How to Sustainably Feed 10 Billion People by 2050, in 21 Charts

by  Janet Ranganathan, Richard Waite, Tim Searchinger and Craig Hanson - December 05, 2018

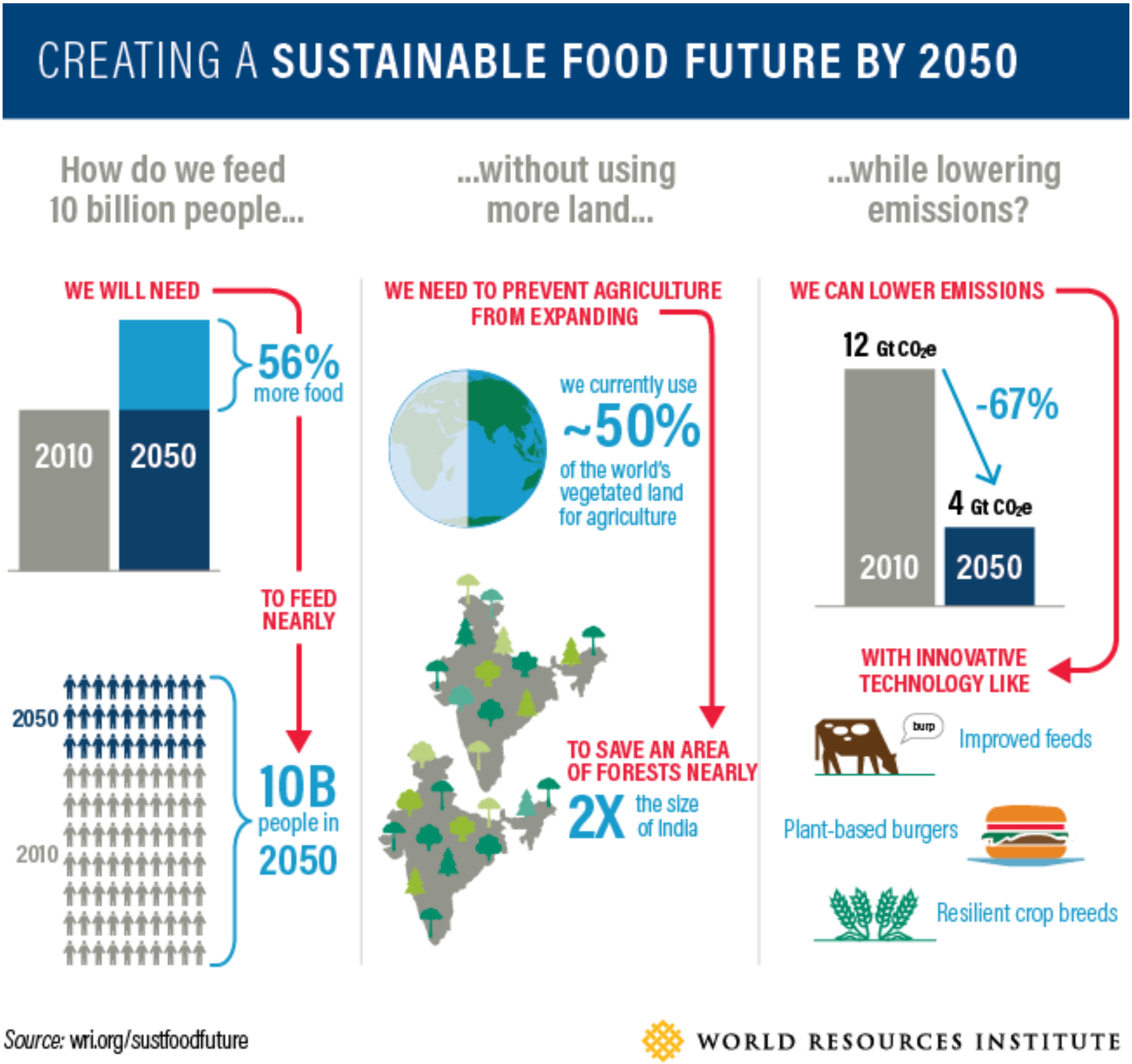
Cambodian rice farmers. Photo by Brad Collis/Wikimedia Commons

There is a big shortfall between the amount of food we produce today and the amount needed to feed everyone in 2050. There will be nearly 10 billion people on Earth by 2050—about 3 billion more mouths to feed than there were in 2010. As incomes rise, people will increasingly consume more resource-intensive, animal-based foods. At the same time, we urgently need to cut greenhouse gas (GHG) emissions from agricultural production and stop conversion of remaining forests to agricultural land.

Feeding 10 billion people *sustainably* by 2050, then, requires closing three gaps:

- **A 56 percent food gap** between crop calories produced in 2010 and those needed in 2050 under "business as usual" growth;
- **A 593 million-hectare land gap** (an area nearly twice the size of India) between global agricultural land area in 2010 and expected agricultural expansion by 2050; and
- **An 11-gigaton GHG mitigation gap** between expected agricultural emissions in 2050 and the target level needed to hold global warming below

2°C (3.6°F), the level necessary for preventing the worst climate impacts.



A Five-Course Menu of Solutions for a Sustainable Food Future

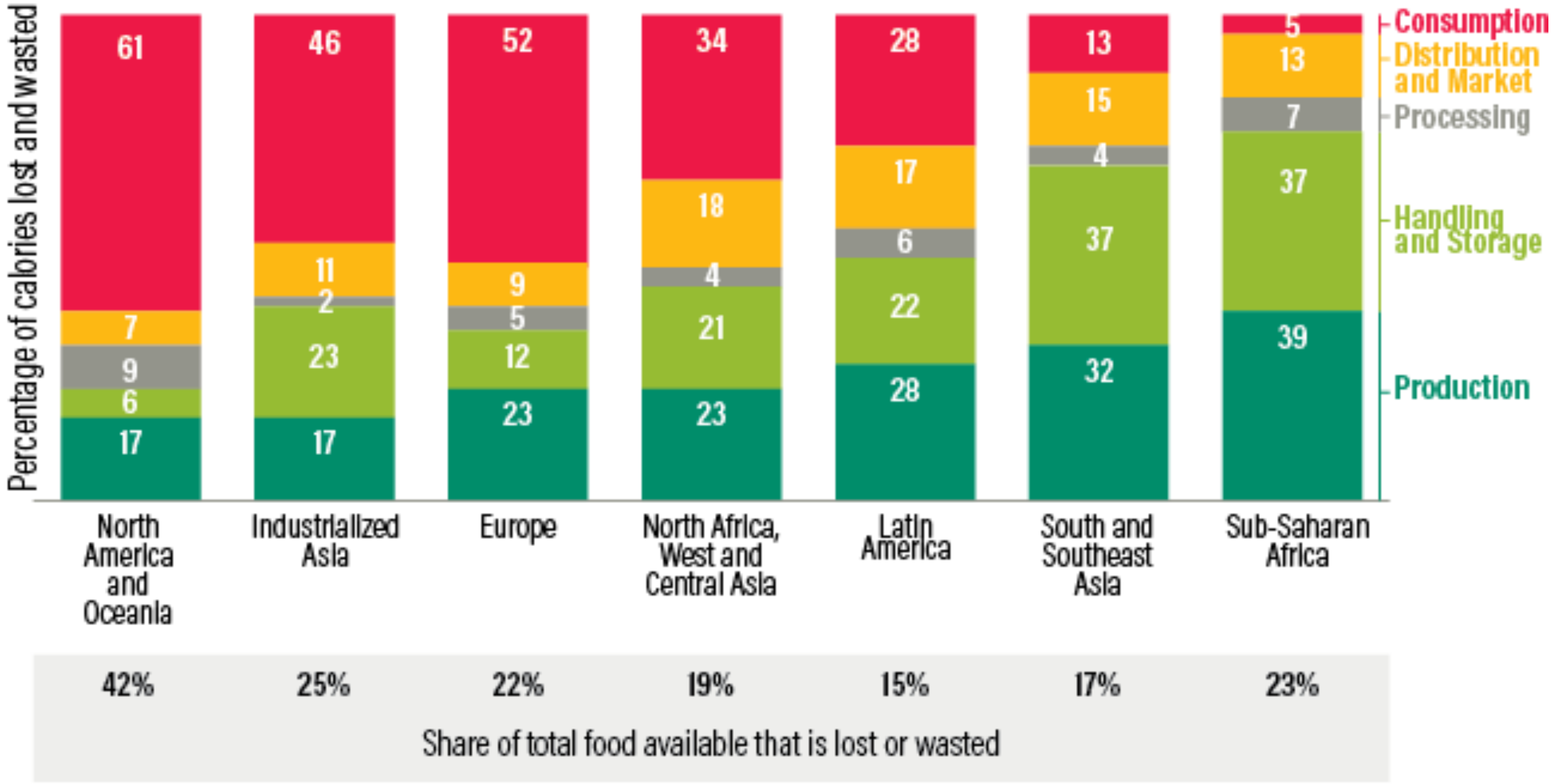
There is no silver bullet to close the food, land and GHG mitigation gaps. WRI research on how to create a sustainable food future has identified 22 solutions that need to be simultaneously applied to close these gaps. The relative importance of each solution varies from country to country. The solutions are organized into a five-course menu: (1) reduce growth in demand for food and other agricultural products; (2) increase food production without expanding agricultural land; (3) protect and restore natural ecosystems; (4) increase fish supply; and (5) reduce GHG emissions from agricultural production.

First Course: Reduce Growth In Demand for Food and Other Agricultural Products

1. Reduce food loss and waste.

Approximately one-quarter of food produced for human consumption goes uneaten. Loss and waste occurs all along the food chain, from field to fork. Reducing food loss and waste by 25 percent by 2050 would close the food gap by 12 percent, the land gap by 27 percent and the GHG mitigation gap by 15 percent. Actions to take include measuring food waste, setting reduction targets, improving food storage in developing countries and streamlining expiration labels.

Where food loss and waste occurs along the food supply chain



Source: WRI analysis based on FAO (2011b).

