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# Revising Public Agricultural Support to Mitigate Climate Change

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**Timothy D. Searchinger** is a research scholar at Princeton University and a senior fellow at the World Resources Institute. His work combines ecology, agronomy, and economics to analyze the challenge of how to feed a growing world population while responding to climate change and reducing greenhouse gas emissions from agriculture. Searchinger is the author of five papers in *Science* and *Nature* (2008–18), reevaluating the climate benefits of bioenergy, agricultural production systems, and diets when factoring in land use change and proposing new methods for evaluating the climate consequences of land use. He was the lead author of a comprehensive report for the United Nations, World Bank, and World Resources Institute—*World Resources Report: Creating a Sustainable Food Future* (2019), which analyzed the challenge of sustainably meeting future feed needs while reducing emissions and land use change. Searchinger has directed projects in Colombia, Rwanda, and Vietnam evaluating the potential to improve livestock production to increase output and reduce emissions; he has authored numerous papers regarding strategies for abating nitrogen pollution. Before joining Princeton, Searchinger was a senior attorney at the Environmental Defense Fund, where he led work on agricultural policy and wetland protection. He was a senior fellow at the Georgetown University Law Center, a fellow at the Smith School at Oxford University, a deputy general counsel to Governor Robert P. Casey of Pennsylvania, and a law clerk to Judge Edward Becker of the U.S. Court of Appeals for the Third Circuit. He is a graduate of Amherst College and holds a J.D. from Yale Law School, where he was senior editor of the *Yale Law Journal*.



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# Executive Summary

The countries that produce two-thirds of the world's agriculture provided US\$600 billion per year in agricultural financial support on average from 2014 to 2016. Half of this support occurred through direct government spending or targeted tax benefits and half occurred through market barriers that increase prices to consumers. This support amounted to nearly 30 percent of the total value added by agricultural production in these countries. This report addresses the extent to which these transfers help boost agricultural production and mitigate emissions from agriculture and how support programs might be changed to do better.

Agriculture generates roughly 25 percent of global greenhouse gas (GHG) emissions, of which slightly more than half come from the production process, which generates mainly methane and nitrous oxide. The remaining GHG emissions from agriculture are generated through the carbon released by the clearing of forests and woody savannas for agricultural expansion and the degradation of peat soils. Absent mitigation, the current agricultural emissions of roughly 12 billion tons per year of carbon dioxide equivalents (CO<sub>2</sub>e) are likely to rise to 15 billion tons per year by 2050. In this scenario, agriculture alone will use up 70 percent of the annual allowable emissions budget for all human emissions, including energy, that will be necessary to hold warming to international climate goals.

The single most important source of mitigation in agriculture results from increases in the efficiency with which agriculture uses natural resources and chemical inputs. That includes more efficient use of land, which includes increasing yields and so helps to avoid land use change. That also involves more efficient use of animals, water, and chemicals. These productivity gains also can contribute to increased incomes for farmers.

For productivity gains to result in climate mitigation they frequently need to be explicitly linked to the protection of forests and other native landscapes because they can otherwise encourage local land expansion. Mitigation depends particularly on improvements in management in the use of ruminant livestock (mainly cattle, sheep, and goats), which generate roughly half of all emissions from production and land conversion. To achieve climate goals, mitigation efforts must also strongly emphasize innovations, for which there are many promising options.

Only a modest portion of current agricultural support has the potential to help mitigate emissions or even to increase production efficiencies generally. The roughly US\$300 billion in market price supports boost prices to some farmers but at costs to others. Of the US\$300 billion in direct spending, roughly 43 percent is designed to support farmer income and another 30 percent supports production. Only 9 percent of direct spending explicitly supports conservation, while another 12 percent supports research and technical assistance.

Over the past two decades, some governments have decoupled payments from conditions on farm production. Governments do so in different ways and to different degrees, but in general, this decoupling reduces the likelihood that subsidies will encourage inefficient production. Input subsidies have been and remain a particularly problematic form of coupled subsidies. Fertilizer subsidies have contributed to the overuse of nitrogen fertilizer in a number of countries, including both China and India, which has resulted in higher GHG emissions and other environmental problems. China has recently phased out fertilizer subsidies. Whether decoupling reduces global emissions depends on how production switches between regions. While decoupling is unlikely to lead to large, global GHG mitigation, the experience of New Zealand, which almost eliminated coupled agricultural subsidies overnight in 1986, illustrates potential gains through increased efficiency and reduced environmental impacts.

Price support payments and trade barriers help reduce farmer risk and maintain income for beneficiaries, but they are inefficient in addressing the risks to poorer, smaller farmers, who are prone to poverty traps. Such supports almost always benefit larger farms within a country, and market price supports benefit domestic farmers at the expense of foreign farmers. Some support payments are capitalized into land values, which benefits existing owners but not farm workers, renters, or subsequent owners.

The United States and the European Union (EU) have moved to impose some environmental conditions on receipt of farm payments. The prospect of environmental conditions holds some promise. Although enforcement is minimal in the United States, conditional payments have probably helped protect some wetlands and modestly reduced soil erosion there. They have helped protect the most valuable grasslands in Europe. Although no studies yet support the assertion, European conditions on support payments have possibly also increased compliance with other environmental laws such as limits on nitrogen. The last round of European agricultural reforms conditioned 30 percent of payments to farmers on additional conservation measures; however, the effect remains unclear and likely modest because criteria were largely unambitious.

Case studies of Brazil, China, India, the United States, EU, and Sub-Saharan Africa explore differences in support levels and approaches that confirm these general observations. Significant portions of U.S. and EU spending classified by the OECD as conservation probably have limited effect. The largest land retirement programs to reforest highly sloped cropland and to restore degraded grasslands in vast parts of the country have been in China. These Chinese programs have had success in reducing soil erosion and moderate success in sequestering carbon. The evidence also suggests that the programs could do more to sequester carbon and that the forest program may have had adverse effects on biodiversity by emphasizing plantation forests.

The case studies also highlight initiatives that hold promise for climate change mitigation. They detail efforts in Brazil to tie farm credit to forest protection while boosting grazing productivity. The India case study highlights

efforts to require that nitrogen be coated with a compound designed to reduce losses and increase efficiency. Finally, the case studies detail some successful efforts in China to increase efficiency of nitrogen use and specific efforts in Africa to increase dairy efficiency by improving forage quality. The case studies also illustrate a small start toward funding integrated, coordinated projects. Such integrated projects target funds to their best uses, encourage farmers to achieve higher levels of performance, and occasionally support these efforts with ongoing research and technical assistance. The United States has created mechanisms for using a portion of its conservation programs for such integrated purposes. Further, integrated projects provide some of the promising uses of EU funding for rural development.

Overall, the study finds that there is substantial potential to redirect farm support toward climate change mitigation. Market price supports are the most challenging to redirect, but Europe has created a model of phasing them down while boosting direct aid. Key recommendations are as follows:

Takeaway 1: Redirect funding to focus on mitigation, including measures that increase efficiency in the use of natural resources.

Takeaway 2: Focus land retirement efforts where land is becoming abandoned, where farmland is unproductive and unimprovable and peatlands, and emphasize restoration of native forests.

Takeaway 3: Condition farm payments on protection of native areas to avoid further land clearing.

Takeaway 4: Structure incentive programs so they offer graduated payments for higher climate performance.

Takeaway 5: Prioritize innovative, performance-based mitigation strategies.

Takeaway 6: Combine financial support for mitigation with requirements for improvements to avoid leakage, moral hazard, and waste of resources.

Takeaway 7: Prioritize coordinated projects across multiple producers, integrated with research and technical assistance.

Because of the importance of this redirection of support for whether countries achieve climate goals, and because of the need for international cooperation to push needed innovations, global action is required.





# Abbreviations

CAP	Common Agricultural Policy
CRP	Conservation Reserve Program
CSP	Conservation Security Program
EQIP	Environmental Quality Incentives Program
EU	European Union
FAOSTAT	United Nations Food and Agriculture Organization Corporate Statistical Database
GGP	Grain for Green Program
GHG	greenhouse gas
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
WTO	World Trade Organization

## UNITS USED IN THIS REPORT

This report uses the metric system and all “tons” therefore refer to metric tons. All emissions, when not otherwise qualified, are of the various greenhouse gases transformed into carbon dioxide equivalents (CO<sub>2</sub>e) based on their 100-year global warming potentials. For methane, the emissions reported by the United Nations Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) use a multiplier of 25. However, the Globagri-WRR model uses 34, which is based on analysis presented in the 2014 Intergovernmental Panel on Climate Change (IPCC) Integrated Assessment.

## GLOSSARY OF KEY TERMS AS USED BY THE OECD OR WTO

*Agricultural support:* Agricultural support is any form of financial support to agricultural activities as a result of government policies. As calculated by the OECD, agricultural support includes payments of various kinds that go directly

to farmers, payments to support agricultural production through general services such as research and development, and market price supports, which are the increased gross returns to farmers from increased prices that result in increased payments from consumers to farmers.

*General service support:* The forms of agricultural support that result from government expenditures that support services of value to agriculture, but that are not in the form of payments to individual farmers. Examples include promotional services, stockholdings, infrastructure development, and research and development.

*Input subsidy:* Input subsidies are payments made to reduce the costs of inputs. This term frequently refers to physical inputs such as chemicals, fertilizer, and machinery, although the OECD also applies the term to transfers reducing the cost of various on-farm services and capital investments.

*Market price support:* Market price support increases gross revenue to farmers as a result of higher prices due to market barriers created by government policies. These policies require price-fixing strategies and import barriers.

*Production payments:* These payments are forms of agricultural support that are paid directly to farmers and can take many different forms.

*Coupled payments:* Coupled payments are payments that are based in some way on the type, quantity, or amount of production. Because of the extent to which payments vary with production, level of coupling payments can also vary.

*Decoupled payments:* Decoupled payments are payments to farmers that do not depend on current or future production. For example, they can be payments based on past production.

*Amber Box:* The Amber Box is a category of agricultural support that is restricted by world trade agreements due to its distortion of markets and of global trade.

*Green Box:* The Green Box is a category of agricultural support that is believed not to distort markets or trade or whose distortion is considered minimal, although the extent to which all Green Box items are truly decoupled is a matter of some debate.

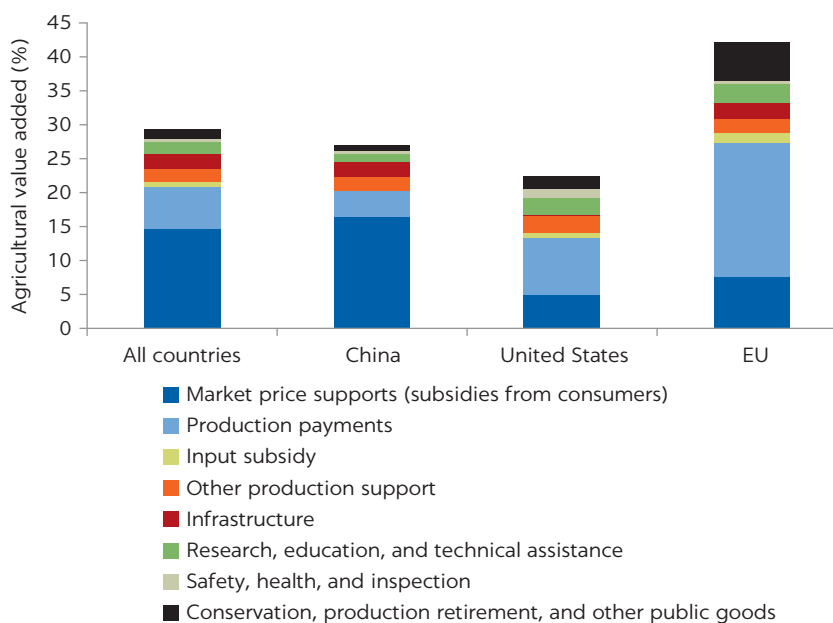
# Introduction

Organisation for Economic Co-operation and Development (OECD) countries plus 11 major developing economies, which generate two-thirds of all agricultural production,<sup>1</sup> provided about \$600 billion per year between 2014 and 2016 in agricultural support either through direct spending, through special tax benefits, or through market barriers that increase prices to consumers.<sup>2</sup> This figure amounts to nearly 30 percent of these countries' total agricultural value-added output of \$2.03 trillion per year.<sup>3</sup> This report analyzes these forms of public support to assess their contribution toward increases in agricultural production and mitigation of agricultural greenhouse gas emissions. The report includes case studies of public support in six regions, and offers recommendations for changes to increase the climate mitigation benefits of support programs.

The analysis of subsidies relies on the database of farm support payments maintained by the OECD. The OECD structures this database based on its characterization of the different support programs around the world. The report also relies on the analysis of a parallel report, *Creating a Sustainable Food Future*, issued by the World Resources Institute (WRI) and the World Bank with other partners. That report draws from the results of the Globagri-WRR model developed by Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Princeton, WRI, and Institut National de la Recherche Agronomique (INRA) under the leadership of Patrice Dumas.

Figure I.1 provides an overview of agricultural support as a fraction of total agricultural added value averaged from 2014 to 2016.

FIGURE I.1

**Agricultural support as a fraction of total agricultural added value, 2014–16**

Source: OECD PSE and GSSE databases.

Note: EU = European Union.

**NOTES**

1. The countries included in the OECD agricultural support databases: OECD nations plus China, Brazil, Colombia, Costa Rica, Indonesia, Kazakhstan, the Philippines, the Russian Federation, South Africa, Ukraine and Vietnam. These countries together account for two-thirds of global agricultural value added.
2. The sum of producer support and general services support listed by the OECD <http://www.oecd.org/tad/agricultural-policies/producerandconsumersupportestimatesdatabase.htm>.
3. The World Bank, Agriculture Value Added Global database <https://data.worldbank.org/indicator/NV.AGR.TOTL.CD>.

# 1 The Food Production and Climate Change Mitigation Challenge

According to nearly all estimates, the world is on course to require a 50 percent or more increase in annual crop production in 2050 compared to 2010 (Alexandratos and Bruinsma 2012; Valin et al. 2014).<sup>1</sup> The driving force is a population likely to grow from 7 billion in 2010 to almost 10 billion in 2050. Population growth will require an annual rate of growth in crop production faster than that experienced from 1961 to 2010. Demand for milk, meat, and fish is likely to grow by 70–100 percent, which exceeds previous annual growth rates back to 1960 (Valin et al. 2014). Such growth will require more land and water resources.

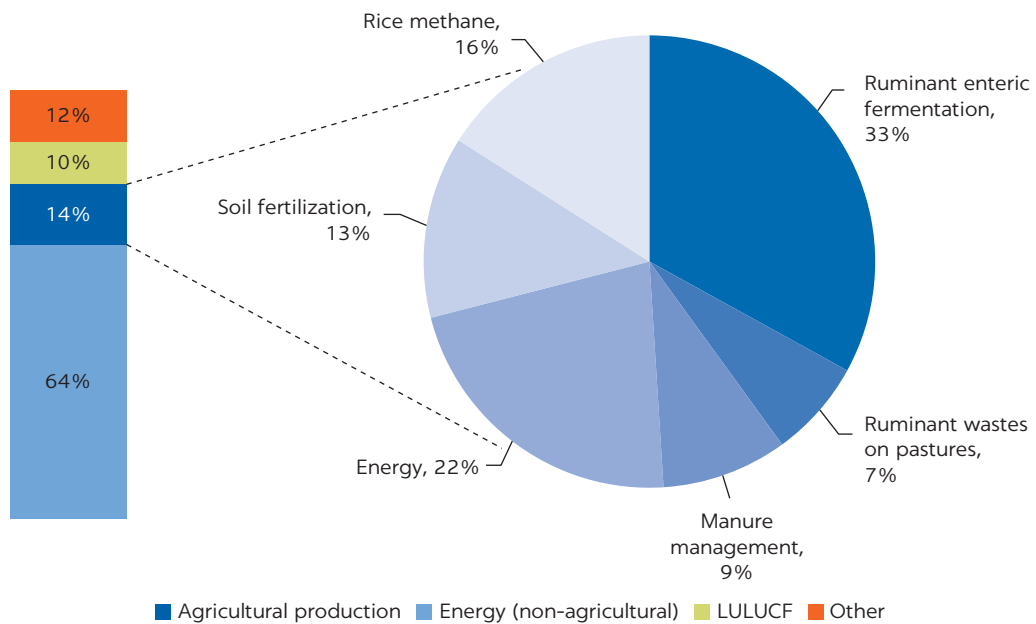
At the same time as the world must produce more food to meet rising demand, it must also reduce greenhouse gas (GHG) emissions from agriculture if it wishes to stabilize the climate. Agricultural production processes and emissions from the conversion of agricultural land contribute roughly one quarter of total global GHG emissions. Figure 1.1 provides a graphic of agricultural contributions to global GHG emissions. Although projections vary in detail, most studies project large increases in agricultural emissions by 2050. The clearing of forests and savannas due to farmland expansion will contribute to this increase in emissions (Schmitz et al. 2014a). Both simple extrapolation and complex Globagri-WRR modeling project emissions from agriculture, absent mitigation, to reach 15 gigatons (billion) per year by 2050. These emissions will take up roughly 70 percent of the estimated allowable annual human emissions budget of 21–22 gigatons in 2050 that most modeling scenarios would require to achieve the international climate goal of 2-degree warming adopted by the 2015 Paris Agreement on climate change.<sup>2</sup> This 15-gigaton projection for agricultural emissions alone would make this climate target practically unachievable because it would leave little room for emissions from other economic activities. To reach emissions levels that meet the criteria for the climate goal of 2-degree warming, a recent report of the World Resources Institute, the World Bank, UN Environment and UN Development Programme considered a target to reduce emissions from the current 12 gigatons down to 4 gigatons by 2050 (Searchinger et al. 2019).

Emissions from agriculture fall into two major categories.

