of four chemical compounds: adenine, thymine, cytosine, and guanine, abbreviated as A, T, C, and G. By identifying genes and manipulating them, scientists hope to create new crops that will help us face the challenges of global warming and population growth.





increasingly precarious for Juma, Kagembe, and other small farmers in the developing world—and for the people they feed. For most of the 20th century humanity managed to stay ahead in the Malthusian race between population growth and food supply. Will we be able to maintain that lead in the 21st century, or will a global catastrophe beset us?

The United Nations forecasts that by 2050 the world's population will grow by more than two billion people. Half will be born in sub-Saharan Africa, and another 30 percent in South and Southeast Asia. Those regions are also where the effects of climate change—drought, heat waves, extreme weather generally—are expected to hit hardest. Last March the Intergovernmental Panel on Climate Change warned that the world's food supply is already jeopardized. "In the last 20 years, particularly for rice, wheat, and corn, there has been a slowdown in the growth rate of crop yields," says Michael Oppenheimer, a climate scientist at Princeton and one of the authors of the IPCC report. "In some areas yields have stopped growing entirely. My personal view is that the breakdown of food systems is the biggest threat of climate change."

Half a century ago disaster loomed just as ominously. Speaking about global hunger at a meeting of the Ford Foundation in 1959, one economist said, "At best the world outlook for the decades ahead is grave; at worst it is frightening." Nine years later Paul Ehrlich's best seller, *The Population Bomb*, predicted that famines, especially in India, would kill hundreds of millions in the 1970s and 1980s.

Before those grim visions could come to pass, the green revolution transformed global agriculture, especially wheat and rice. Through selective breeding, Norman Borlaug, an American biologist, created a dwarf variety of wheat that put most of its energy into edible kernels rather than long, inedible stems. The result: more grain per acre. Similar work at the International Rice

Research Institute (IRRI) in the Philippines dramatically improved the productivity of the grain that feeds nearly half the world.

From the 1960s through the 1990s, yields of rice and wheat in Asia doubled. Even as the continent's population increased by 60 percent, grain prices fell, the average Asian consumed nearly a third more calories, and the poverty rate was cut in half. When Borlaug won the Nobel Peace Prize in 1970, the citation read, "More than any other person of this age, he helped provide bread for a hungry world."

To keep doing that between now and 2050, we'll need another green revolution. There are two competing visions of how it will happen. One is high-tech, with a heavy emphasis on continuing Borlaug's work of breeding better crops, but with modern genetic techniques. "The next green revolution will supercharge the tools of the old one," says Robert Fraley, chief technology officer at Monsanto and a winner of the prestigious World Food Prize in 2013. Scientists, he argues, can now identify and manipulate a huge variety of plant genes, for traits like disease resistance and drought tolerance. That's going to make farming more productive and resilient.

The signature technology of this approach—and the one that has brought both success and controversy to Monsanto—is genetically modified, or GM, crops. First released in the 1990s, they've been adopted by 28 countries and planted on 11 percent of the world's arable land, including half the cropland in the U.S. About 90 percent of the corn, cotton, and soybeans grown in the U.S. are genetically modified. Americans have been eating GM products for nearly two decades. But in Europe and much of Africa, debates over the safety and environmental effects of GM crops have largely blocked their use.

Proponents like Fraley say such crops have prevented billions of dollars in losses in the U.S. alone and have actually benefited the environment. A recent study by the U.S. Department of Agriculture found that pesticide use on corn crops has dropped 90 percent since the introduction of Bt corn, which contains genes from the bacterium *Bacillus thuringiensis* that help it



The cassava plants in this petri dish have been genetically engineered to resist brown streak virus, a disease that's spreading across sub-Saharan Africa, where cassava is a staple for 250 million people. Field tests began last spring in Uganda. Only four African countries allow the planting of genetically modified crops.

ward off corn borers and other pests. Reports from China indicate that harmful aphids have decreased—and ladybugs and other beneficial insects have increased—in provinces where GM cotton has been planted.