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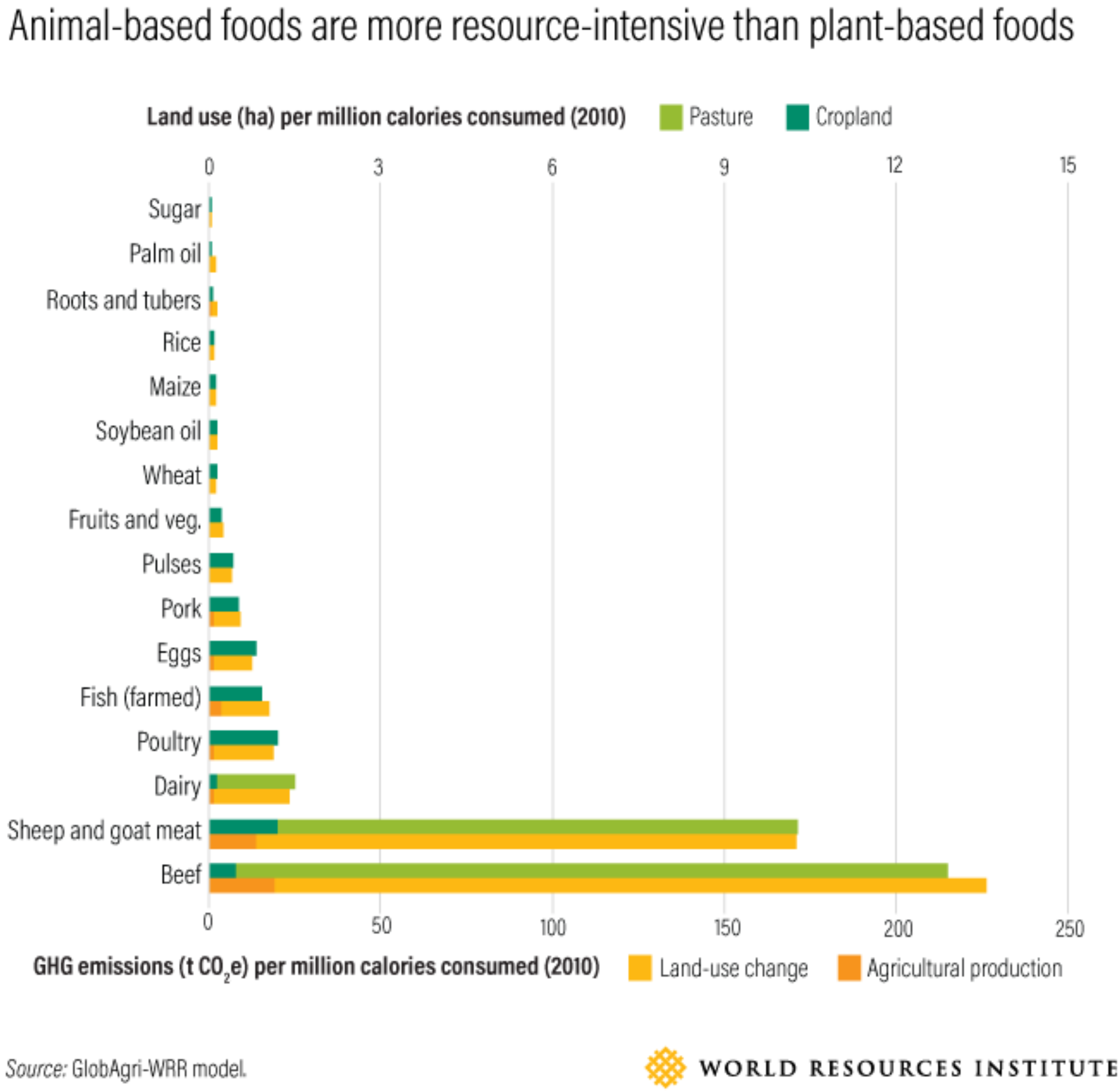
2. Shift to healthier, more sustainable diets.

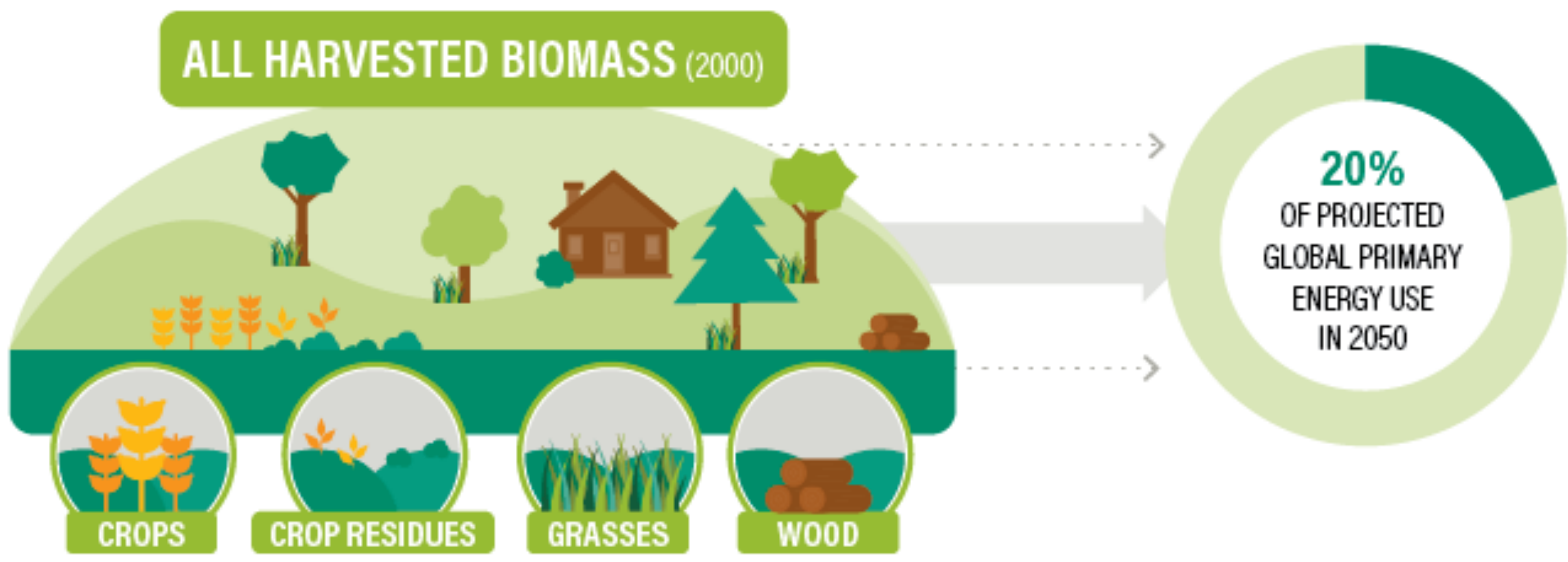
Consumption of ruminant meat (beef, lamb and goat) is projected to rise 88 percent between 2010 and 2050. Beef, the most commonly consumed ruminant meat, is resource-intensive to produce, requiring 20 times more land and emitting 20 times more GHGs per gram of edible protein than common plant proteins, such as beans, peas and lentils. Limiting ruminant meat consumption to 52 calories per person per day by 2050—about 1.5 hamburgers per week—would reduce the GHG mitigation gap by half and nearly close the land gap. In North America this would require reducing current beef and lamb consumption by nearly half. Actions to take include improving the marketing of plant-based foods, improving meat substitutes and implementing policies that favor consumption of plant-based foods.



3. Avoid competition from bioenergy for food crops and land.

If bioenergy competes with food production by using food or energy crops or dedicated land, it widens the food, land and GHG mitigation gaps. Biomass is also an inefficient energy source: Using all the harvested biomass on Earth in the year 2000—including crops, crop residues, grass eaten by livestock and wood—would only provide about 20 percent of global energy needs in 2050. Phasing out existing biofuel production on agricultural lands would reduce the food gap from 56 to 49 percent. Actions to take include eliminating biofuel subsidies and not treating bioenergy as "carbon-neutral" in renewable energy policies and GHG trading programs.

All of world's harvested biomass would supply only 20% of global energy needs in 2050



Note: Assumes primary to final energy conversion for biomass is 24% lower than for fossil energy.
Source: Authors' calculations based on Haberl et al. (2007); IEA (2017); and JRC (2011).

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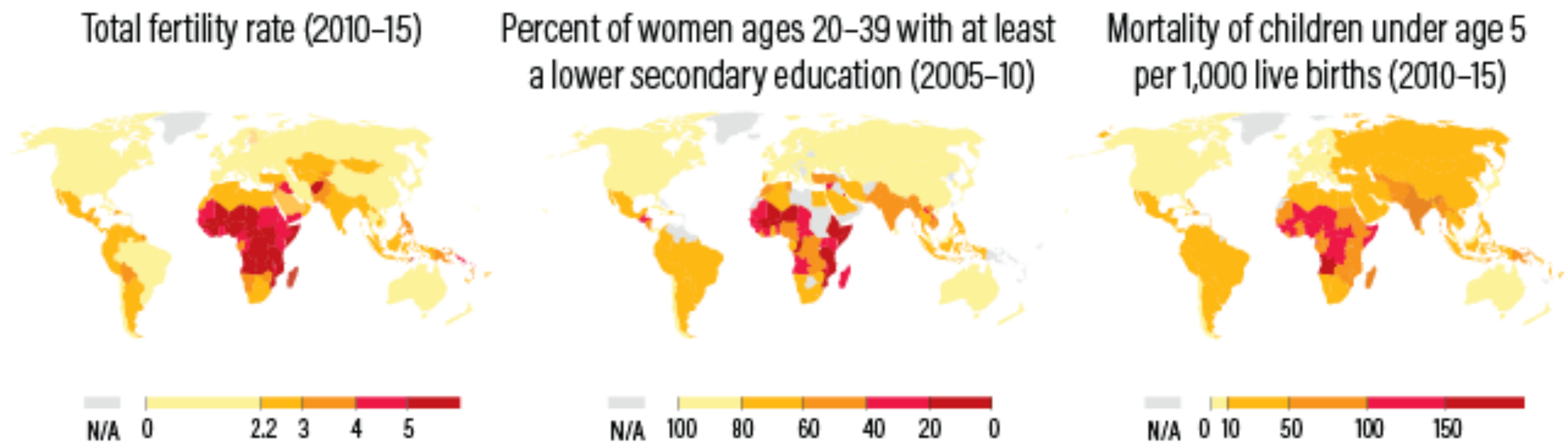
4. Achieve replacement-level fertility rates.