The first category involves emissions from agricultural production resulting from the release of methane and nitrous oxide and carbon dioxide from the use of fossil fuels for energy. Methane and nitrous oxide are released from the enteric (digestive) methane emissions of ruminants (cattle, sheep, goats, etc.), methane and nitrous oxide emissions arise in manure management, methane emissions arise from rice irrigation, and nitrous oxide emissions result from the application of nitrogen fertilizer or animal manure and urine to soils. According to the Globagri-WRR model, these emissions are likely to grow to 9 billion tons CO<sub>2</sub>e per year by 2050 despite large increases in productivity built into the 2050 baseline. Table 1.1 provides a summary of global agricultural emissions by category in 2010 and 2050.

The second category of emissions consists of those that result from agricultural expansion. Agricultural expansion includes both the conversion of forests and savannas to agricultural land and the conversion of pastured grasslands to croplands. Both of these processes release carbon from vegetation and soils. A majority of models suggest that agricultural expansion is likely to continue in the hundreds of millions of hectares<sup>3</sup> (Bajželj et al. 2014; Schmitz et al. 2014b; Tilman and Clark 2014). The majority of strategies for stabilizing the climate assume no net expansion of agricultural land and many strategies assume net declines in agricultural area and resulting gains in forest (Edenhofer et al. 2015). These zero or net decline strategies will require producing far more food on roughly the same land area.

**FIGURE 1.1**  
**Contribution of agricultural production processes to global GHG emissions**



Source: Creating a Sustainable Food Future: Synthesis Report 2018.  
 Note: GHG = greenhouse gas; LULUCF = land use, land-use change and forestry.

**TABLE 1.1 Estimated global agricultural emissions, 2010 and 2050 (million tons CO<sub>2</sub>e)**

GLOBAGRI-WRR			FAOSTAT—EXCLUDING ENERGY IN AGRICULTURE	
CATEGORY	2010	2050	CATEGORY	2010
Enteric emissions	2,260	3,419	Enteric emissions	1,987
Manure management	588	770	Manure management	337
Rice	1,120	1,266	Rice	518
Pasture & paddock	446	653	Pasture & paddock	795
Nitrogen	1,212	1,681	Synthetic fertilizer	651
Other fertilizers	77	60	Manure applied to soils	184
On-farm energy	906	1,062	Crop residues	189
Pesticides	159	112	Burning—Crop residues	28
			Burning—Savanna	218
	<b>6,769</b>	<b>9,023</b>		<b>4,689</b>

Source: Globagri-WRR Model and FAOSTAT.

## NOTES

1. The Searchinger et al. report contains support for this section and should be viewed as the reference for any non-cited factual claim. The report is occasionally cited again for emphasis. Papers tend to use different starting dates. If properly understood, all papers imply a comparable level of food demand growth, which can be expressed in different units such as by either food value or calories.
2. The goal of 21–22 total gigatons CO<sub>2</sub>e follows climate stabilization strategies estimated by various models to hold temperature increases to no more than 2 degrees Celsius warmer than pre-industrial levels as summarized in (Sanderson, O’Neill, and Tebaldi 2016) and (UNEP 2017). This choice of emissions scenarios excludes those that rely on extensive employment of negative emissions after 2050, which are highly uncertain at best. The target is to have a greater than two thirds chance of holding temperature increases to the 2 degree goal given the uncertainties of climate sensitivity to higher GHGs. This single target ignores many possible complexities, particularly what the cumulative emissions are between now and then and the proportion of total emissions of different GHGs. There are so many variations in these scenarios that this target for total emissions in 2050 provides only one useful benchmark.
3. An FAO analysis from 2050 projects 70 million hectares of net land use change by 2050 (Alexandratos and Bruinsma 2012), but this analysis did not project increases in pasture, which are often larger than increases in cropland. It also assumed a population in 2050 of 9 billion based on mid-range UN estimates when the FAO started its analysis, instead of present projections of 9.8 billion. Assuming the same yields, this is a 9 percent greater population that must be fed exclusively by expanding agricultural land, which through extrapolation brings FAO cropland projections roughly in line with those of other models.





## 2 Opportunities to Mitigate Agricultural Emissions

In general, four major opportunities exist to mitigate greenhouse gas emissions from agriculture: (1) increasing the efficiency of agricultural production; (2) avoiding or managing agricultural land expansion and restoring marginal lands to natural ecosystems; (3) implementing known agricultural management practices that mitigate emissions; and (4) strongly pushing innovations to increase those opportunities.

### **INCREASING AGRICULTURAL PRODUCTIVITY THROUGH ENHANCED EFFICIENCY IN THE USE OF NATURAL RESOURCES**

Increasing the productivity of agriculture by increasing the efficiency in use of natural resources—the output of food per input—provides the single most important strategy for mitigating agricultural emissions. That means increasing output: a) per hectare of cropland or pasture; b) per kilogram of fertilizer and other chemical inputs; c) per animal; d) per kilogram of animal feed; and e) per liter of diesel or kilowatt hour of electricity. Increasing efficiency of all natural resources—not just land—has the added benefit of addressing other environmental challenges.

Increasing output per hectare is necessary to eliminate emissions from land use change because producing more than 50 percent more crops with more agricultural land will require that output of crops per hectare also increase more than 50 percent. Because ruminant meat and milk consumption, which rely primarily on grazing lands and other forages, are likely to grow by more than 70 percent,<sup>1</sup> avoiding expansion of pasture into forests and savannas also requires increasing the milk and meat produced per hectare of grazing land. Increasing the efficiency of other natural resource inputs is also critical to reducing the recurring emissions from the production process itself. Of these production processes, the first priority is to increase the efficiency of generating meat and milk from ruminants (bovines, sheep and goats) per hectare, per animal and per kilogram of feed (Havlik et al. 2014; Herrero et al. 2013). Ruminants generate roughly half of all agricultural production emissions (figure 1.1). Most of these emissions result from the enteric methane created in ruminant digestion.

A significant quantity of emissions also results from the urine and manure that ruminants deposit in pastures and paddocks or that is managed in pits for non-grazing animals. Emissions from bovine production vary significantly around the world. Map 2.1 illustrates the significant variance in the amount of emissions generated per kilogram of bovine meat.

Improving the quality of feed can reduce emissions per kilogram of milk or meat because animals consuming more nutritious fodders grow faster or produce more milk without comparably increasing emissions. Feed quality can be improved through improved grazing practices, by using more nutritious grasses, and by employing better cut and carry forages and some crop supplements. Improved health care and breeding also play important roles.

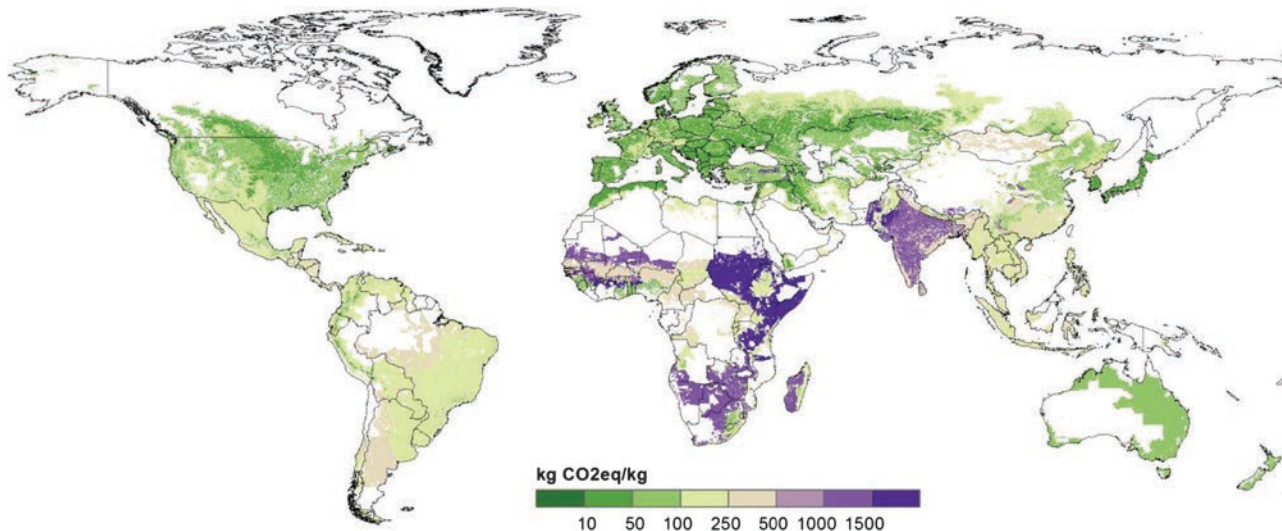
Mitigating the growth in GHG emissions from livestock can also be achieved by increasing the share of animal-source foods from more efficient sources of animal protein, including poultry, meat, eggs, and pork (Ranganathan et al. 2016). Not only do ruminants generate multiple times the GHG emissions of non-ruminant animals, but they generate only a fraction of the calories and protein per hectare.

Improved efficiency in the use of natural resource inputs can also mitigate all other categories of production-related emissions. Crops absorb only around 40 percent of all the nitrogen applied to fields. Increasing that nitrogen efficiency to 70 percent is necessary just to prevent the already large emissions associated with nitrogen from growing (Zhang et al. 2015). Irrigated rice generates large emissions from methane, but because these emissions scale with the area of rice, each 1 percent increase in rice yields will roughly reduce these emissions by 1 percent per ton of rice (Yan et al. 2009). Switching agricultural energy consumption from fossil fuels to renewable solar and wind can reduce emissions as can the more efficient operation of tractors, pumps, and drying facilities.

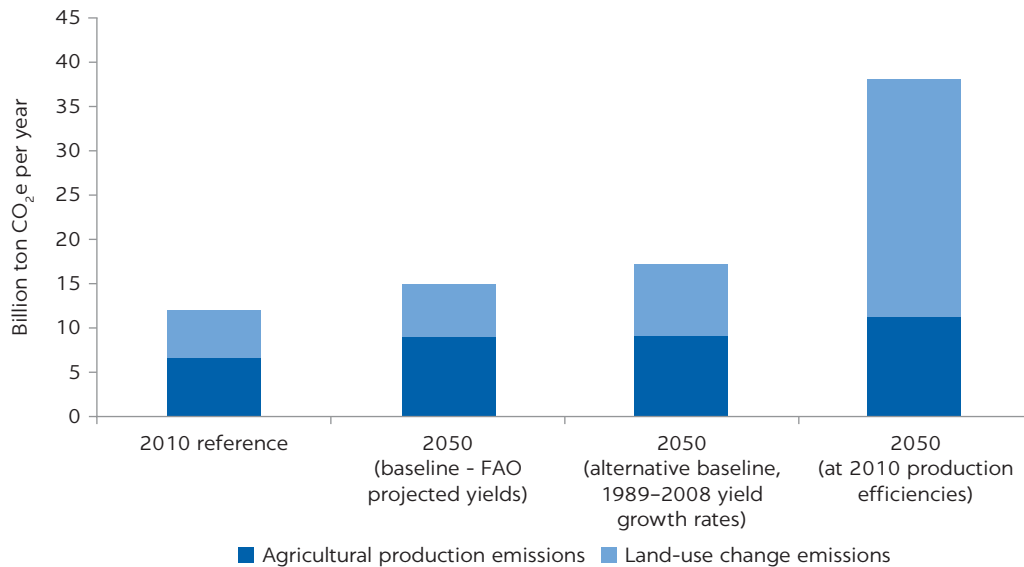
Reducing food loss and waste provides another method for increasing efficiency in the use of natural resources. Overall, the best estimates are that roughly one third of all food produced when measured by weight and one quarter when measured by calories is lost or wasted before that food is consumed by people (Lipinski et al. 2013). This inefficiency results in losses of food valued at one trillion dollars per year, and generates several gigatons of extra emissions

MAP 2.1

**Global emission intensities of beef production (kg CO<sub>2</sub>e/gram of protein), 2000**



Source: Reproduced from Herrero et al. 2013.

**FIGURE 2.1****Illustration of the role of improved production efficiency in limiting agricultural emissions—Increase in agricultural emissions, 2010–50**

Source: GlobAgri-WRR model.

through the need for additional food production (Food and Agriculture Organization of the United Nations 2015). In developed countries, most of these losses occur in the later parts of the food supply chain, particularly in retail, in restaurants and caterers and in people’s homes. But in most poorer countries, most of these losses occur in the harvesting and storage processes. For example, in Africa, the World Bank has previously estimated post-harvest losses of grain at US\$4 billion per year (World Bank 2011). Harvesting wastes can be reduced by agronomic improvements that ensure crops achieve more consistent qualities and ripen at more consistent times and through improved harvesting equipment. A variety of technologies exist to improve storage, many of which do not require cooling and use simple equipment and could therefore be used by even smallscale and poor farmers.

One way to demonstrate the importance of efficiency gains is to model the emissions and land use needed to meet projected demands for land in 2050 using today’s production systems and efficiencies. According to Globagri-WRR, if such systems do not change, agricultural land use would have to expand by more than 3 billion hectares and total GHG emissions would reach 33 gigatons per year. This predicted level of emissions would be roughly 50 percent greater than the total allowable maximum from all emissions sources to have a good chance of limiting warming to 2 degrees Celsius. Figure 2.1 illustrates the role of improved production efficiencies in limiting agricultural emissions from 2010 to 2050.

### **AVOIDING OR MANAGING AGRICULTURAL LAND EXPANSION AND RESTORING UNIMPROVABLE, LOW PRODUCTIVITY LANDS**

The complex relationship between agricultural expansion and advancement and the protection of natural ecosystems presents many social and political challenges that governments need to manage if productivity gains are to lead to

climate mitigation. Road improvements in Africa, for example, are critical to support advances on existing agricultural land, but can also spur expansion depending on where and how these roads are located. Locating road improvements to do primarily the first and little of the second is therefore one important need.

In some countries, particularly in Sub-Saharan Africa, at least some agricultural expansion is inevitable as populations and food requirements grow. In these countries, the challenge will be to avoid unnecessary expansion and to target the necessary expansion only where yield potential is relatively high and the loss of carbon is relatively low.

To fully realize climate benefits, governments also need to explicitly link their support for productivity gains with protection of natural lands. Although increases in yields are critical to reducing global land expansion, they can sometimes lead to increases in local land expansion. They can do so by increasing farm income, providing the revenue to finance more agricultural expansion in areas with an open frontier. Efficiency gains can also make local agriculture more globally competitive. They can therefore lead to increases in exports, which farmers then supply by expanding agricultural area and clearing more forest locally. The well-known examples of soybean expansion in Brazil and palm oil expansion in Indonesia and Malaysia illustrate this phenomenon.

Productivity gains also provide governments opportunities to sequester carbon by reclaiming marginally productive lands to their natural state when it is not practical to improve them for agriculture. Land can become marginally productive as result of degraded soil, market conditions, or shifts in agronomic practices. Despite their low productivity, such lands may continue to be used by farmers with limited benefits. Although some such lands will eventually be abandoned, restoring these lands can both mitigate climate change and redirect agricultural resources to more productive uses. Prominent candidates include grazing on highly sloped, but previously forested, land such as in the region of the Atlantic Coastal Rainforest of Brazil.

Drained, but unused, peatlands also offer a key opportunity to reclaim unproductive agricultural land. Peatlands are saturated nearly year-round and built up enormous reserves of soil carbon as the water-logging prevents microorganisms from breaking down the carbon in deposited vegetation. Once drained, microorganisms can release this carbon and peatlands can catch on fire. Globally, the best estimates suggest around 26 million hectares of drained peatlands, around half of one percent of global agricultural lands, emit around 2 percent of total human emissions and will continue to do so unless water is restored (Searchinger et al. 2019). Yet half of these drained peatlands do not have intensive agricultural uses. Mitigation of these emissions will require pro-active government efforts to restore these inherently marginal agricultural lands.

There are several agricultural support mechanisms that can effectively address agricultural land expansion and ecosystem protection. Most directly, governments can condition access to support payments or subsidized credit programs for farmers on conduct that avoids clearing natural areas. Governments can, at a minimum, deny subsidies for food produced on newly cleared lands. In much of the world, governments own many of the natural lands that might be converted, and they can protect lands to a large extent just by not granting them to private owners. Where expansion is inevitable, governments can develop and follow land use plans to target their support for agricultural development where carbon impacts will be smallest (Estes et al. 2016).

## IMPLEMENTING KNOWN MANAGEMENT PRACTICES

Even with large increases in productivity, enteric fermentation, manure management, fertilizer use, energy use, and rice production will continue to cause significant emissions. In all cases, however, adopting known agricultural management practices can help mitigate these emissions. For example, separating manure solids from liquids and capturing and burning the methane generated by manure pits can reduce manure emissions. Dry-seeding and temporarily drawing down paddy rice fields can lower rice methane emissions.

Some of these management measures may also be able to increase agricultural productivity or generate economic returns. For example, in some locations, alternating flood water management of rice appears to boost yields. Better management and use of manure can generate energy and/or substitute for chemical fertilizer. In most circumstances, measures that reduce GHG emissions can have other important environmental benefits. For example, runoff of nitrogen fertilizer and poorly managed manure are major sources of water pollution. They can make drinking water unsafe and spoil coastal fisheries and beaches with algal blooms. Despite these social costs, farmers often do not find the management measures sufficiently profitable to pursue them on their own.

Government agricultural support can be targeted to improve agricultural management. Incentive subsidies can build up experience and knowledge in implementing low carbon management measures. Government policies can also condition cost-share support upon the requirement that farms employ improved management practices. This “shared support” approach has potential advantages over purely voluntary approaches. Among other challenges, because purely voluntary approaches typically compensate farmers with poor management for improving their environmental performance but do not compensate farmers who meet environmental standards on their own, they can effectively discourage farmers from achieving higher environmental standards on their own.