The particular GM crops Fraley pioneered at Monsanto have been profitable for the company and many farmers, but have not helped sell the cause of high-tech agriculture to the public. Monsanto's Roundup Ready crops are genetically modified to be immune to the herbicide Roundup, which Monsanto also manufactures.

That means farmers can spray the herbicide freely to eliminate weeds without damaging their GM corn, cotton, or soybeans. Their contract with Monsanto does not allow them to save seeds for planting; they must purchase its patented seeds each year.

Though there's no clear evidence that Roundup or Roundup Ready crops are unsafe, proponents of an alternative vision of agriculture see those expensive GM seeds as a costly input to a broken system. Modern agriculture, they say, already relies too heavily on synthetic fertilizers

---

*Tim Folger's last feature was the September 2013 cover story on sea-level rise. This is photographer Craigh Cutler's first article for the magazine.*



## Breeding Better Crops

Genetic modification gets the public attention—and the controversy—but plant breeders today have numerous tools for creating crops with new traits. The goal: continually increasing yields in an increasingly challenging climate.

### Traditional breeding

Desired traits are identified in separate individuals of the same species, which are then bred to combine those traits in a new hybrid variety.



### Interspecies crosses

Breeders can also cross different yet similar species. Modern wheat comes from such hybridizations, some of which happened naturally.



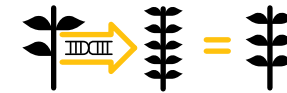
### Marker-assisted selection

When genes for a trait aren't precisely known, targeting a DNA marker near them can speed up breeding: It identifies plants with the trait even before they mature.



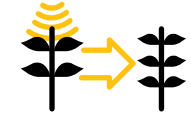
### Genetic modification

Genes identified in one species can be transferred directly to an unrelated species, giving it an entirely new trait—resistance to a pest, say, or to a weed killer.



### Mutation breeding

Seeds are irradiated to promote random mutations in their DNA. If a mutation happens to produce a desirable trait, the plant is selected for further breeding.



and pesticides. Not only are they unaffordable for a small farmer like Juma; they pollute land, water, and air. Synthetic fertilizers are manufactured using fossil fuels, and they themselves emit potent greenhouse gases when they're applied to fields.

"The choice is clear," says Hans Herren, another World Food Prize laureate and the director of Biovision, a Swiss nonprofit. "We need a farming system that is much more mindful of the landscape and ecological resources. We need to change the paradigm of the green revolution. Heavy-input agriculture has no future—we need something different." There are ways to deter pests and increase yields, he thinks, that are more suitable for the Jumans of this world.

MONSANTO IS NOT THE ONLY organization that believes modern plant genetics can help feed the world. Late on a warm February afternoon Glenn Gregorio, a plant geneticist at the International Rice Research Institute, shows me the rice that started the green revolution in Asia. We're in Los Baños, a town about 40 miles southeast of Manila, walking along the edge of some very special rice fields, of which there are many on the institute's 500 acres.

"This is the miracle rice—IR8," says Gregorio, as we stop beside an emerald patch of crowded, thigh-high rice plants. Roosters crow in the distance; egrets gleam white against so much

green; silvery light glints off the flooded fields. IRRI, a nonprofit, was founded by the Ford and Rockefeller Foundations in 1960. Two years later a plant pathologist named Peter Jennings began a series of crossbreeding experiments. He had 10,000 varieties of rice seeds to work with. His eighth cross—between a dwarf strain from Taiwan and a taller variety from Indonesia—created the fast-growing, high-yielding strain later known as India Rice 8 for its role in preventing famine in that country. "It revolutionized rice production in Asia," says Gregorio. "Some parents in India named their sons IR8."

Walking along the paddies, we pass other landmark breeds, each designated with a neatly painted wooden sign. The institute releases dozens of new varieties every year; about a thousand have been planted around the world since the 1960s. Yields have typically improved by just under one percent a year. "We want to raise that to 2 percent," Gregorio says. The world's population growth rate, now 1.14 percent a year, is projected to slow to 0.5 percent by 2050.