The food gap is mostly driven by population growth, of which half is expected to occur in Africa, and one third in Asia. Most of the world is close to achieving replacement-level fertility by 2050 (2.1 children per woman). Sub-Saharan Africa is the exception, with a current fertility rate above 5 children per woman and a projected rate of 3.2 in 2050. If sub-Saharan Africa achieved replacement-level fertility rates along with all other regions by 2050, it would close the land gap by one quarter and the GHG mitigation gap by 17 percent while reducing hunger. Actions to take include achieving the three forms of social progress that have led all others to voluntarily reduce fertility rates: increasing educational opportunities for girls, expanding access to reproductive health services, and reducing infant and child mortality so that parents do not need to have as many children to ensure survival of their desired number.

Sub-Saharan Africa has the world's lowest performance in key indicators of total fertility rate, women's education, and child mortality



Sources: UNDESA (2017); Harper (2012); World Bank (2017a).

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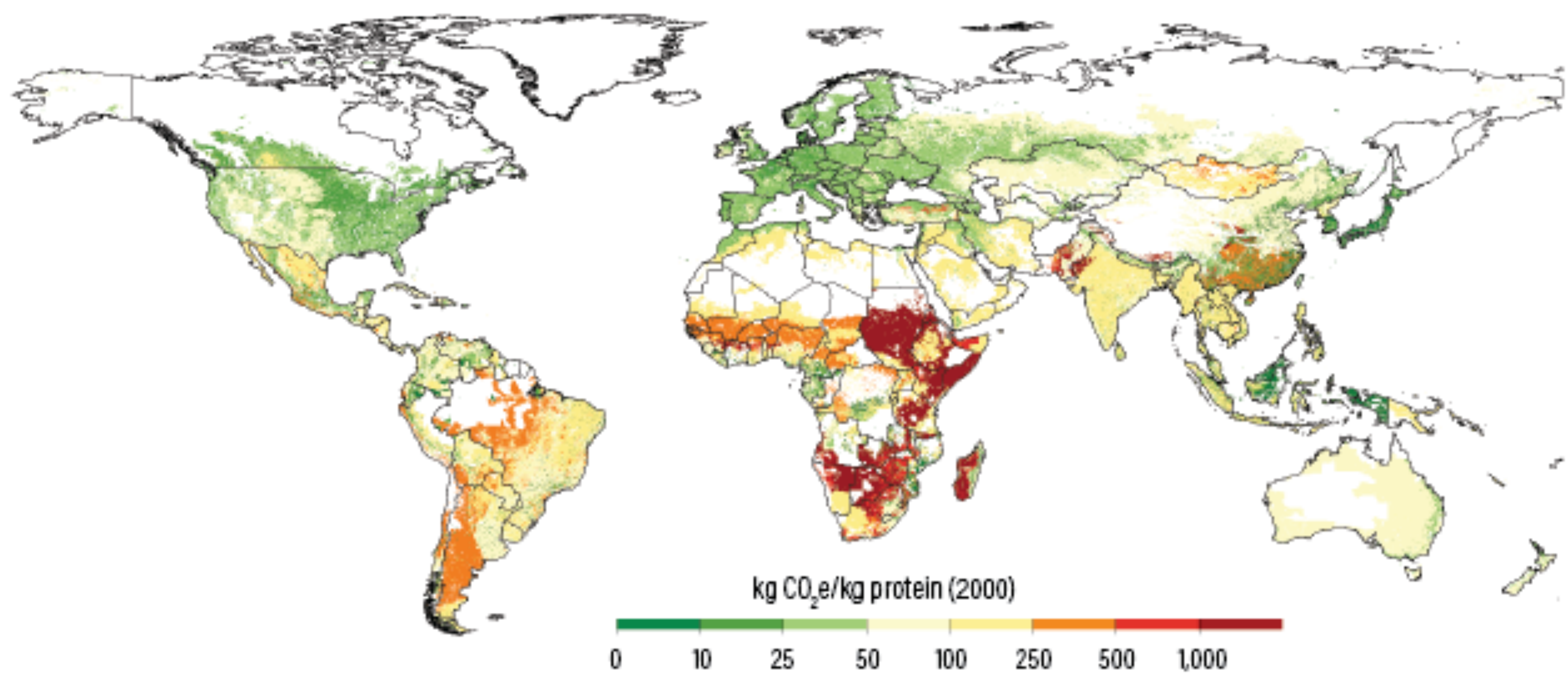
Course 2: Increase Food Production Without Expanding Agricultural Land

5. Increase livestock and pasture productivity.

Livestock production per hectare varies significantly from country to country and is lowest in the tropics. Given that demand for animal-based foods is projected to grow by 70 percent by 2050 and that pastureland accounts for two thirds of agricultural land use, boosting pasture productivity is an important solution. A 25 percent faster increase in the output of meat and milk per hectare of pasture between 2010 and 2050 could close the land gap by 20 percent and the GHG mitigation gap by 11 percent. Actions farmers can take include improving fertilization of pasture, feed quality and veterinary care; raising improved animal breeds; and employing rotational grazing. Governments can set productivity targets and support farmers with financial and technical assistance.

Emissions intensity of beef production varies across the world



Sources: Herrero et al. (2013).

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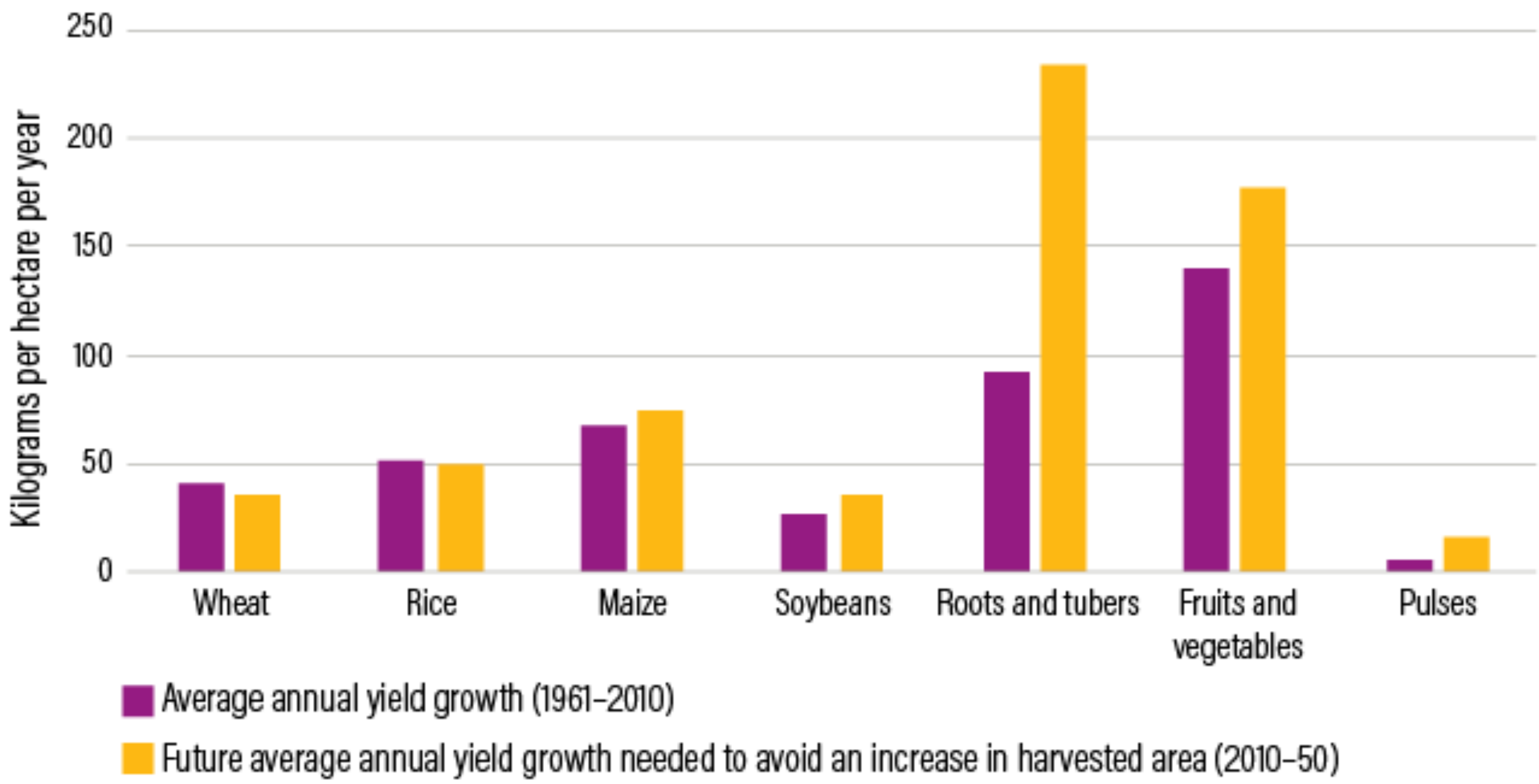
6. Improve crop breeding.

Future yield growth is essential to keep up with demand. Conventional breeding, the selection of best-performing crops based on genetic traits, accounted for around half of historical crop yield gains. New advances in molecular biology offer great promise for additional yield gains by making it cheaper and faster to map genetic codes of plants, test for desired DNA traits, purify crop strains, and turn genes on and off. Actions to take include significantly increasing public and private crop-breeding budgets, especially for “orphan crops” like millet and yam, which are regionally important, but not traded globally.

Future yield growth in many crops will need to be higher than in the past to meet projected food demand on existing agricultural land



Source: GlobAgri-WRR model, WRI and ACE analysis based on Alexandratos and Bruinsma (2012).