## ADVANCING INNOVATION IN MANAGEMENT

To achieve high levels of mitigation, innovations in management are required, and potential innovations exist at different stages of development that address virtually all forms of emissions. Some of these innovations are now in the research stage. For example, researchers have identified chemicals exuded by a valuable, tropical grass species that inhibit the GHG emissions from the loss of nitrogen in soils (biological nitrification inhibition). Researchers have also found such traits present in domestic or wild varieties of all the major grain crops and are working to strengthen their role and to breed these traits into the highest yielding varieties of these crops. If successful, this effort might both reduce emissions and decrease the need for, and costs of, nitrogen fertilizer. At least one promising compound has also been shown to reduce methane emissions from cattle digestion (Hristov et al. 2015a). This compound may also help boost weight gain. It probably requires only modest additional development to be implemented.

Other innovative technologies are available for implementation now, but the potential impact of these technologies can be improved and their uses under differing farm conditions refined. For example, enhanced efficiency fertilizers exist that reduce losses of nitrogen, and there is significant evidence that these

often boost yields. However, few farmers use these chemicals, limiting their use only to fields that experience high losses, probably because the performance of these chemicals varies significantly. Increased investment in the improved chemistry of these compounds will require additional funds. Further investment could better determine where and under which conditions different chemicals could be or should be deployed (Kanter and Searchinger 2018).

Government funding can play a major role in supporting the development, adoption, and refinement of new technologies and innovations. Government funding can support research and development, can provide incentives for farmers to adopt innovations, and can refine innovations to serve different types of farms. Finally, governments can support combined efforts for farmers and researchers to jointly explore innovations and measure progress.

## NOTE

1. These projections are based on the FAO's estimated diets in 2050, which are actually lower than those of many other models, but still result in large increases of ruminant meat and milk between 2010 and 2050. (Searchinger et al. 2018).

# 3 Agricultural Support Today

Most developed and middle-income countries provide substantial support to agricultural producers. The Organisation for Economic Co-operation and Development (OECD) estimates the level of that support for all OECD countries as well as for several major agricultural producing middle-income countries including China, Brazil, and the Russian Federation (India, the world's fourth largest agricultural producer, as well as Argentina and all of Africa except South Africa are omitted from the analysis).

This report reorganizes OECD data on agriculture support to focus on how agricultural support interacts with climate change mitigation. The restructured data include support listed in the OECD's "producer support estimates" and "general services support estimates" (see the glossary of terms at the beginning of this report for a description of different forms of agricultural support).

The OECD system does not include all ways in which government supports agriculture. For example, although it may include subsidized costs of running irrigation systems, it does not include the lack of a price or a low price for the water itself, which is often considered one of the largest subsidies to agriculture. The OECD also only includes some of the most specific tax credits rather than the broad array of tax policies that often benefit agriculture.

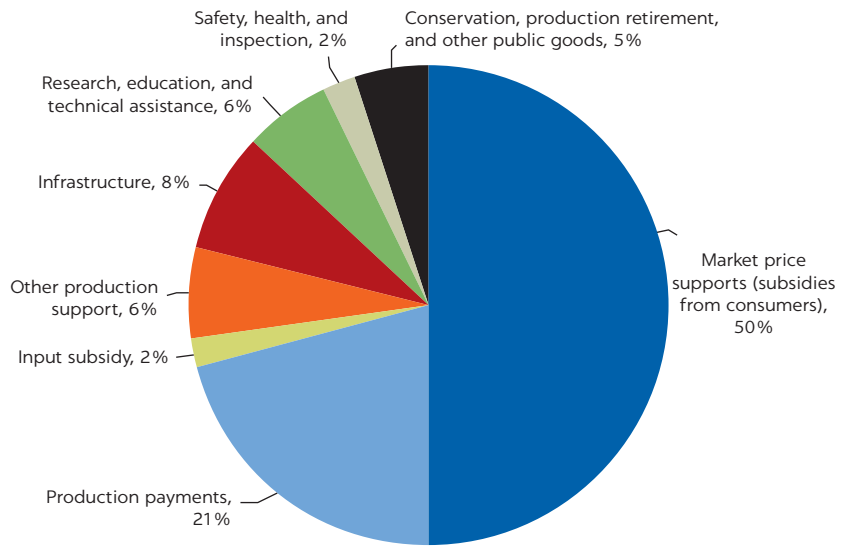
The analysis also does not consider "transfers to consumers from taxpayers" in the OECD database. That categories primarily includes food aid to poor consumers, which may ultimately help agriculture through higher demand but do not directly support agricultural producers.<sup>1</sup>

## **CURRENT LEVELS AND MECHANISMS FOR AGRICULTURAL SUPPORT**

In the countries covered by the OECD, support provided to agriculture through government policy equals 30 percent of the value-added contribution by agriculture.<sup>2</sup> This figure, however, masks the widely different levels of support between countries. In the United States, China, and the EU, support averaged from 2014 to 2016 as a fraction of value added in agriculture was 24 percent, 27 percent, and 48 percent, respectively. In Japan, agricultural support was equivalent to 92 percent of added value and in Switzerland was well over 100 percent. In Brazil and

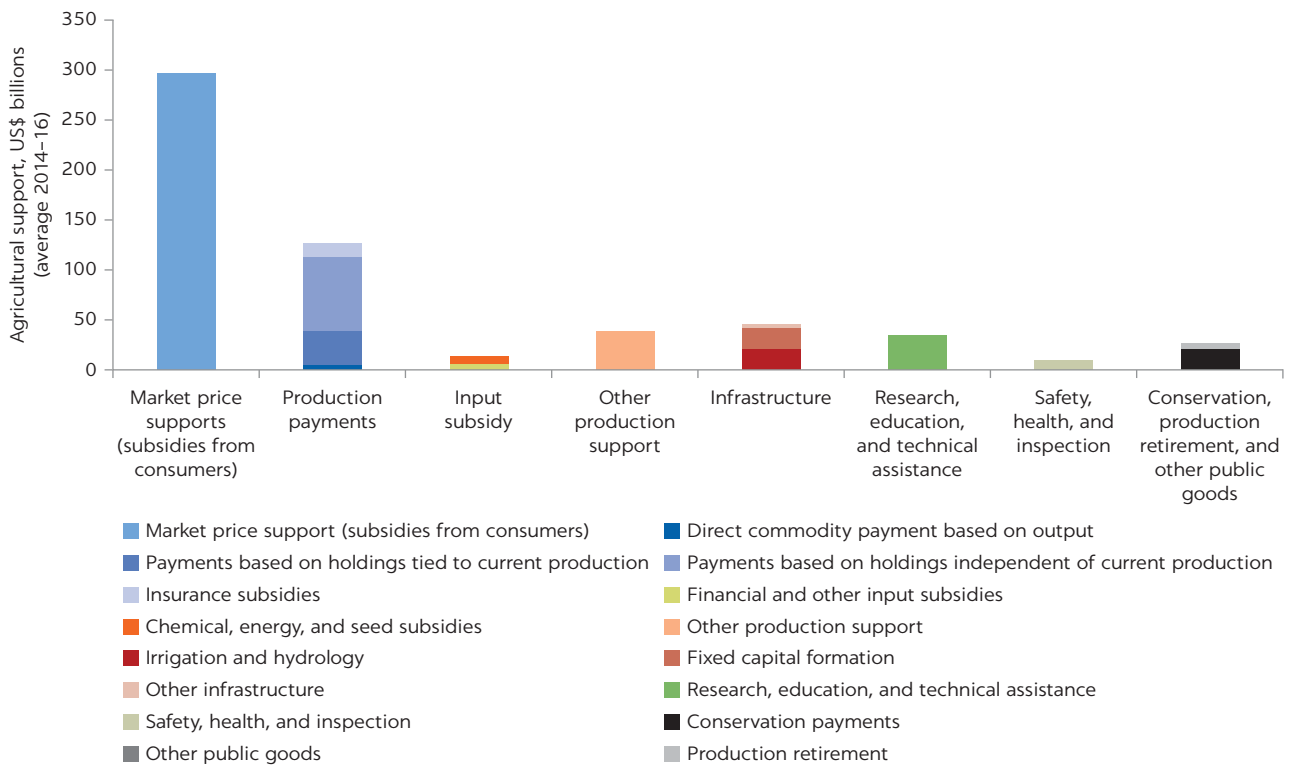
New Zealand, it was only 10 percent and 4 percent respectively. Figures 3.1 and 3.2 show the division of support between categories and the absolute level of support in each category for all countries analyzed. The following section provides a description of the various agricultural support mechanism broken down into two categories: market price supports and direct payments.

**FIGURE 3.1**  
**Fraction of agricultural support, by category, for all countries analyzed**



Source: OECD PSE and GSSE.

**FIGURE 3.2**  
**Level of agricultural support, by category/subcategory, for all countries analyzed**



Source: OECD PSE and GSSE databases.

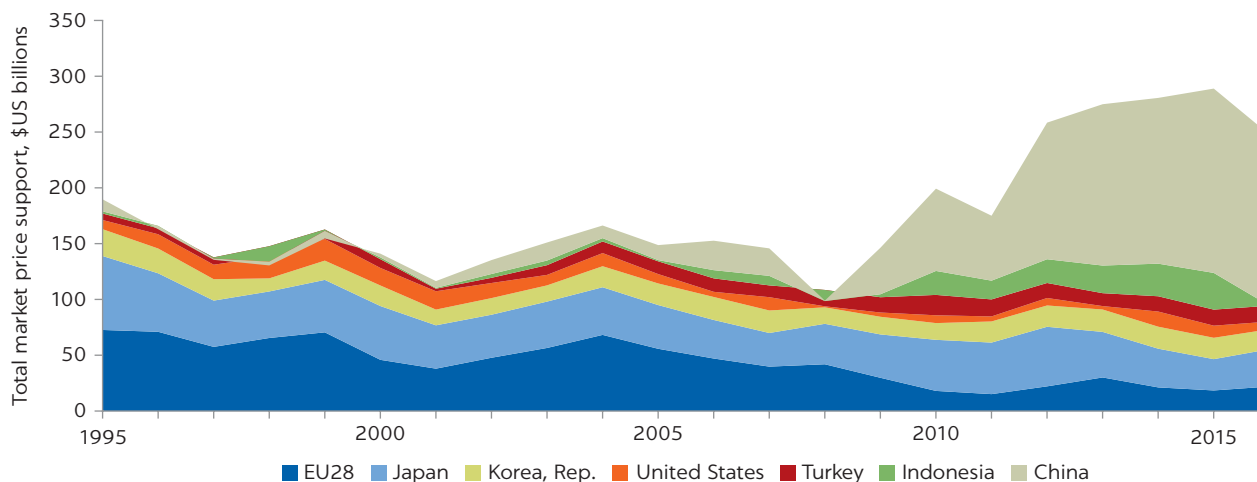


## Market price support

Of the total US\$600 billion in farm support per year between 2014 and 2016, half (~ US\$300 billion) occurred in the form of market barriers that raise prices received by producers at a cost to consumers. These market barriers mostly occur through tariffs and other trade barriers, but they can also occur through efforts by governments to fix or raise prices above international levels. Market barriers do not necessarily require government spending and the support they provide to agriculture is not based on the amount of that spending. Instead, the OECD calculates this support based on the difference between domestic prices received by farmers and average international prices.

In most countries, market price support has fallen over recent decades with China being a notable exception (figure 3.3). Frequently, governments employ a combination of tariffs and domestic price guarantees. For example, the U.S. sugar program simultaneously (1) creates a guaranteed market price that is typically higher than international prices, (2) restricts sugar production in the United States both in total and through allotments to individual producers, and (3) imposes limits on imports and tariffs to limit competition.<sup>3</sup> Only some direct government funding is involved. Although the sugar program is designed to limit supply to maintain the guaranteed market price, it occasionally fails. When prices fall below the guaranteed price, the government covers the cost. Some programs to limit supply of the crops, milk, or meat at guaranteed, above-market prices may also require government expenditures to purchase surplus crops at the guaranteed price. Although market price supports vary greatly by commodity and by country, these policies in 2013–16 kept domestic prices 13 percent above international price on average (OECD 2017). The precise levels and percentages of these market price supports can vary significantly from year to year as global prices fluctuate and the price supports are based on the difference between domestic and global prices. The justifications for these programs are either to encourage domestic production in order to benefit local farmers, to reduce price risk and uncertainty for farmers, or to increase domestic food security by boosting domestic production.

**FIGURE 3.3**  
Changes in market price support since 1995 for selected countries



Source: OECD PSE database.

According to OECD calculations China now has the strongest market price support program, contributing to roughly half of all global market price support. Most of this support occurs through market-price guarantees through government purchases and import tariffs (Gale 2013). As a result, China's overall prices are around 13 percent higher than international prices. Japan and Indonesia have the highest price supports as percentages of their agricultural sectors. Japanese agricultural prices are 75 percent higher than international levels overall and Indonesian prices are 98 percent above international levels. Together, China, Japan, and Indonesia provide two thirds of the world's market price supports. These countries have justified these programs on the grounds of food security.

The EU formerly had a variety of market price support measures. However, in 1992, the EU revised its Common Agricultural Policy (CAP) away from market interventions and toward direct income support. Further reform has continued to move in this direction. Europe's domestic agricultural prices in 1986–88 were on average 69 percent above global prices. From 2014 to 2016, domestic agricultural prices in Europe were only 5 percent higher (OECD 2017). In the United States, current market price supports total approximately US\$7 billion, or around a 3 percent top-up on global prices, down from 12 percent in 1986–88 (OECD 2017). Remaining US price supports now focus heavily on sugar.

### Direct government spending

The other half of government support for agriculture from 2014 to 2016—US\$300 billion—came in the form of direct government spending or targeted tax benefits.<sup>4</sup> Figure 3.4 and table 3.1 show how these funds were spent. A total of \$181 billion could be categorized as income support. Of these, US\$128 billion came in the form of payments for production. Another US\$14 billion were roughly evenly divided between physical input subsidies such as those for fertilizer and direct financial subsidies. A further US\$39 billion came in some form of market support. These market support investments included marketing and promotion payments as well as the costs of holding public stocks, which occurs primarily in China.

Governments provided another US\$46 billion for various agricultural infrastructure projects. Half of this funding supported irrigation. The OECD has categorized the remaining half of agricultural infrastructure investment as “fixed capital formation,” which includes subsidies for individual farm infrastructure projects such as barns, terracing, or tractor procurement.

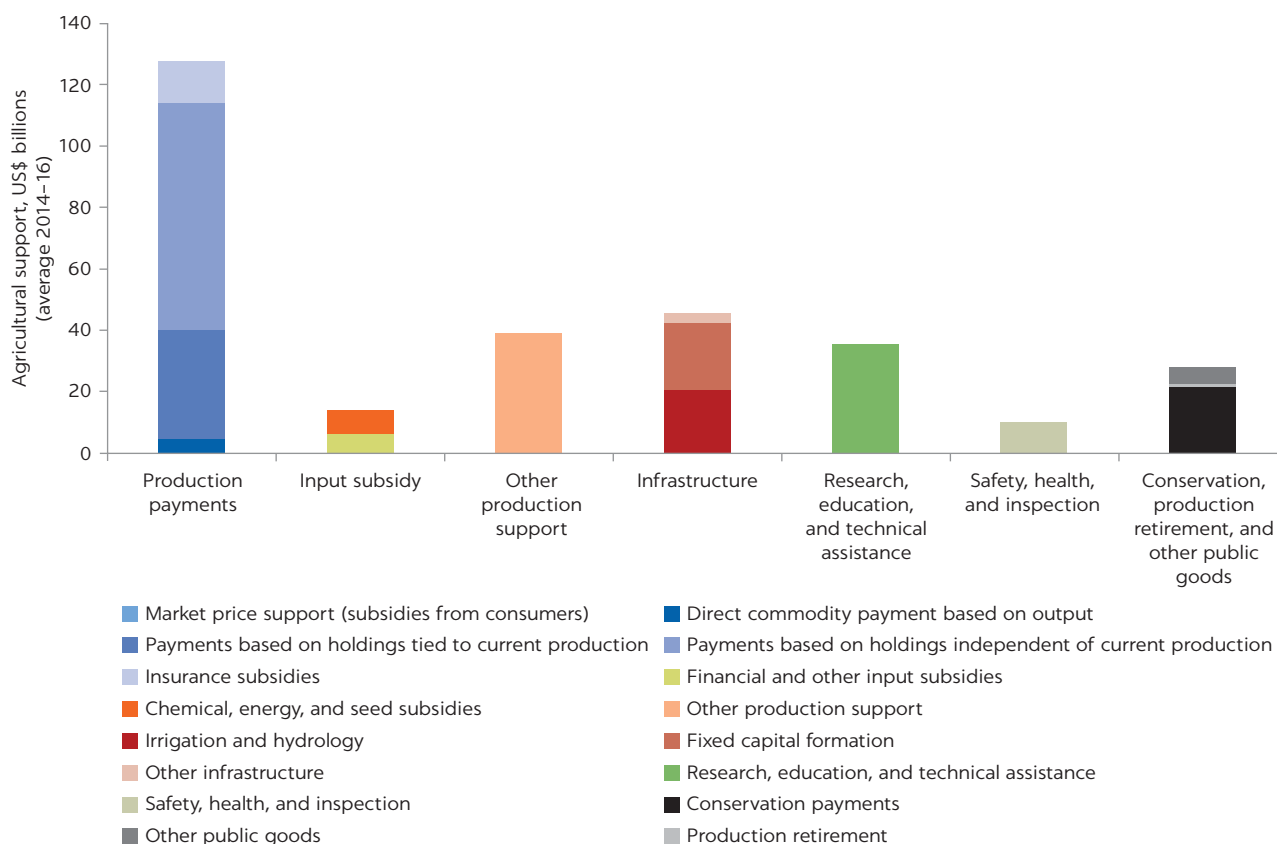
Governments provided US\$35.5 billion for all government-funded agricultural research and technical assistance to farmers and US\$10.5 billion for safety, health, and inspections.