For many decades IRRI focused on improving traditional varieties of rice, grown in fields that are flooded at planting time. Lately it has shifted its attention to climate change. It now offers drought-tolerant varieties, including one that can be planted in dry fields and subsist on rainfall, as corn and wheat do. There's a salt-tolerant rice for countries like Bangladesh, where rising

seas are poisoning rice fields. "Farmers don't realize the salt water is coming into their fields," says Gregorio. "By the time the water is salty enough to taste, the plants are already dying."

Only a few of the rice varieties at IRRI are GM crops, in the sense that they contain a gene transferred from a different species, and none of those are publicly available yet. One is Golden Rice, which contains genes from corn that allow it to produce beta-carotene; its purpose is to combat the global scourge of vitamin A deficiency. Last summer an IRRI test plot of Golden Rice was trampled by anti-GM activists. IRRI creates GM varieties only as a last resort, says director Robert Zeigler, when it can't find the desired trait in rice itself.

Yet the institute's entire breeding operation has been accelerated by modern genetics. For decades IRRI breeders patiently followed the ancient recipe: Select plants with the desired trait, cross-pollinate, wait for the offspring to reach maturity, select the best performers, repeat. Now there's an alternative to that painstaking process. In 2004 an international consortium of researchers mapped the entire rice genome, which comprises some 40,000 individual genes. Since then, researchers around the world have been pinpointing genes that control valuable traits and can be selected directly.

In 2006, for example, plant pathologist Pamela Ronald of the University of California, Davis,

isolated a gene called *Sub1* from an East Indian rice variety. Seldom grown now because of its low yields, the East Indian rice has one remarkable characteristic: It can survive for two weeks underwater. Most varieties die after three days.

Researchers at IRRI cross-pollinated *Sub1* rice with a high-yielding, flavorful variety called Swarna, which is popular in India and Bangladesh. Then they screened the DNA to determine which seedlings had actually inherited the *Sub1* gene. The technology, called marker-assisted breeding, is more accurate and saves time. The researchers didn't have to plant the seedlings, grow them, and then submerge them for two weeks to see which would survive.

The new flood-tolerant rice, called Swarna-Sub1, has been planted by nearly four million farmers in Asia, where every year floods destroy about 50 million acres of rice. One recent study found that farmers in 128 villages in the Indian state of Odisha, on the Bay of Bengal, increased their yields by more than 25 percent. The most marginal farmers reaped the most benefit.

"The lowest castes in India are given the worst land, and the worst lands in Odisha are prone to flooding," says Zeigler. "So here is a very sophisticated biotechnology—flood-tolerant rice—that preferentially benefits the poorest of the poor, the Untouchables. That's a helluva story, I think."

The institute's most ambitious project would transform rice fundamentally and perhaps



## “We do feel a bit betrayed by the environmental movement, I can tell you that.” —Robert Zeigler

increase yields dramatically. Rice, wheat, and many other plants use a type of photosynthesis known as C3, for the three-carbon compound they produce when sunlight is absorbed. Corn, sugarcane, and some other plants use C4 photosynthesis. Such crops require far less water and nitrogen than C3 crops do, “and typically have 50 percent higher yields,” says William Paul Quick of IRRI. His plan is to convert rice into a C4 crop by manipulating its own genes.

C4 photosynthesis, unlike the submergence tolerance of *Sub1* rice, is controlled by many genes, not just one, which makes it a challenging trait to introduce. On the other hand, says Quick, “it has evolved independently 62 times. That suggests it can’t be that difficult to do.” By “knocking out” genes one by one, he and his colleagues are systematically identifying all the genes responsible for photosynthesis in *Setaria viridis*, a small, fast-growing C4 grass. So far all the genes they’ve found are also present in C3 plants. They’re just not used in the same way.