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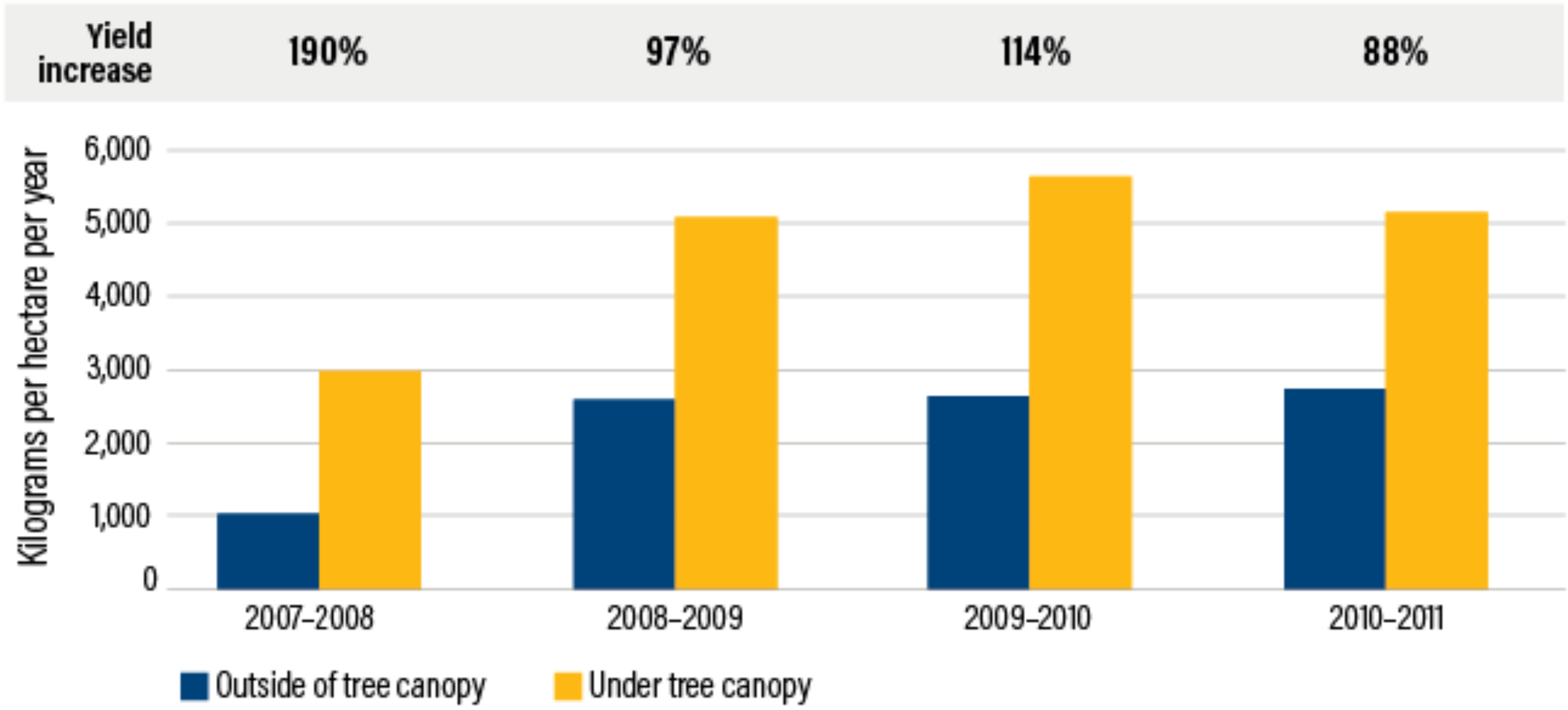
7. Improve soil and water management.

Degraded soils, especially in Africa's drylands, may affect one quarter of the world's cropland. Farmers can boost crop yields in degraded soils—particularly drylands and areas with low carbon—by improving soil and water management practices. For example, agroforestry, or incorporating trees on farms and pastures, can help regenerate degraded land and boost yields. Trial sites in Zambia integrating *Faidherbia albida* trees yielded 88–190 percent more maize than sites without trees. A 20 percent faster increase in crop yields between 2010 and 2050—as a result of improvements in crop breeding and soil and water management—could close the land gap by 16 percent and the GHG mitigation gap by 7 percent. Actions to take include increasing aid agencies' support for rainwater harvesting, agroforestry and farmer-to-farmer education; and reforming tree-ownership laws that impede farmers' adoption of agroforestry. Agencies can also experiment with programs that help farmers rebuild soil health.

Agroforestry increases maize yields in Zambia



Note: Average maize grain yields from trial sites under and outside canopies of mature Faidherbia albida trees across regions in Zambia.
Source: Shitumbanuma (2012).

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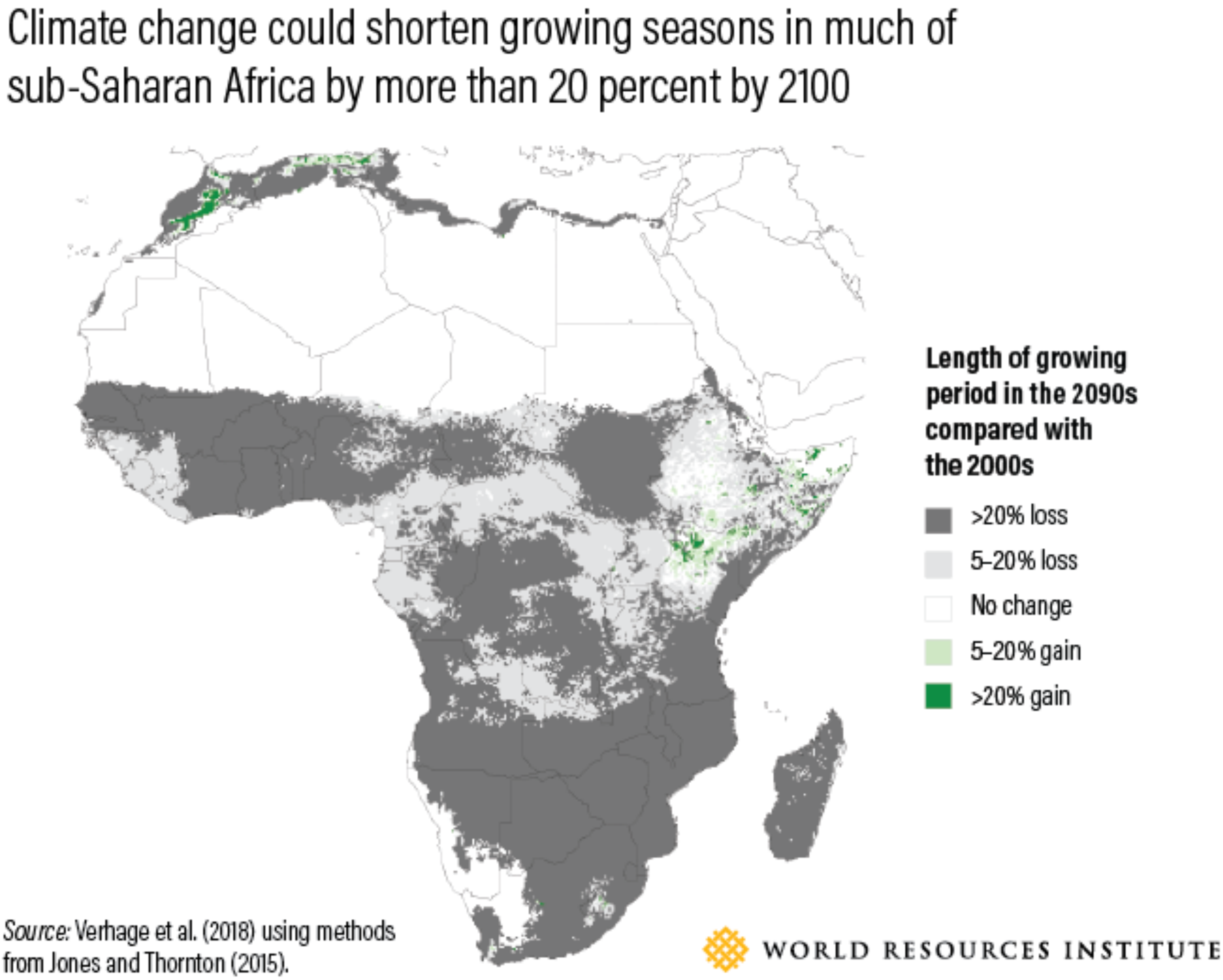
8. Plant existing cropland more frequently.

Planting and harvesting existing croplands more frequently, either by reducing fallow land or by increasing "double cropping" (planting two crops in a field in the same year), can boost food production without requiring new land. Increasing annual cropping intensity by 5 percent beyond the 2050 baseline of 87 percent would shrink the land gap by 14 percent and the GHG mitigation gap by 6 percent. Researchers should conduct more spatially explicit analyses to determine where cropping intensity increases are most feasible, factoring in water, emissions and other environmental constraints.

9. Adapt to climate change.

The 2014 Intergovernmental Panel on Climate Change report projected that without adaptation, global crop yields will likely decline by at least 5 percent by 2050, with steeper declines by 2100. For example, growing seasons in much of sub-Saharan Africa are projected to be more than 20 percent shorter by 2100. A 10 percent decline in crop yields would increase the land gap by 45 percent. Adaptation will require implementing other menu items, as well as breeding crops to cope with higher temperatures, establishing water conservation systems, and changing production systems where major climate changes will make it impossible to grow certain crops.