Finally, governments provided US\$28 billion directed at some kind of “conservation” objective, some of which arguably could be placed in one of the other categories.

Figure 3.5 shows the total value of non-market price support by country. For direct outlays, China and the EU together provide almost two thirds at roughly US\$100 billion each, although those shares of their agriculture value added are quite different at around 10 percent for China and 39 percent for the EU. To some extent, this difference reflects the difference in the use of market price supports versus direct outlays. The U.S. level of non-market price support at US\$37 billion is 24 percent of agricultural value added.

FIGURE 3.4

## Distribution of government support to agriculture (excluding market price support)

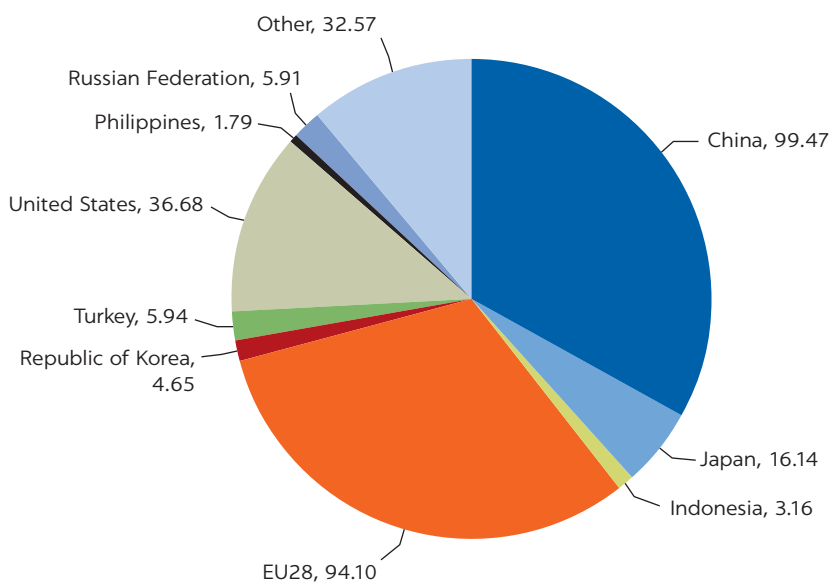


Source: OECD PSE and GSSE databases.

TABLE 3.1 Categories of spending of direct government agricultural outlays

CATEGORY	SUBCATEGORY	AVERAGE SUPPORT 2014-16, BILLION US\$
Market price supports (subsidies from consumers)		297,446
Total direct outlays		300,430
	<i>Total production payments</i>	<i>127,917</i>
Production payments	Direct commodity payments based on output	4,996
	Payments based on holdings tied to current production	35,156
	Payments based on holdings independent of current production	73,846
	Insurance subsidies	13,919
Input subsidy	Chemical, energy, and seed subsidies	7,431
	Financial and other input subsidies	6,580
Other production support (e.g., promotion/marketing, public stockholding)		39,071
Infrastructure	Irrigation and hydrology	21,059
	Fixed capital formation	21,309
	Other infrastructure	3,333
Research, education, and technical assistance		35,477
Safety, health, and inspection		10,454
Conservation, production retirement, and other public goods	Conservation payments	21,639
	Production retirement	5,659
	Other public goods	501

Source: OECD PSE and GSSE databases.

**FIGURE 3.5****Non-MPS agricultural support, by country, 2014–16  
(average, \$US billions)**

Source: OECD PSE and GSSE.

Note: MPS = market price support.

## ASSESSING THE CONTRIBUTION OF PUBLIC AGRICULTURAL SUPPORT TO PRODUCTIVITY GAINS AND CLIMATE CHANGE MITIGATION

To what extent do these funds contribute toward climate change mitigation? The OECD data cannot fully capture the diversity of different agricultural programs, but we use possible criteria to evaluate this question from different perspectives, using a generous approach to identifying what forms of support might help to boost productivity or mitigate climate change, including measures that could boost yields and therefore contribute toward avoiding land use change.

### Question 1: To what extent does the support mechanism directly target environmental goals?

Perhaps the simplest way to evaluate a support mechanism's potential contribution toward Greenhouse Gas (GHG) mitigation is to examine the degree to which it explicitly targets concrete environmental goals. Using this broad categorization, this study identified US\$28 billion in support that is categorized as either production retirement (\$6 billion), which includes taking either agricultural land or animals out of production, or conservation (\$22 billion).

Land retirement can sometimes be permanent. For example, the Wetland Reserve Program in the United States pays farmers to restore wetlands with a permanent easement. This program leaves the land in private ownership but requires permanent preservation. Land retirement can also be temporary. Much of the world's total expenditure on land retirement comes from the U.S. Conservation Reserve Program, which pays farmers to reestablish grasses and woodlands through 10- to 15-year contracts. The world's other largest land retirement programs in China also support temporary retirement.

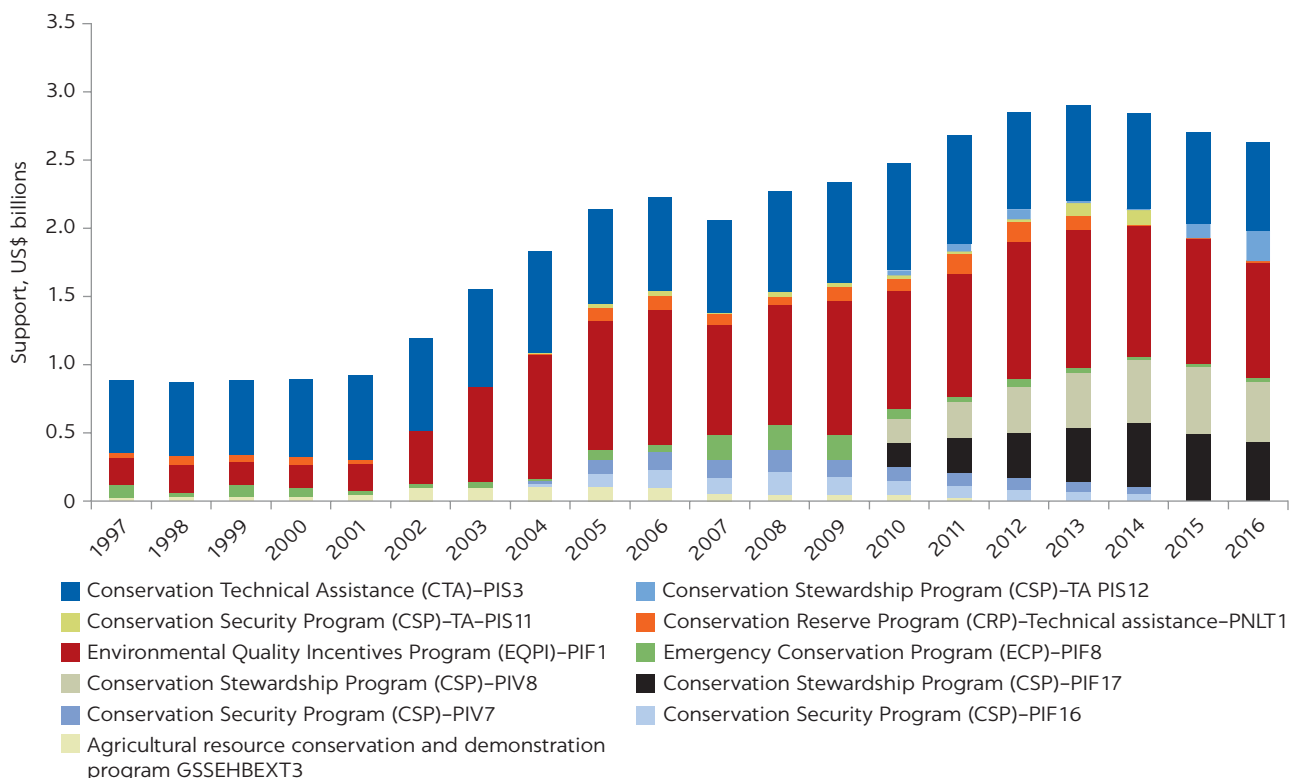
One aim of many land retirement programs is to reduce crop surpluses to boost prices. For example, the United States has a long history of land retirement programs that have grown and shrunk in response to market pressures. The two major U.S. programs today came into being with the 1985 U.S. Farm Bill, which was passed to ease a farming crisis due to low prices. The waxing and waning evolution of conservation support mechanisms over the last 20 years is illustrated in figure 3.6.

Re-establishing grasslands or forests through land retirement also leads to carbon sequestration. In the United States, this benefit has sometimes been calculated and held up as a program achievement (e.g., Karlen et al. 1999). The estimated effects of China’s retirement program are discussed in the case study section. Taking animals out of production also decreases emissions from animal production. Whether land retirements result in more carbon storage (or reduced carbon emissions) on a global scale is challenging to measure. Much of the food not produced in one location is likely to be produced in another. Net gains from retirement depend on how productive the land would have been and how it has been restored.

As a general rule, land retirements are likely to focus on less productive agricultural land. Governments often retire lands that the domestic agricultural industry has already downsized due to low market demand. These land retirements can play a role in speeding impending market transitions. If these programs encourage planting of native vegetation, land retirement has the potential to improve the speed and quality of regeneration.

Figure 3.7 illustrates the growth of the world’s larger conservation programs from 1997 to 2016. To understand this figure, a definition of the term

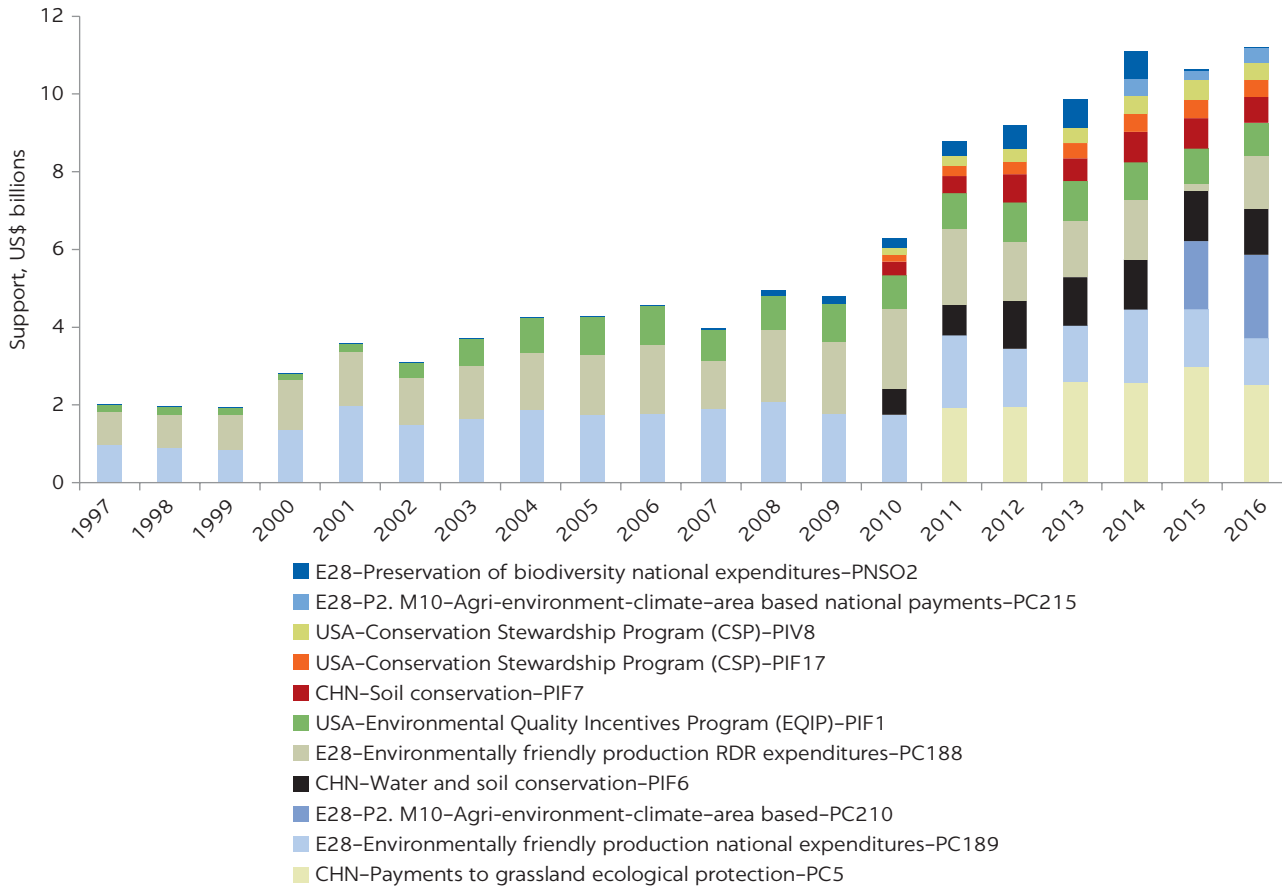
**FIGURE 3.6**  
**Support to the largest U.S. agricultural support schemes identified as conservation related, 1997–2016**



Source: OECD PSE and GSSE databases.

FIGURE 3.7

## Evolution of the world's largest conservation-related agricultural support programs, 1997–2016



Source: OECD PSE and GSSE databases.

“conservation” is needed. Among ecologists, conservation refers to an effort to preserve natural landscapes and wildlife or to the preservation of public resources. In agriculture, conservation often refers to efforts to preserve the long-term sustainability of production. Sometimes, efforts can contribute to conservation in both the ecological and agricultural senses. Efforts to control soil erosion both preserve agricultural productivity and reduce sediment pollution in streams, lakes, and rivers. At other times, there can be tensions between the two conservation goals. For example, in the past, the agricultural conservation agencies in the United States were heavily involved in the drainage of wetlands. Further, land leveling, which can increase irrigation efficiency, can eliminate pockets of wetland wildlife habitat.

In addition, not all conservation practices reduce agricultural GHG emissions or are designed to maximize GHG benefits. For example, US conservation programs have paid for improved manure storage for large, concentrated livestock to avoid uncontrolled manure losses to water quality and to reduce disease-bearing organisms. Despite these benefits, without design elements to capture the methane, such open storage pits can increase GHG emissions.

While not overwhelming, some portion of agricultural research and development funds also have strong conservation and climate mitigation contributions. Overall, however, funds dedicated for conservation are around 5 percent of agricultural support costs.

## **Question 2: To what extent does funding support general services versus directly subsidizing farmers?**

The OECD has long made a strong distinction between agricultural support in the form of “general services” and support for “individual agricultural producers.” It reasons that only the latter have strong benefits:

Investments in people (education and skills training) and in physical infrastructure (including digital technologies), in a well-functioning innovation, knowledge and information system, and in biosecurity inspections and controls adapted to the sector’s needs, contribute to an enabling environment that allows agricultural and food production to be responsive, sustainable and resilient to external shocks. (OECD 2017)

There is good evidence that spending on general services can often increase agricultural productivity. For example, spending on agricultural research, particularly when combined with good extension services, has a strong response in productivity (Alston et al. 2000). Various forms of infrastructure development including improved transportation routes and veterinary services may also contribute to productivity gains. These general services can also include more healthy livestock populations that are less likely to endanger herd health (Gulati and Narayanan 2003; Fan, Gulati, and Thorat 2007; Gale 2013).

By contrast, according to general economic thinking, providing agricultural support to individual farmers is justified only “when there are potential economies of scale, strong learning-by-doing effects, the potential for innovations with large transformative impacts,” or strong social equity returns (Gautam 2015). To avoid encouraging inefficient use of natural resources, income and price supports must also be carefully structured. Mere support for farm income or prices is unlikely to be a cost-effective way of increasing production efficiencies because most of the funds are likely to continue to support current, less productive forms of production.

This study does not primarily follow the distinction of general services from producer support because it is less useful as a means of segregating payments that mitigate climate change or boost productivity.<sup>5</sup> Yet it provides some utility by distinguishing support for the entire agricultural sector from support for costs that farmers should generally bear on their own. According to the OECD analysis, US\$91 billion of the US\$600 billion of total agricultural support is given to general agricultural services measured in this way. By this admittedly crude measure, only 15 percent of support is the most appropriate public spending.

## **Question 3: To what extent does the support mechanism distort markets?**

There is a long history of research arguing that market-distorting subsidies also harm the environment. One position argues that by increasing the economic return to agriculture domestically, subsidies encourage more agriculture and therefore increased use of land, fertilizer, water, and chemicals (Congressional Budget Office 2017; National Research Council 2010; OECD 2001, 2006). In the United States, subsidies have supported row crops, but not hay, which uses far fewer inputs. These subsidies may therefore have led to more use of row crops (Claassen et al. 2011; Congressional Budget Office 2017). A second position argues that those subsidies tied to specific crops may discourage farmers from employing more complex crop rotations. Because diversification can break weed

and insect cycles and often employs legumes, which fix nitrogen, non-rotational cropping patterns can require more pesticides and more fertilizer (Davis et al. 2012; (Nemecek et al. 2015). A third position argues that subsidies can cause increased production on lands that are more environmentally sensitive (Lubowski et al. 2006; National Research Council 2010).

Much of the research on agricultural subsidies has focused on their role in distorting markets and serving as explicit or *de facto* barriers to free trade. These distinctions are incorporated explicitly into the agricultural agreement of the World Trade Organization (WTO), which includes mutual commitments for countries to reduce their distortions and barriers to obtain the benefits of freer trade. The WTO agreement implicitly limits tariffs that boost domestic prices above international prices. The agreement specifies tariff levels for each country.

The WTO has limits designed to reduce market distortions due to domestic agriculture support measures that distort trade. It groups spending into three boxes. The Amber Box consists of subsidies with a “more than minimal” trade-distorting effect. Amber Box support includes any direct payments to farmers based on what they produce, how much they produce, or current prices. Using a prescribed formula, these different subsidies are converted into a total level of support and each country’s total level is capped.