Quick and his colleagues hope to learn how to switch them on in rice. “We think it will take a minimum of 15 years to do this,” Quick says. “We’re in year four.” If they succeed, the same techniques might help enhance the productivity of potatoes, wheat, and other C3 plants. It would be an unprecedented boon to food security; in theory yields could jump by 50 percent.

Prospects like that have made Zeigler a passionate advocate of biotechnology. White-bearded and avuncular, a self-described old lefty, Zeigler believes the public debate over genetically modified crops has become horribly muddled. “When I was starting out in the ’60s, a lot of us got into genetic engineering because we thought we could do a lot of good for the world,” he says. “We thought, These tools are fantastic!

“We do feel a bit betrayed by the environmental movement, I can tell you that. If you want to have a conversation about what the role of large corporations should be in our food supply, we can have that conversation—it’s really important. But it’s not the same conversation about whether we should use these tools of genetics to improve our crops. They’re

both important, but let’s not confound them.”

Zeigler decided on his career after a stint as a science teacher in the Peace Corps in 1972. “When I was in the Democratic Republic of the Congo, I saw a cassava famine,” he says. “That’s what made me become a plant pathologist.”

WHICH VISION OF AGRICULTURE is right for the farmers of sub-Saharan Africa? Today, says Nigel Taylor, a geneticist at the Donald Danforth Plant Science Center in St. Louis, Missouri, the brown streak virus has the potential to cause another cassava famine. “It has become an epidemic in the last five to ten years, and it’s getting worse,” he says. “With higher temperatures, the whitefly’s range is expanding. The great concern is that brown streak is starting to move into central Africa, and if it hits the massive cassava-growing areas of West Africa, you’ve got a major food-security issue.”

Taylor and other researchers are in the early stages of developing genetically modified cassava varieties that are immune to the brown streak virus. Taylor is collaborating with Ugandan researchers on a field trial, and another is under way in Kenya. But only four African countries—Egypt, Sudan, South Africa, and Burkina Faso—currently allow the commercial planting of GM crops.

In Africa, as elsewhere, people fear GM crops, even though there’s little scientific evidence to justify the fear. There’s a stronger argument that high-tech plant breeds are not a panacea and maybe not even what African farmers need most. Even in the United States some farmers are having problems with them.

A paper published last March, for instance, documented an unsettling trend: Corn rootworms are evolving resistance to the bacterial toxins in Bt corn. “I was surprised when I saw the data, because I knew what it meant—that this technology was starting to fail,” says Aaron Gassmann, an entomologist at Iowa State University and co-author of the report. One problem, he says, is that some farmers don’t follow the legal requirement to plant “refuge fields” with non-Bt corn, which slow the spread of resistant genes by supporting rootworms that remain vulnerable to the Bt toxins.



IR8, the rice in this test plot at the International Rice Research Institute (IRRI) in the Philippines, became known in Vietnam as Honda rice: Bumper crops paid for farmers’ motorcycles. In 1966 it started the green revolution, which allowed farmers in Asia to double their yields—and rev up their incomes.

In Tanzania there are no GM crops yet. But some farmers are learning that a simple, low-tech solution—planting a diversity of crops—is one of the best ways to deter pests. Tanzania now has the fourth largest number of certified organic farmers in the world. Part of the credit belongs to a young woman named Janet Maro.

Maro grew up on a farm near Kilimanjaro, the fifth of eight children. In 2009, while still an undergraduate at the Sokoine University of Agriculture in Morogoro, she helped start a nonprofit called Sustainable Agriculture Tanzania

(SAT). Since then she and her small staff have been training local farmers in organic practices. SAT now receives support from Biovision, the Swiss organization headed by Hans Herren.