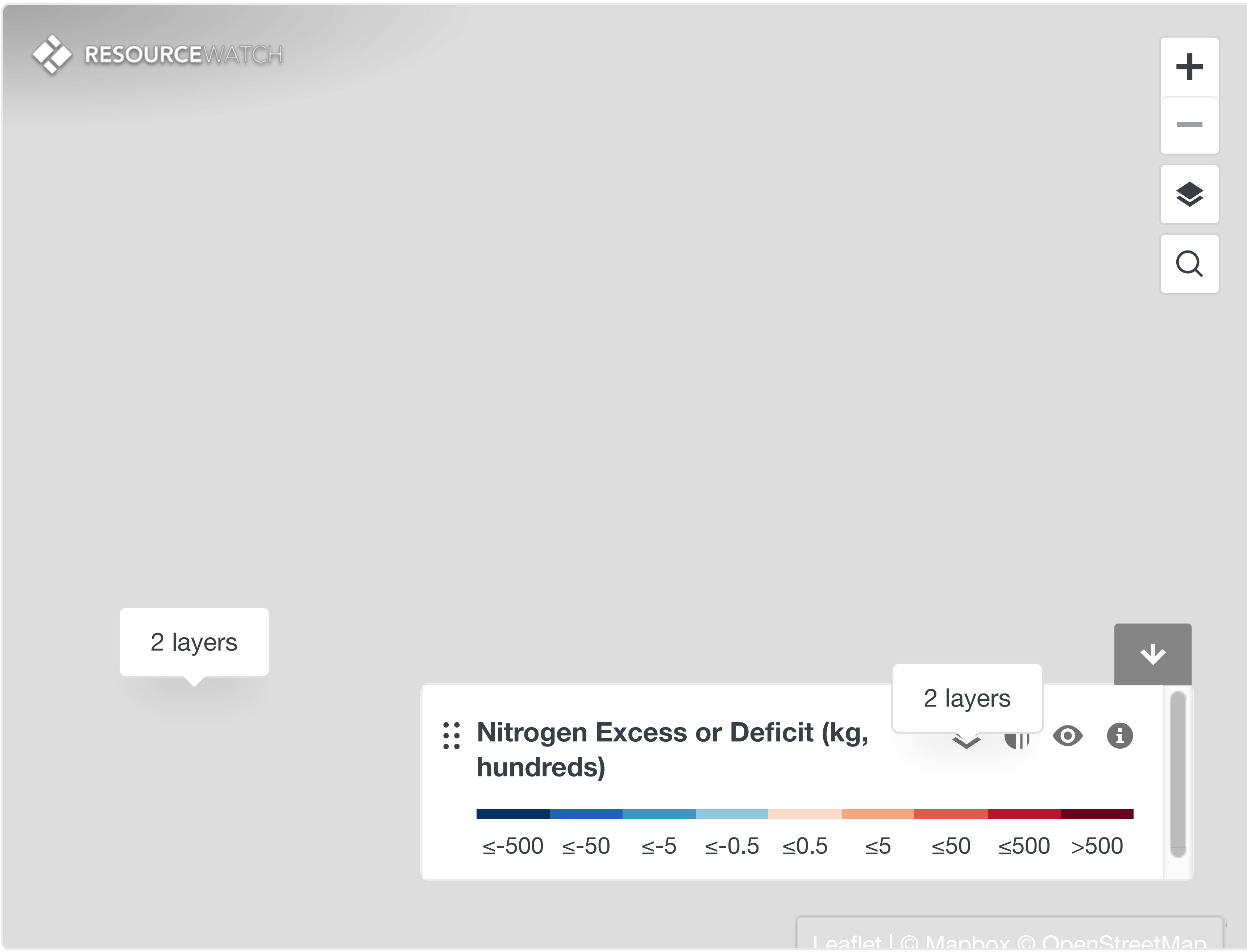


Course 3: Protect and Restore Natural Ecosystems and

Limit Agricultural Land-Shifting

10. Link productivity gains with protection of natural ecosystems.

While improving agricultural productivity can save forests and savannas globally, in some cases it can actually cause more land clearing locally. To avoid these results, productivity gains must be explicitly linked with efforts to protect natural ecosystems from conversion to agriculture. Governments, financiers and others can tie low interest credit to protection of forests, as Brazil has done, and ensure that infrastructure investments do not come at the expense of ecosystems.



Deforestation in South America is largely driven by agricultural commodities.

11. Limit inevitable cropland expansion to lands with low

environmental opportunity costs.

When cropland expansion is inevitable—such as for local food production in Africa and for oil palm in Southeast Asia—governments and investors should support expansion onto land with low environmental opportunity costs. This includes lands with limited biodiversity or carbon storage potential, but high food production potential. For example, analysis that applies environmental, economic and legal filters in Indonesia can develop more accurate estimates of land suitable for oil palm expansion. Governments need tools and models to estimate yields and effects on biodiversity and climate change, and they should use these tools to guide land-use regulations, plan roads and manage public lands.

12. Reforest agricultural lands with little intensification potential.

In some cases, the most efficient use of land may be to restore abandoned or unproductive agricultural lands back into forests or other natural habitats. This can help offset the inevitable expansion of agriculture into other areas. This should be limited to low productivity agricultural land with limited improvement potential, such as steeply sloping pastures in Brazil’s Atlantic Forest.

Before and After, Reforesting Brazil's Atlantic Forest

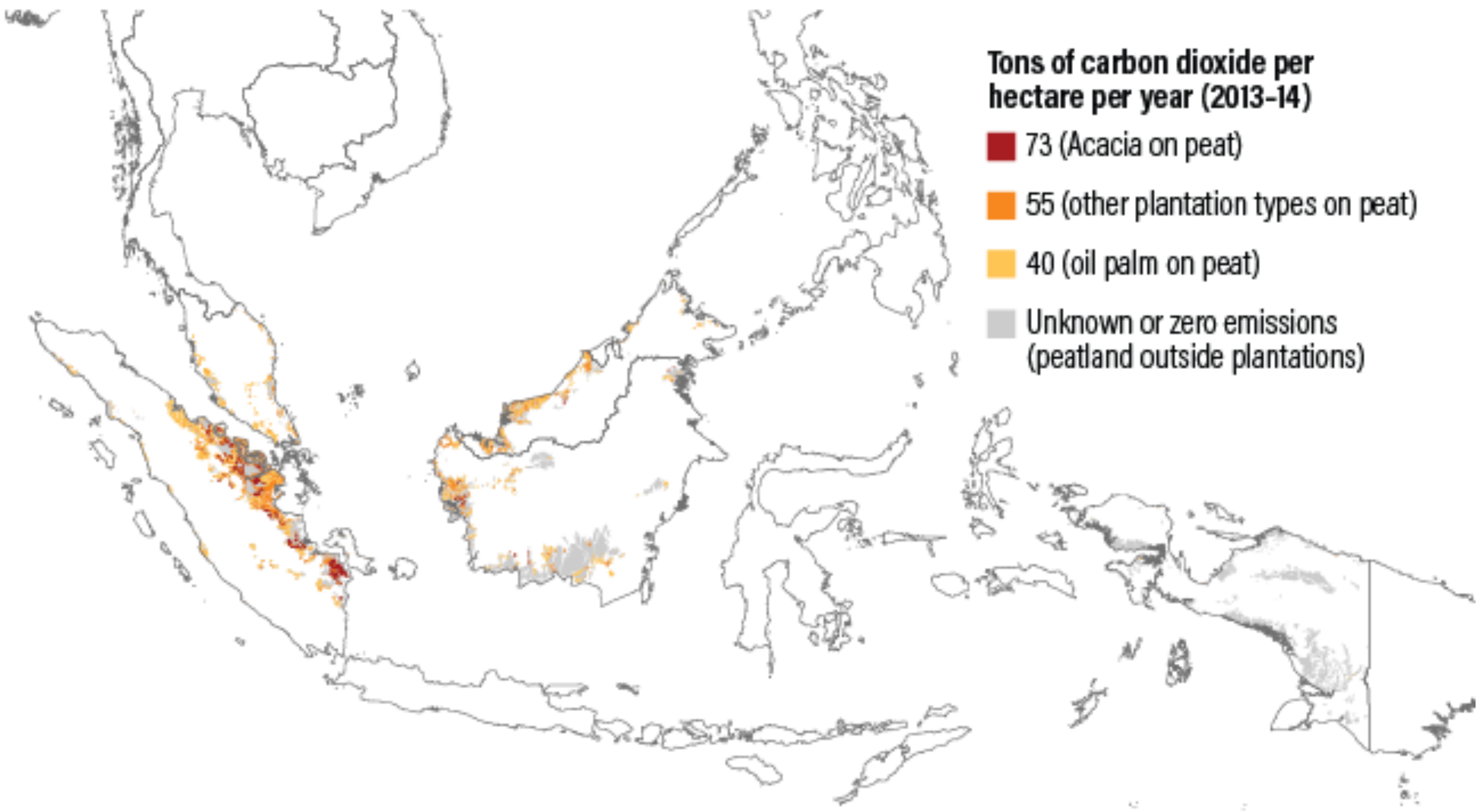
A Flourish data visualisation

A Flourish data visualisation

13. Conserve and restore peatlands.

Peatlands' conversion for agriculture requires drainage, which releases large amounts of carbon into the atmosphere. The world's 26 million hectares of drained peatlands account for 2 percent of annual greenhouse gas emissions. Restoring them to wetlands should be a high priority and would close the GHG mitigation gap by up to 7 percent. Actions to take include providing funds for peatland restoration, improving peatland mapping and establishing laws that prevent peatlands from being drained.

Greenhouse Gas Emissions from Drained Peat in Indonesia and Malaysia



Source: WRI (2017).

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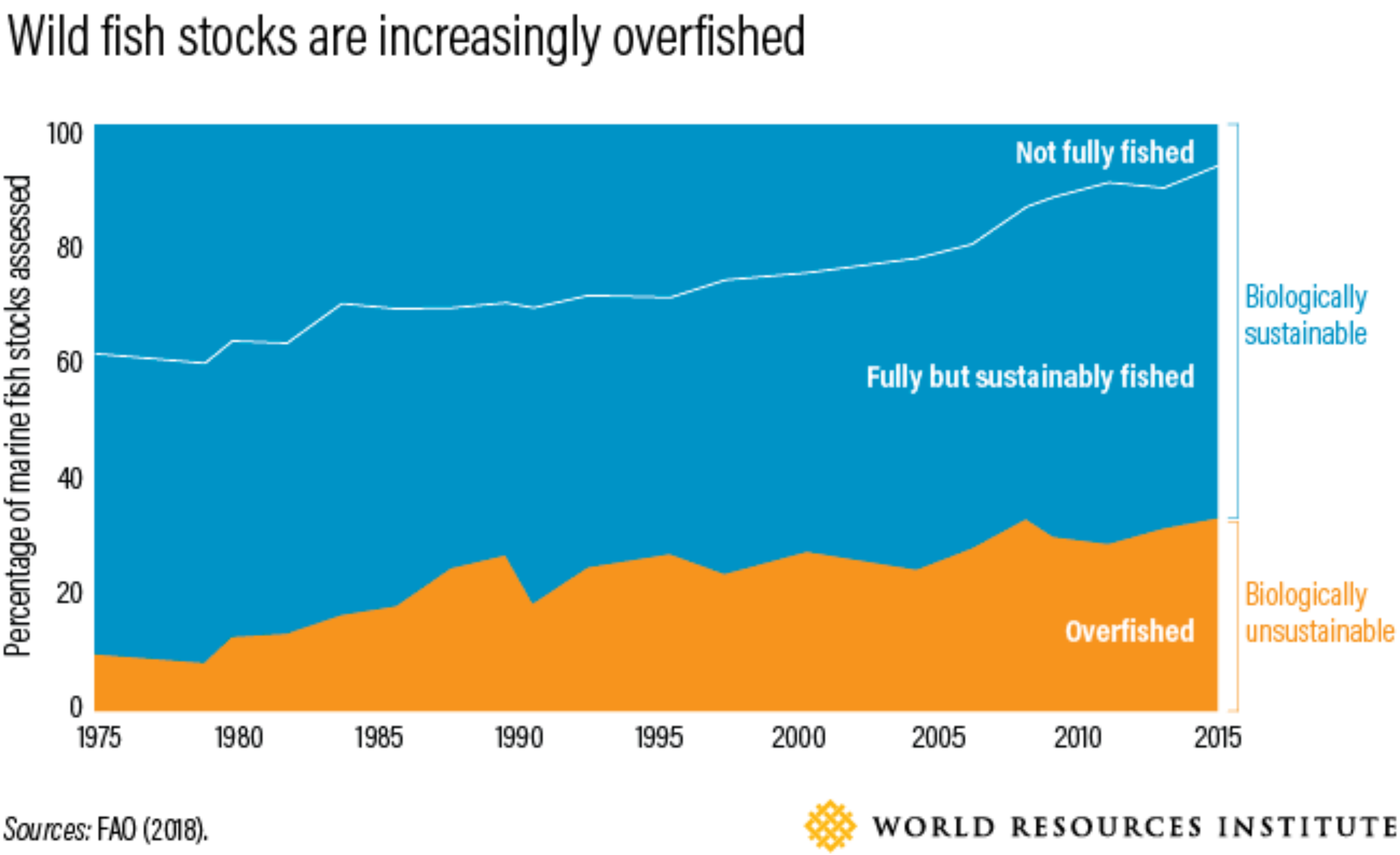
Course 4: Increase Fish Supply