Subsidies viewed as having only minimal effects on trade are exempt from these limits and are included in the Green Box. To be included in the Green Box, government payments must not be based on current production or market prices, not support higher domestic prices, and must meet additional criteria.<sup>6</sup> For example, the Green Box covers virtually all general services as categorized by OECD including research and extension, pest and disease control, inspection services, marketing and promotion services, and infrastructure. Green Box support even includes public stockholdings so long as they are limited to those necessary for food security. The Green Box also covers “payments under environmental programs” and includes program compliance costs. Finally, the Green Box covers payments for both permanent and temporary resource retirements.

Perhaps most significantly, the Green Box covers two kinds of direct payments to farmers that are designed to boost income. One is the broad category of payments to farmers that are decoupled from the type or volume of current production, from prices, and from inputs. The other category extends to forms of crop insurance and disaster assistance up to specified limits and includes coverage for declines in prices or the effects of weather.

Over time, countries have structured more of their support payments to fit the Green Box definition of decoupled payments (Banga 2014). In Europe, for example, coupled payments to farmers provided more than 98 percent of total support as late as 2004. By 2016, those coupled payments accounted for less than 60 percent. Even as the share of Green Box payments has grown, many researchers have claimed that many of these subsidies continue to have distorting effects.

In theory, fully decoupled payments should mean that farmers obtain the same payment regardless of what they farm or whether they farm at all. In reality, many Green Box payments have subtler requirements that encourage farmers receiving payments to keep farming despite poor harvests (Blandford and Josling 2007). Farming in bad years, whether due to low prices or poor weather,



is part of the economics of farming. Government financial support even in bad years increases average profitability.

New Zealand illustrates the potential gains resulting from the removal of agricultural market distortions. By 1983, New Zealand employed 30 different forms of assistance to farmers. These diverse support mechanisms had led to a support total equal to 123 percent of agricultural value added (Vitalis 2007). Prices and markets were highly distorted. In 1986, largely due to the financial burden, New Zealand slashed agricultural support by abolishing minimum prices, tax concessions, land development loans, and other free government services. Value added support was cut to a few percentage points by 1989. The transitional resulted in hardship for New Zealand farmers, but only 1 percent of farmers left the sector.

In the long run, these changes led New Zealand agriculture to thrive and become dramatically more efficient. By 2007, while the sheep herd had declined by 43 percent, carcass weights had increased by 25 percent and improvements in quality had led to growth in export revenue. This decline in sheep production occurred largely on steeply sloped areas of low productivity and freed up land for reforestation. Meanwhile, the dairy industry grew dramatically. The herd count more than doubled and was accompanied by a 75 percent increase in the volume of dairy production. A venison industry emerged and wine growing expanded. Farmland values declined initially but had recovered by 2007 in real terms. Forest area grew by almost 2 million hectares and fertilizer use declined. Although the rise of the dairy herd increased domestic water problems and emissions, on the global scale New Zealand still has low emissions per kg of milk (Herrero and Thornton 2013). New Zealand provides an excellent example of the potential gains from a severe reduction of market-distorting supports.

Despite this substantial body of work, market distortion analyses tend to focus on domestic, not global, effects. Increased production and the consequential environmental effects in one country generally lead to less production and fewer environmental effects in other countries. The land use and GHG consequences of crop and livestock production tend to vary greatly from one country to another and by crop (Carlson et al. 2016; Herrero and Thornton 2013; West et al. 2010). As a result, the global GHG effects of market-distorting subsidies in any one country probably depend on which country and food items are supported.

Although some models estimate GHG benefits from freer trade, other models project higher emissions primarily due to land use change, for example if shifting of agriculture into Latin America leads to a greater clearance of forest (Havlik et al. 2014; Schmitz et al. 2012; Verburg et al. 2009). Other papers have found that a shift toward Green Box payments, which also includes general support services, can lead to productivity gains and these gains have resulted in reduced emissions (Banga 2014, 2016).

Overall, the GHG effects of the switch toward more decoupled payments depend on the details of the program. Decoupled payments create the potential for efficiency gains that reduce emissions, but also create the potential for harm if not combined with measures to prevent clearing of forests due to land use shifts from one region to another. The switch toward less distorting payments contributes toward greater global equity. Alone, however, these changes cannot be counted as making major contributions to climate change mitigation in agriculture.

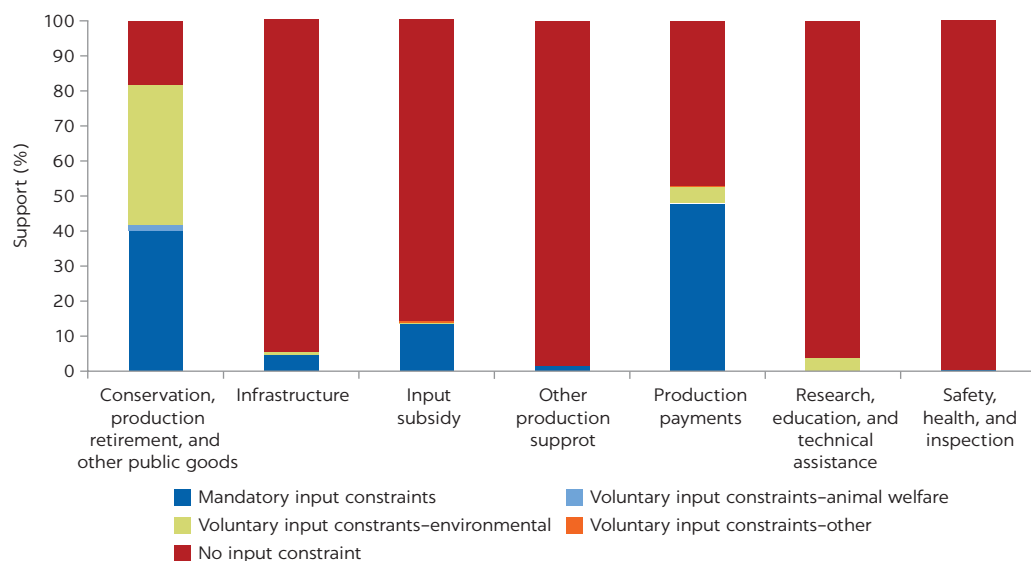
### Question 4: To what extent does the mechanism include environmental conditionality for payment?

Another mechanism to promote climate change mitigation conditions agricultural payments on farmer compliance with specific environmental activities. Countries are increasingly imposing conditions linked to environmental considerations for direct government spending. The OECD database divides such conditionality between those that are mandatory and those that are voluntary. Mandatory input constraints implement conditionality based on an existing legal requirement. Voluntary input constraints implement conditionality on activities that farmers undertake voluntarily in order to receive a payment. The OECD database does not record the nature of mandatory constraints, but divides the voluntary constraints into environmental, animal welfare, and others. Figure 3.8 illustrates that roughly 40 percent of global production constraints are subject to either environmental, social, or welfare conditionality, but the majority of conditions relate only to compliance with existing laws.

Some conditions attempt to limit some kinds of land expansion. In the United States, farmers must not drain or have drained wetlands since 1985 to be eligible for most farm payments. Farming on wetlands drained before 1985 is allowed. As wetlands tend to be carbon rich and release much of their long-stored soil carbon when drained, this condition directly addresses climate change mitigation (Stubbs 2012).

Since 1993, European farmers have been prohibited from expanding cropping into certain biologically diverse lands such as high value grasslands. Over the last 15 years, the Brazilian government has tied eligibility for government-sponsored, low-interest agricultural loans to compliance with the Forest Code, which restricts the amount of forest land that farmers can clear. Other restrictions condition subsidies on the use of certain farming methods. Both the United States and Europe have had versions of these conditions for many years.

**FIGURE 3.8**  
**Percentage of agricultural support payments in countries that are made with some environmental, social, or welfare requirement**



Source: OECD PSE and GSSE databases.

The three major questions for conditions are: (1) how significant they are from an environmental perspective; (2) to what extent are they enforced; and (3) to what form of support are they tied? Across the surveyed countries, conditionality often requires a minimum level of efficient farm management as well as protection for specific land areas from clearing. In the United States, the restrictions on additional land clearing have extended only to wetlands and efforts to do the same for native grasslands have stalled.

The extent to which these conditions have been enforced is hard to assess. In the United States, the Department of Agriculture (USDA) made a major effort to work with farmers to develop soil erosion plans immediately after the 1985 Farm Bill. A wide variety of legal provisions make it difficult to actually penalize farmers for non-compliance, which has led to minimal penalties.<sup>7</sup> A recent USDA study concluded that most of the large reductions in soil erosion after 1985 were due to broader changes in farming practices such as the spread of reduced tillage. However, the study also estimated that these soil erosion rules probably contributed significantly to water erosion reductions on highly erodible land (USDA ERS 2017). For wetlands, there have been great debates about which lands qualify for protection.<sup>8</sup> A 2004 study concluded that wetland protection had had a significant effect based on a finding that farmers had not converted millions of hectares of wetlands that would have been profitable to convert (Claassen et al. 2004). Most observers, however, believe that enforcement since 2004 has been weak. A final question is which support payments are tied to these conditions. In Europe and the United States, conditions apply to virtually all farmer payments. In Brazil, conditions are associated with easier agricultural credit. These agricultural credits can contribute toward gains in cropland yield or pasture areas that are a necessary part of climate-smart agriculture.

### **Question 5: To what extent do support mechanisms boost production by helping farmers manage risk?**

Maintaining and boosting yields is an important component of mitigating climate change, so one criterion for evaluating support programs is whether and how they help farmers to do by reducing risk. At some level, there is little doubt that support payments can indeed reduce risk. Guaranteeing higher crop prices or reimbursing farmers in bad years reduces farmer risks.

For poor farmers in developing countries, there is strong evidence that risk significantly hinders the adoption of both income-improving production strategies and alternative crops. Income support for risk management can help smallholder farmers to avoid poverty traps. Poor weather, price volatility, and even sickness can require the sell-off of productive assets, which undermines the ability to produce even in good years.

By contrast, there is no particular evidence that larger farmers, particularly those in developed countries, are unable to pursue market-based opportunities as a whole. They are the primary recipients of the support analyzed by the OECD. There are also several limitations in using market price supports or any of the various forms of traditional farm payments to reduce risk. First, to the extent these benefits to some farmers result from market price supports, they come not only at the expense of consumers but at the expense of farmers in other countries who have lower prices because of reduced access to these markets.

Second, although direct payments might in theory be restricted to small, poorer farmers who are most likely to boost production as a result, in practice they tend to go to wealthier farmers within countries. Because market price supports boost the price for a food item, the more a farm produces, the more it benefits. For example, in the United States, the top 10 percent of all farmers received 77 percent of all agricultural subsidies from 1995 to 2016, with much of the payments going to owners who no longer live on their farms. For crop insurance, which now provide most of the U.S. farm payments, 50 percent of subsidies flow to the top 10 percent, largest-selling farms, with an average net worth greater than US\$6 million (Bekkerman, Belasco, and Smith 2018). In Europe, 80 percent of direct payments go to 20 percent of farmers (Matthews 2017). These are farmers who are less likely to face poverty traps or to be unable to pursue more specialized agricultural opportunities because of risk.

Third, farm subsidies are expensive and tend to be concentrated in developed countries such as the EU and US and in large emerging developing countries such as China and India. Most of the world's poorest farmers tend to reside in Africa and Latin America, which cannot compete with wealthier countries.

Fourth, support payments have some limitations for benefiting working farmers because at least some of their value tends to be capitalized into higher land values (Latruffe and Mouël 2009). The result of capitalization is a one-time gain for landowners, some of whom may be poor but many of whom will be relatively wealthy.<sup>2</sup> This capitalization also means that some of the benefit does not accrue to farm laborers, to those who subsequently acquire farms (and pay higher prices), or to those farmers who lease their land (Kirwan 2009; Klaiber, Salhofer, and Thompson 2017; Roe, Somwaru, and Diao 2003). Finally, farm support often mutes market signals and distorts the types and forms of agricultural production. As the climate changes, the most efficient solution is often for farmers to shift their production practices not just to continue current practices because they are compensated by the government. Crop insurance can pose particular risks for sending the wrong market signal.

## NOTES

1. We exclude transfers to consumers from taxpayers (TCT) because they do not necessarily benefit a country's own domestic agricultural industry, particularly if the country has relatively open markets and its domestic prices track global prices. That applies to the overwhelming majority of TCT counted by the OECD, which occurs in the United States, and whose programs mainly protect only dairy and sugar. In addition, other countries support food consumption by the poor as well, but do so through more general assistance programs rather than assistance tied to food consumption, as in the United States. Although the OECD does not count that assistance as TCT, the distinction in significant part just reflects the different forms of social support in the United States and other countries (India also has a very large food assistance program, but is not counted yet by the OECD).
2. Agricultural production can be economically measured by gross receipts, which is the total payments to farmers at the farmgate level, or by value added, which subtracts input expenses and taxes from gross receipts.
3. <https://www.ers.usda.gov/topics/crops/sugar-sweeteners/policy.aspx>
4. The OECD counts tax benefits only for tax credits or deductions that are highly specific and therefore probably leaves out a variety of more general tax rules that offer unusual benefits to the agricultural sector.
5. For example, the infrastructure category does not separate public and private infrastructure. OECD includes some agricultural promotion services and public stockholdings among general services, which are identified separately as primarily oriented at

promoting production. OECD does not clearly segregate funding oriented toward conservation versus funding oriented toward boosting production or distinguish activities that promote production, which could be achieved by expanding agricultural area, from those that promote productivity and efficiency. The OECD distinction manages to separate out spending that advances the entire agricultural sector from spending on individual farms. Economists generally believe farmers should bear their own costs to make sure farming decisions are made efficiently.

6. The criteria are set forth in Appendix A of the agriculture agreement: [https://www.wto.org/english/docs\\_e/legal\\_e/14-ag\\_02\\_e.htm#annII](https://www.wto.org/english/docs_e/legal_e/14-ag_02_e.htm#annII). Green box categories include: Provision of general services that provide benefits to agriculture or the rural community such as research and extension, pest and disease control, inspection services, marketing and promotion services and infrastructural services (paragraph 2)
  1. Public stockholding programs for food security purposes (paragraph 3)
  2. Domestic food aid programs (paragraph 4)
  3. Decoupled support to producers (paragraph 6)
  4. Government financial participation in income insurance and income safety-net programs (paragraph 7)
  5. Payments (made either directly or by way of government financial participation in crop insurance schemes) for relief from natural disasters (paragraph 8)
  6. Structural adjustment assistance provided through producer retirement programs (paragraph 9)
  7. Structural adjustment assistance provided through resource retirement programs (paragraph 10)
  8. Structural adjustment assistance provided through investment aids (paragraph 11)
  9. Programs for environmental programs (paragraph 12)
  10. Payments to producers in disadvantaged regions under regional investment programs (paragraph 13)
7. This was a finding in 2003 by the U.S. General Accounting Office. Although we are aware of no subsequent studies, knowledgeable observers agree that even the initiation of enforcement actions is extremely rare.
8. There have been almost no independent assessments. The last significant assessment occurred in 2003, when the U.S. General Accounting Office found many limitations in enforcement. General Accounting Office, *Agriculture Conservation: USDA Needs to Better Ensure Protection of Highly Erodible Cropland and Wetlands*, GAO-03-418, April 2003.
9. Land ownership patterns vary from country to country, but there is often a large area of ownership by larger farms and often by non-farmers. In the United States, for example, more than half of cropland is rented, and half of agricultural land is held in mid or large farms (Bigelow, Borchers, and Hubbs 2016).



# 4 Country and Regional Case Studies

To further explore government support programs, we provide six national or regional case studies. The focus of each case study varies to reflect the different issues highlighted by the different types of agricultural support programs. The United States case identifies agriculture support that promotes conservation through partnership programs for land retirement, agricultural land expansion management, and improved production efficiency. China's case study illustrates the use of production efficiencies, the reclamation of natural ecosystems, and limited land expansion in promoting climate change mitigation. The third case study examines the EU's Common Agricultural Policy (CAP) and the extent of its contributions to environmental improvement through minimum conservation conditions, greening requirements for additional funding, and investments in effective agricultural practices through rural development funding. The fourth case study, Brazil, examines the country's recent efforts at forest protection. The fifth case study of India explores its fertilizer subsidies and efforts at reform to avoid nitrogen over-application. Unlike the other five case studies, the case study on Sub-Saharan Africa does not address a single agricultural support reform or climate change mitigation. Due to Africa's unique context and challenges, the case study focuses on current challenges to agricultural input support programs and the many issues facing the region in addressing the underlying problem of poor soil conditions.

## THE UNITED STATES

The United States case devotes only approximately 20 percent of its agricultural support to research and technical assistance or to conservation of some kind. This case study focuses in particular on the evolution of U.S. conservation spending, on the sources of U.S. greenhouse gas (GHG) emissions and how innovative partnerships of conservation spending with researchers, NGOs, academia, and other stakeholders provide a potential model for addressing climate change mitigation.

### Agricultural support spending overall

The United States provides approximately US\$45 billion in public support annually to agricultural producers, the vast majority of which is in the form of production payments, other production support, market price support, and input subsidies. Less than a quarter of funds support climate change mitigation, research, technical assistance, and conservation and retirement.

Figure 4.1 provides a graphic representation of the breakdown in average annual US agricultural support spending averaged from 2014 to 2016.