Morogoro lies about a hundred miles west of Dar es Salaam, at the base of the Uluguru Mountains. A few days after my visit with Juma in Bagamoyo, Maro takes me into the mountains to visit three of the first certified organic farms in Tanzania. “Agricultural agents don’t come here,” she says as we lurch up a steep, rutted dirt road in a pickup. Greened by rains drifting in from





Global warming is raising sea levels and inundating coastal areas. A new strain of rice called IR64 Sub1, seen here in an aquarium at IRRI in the Philippines, can survive for two weeks underwater—a boon for poor farmers in low-lying regions of Asia, where floods destroy 50 million acres of rice every year.



## The central problem isn't choosing low-tech or high-tech. It's getting knowledge that works to people like Juma.

the Indian Ocean, the slopes remain heavily forested. But increasingly they've been cleared for farming by the Luguru people.

Every quarter mile or so we pass women walking alone or in small groups, balancing baskets of cassavas, papayas, or bananas on their heads. It's market day in Morogoro, 3,000 feet below us. Women here are more than porters. Among the Luguru, landownership in a family passes down the female line. "If a woman doesn't like a man, out he goes!" Maro says.

She stops at a one-room brick house with partially plastered walls and a corrugated metal roof. Habija Kibwana, a tall woman in a short-sleeved white blouse and wraparound skirt, invites us and two neighbors to sit on her porch.

Unlike the farmers in Bagamoyo, Kibwana and her neighbors raise a variety of crops: Bananas, avocados, and passion fruit are in season now. Soon they'll be planting carrots, spinach, and other leafy vegetables, all for local consumption. The mix provides a backup in case one crop fails; it also helps cut down on pests. The farmers here are learning to plant strategically, setting out rows of *Tithonia diversifolia*, a wild sunflower that whiteflies prefer, to draw the pests away from the cassavas. The use of compost instead of synthetic fertilizers has improved the soil so much that one of the farmers, Pius Paulini, has doubled his spinach production. Runoff from his fields no longer contaminates streams that supply Morogoro's water.

Perhaps the most life-altering result of organic farming has been the liberation from debt. Even with government subsidies, it costs 500,000 Tanzanian shillings, more than \$300, to buy enough fertilizer and pesticide to treat a single acre—a crippling expense in a country where the annual per capita income is less than \$1,600. "Before, when we had to buy fertilizer, we had no money left over to send our children to school," says Kibwana. Her oldest daughter has now finished high school.

And the farms are more productive too. "Most of the food in our markets is from small farmers," says Maro. "They feed our nation."