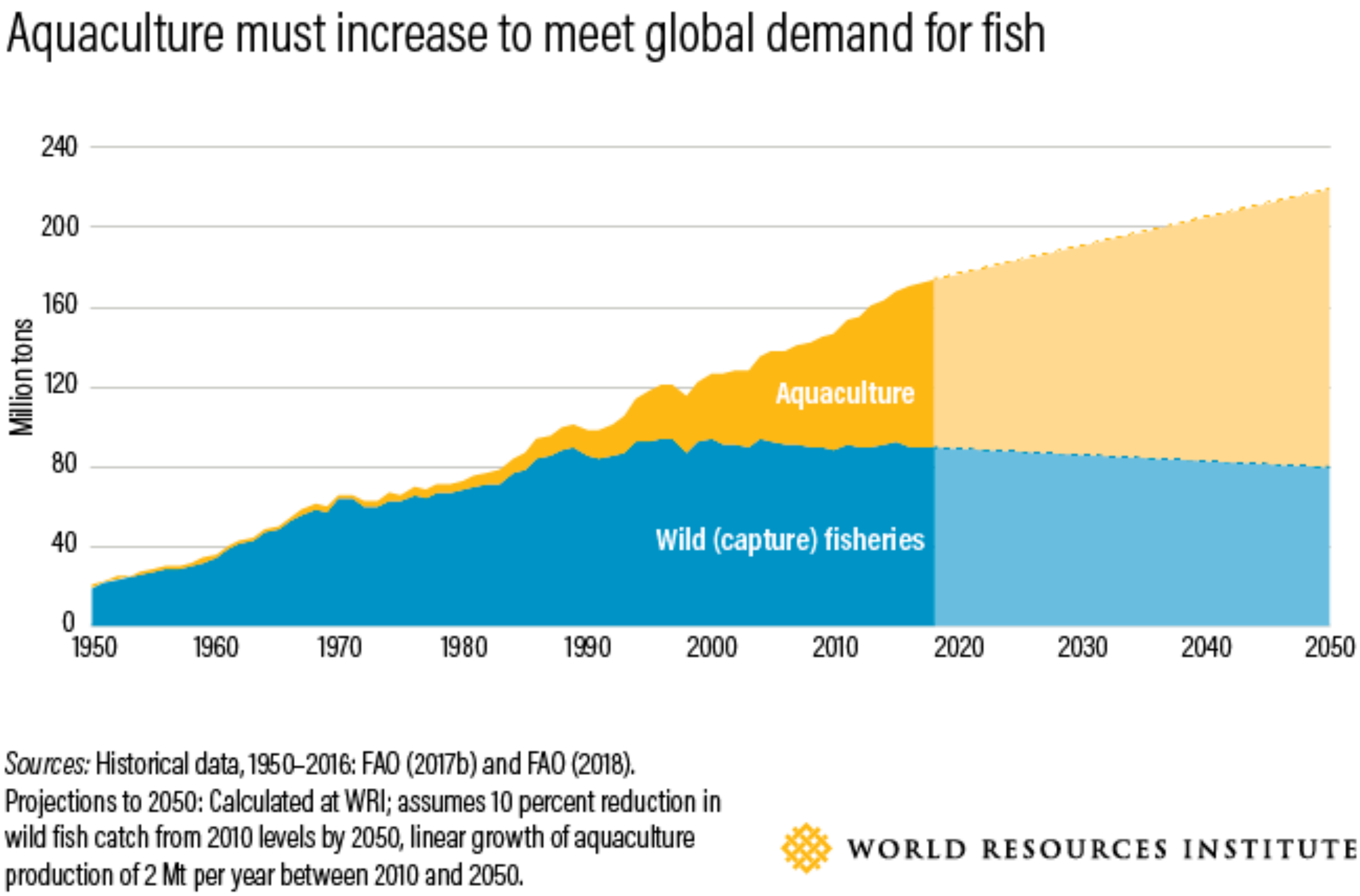
14. Improve wild fisheries management.

One third of marine stocks were overfished in 2015, with another 60 percent fished at maximum sustainable levels. Catches need to be reduced today to allow wild fisheries to recover enough just to maintain the 2010 fish-catch level in 2050. This would avoid the need to convert 5 million hectares of land to supply the equivalent amount of fish from aquaculture. Actions to take include implementing catch shares and community-based management systems, and removing perverse subsidies that support overfishing, estimated at $35 billion annually.



15. Improve productivity and environmental performance of aquaculture.

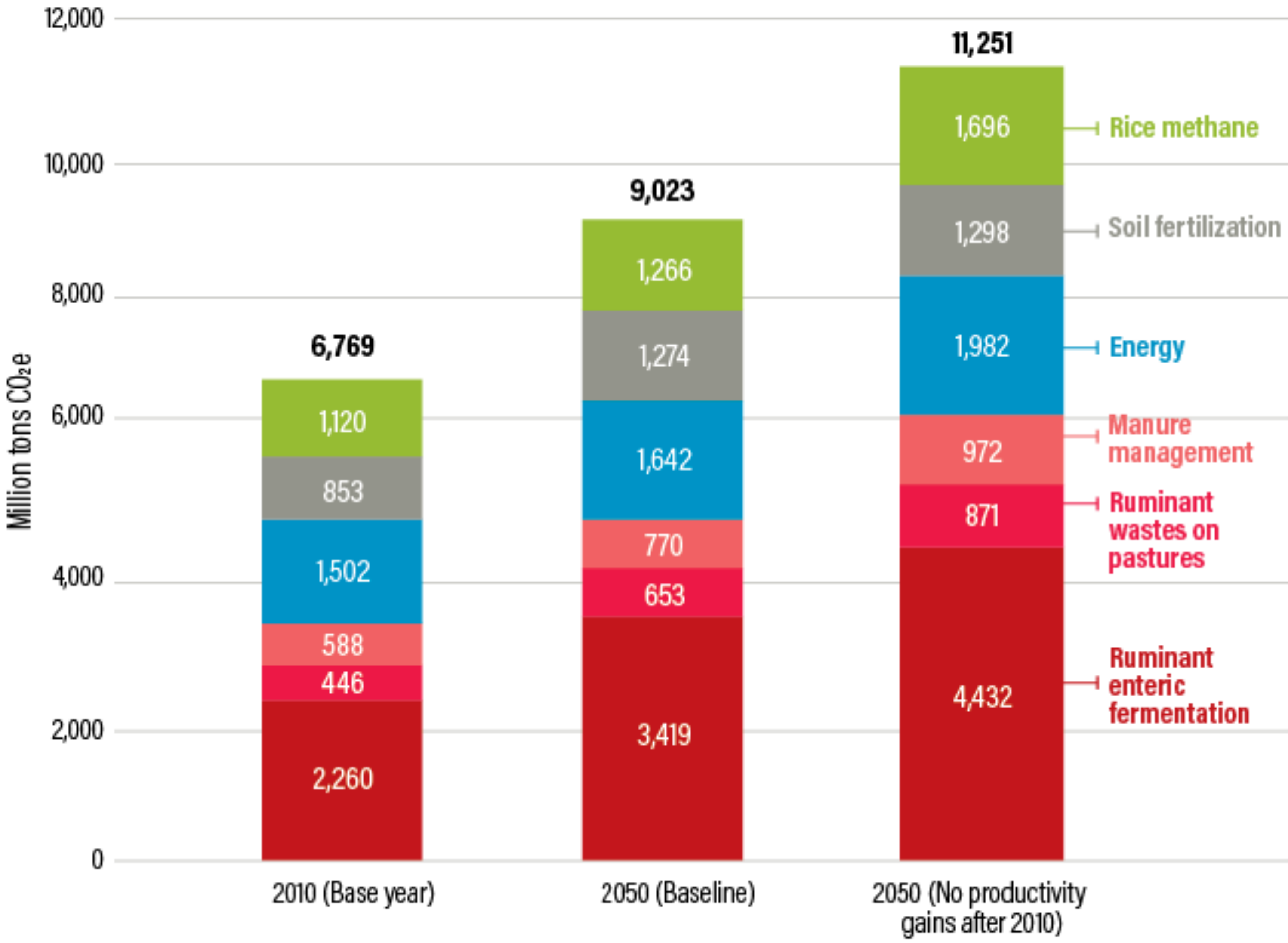
As wild fish catches decline, aquaculture production needs to more than double to meet a projected 58 percent increase in fish consumption between 2010 and 2050. This doubling requires improving aquaculture productivity and addressing fish farms' current environmental challenges, including conversion of wetlands, use of wild-caught fish in feeds, high freshwater demand and water pollution. Actions to take include selective breeding to improve growth rates of fish, improving feeds and disease control, adoption of water recirculation and other pollution controls, better spatial planning to guide new farms and expansion of marine-based fish farms.