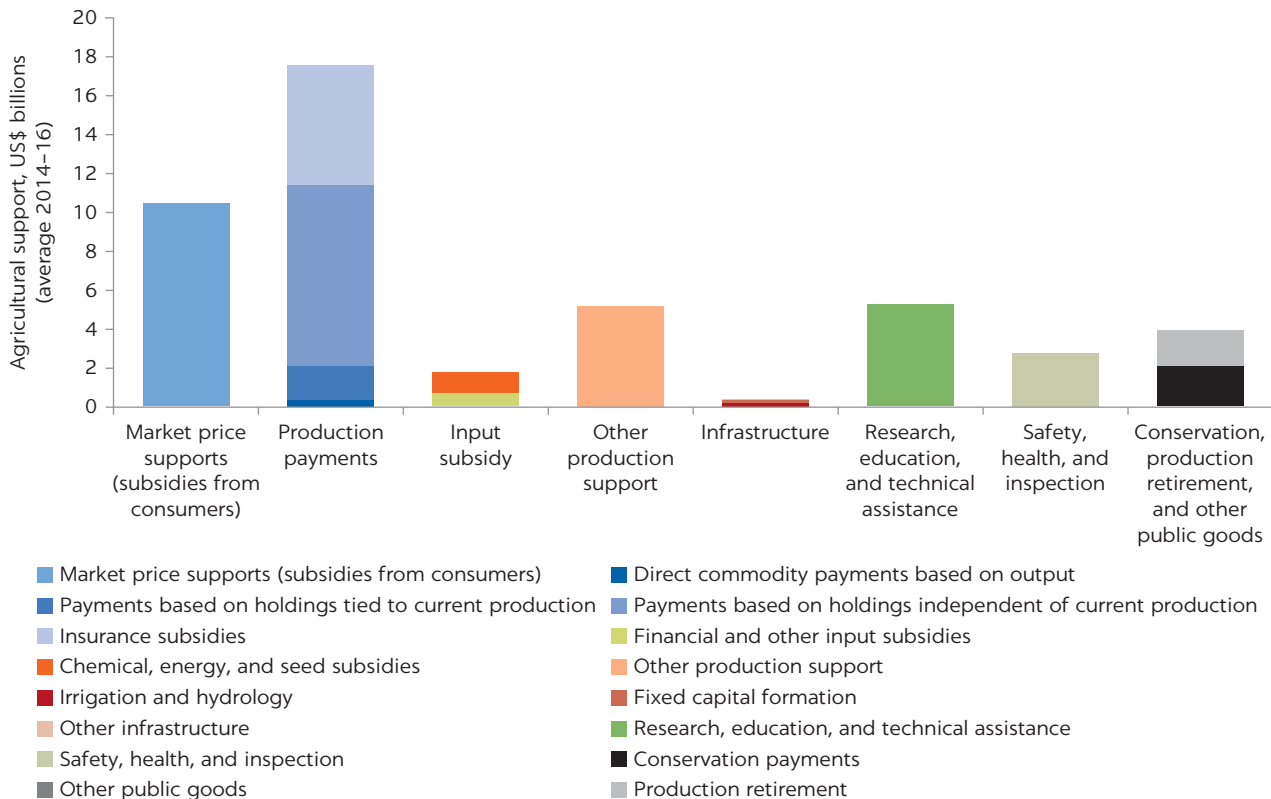
### Agricultural research and development

Public investment in agricultural research and development (R&D) is one means of potentially supporting climate change mitigation. This spending rose in real terms from US\$3.5 billion in 1970 to US\$6 billion 2002 as measured by 2013 price levels, yet this spending fell back to US\$4.4 billion in 2015<sup>1</sup> (figure 4.2). Private R&D investment rose at the same time. The extent to which the rise in private sector investment compensates for the recent fall-off in public investment is unclear and likely depends on the precise focus of research.

### Conservation spending

Although conservation spending, including land retirement, provides only 8 percent of total agricultural support, that funding grew by roughly US\$2 billion

**FIGURE 4.1**  
**Agricultural support in the United States, 2014–16**

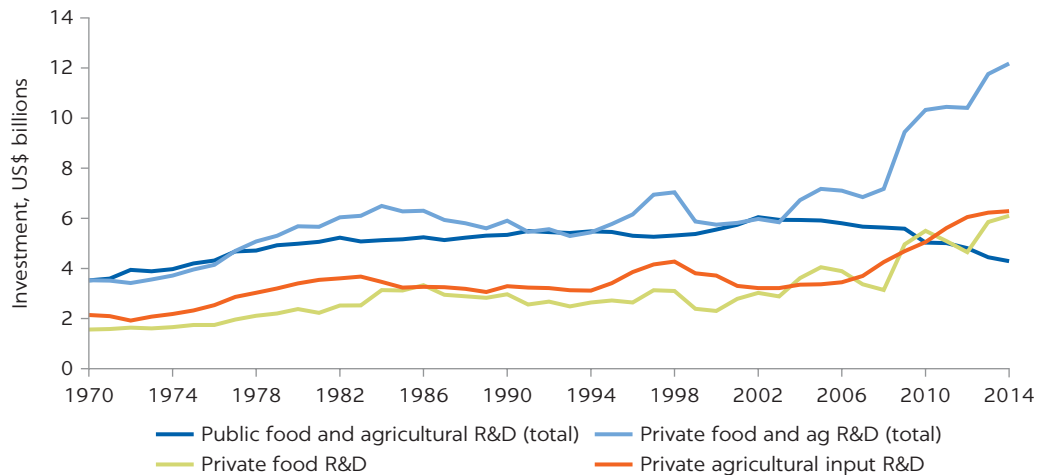


Source: OECD PSE and GSSE.



FIGURE 4.2

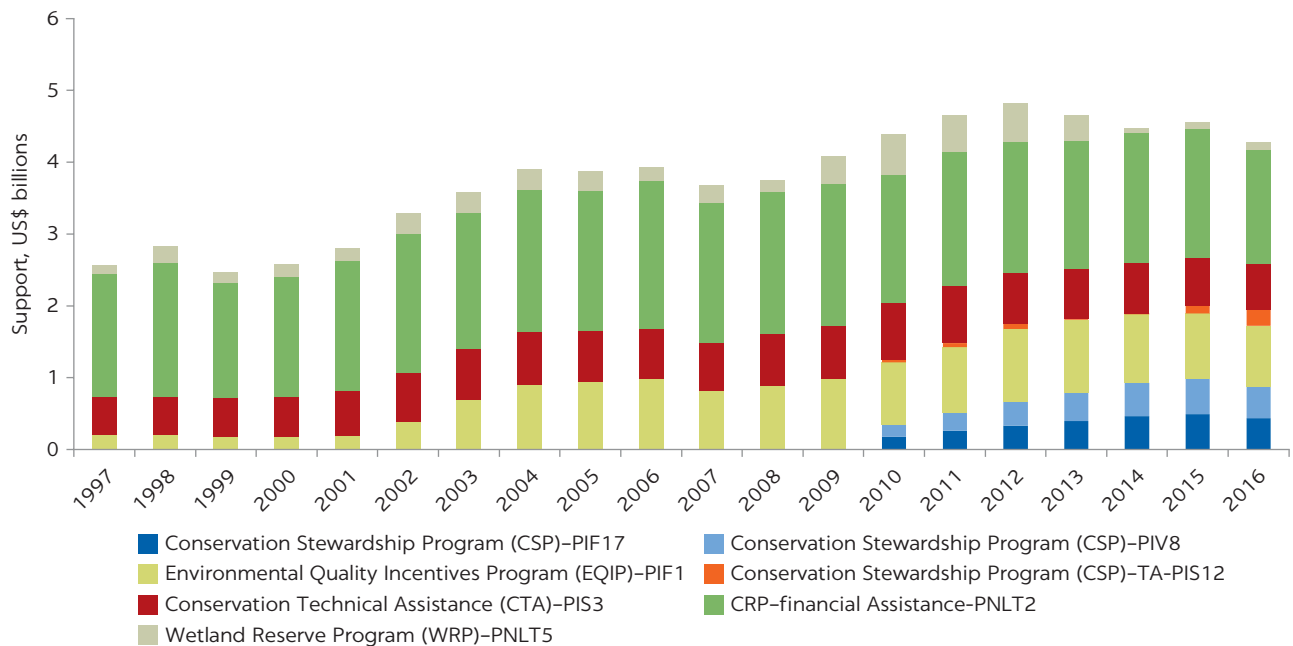
## U.S. public and private agricultural research investment, 1970–2014



Source: USDA ERS 2017.

FIGURE 4.3

## Funding for major U.S. conservation programs and related technical assistance, 1997–2016



Source: OECD PSE and GSSE databases.

over the 5-year period 2012–16 compared to 1997–2002, an 80 percent increase. Funding for conservation flows through multiple conservation programs (figure 4.3), but it grew particularly through three: the Conservation Reserve Program (CRP); the Environmental Quality Incentives Program (EQIP); and the Conservation Security Program (CSP).

The CRP originated in 1985 to boost prices at a time of large domestic farm surpluses. The CRP represented 55 percent of all conservation payments to

farmers over 1997–2016 or between US\$1.6 to US\$2.1 billion annually. It provides for temporary land retirement through 10-year contracts to take highly erodible and other environmentally sensitive lands out of production. To date, the CRP has retired about 10 percent of all U.S. cropland. However, the land area enrolled in the CRP declined by 9.4 million hectares from 32.8 million to 23.4 million despite relatively stable funding to farmers. As agricultural prices rose in the 2000s and as ethanol started to expand, farmer groups and politicians became less support of CRP.

The EQIP offers cost-share assistance or incentive payments to farmers. EQIP saw a progressive increase in its budgetary authority from approximately US\$200 million in 1992, to US\$1 billion in the early 2000s, then to US\$1.5 billion in 2016<sup>2</sup> (USDA 2018). A little more than half of EQIP funding supports farm conservation infrastructure such as fencing, irrigation efficiency improvements, wells, and manure management structures. Slightly less than half of the funding supports efficient management practices such as prescribed grazing or integrated pest management.<sup>3</sup> The related CSP saw a budget increase to US\$1.3 billion in 2016 (USDA 2018). CSP supports activities similar to EQIP, but also develops management plans for farms and provides funding to reward existing good management.

One critical question about these programs is the extent to which they support additional conservation or simply support conservation efforts that farmers would have undertaken without the payment. One report estimated that 80 percent of conservation cost-share payments for grassed waterways, terraces and other environmental infrastructure led to additional measures (Claassen et al. 2014). But this report also estimated that only half of financial support for changed tillage practices led to practices that farmers would not otherwise have employed anyway.

For CSP, this limited additionality is intentional. A little less than half of CSP funds reward farmers for good management practices they already undertake, while the remaining funding supports farmers that introduce new practices.<sup>4</sup> The justification for supporting existing good practices is partially that it is unfair only to help poorer-performing farmers improve their practices while leaving farmers employing good practices without payments. Another rationale is that rewarding good farmers provides incentives for other farmers to improve their management. Paying farmers for all their existing good practices, however, would be extremely expensive.

Another challenge is the sustainability of conservation efforts promoted under the programs because they are voluntary. This issue has become significant for the CRP, which has now existed long enough for contracts to expire. While CRP pays farmers for the cost of planting grasses or trees on land enrolled in the program, much of the land eventually exits the program and is re-plowed. Between 2007 and 2014, nearly 16 million acres, almost half of the enrolled area, exited the CRP. Some of these losses resulted from improved targeting of environmentally sensitive land as original enrollments has focused primarily on reducing crop surpluses. However, spatial analysis has shown that even large areas of riparian buffers, which are valuable for protecting water quality, have disappeared in recent years (Rundquist and Cox 2018).

### **Innovation through conservation partnerships**

A highly promising use of conservation funding integrates conservation payments into projects developed in partnership with states. Established in the

1990s, the Conservation Reserve Enhancement Program (CREP) allowed states to submit plans to target CRP support contracts for coordinated restoration efforts including those protecting buffer zones or wetlands. Farmers that enrolled lands received special incentives. States sometimes offered payments on top of CRP contracts to secure permanent conservation easements.

Today, 30 states have CREP-related programs and have restored 1.2 million acres<sup>5</sup> (USDA 2016). These programs have the potential to produce far greater environmental impact per hectare because the choices of land and the types of revegetation targeted under these programs use more precise science. The programs have the potential to achieve critical mass by enrolling multiple farms in a single geographic area. State plans also tend to combine conservation efforts with improved management practices and thereby achieve a higher level of overall conservation. When the USDA issued its plan for reducing GHG emissions in 2016, it highlighted a new program to boost cooperative efforts, the Regional Conservation Partnership Program (RCPP) (USDA 2016). RCPP allows almost any organization to apply for funds from the EQIP, CSP, and smaller easement programs to achieve a conservation objective.<sup>6</sup> Grants are awarded competitively. Award criteria include innovation, collaboration, and the contributions of partners through funding or in-kind support. In 2018, USDA provided US\$220 million in funding for 91 projects, of which many focus on enhancing agricultural habitat values, improving water quality, and advancing irrigation efficiency.

One project of particular potential to reduce emissions combines the efforts of 40 partners including agricultural groups, researchers, industry, and NGOs to increase nitrogen use efficiency in the Corn Belt of the United States through more precise soil and fertilizer needs analysis and application.<sup>7</sup> Despite these efforts, the USDA mitigation plan has only modest goals to reduce agricultural emissions. Its reduction targets are 6–8 percent of the total emissions from agriculture by 2025, and 5–7 percent if energy use in agriculture is counted.<sup>8</sup> Much of these reductions are to be realized through soil carbon sequestration offsets rather than actual emission reductions. The USDA report also proposes to reduce emissions from the decomposition of organic soils (essentially peatlands) but leaves both the amount and mechanism for doing so vague.

### **Opportunities for U.S. leadership on climate change mitigation**

How could agricultural support payments in the United States best support climate change mitigation? Agricultural emissions reported by the United States are shown in table 4.1. Although these emissions amount only to 6.5 percent of total U.S. emissions excluding energy use in farming, and 10 percent including that energy use,<sup>9</sup> total U.S. emissions are still high. Counting energy use in agriculture, emissions in 2010 of 700 million tons (CO<sub>2</sub>e) were roughly equal to the total emissions of Canada from all sources. Even so, the highly intensive agriculture of the United States, although it leads to other water quality and other environmental challenges, is also highly efficient from a GHG perspective per unit of food (Carlson et al. 2016; Herrero et al. 2013). For example, the United States, has been increasing the nitrogen use efficiency of its crops, particularly of maize, which now absorbs 70 percent of the nitrogen applied for its production (Zhang et al. 2015). Yet because total production has been growing, neither associated emissions nor nitrogen-level water quality problems have generally declined.

**TABLE 4.1 Estimated U.S. agricultural emissions, by category, 2010 and 2050 (million tons CO<sub>2</sub>e)**

GLOBAGRI-WRR			FAOSTAT	
CATEGORY	2010	2050	CATEGORY	2010
Enteric emissions	166	241	Enteric emissions	142
Manure management	89	114	Manure management	49
Rice	16	27	Rice	11
Pasture & paddock	36	53	Pasture & paddock	46
Nitrogen	159	234	Synthetic fertilizer	85
Other fertilizers	9	8	Manure applied to soils	18
On-farm energy	93	105	Crop residues	32
Pesticides	13	12	Burning—Crop residues	4
			Burning—Savanna	1
<b>Total</b>	<b>580</b>	<b>795</b>		<b>387</b>

Source: Globagri-WRR and FAOSTAT.

Achieving real reductions in the United States will require more than just standard good management practices. For nitrogen, that mainly means applying nitrogen at an agronomically recommended rate, but advanced technological approaches to enable crops to absorb even more of the available nitrogen. (See as one example the discussion of enhanced efficiency fertilizers in the India case study.) The United States also emits vast quantities of methane from enteric methane (ruminant digestion), and tends to store manure in concentrated, wet forms that lead to the highest emissions. Technologists are developing innovative approaches to reduce both forms of emissions (Hristov et al. 2015a). As a highly sophisticated agricultural producer, the United States could play a major role in advancing agricultural climate mitigation by using its funds to support these innovations.

The conservation partnership approach provides a small, but promising model for climate change mitigation. Explicit U.S. support for conservation today is now modest and focused heavily on land retirements of a temporary nature. Using the partnership model, the United States could combine funds for land retirement with broader efforts to promote the kinds of innovations needed to achieve improved mitigation outcomes on a broader scale.

## CHINA

China is the world's largest agricultural producer and has been able to feed more than 20 percent of the world's population on less than 10 percent of global arable land. Value added in Chinese agriculture grew from US\$57 billion in 1980 to US\$958 billion in 2016 as measured in current dollars. (World Bank 2018) When factoring in energy use in agriculture, China also has the highest level of agricultural emissions in the world. Significant input subsidies in the past have contributed high levels of nitrogen use whose emissions have even exceeded the levels of emissions from enteric digestion.

Although China's market price supports remain extremely high, China has also taken a number of actions toward environmental goals, some of which could

help to mitigate climate change. It has phased out its nitrogen subsidies in the last few years, increased support for reforestation and regenerating grasslands, and increased support for research toward farm practices that could help reduce emissions.