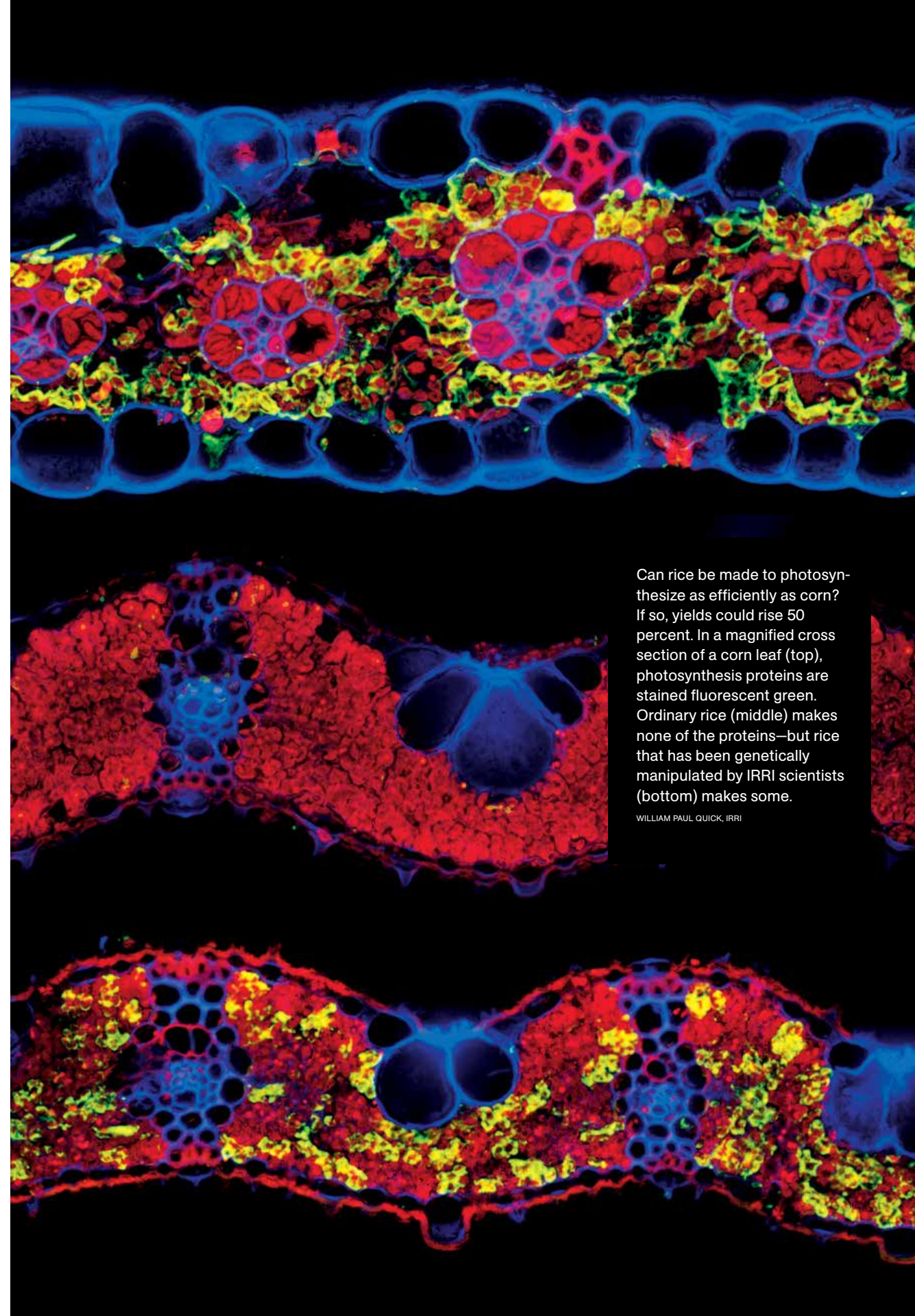
When I ask Maro if genetically modified seeds

might also help those farmers, she's skeptical. "It's not realistic," she says. How could they afford the seeds when they can't even afford fertilizer? How likely is it, she asks, in a country where few farmers ever see a government agricultural adviser, or are even aware of the diseases threatening their crops, that they'll get the support they need to grow GM crops properly? From Kibwana's porch we have sweeping views of richly cultivated terraced slopes—but also of slopes scarred by the brown, eroded fields of nonorganic farmers, most of whom don't build terraces to retain their precious soil. Kibwana and Paulini say their own success has attracted the attention of their neighbors. Organic farming is spreading here. But it's spreading slowly.

That's the central problem, I thought as I left Tanzania: getting knowledge that works from organizations like SAT or IRRI to people like Juma. It's not choosing one type of knowledge—low-tech versus high-tech, organic versus GM—once and for all. There's more than one way to increase yields or to stop a whitefly. "Organic farming can be the right approach in some areas," says Monsanto executive Mark Edge. "By no means do we think that GM crops are the solution for all the problems in Africa." Since the first green revolution, says Robert Zeigler, ecological science has advanced along with genetics. IRRI uses those advances too.

"You see the egrets flying out there?" he asks toward the end of our conversation. Outside his office a flock is descending on the green paddies; the mountains beyond glow with evening light. "In the early '90s you didn't see birds here. The pesticides we used killed the birds and snails and everything else. Then we invested a lot to understand the ecological structures of rice paddies. You have these complex webs, and if you disrupt them, you have pest outbreaks. We learned that in the vast majority of cases, you don't need pesticides. Rice is a tough plant. You can build resistance into it. We now have a rich ecology here, and our yields haven't dropped.