Course 5: Reduce Greenhouse Gas Emissions from Agricultural Production

GHG emissions from agricultural production arise from livestock farming, application of nitrogen fertilizers, rice cultivation and energy use. They're projected to rise from 7 to 9 gigatons per year or more by 2050 (in addition to 6 gigatons per year or more from land-use change, not shown in the chart below). This course addresses each of these major emissions sources.

Annual agricultural production emissions could reach 9 gigatons or more by 2050



Note: numbers in columns may not sum correctly due to rounding.
Source: GlobAgri-WRR model.

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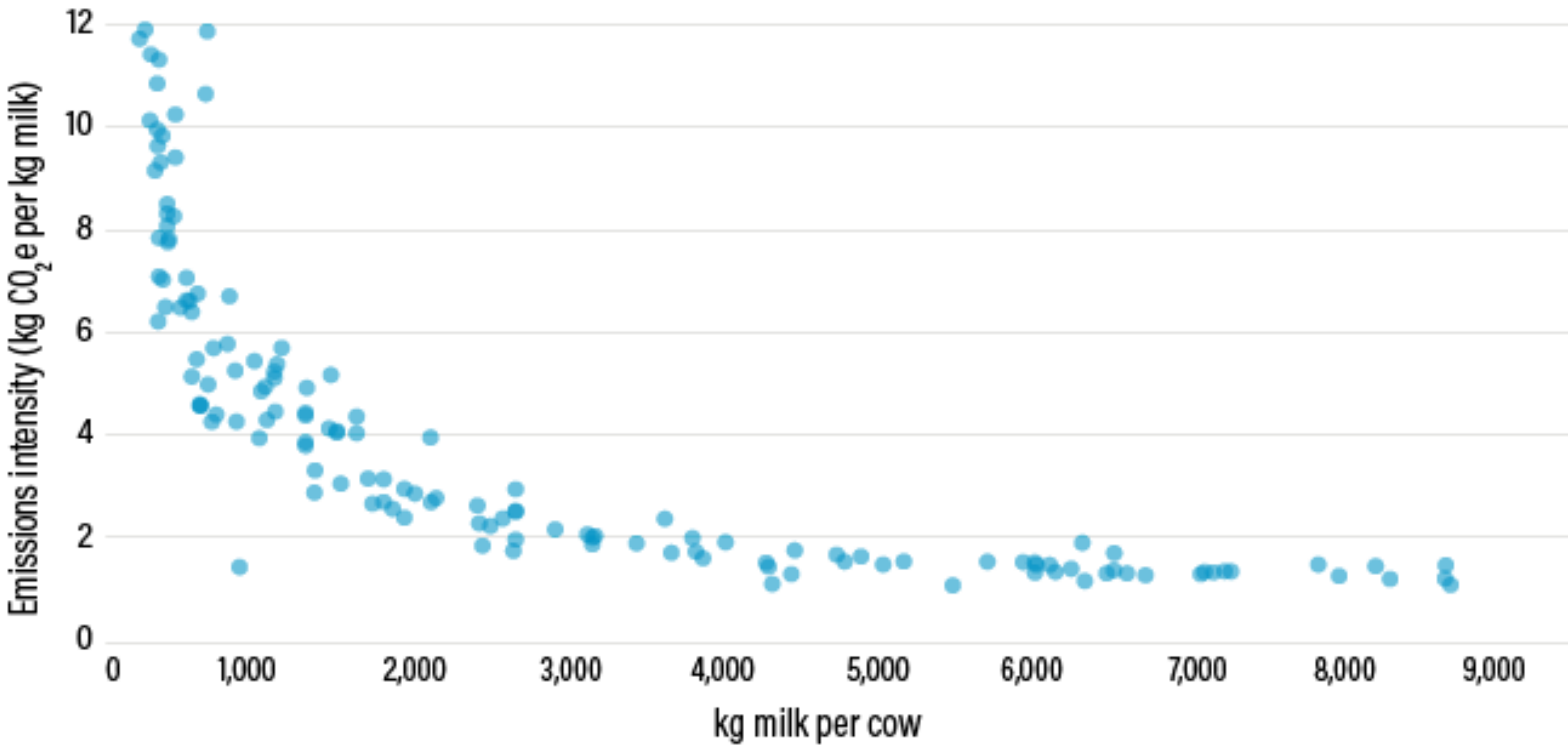
16. Reduce enteric fermentation through new technologies.

Ruminant livestock were responsible for around half of all agricultural production emissions in 2010. Of these emissions, the largest source is “enteric methane,” or cow burps. Increasing productivity of ruminants also reduces methane emissions, mainly because more milk and meat is produced per kilogram of feed. In addition, new technologies can reduce enteric fermentation. For example, 3-nitrooxypropan (3-NOP), a chemical additive that inhibits microbial methane, was tested in New

Zealand and cut methane emissions by 30 percent and may increase animal growth rates. Governments should expand public research into compounds like 3-NOP and require or incentivize adoption of the most promising.

More efficient milk production reduces greenhouse gas emissions dramatically



Note: Dots represent country averages.
Source: Gerber et al. (2013).

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17. Reduce emissions through improved manure management.

Emissions from "managed" manure, originating from animals raised in confined settings, represented around 9 percent of agricultural production emissions in 2010. Improving manure management by better separating liquids from solids, capturing methane, and other strategies can greatly reduce emissions. For example, using highly sophisticated systems to reduce virtually all forms of pollution from U.S. pig farms would only increase the price of pork by 2 percent while reducing GHGs and creating many health, water and pollution benefits. Measures governments can take include regulating farms, providing competitive funding for technology development, and establishing monitoring programs to detect and remediate leakages from digesters.

18. Reduce emissions from manure left on pasture.

Livestock feces and urine deposited in fields turns into nitrous oxide, a potent greenhouse gas. This unmanaged manure accounted for 12 percent of agricultural production emissions in 2010. Emerging approaches involve applying chemicals that prevent nitrogen from turning into nitrous oxide, and growing grasses that prevent this process naturally. Governments can increase support for research into such chemical and biological nitrification inhibitors and incentivize adoption by farmers.

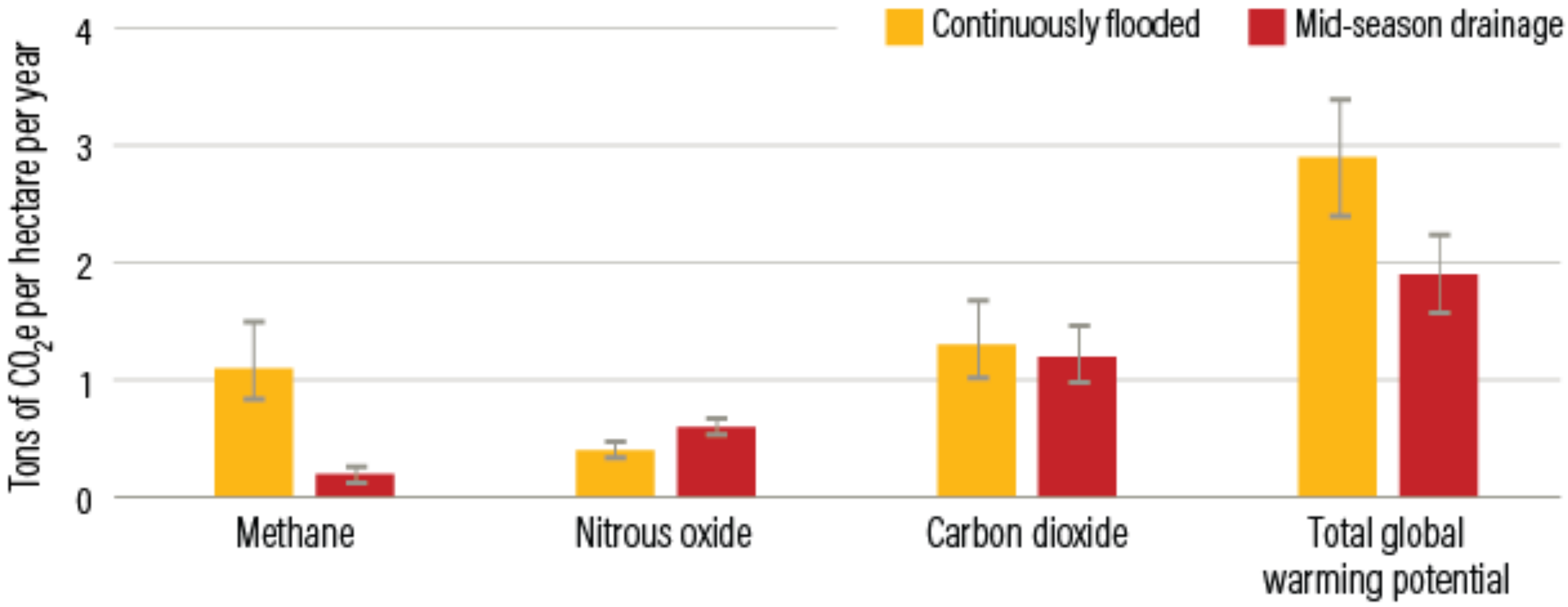
19. Reduce emissions from fertilizers by increasing nitrogen use efficiency.

Emissions from fertilizers accounted for around 19 percent of agricultural production emissions in 2010. Globally, crops absorb less than half the nitrogen applied as fertilizer, with the rest emitted to the atmosphere or lost as run off. Increasing nitrogen use efficiency, the percentage of applied nitrogen absorbed by crops, involves improving fertilizers and their management—or the composition of the fertilizers themselves—to increase the rate of nitrogen uptake, thus reducing the amount of fertilizer needed. Actions governments can take include shifting subsidies from fertilizers to support higher nitrogen use efficiency, implementing regulatory targets for fertilizer companies to develop improved fertilizers, and funding demonstration projects that increase nitrogen use efficiency.