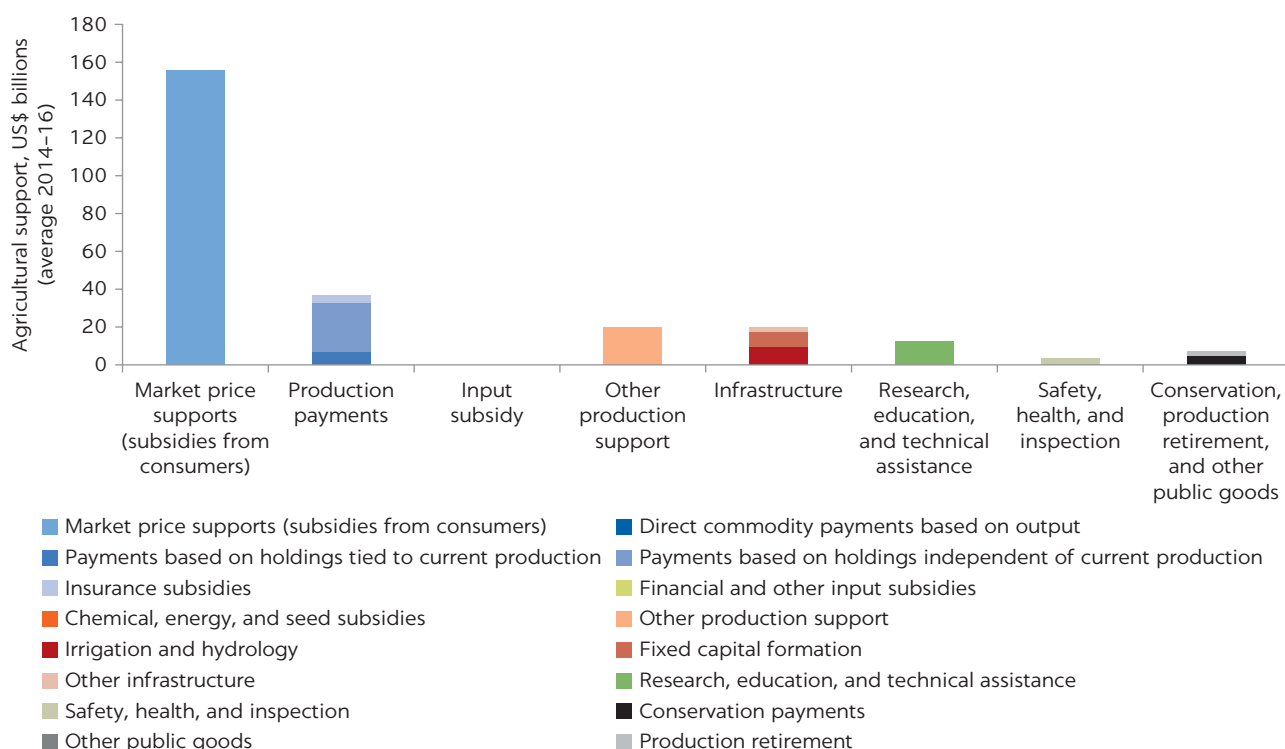
## Overview of agricultural support

Although China now provides strong financial support for agriculture, that was not always the case. Chinese policy actually imposed net taxes and fees on agriculture until they were abolished in 2004. (Luo et al. 2007; Tao and Qin 2007) Since then support for agriculture has expanded to US\$255 billion averaged from 2014 to 2016, the world's highest level of absolute support. However, Chinese support as a percentage of value added has been around 27 percent. That level is only slightly above support in the United States and still well below EU levels.

Most of the government agricultural investment occurs in the form of market price support (figure 4.4). These supports are calculated based on the prices paid to farmers compared to global market prices as a result of a combination of guaranteed government prices, government purchases, government storage and distribution, and tariffs. Commodities receiving price support include rice, wheat, and cotton. The OECD estimated that domestic prices were on average 13 percent higher than international prices.

While Chinese market price support remained comparatively low from 2001 to 2008 at less than US\$20 billion per year, price support increased rapidly after

**FIGURE 4.4**  
**Chinese agricultural support, 2014–16**



Source: OECD PSE and GSSE databases.

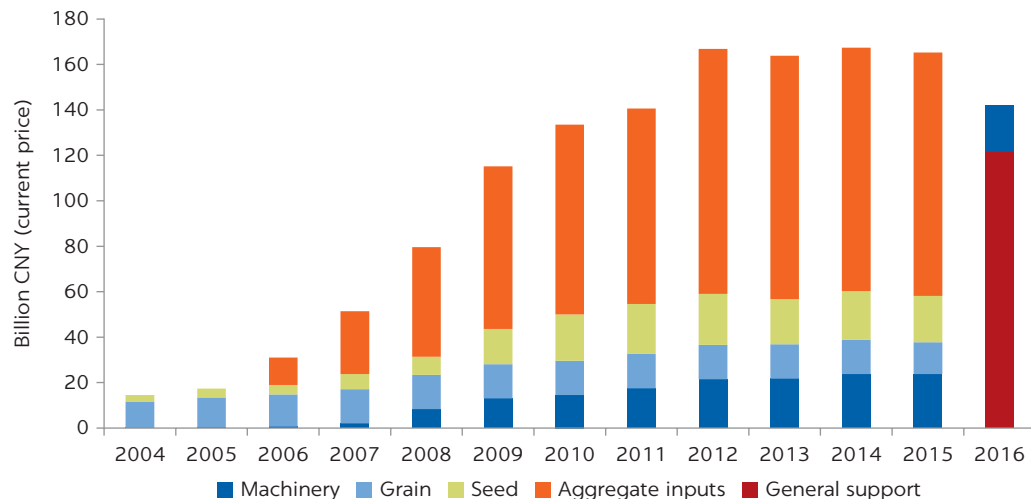
2009 as China expanded its exports of high value products such as fruits, vegetables, and fish. China has recently discontinued price support for cotton, soybeans, rapeseed, and maize. However, market price support is likely to remain high based on present policy overall.

China has also provided direct support to farming over the years. The OECD calculated this support at US\$100 billion per year averaged over 2014–16. This support included US\$37 billion in production payments to farmers and US\$40 billion in other production support and infrastructure. Research and technical assistance accounted for US\$12.5 billion while conservation and production retirement totaled US\$7 billion. In absolute terms, the total amount of direct assistance greatly exceeded that of the United States.

China offers a variety of direct payments to farmers but the amount per farm has been small and China has been moving away from forms of subsidies that distort production. Technically, China's direct farm payments came in the form of distinct support payments for seeds, grain, machinery, and aggregate inputs such as agricultural chemicals. Direct payments grew steadily from their introduction in 2004 to average more than US\$25 billion per year from 2012 through 2015 as measured in today's dollars. This total accounts for roughly 3 percent of agricultural gross domestic product (GDP). Despite the large absolute total, in practice China allocates these subsidies based on area of farmland rather than quantities of subsidies. Hence, individual subsidies average only roughly US\$130 per farm. These subsidies are decoupled from current production and therefore do not or only minimally distort markets (Huang et al. 2011; Huang, Wang, and Rozelle 2013).

In 2016, China made almost all of these payments a form of income support, leaving only machinery subsidies separate. It also shifted 20 percent of these funds to support formation of farm consolidation through rental farms, cooperative farms and other larger farms through credit programs and support services (figure 4.5). China has also been pushing to increase its crop insurance program, which increased to an annual average of US\$4 billion in our focus years.

**FIGURE 4.5**  
**Four major agricultural subsidies, 2004–15**



Source: Data are from various official documents.

## Environmental challenges and GHG emissions

China's agricultural growth has been accompanied by significant environmental challenges. The overapplication of nitrogen fertilizer has led to extensive contamination of drinking water, acidified soils, toxic algal blooms in coastal waters, and increased air pollution. (Norse and Zhu 2004; Gao et al. 2012; Guo et al. 2010) Poor manure management has exacerbated the environmental problems. (Strokal et al. 2016). Agricultural GHG emissions are high at more than 1.3 gigatons of CO<sub>2</sub>e when factoring in the emissions involved in the production of synthetic nitrogen<sup>10</sup> (table 4.2). These emissions are primarily due to nitrogen use, enteric fermentation, and rice and manure management.

## Relation of agricultural spending to climate change mitigation

### Research and development

One change in Chinese spending has been a steady growth in spending on agricultural R&D and technical assistance. (figure 4.6) The combined expenditures, as assessed by the OECD, reached US\$12.5 billion in 2014–16. Some of that funding is for technical assistance, and researchers have expressed doubts about the effectiveness of China's extension program. But most of that funding is for R&D. Using a somewhat separate measure, IFPRI estimated that public spending on R&D for true research has also grown sharply in recent years from US\$2.6 billion in 2001 to US\$9.4 billion 2013 (in 2011 purchase parity dollars).<sup>11</sup> There is little doubt that China's agricultural R&D has played a major role in contributing to China's large yield gains.

### Phasing out fertilizer subsidies

Of high environmental significance, from 1998 to 2016, China provided a variety of subsidies for the production of fertilizers (Huang, Gulati, and Gregory 2017b; Li et al. 2013). China offered fertilizer manufacturers preferential prices on

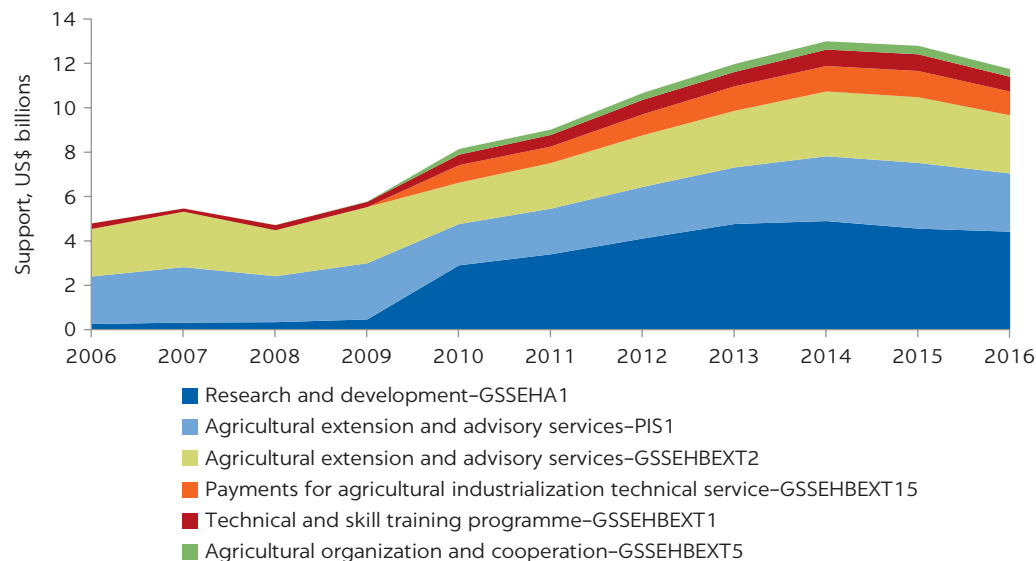
**TABLE 4.2** Estimated agricultural emissions in China, by category, 2010 and 2050 (million tons CO<sub>2</sub>e)

GLOBAGRI-WRR			FAOSTAT	
CATEGORY	2010	2050	CATEGORY	2010
Enteric emissions	230	313	Enteric emissions	160
Manure management	107	99	Manure management	67
Rice	252	186	Rice	111
Pasture & paddock	58	61	Pasture & paddock	69
Nitrogen <sup>a</sup>	403	397	Synthetic fertilizer <sup>a</sup>	359
Other fertilizers	23	13	Manure applied to soils	36
On-farm energy	229	192	Crop residues	33
Pesticides	89	52	Burning—Crop residues	5
			Burning—Savanna	0
<b>Total</b>	<b>1,391</b>	<b>1,313</b>		<b>840</b>

Source: Globagri-WRR and FAOSTAT.

a. Globagri-WRR nitrogen includes emissions from production and transportation of synthetic fertilizer plus soil nitrous oxide from all agricultural sources (synthetic fertilizer, manure, fixation) while FAOSTAT column incorporates estimates of all parts of synthetic fertilizer from Zhang et al. 2013 but no other nitrogen sources.

**FIGURE 4.6**  
**China's expenditure on agricultural R&D**



Source: OECD PSE and GSSE.

electricity, natural gas, and transportation. China subsidized loans for a fertilizer reserve and provided exemptions from the value-added sales tax for different forms of fertilizer production. Yet China also imposed a variety of limitations on imports. The net effect raised domestic fertilizer prices above international prices through to 2004. In 2004, however, China began to impose export limitations which varied by product and year. These export limitations decreased China's fertilizer prices, which declined to roughly 40 percent of US urea prices in 2008 and rose to almost half for 2008–10. The subsidy to the fertilizer industry averaged US\$7 billion per year from 2008 to 2010.

The fertilizer subsidies most likely contributed to a significant over application of nitrogen fertilizers. On average, nitrogen application for all crops ranged from 30 percent to 60 percent above agronomically sound levels and was estimated at approximately four-times the amount of nitrogen taken up by fruits and vegetation (Ju et al. 2009; Zhang et al. 2013). China's high use of fertilizer has contributed to extensive nitrate and phosphorous pollution in all major lakes, rivers, and in ground water located in agricultural areas.

Significantly, however, in 2015, China took steps to phase out the production subsidies for fertilizer, and they were eliminated by 2017 (Huang, Gulati, and Gregory 2017b).

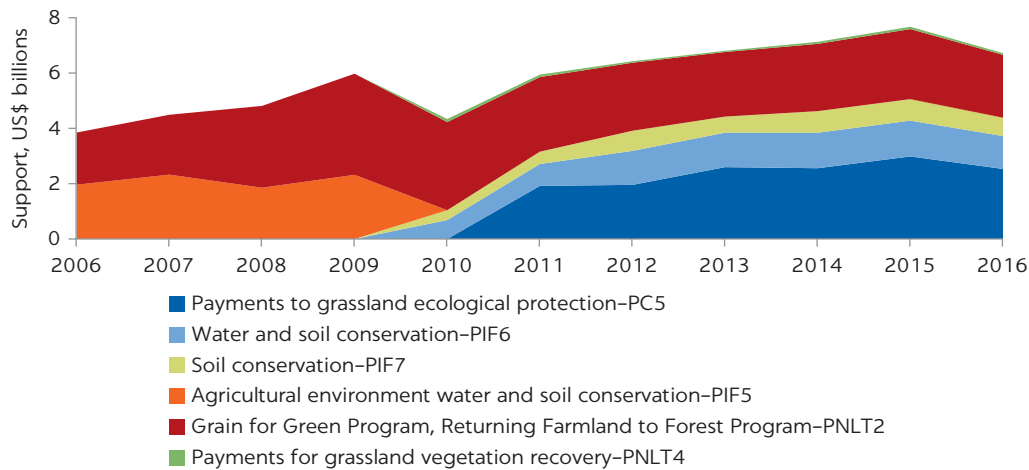
#### **Land retirement**

In the last 12 years, China has dedicated increasing funds to support programs toward agricultural conservation. These programs include the Grain for Green Program (GGP), a program to control land expansion on natural grasslands, and a program to improve production efficiency through water and soil improvements. Total annual conservation program expenditure has hovered around US\$7 billion in recent years (figure 4.7).

GGP, China's oldest conservation program, focuses on the conversion of steep-sloped and degraded cropland into forest to reclaim natural ecosystems. GGP has been implemented in provinces that occupy roughly 80 percent of



**FIGURE 4.7**  
**Chinese support for conservation, 2006–16**



Source: OECD PSE and GSSE databases.

China's total land area (Song et al. 2014). During the early phase of the program, compensation to farmers was provided in grain. From 2004, compensation was given in cash payments (Kwieciński and Bossard 2016). By 2013, the government had reportedly spent US\$47 billion for GGP (Hua et al. 2016).

Researchers have made various assessments of GGP over the years. A meta-analysis of different sites found a substantial increase in organic soil carbon as a result of GGP (Song et al. 2014). One study estimated that over the first 10 years, GGP sequestered carbon in vegetation equal to 1.4 percent of China's annual carbon dioxide emissions (Persson et al. 2013).<sup>12</sup> Studies have also questioned two aspects of the program. Overall, the program has established far more plantation forests as opposed to native forests. A study in one region found that these plantation forests had even less bird and bee wildlife and diversity than croplands (Hua et al. 2016). This study found that mixing different plantation varieties would generate substantially more biodiversity than planting a single variety although still far less than planting native forests. Another more recent study questioned the degree of success of reestablishing forests in arid areas. Government statistics claim China has reforested 117 million hectares of land between 1992 and 2013—of which roughly one quarter has been through the GGP. This study found that half of such lands had gained relatively dense forest cover (50 percent canopy cover), but in arid areas, forest restoration mostly achieved low-height, sparse and/or scattered plantations (Ahrends et al. 2017).

The grasslands program offered funding for suspending grazing of overgrazed areas for some years, rewards for not overstocking, and various input subsidies. Evaluations of the grasslands program have found successful expansion of grassland cover, and gains in soil carbon in some locations, but, surprisingly, not soil carbon gains overall (Ma Anna et al. 2017).

### **On-farm management**

Probably the major threat posed by climate change to Chinese agriculture is the exacerbation of water shortages (Ding, Ren, and Shi 2006; Wang, Huang, and Yan 2013). Currently about half of cultivated land is irrigated, and rising demand for irrigation water has resulted in overdraft of groundwater and therefore a falling groundwater table and land degradation in most of northern China (Ministry of

Water Resources 2016) as well as water pollution. China made a decision in 2011 to invest about US\$630 billion during 2012–20 for additional irrigation and on-farm water conservation. China has stated that it will establish a pricing mechanism that appropriately reflects the cost of water to encourage water saving within a decade.

To address the nitrogen pollution, including GHG emissions, resulting from the over application of nitrogen, China has recently expanded several largescale pilot programs to improve production efficiency through improved nitrogen use and the increased use of natural fertilizers. A pilot program to improve nitrogen efficiency in maize has been implemented in 14 counties of the Huang-Huai-Hai region and Northeast China. A pilot vegetable program for nitrogen was launched in the 20 counties where greenhouse vegetable production is the most concentrated. Authorities have piloted an apple program in 14 counties in the Loess Plateau and the Bohai Bay region. The number of counties covered in this pilot apple program increased from 48 in 2015, to 200 in 2016, and to 300 in 2017. This pilot program is expected to scale up across the launch counties and become nationwide in the coming years.

In 2017, the Chinese Ministry of Agriculture initiated another pilot program to replace chemical fertilizers with organic fertilizer for the productions of fruits, vegetables, and tea in 100 counties. Under this program, subsidies are provided to organic fertilizer manufacturers to increase affordability and uptake.

### **Opportunities for improvement**

China's rapid growth in agriculture production has been accompanied by rapid growth in the emissions of GHGs and related water and air pollution problems. China has invested large sums to boost productivity, and it has also spent large sums to restore forests and regenerate grasslands. The evidence also suggests potential to improve these programs, particularly by focusing on more native species, and possibly on alternatives to forests in arid areas.