"At certain times of the day we get a hundred or so of those egrets. It's really uplifting to see. Things can get better." □



Can rice be made to photosynthesize as efficiently as corn? If so, yields could rise 50 percent. In a magnified cross section of a corn leaf (top), photosynthesis proteins are stained fluorescent green. Ordinary rice (middle) makes none of the proteins—but rice that has been genetically manipulated by IRRI scientists (bottom) makes some.

WILLIAM PAUL QUICK, IRRI



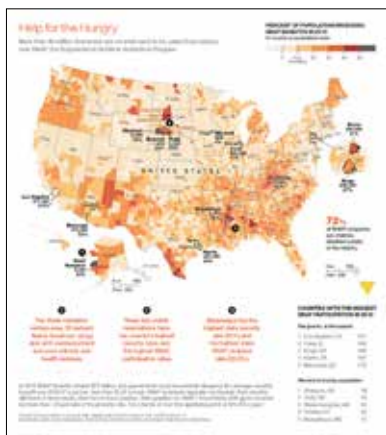


**Eat: The Story of Food**  
natgeotv.com/eat



**José Andrés: Exploring Food in Japan**

**The Plate food blog**  
theplate.nationalgeographic.com



**The Future of Food app**  
natgeofoodapp.com

By 2050, we'll need to feed two billion more people. In 2014 National Geographic launched a multiplatform initiative to explore how we can do that—without overwhelming the planet.

On November 21 **Eat: The Story of Food** airs on the National Geographic Channel. The six-part series covers everything from bluefin tuna to beer, and honors the revolutionaries—including Julia Child and Christopher Columbus—who changed the way we eat.

Our blog, **The Plate**, features a diverse roster of food-obsessed contributors, including a celebrity chef, a food lawyer, and a millennial with a penchant for Instagramming what she cooks. Their posts celebrate the history, science, culture, and politics of food.

Our digital version of **The Future of Food** contains additional articles exploring solutions for farming a better fish through aquaculture and curbing food waste—from our farms to grocery stores to dinner tables, one-third of the food we grow is lost or wasted.



**Gary E. Knell**  
President and CEO

**Declan Moore**  
Chief Media Officer

**Chris Johns**  
Chief Content Officer

**Susan Goldberg**  
Editor in Chief

**Dennis Dimick**  
Executive Editor

**Kaitlin Yarnall**  
Food Initiative Director

**Claudia Malley**  
Executive Vice President and Worldwide Publisher

**Beth Foster**  
Vice President, Communications

Copyright © 2014 National Geographic Society  
All rights reserved. National Geographic and Yellow Border:  
Registered Trademarks © Marcas Registradas. National Geographic  
assumes no responsibility for unsolicited materials. Printed in U.S.A.

Comment on our stories at [ngsforum@ngm.com](mailto:ngsforum@ngm.com)  
PHOTOGRAPH (TOP) BY WYATT ROGOWSKI, NATIONAL GEOGRAPHIC TELEVISION

# SEE MORE OF THE WORLD, WHEREVER YOU ARE.



Subscribe to *National Geographic* magazine today and have the whole world delivered to your door—and your tablet!

[ngm.com/subscribe](http://ngm.com/subscribe)



iPad and iPhone are trademarks of Apple Inc., registered in the U.S. and other countries.

2014 © National Geographic Society



7

Billion People

1

Billion Hungry

1

Global Challenge

**We live in a world of more than 7 billion people.  
By 2050 that number will be 9.6 billion.**

Land O'Lakes, Inc. has created the Global Food Challenge to convene agricultural experts, student leaders, and concerned citizens to explore new and sustainable solutions. You can be part of the conversation. Together, we can feed the world.

Go to [foodchallenge.landolakesinc.com](http://foodchallenge.landolakesinc.com) to follow the conversation.

 **LAND O'LAKES, INC.**

**GLOBAL FOOD CHALLENGE**