20. Adopt emissions-reducing rice management and varieties.

Rice paddies contributed at least 10 percent of agricultural production emissions in 2010, primarily in the form of methane. But there are less emissions- and resource-intensive rice production methods. For example, shortening the duration of field flooding can reduce water levels to decrease the growth of methane-producing bacteria. This practice can reduce emissions by up to 90 percent while saving water and increasing rice yields on some farms. Some rice varieties also generate less methane. Actions to take include conducting engineering analyses to identify promising opportunities for reducing water levels, rewarding farmers who practice water-efficient farming, investing in breeding programs that shift to lower-methane rice varieties and boosting rice yields.

Mid-season drainage reduces greenhouse gas emissions from rice production in Punjab, India by one-third



Notes: Sold bars show state-wide averages.
Error bars represent one standard deviation.
Source: Pathak et al. (2012).

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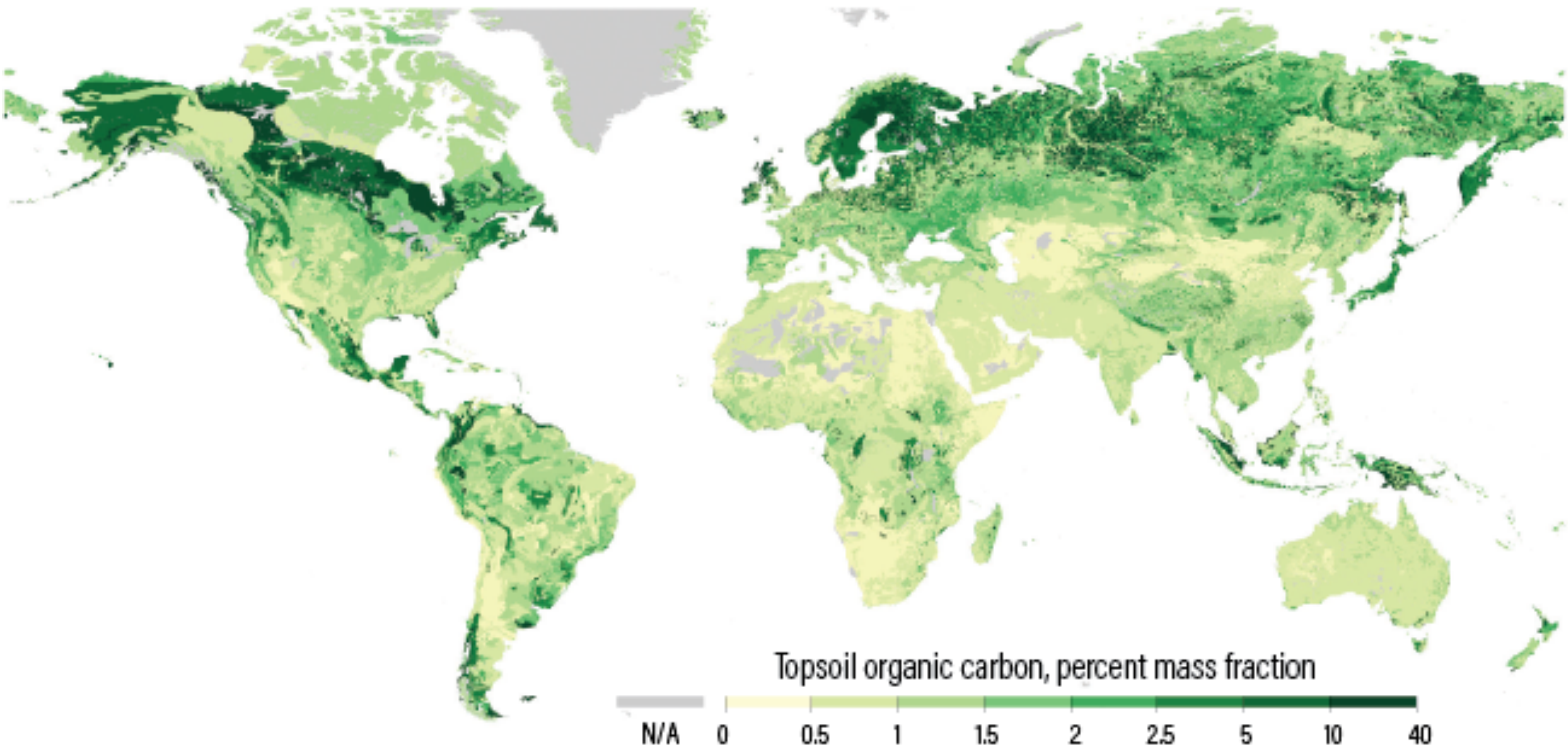
21. Increase agricultural energy efficiency and shift to non-fossil energy sources.

Emissions from fossil energy use in agriculture accounted for 24 percent of agricultural production emissions in 2010. The basic opportunities include increasing energy efficiency, which has been only modestly explored in agricultural settings, and switching to solar and wind. Reducing emissions per unit of energy used by 75 percent would reduce the GHG mitigation gap by 8 percent. Actions to take include integrating low-carbon energy sources and efficiency programs into agriculture programs and using renewable energy in nitrogen fertilizer manufacturing.

22. Implement realistic options to sequester carbon in soils.

Efforts to mitigate agricultural emissions have primarily focused on sequestering carbon in soils, but recent research suggests this is harder to achieve than previously thought. For example, practices to increase carbon, such as no-till farming, produced little or no carbon increases when measured at deeper soil depths. Important strategies include avoiding further loss of carbon from soils by halting conversion of forests, protecting or increasing soil carbon by boosting productivity of grasslands and croplands, increasing agroforestry, and developing innovative strategies for building carbon where soil fertility is critical for food security.

Soils in Africa are relatively low in organic carbon



Sources: Hengl and Reuter (2009).

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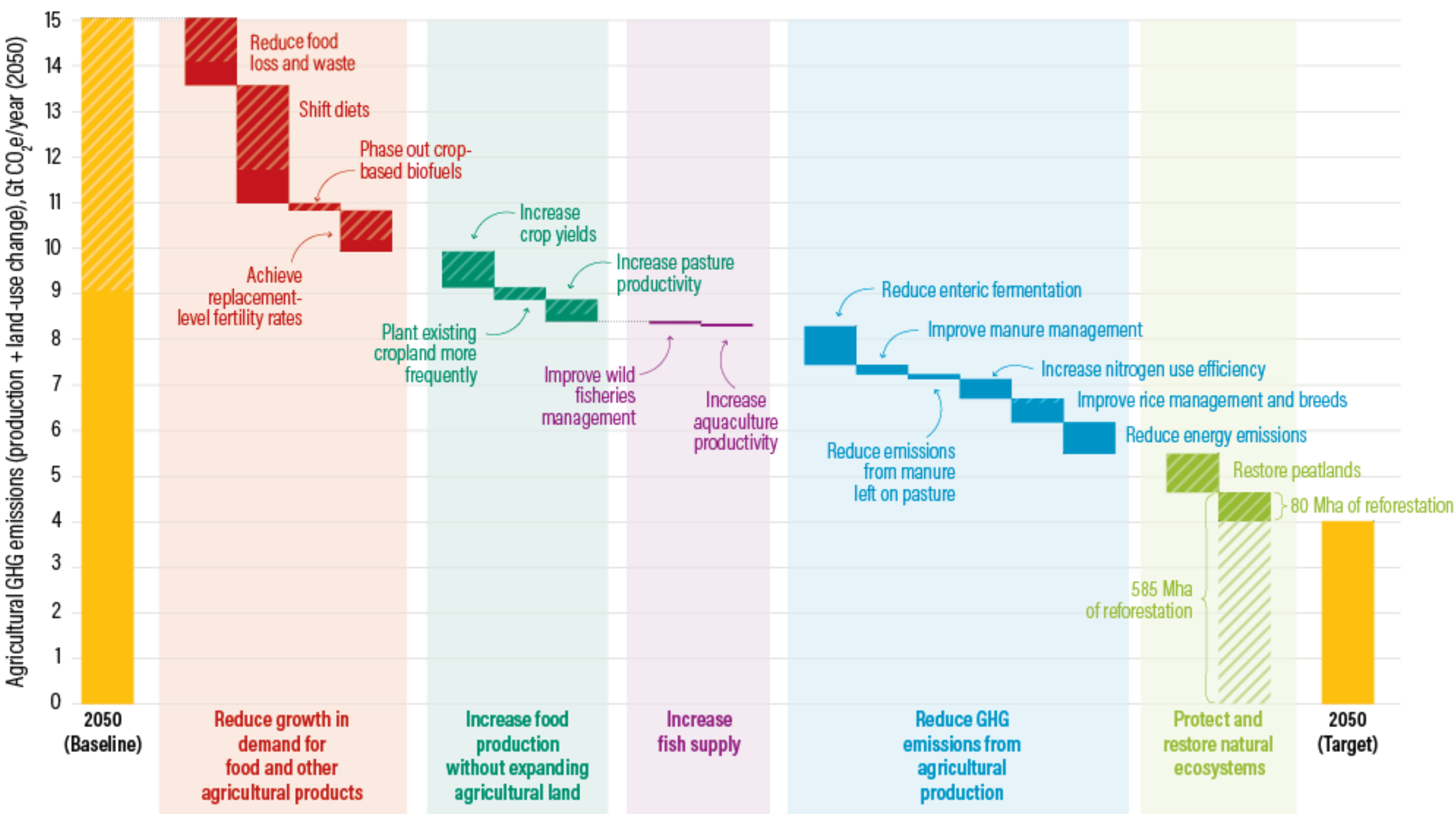
Moving Toward a Sustainable Food Future

The challenge of feeding 10 billion people sustainably by 2050 is much harder than people realize. These menu items are not optional—the world must implement all 22 of them to close the food, land and GHG mitigation gaps.

The good news is that all five courses *can* close the gaps, while delivering co-benefits for farmers, society and human health. It will require a herculean effort and major changes to how we produce and consume food. So, let's get started and order everything on the menu!

A 5-Course Menu of Solutions Can Reduce Agricultural Emissions by More than 70%



Note: Solid areas represent agricultural production emissions. Hatched areas represent emissions from land-use change.
Source: GlobAgri-WRR model.

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Download the full report, Creating a Sustainable Food Future, authored by Tim Searchinger, Richard Waite, Craig Hanson, Janet Ranganathan, Patrice Dumas and Emily Matthews

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