The evidence also suggests opportunities to improve on-farm management. Chinese researchers have developed a large body of evidence finding that most farms could both boost yields and reduce losses of fertilizers just by adopting relatively standard better fertilizer management practices. Demonstrating this potential, from 2005 to 2015, researchers partnered with 21 million farmers across 452 counties to change nutrient management on 38 million hectares of land using resources available from a variety of Chinese programs (Cui et al. 2018). Under the program, the application of nitrogen decreased by 15–18 percent. Further, GHG emissions per ton of maize, rice, and wheat declined 14–23 percent depending on the grain. The project illustrated the potential gains of linking R&D and farm management improvements through a coordinated program. The researchers estimated the potential to expand the program to the remainder of Chinese grain production at an additional cost of US\$1.3 billion per year.

China also has the opportunity to go beyond standard management practices and to become a leader in innovative practices to reduce emissions. Given the intensity of its production, China is unlikely to fully solve its nitrogen pollution problems without innovative measures, and therefore would be an ideal location to pioneer increased use of and improvements in nitrification inhibitors (Kanter and Searchinger 2018). As the world's largest producer of rice, China could be a leader in developing and implementing low-methane rice varieties, particularly because its researchers have led research in this arena (Su et al. 2015). China also has such limited management of manure from pork operations today, with large

quantities of manure discharged directly into streams (Strokal et al. 2016), that it could move immediately toward manure management methods that not only store manure better but keep down methane emissions. Redirection of government funding could help further these steps toward climate change mitigation.

## EUROPEAN UNION

The EU already has a high level of agricultural efficiency and therefore a relatively low intensity of emissions from its agricultural production. Yet, its aggregate emissions remain high. Europe also continues to provide a high level of agricultural support primarily through its CAP. The CAP has been evolving to increase environmental conditions, and to shift more funds toward flexible support for rural development. To date, the uses of these funds do not appear to be purchasing much environmental improvement but they create a structure that could evolve into significant support for climate change mitigation.

### Overview of EU agricultural support

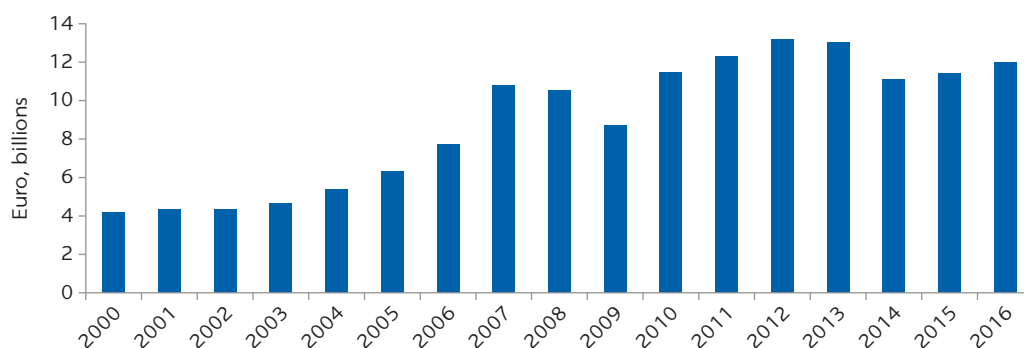
The European Union produces 7 percent of the world's agricultural value-added output and it provides the highest level of agricultural support as a percentage of value added at 37 percent. Of this support, 61 percent comes through direct production or income support as well as through support for on-farm infrastructure. A further 21 percent invests in R&D, safety, health, and conservation. The remaining 18 percent results from market price supports (figure 4.8).

### The EU Common Agricultural Policy

The vast majority of government support for European agriculture comes through the CAP, which currently costs US\$60 billion per year as averaged from 2014 to 2016 and represents approximately 40 percent of the entire EU budget. National governments also contribute around US\$21 billion to complement EU programs, and the OECD identifies another US\$13 billion in national agricultural spending on general services support.

The CAP originated with the creation of the European Union in 1957 and has evolved over time. In its early years, much CAP funding was structured to support price guarantees above international levels. These price guarantees required

**FIGURE 4.8**  
EU rural development budget, 2000–16



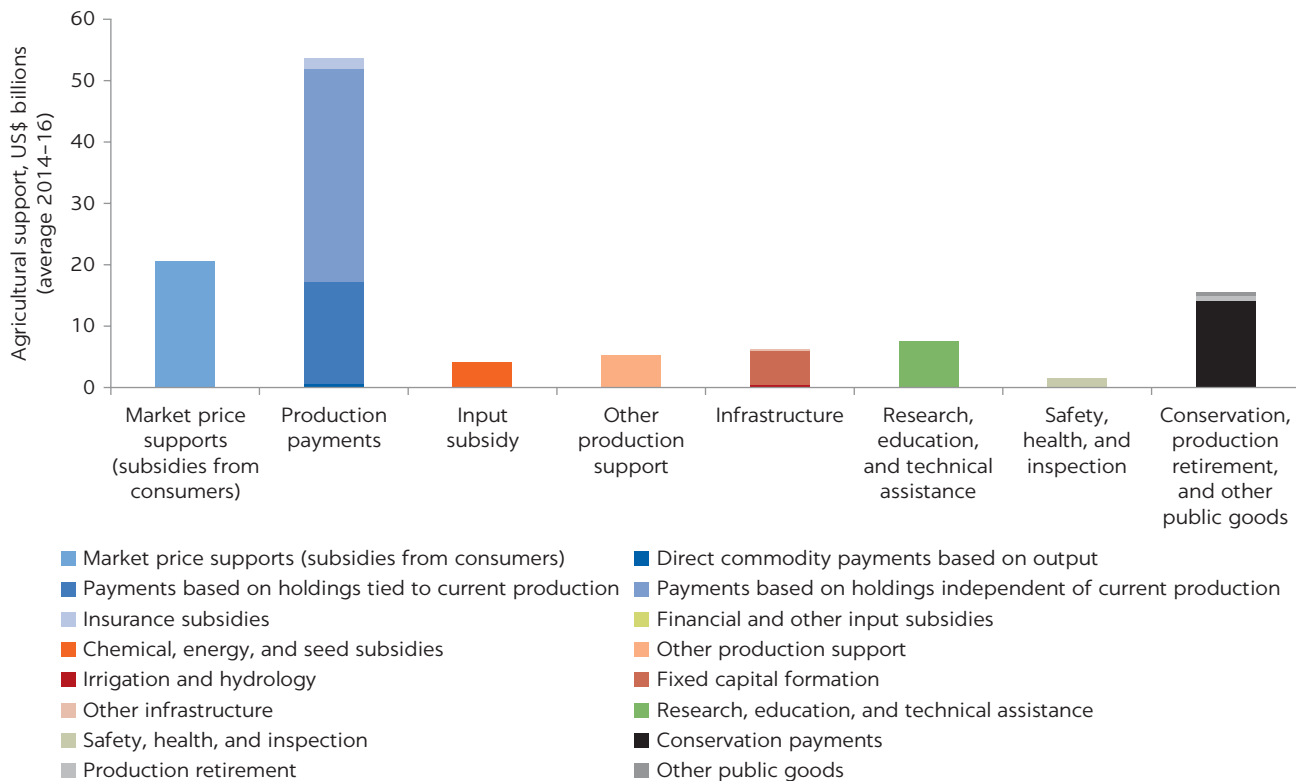
Source: [http://ec.europa.eu/budget/figures/interactive/index\\_en.cfm](http://ec.europa.eu/budget/figures/interactive/index_en.cfm).

import tariffs, large government purchases, and export subsidies to help dispose of the surpluses created by these government purchases. The CAP underwent major reforms in 1992. These reforms reduced price supports and substituted less coupled income supports while still retaining some supply controls. As a result, market price supports declined while payments to producers increased. The EU accelerated this approach in 2003 with more decoupling, an increase in country-level funding for rural development, and more direct farm payments. As evaluated by the OECD, the share of trade-distorting price supports dropped from 92 percent in 1986–88 to 29 percent in 2008–10.

The current CAP runs from 2014 through 2020. It consists of two pillars. The first pillar incorporates direct payments to farmers. The EU will provide €41 billion in direct payments from 2013 to 2015 while national governments will provide another €17 billion over the same period. The extent to which these payments are decoupled is subject to debate. In general, these payments are not tied to how much is produced each year. However, farmers are required to maintain their land in good agricultural condition and payments are tied to livestock production. Other payments are tied to the number of dairy cattle and apply to half of all dairy cattle in the EU (Matthews 2016a). Overall, payments commonly range from €200–300 per hectare per year with an average payment of €267 per eligible hectare (DG Agriculture and Rural Development, Unit Farm Economics 2017).

The second pillar consists of funds provided to national governments for rural development (figure 4.8). National governments must match these funds at differing percentages. Under the second pillar, the EU has provided up to approximately €14 billion per year and member states have provide another €8 billion (figure 4.9). In practice, however, the combined €22 billion for pillar

**FIGURE 4.9**  
EU agricultural support, 2014–16



Source: OECD PSE and GSSE databases.

two became €19 billion as countries were allowed to switch €3 billion back into direct payments (Dwyer et al. 2016). Countries can choose to devote rural development funds to six strategic priorities that cover a wide range of goals including economic development, enhancing competitiveness of all types of agriculture, preserving and enhancing ecosystems, resource efficiency, and reducing GHG emissions.

The total financial aid counted by the OECD includes market price supports and national funding, but it does not include all types of rural development spending. These market price support levels should drop in the future as the EU ended its milk production quota in 2015 and its sugar quota in 2017.

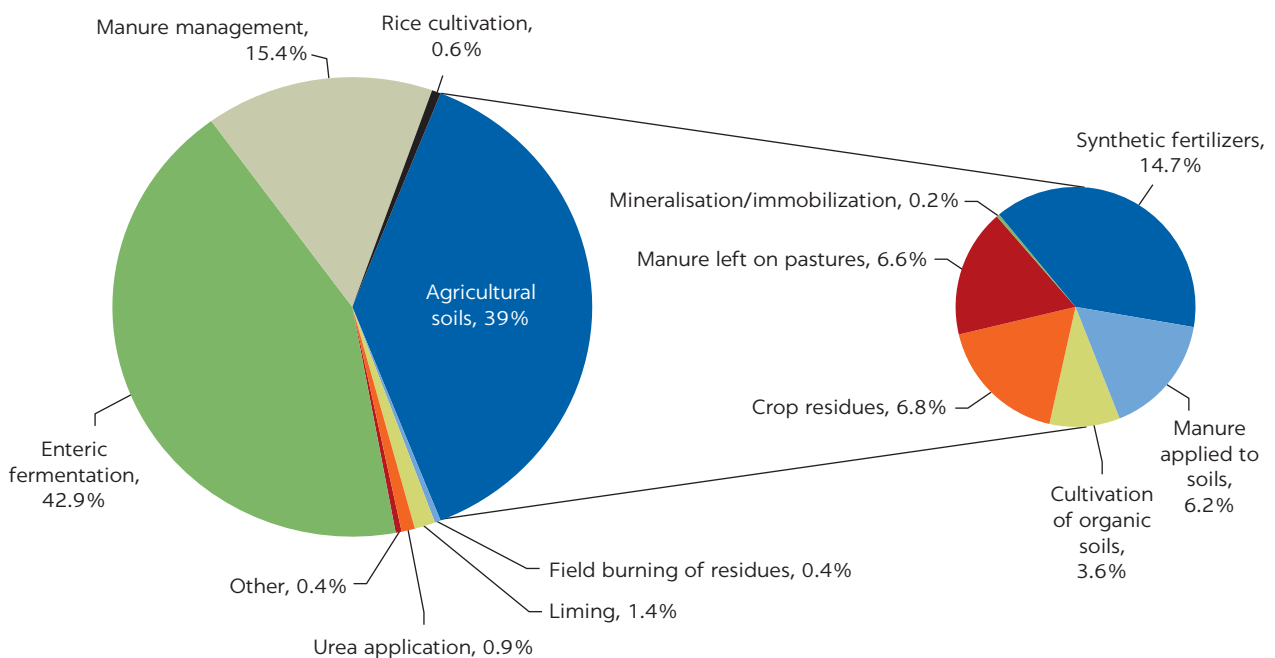
## EU GHG emissions

Excluding land use, land-use change and forestry (LULUCF), the European Commission estimates that agriculture in 2014 emitted 514 million tons of GHGs when including fuel use in agriculture (European Environment Agency 2017b). This figure represented roughly 11 percent of all EU emissions. Figure 4.10 provides a breakdown of different sources of emissions from EU agriculture in 2014, excluding LULUCF and fuel use, based on data from national emission reports presented by the European Commission's Joint Research Centre. Adding enteric fermentation, manure management and the manure component of emissions from agricultural soils suggests that 71 percent of all emissions are directly attributable to livestock even when excluding emissions from producing fodder crops.

The emissions from methane and nitrous oxide in agriculture fell by 21 percent from 1990 to 2014 although the rate of decline was much steeper in the earlier years from 1990 to 2000 (European Commission 2018). Much of this early decline was due to quick changes in the agricultural practices of new member countries. In the original 15 EU countries, the decline from 1990 to 2014 was

FIGURE 4.10

### EU agricultural emissions, by source, 2014



Source: JRC.

12 percent. The reasons for this decline include reductions in livestock numbers because of increasing yields per animal, reduced emissions from enteric fermentation, and reduced emissions related to manure (European Environment Agency 2017a). Europe also improved the efficiency of nitrogen use. This improved efficiency was partially due to the Nitrates Directive, which led to more efficient uses of manure and resulted in reductions of synthetic fertilizer.

### Evaluating the climate change mitigation and broader environmental contribution of the CAP

Since 2003, environmental benefits have provided important justifications for CAP reform efforts. A 2013 CAP reform listed *sustainable management of natural resources and climate action* as one of its three main objectives (Hart et al. 2017). These benefits are to be achieved in three ways: conservation compliance; greening requirements; and the inclusion of conservation into rural development spending. Each component has potential to contribute to climate change mitigation through improved production efficiency, effective management of agricultural land expansion, and changes in farm practices that reduce emissions, but how much do they do so today?

#### Conservation compliance

Conservation compliance links farm support payments to some forms of conservation management. The bulk of CAP's direct payments are now tied to conservation compliance, which itself has two components. One requires that farmers should only receive EU funds if they comply with applicable environmental and food safety laws that are already mandatory. Examples include an EU-wide directive on nitrogen use and authorization requirements on irrigation use where they exist.

The second type of condition consists of additional minimum requirements, entitled Standards of Good Agricultural and Environmental Condition (GAEC), that countries must specify based on broad EU standards (table 4.3). For example, the Standards require that country rules protect against soil erosion, protect soil organic matter, and recommend the protection of

**TABLE 4.3 Factors countries must consider in establishing Good Agricultural and Environmental Conditions for conservation compliance**

MAIN ISSUE	REQUIREMENTS AND STANDARDS
Water	<b>GAEC 1:</b> Establishment of buffer strips along water courses
	<b>GAEC 2:</b> Where use of water for irrigation is subject to authorisation, compliance with authorisation procedures
	<b>GAEC 3:</b> Protection of ground water against pollution: prohibition of direct discharge into groundwater and measures to prevent indirect pollution of groundwater through discharge on the ground and percolation through the soil of dangerous substances
Soil and carbon stock	<b>GAEC 4:</b> Minimum soil cover
	<b>GAEC 5:</b> Minimum land management reflecting site specific conditions to limit erosion
	<b>GAEC 6:</b> Maintenance of soil organic matter level through appropriate practices including ban on burning arable stubbles, except for plant health reasons
<b>Landscape, minimum level of maintenance</b>	<b>GAEC 7:</b> Retention of landscape features including, where appropriate, hedges, ponds, ditches, trees in line, in group or isolated, field margins and terraces, and including a ban on cutting hedges and trees during the bird breeding and rearing season and, as an option, measures for avoiding invasive plant species

Source: Hart et al. 2017.

Note: GAEC = Good Agricultural and Environmental Condition.

important “landscape features” to provide some buffering of streams and hedgerows (Hart et al. 2017).

Although there are very few analyses that indicate what conservation compliance has achieved in practice, we believe the achievements have probably been modest. We could not find any analysis of whether the condition of payments upon compliance with existing European laws, the first type of mandate, has actually increased compliance. In addition, because the EU-level requirements for GAEC standards are vague, the actual standards adopted by countries are often limited. For example, in 15 of the 28 EU countries, the only soil carbon requirement is not to burn crop stubble (Hart et al. 2017). Similarly, the EU-wide requirement related to retention of landscape features demands that countries protect only “where appropriate hedges, ponds, ditches, trees in line, in group or isolated, field margins and terraces.” Because what should be considered appropriate is unclear, countries vary greatly as to what or how much they do. For example, the UK protects streams, but the requirement is to maintain only a one-meter buffer from the top bank of a stream. Some countries do not have stream buffer requirements at all. Ecologists recommend buffers that are much larger than one meter to effectively filter out pollutants or provide shade.<sup>13</sup> Overall, therefore, there is little evidence that conservation compliance to date has substantial environmental effects.

### ***Greening requirements***

The second environmental condition requires that 30 percent of the direct payments, or approximately €12.6 billion per year, only be made available to farmers who meet three additional “greening” requirements (European Commission 2016). Because of various exceptions, this condition applied to 72 percent of agricultural area in 2015. This new condition for direct payments, imposed for the first time in 2015, led the OECD to estimate that the EU sharply increased its conservation spending from 2014 to 2015. However, the greening requirements are modest.

The first greening requirement is crop diversification, which mandates that farmers with at least 10 hectares of arable land grow two separate crops and that those with 30 hectares grow at least 3. Crop diversification can contribute to improved production efficiency and reduction of inputs, thereby contributing to CSA’s efforts to mitigate GHG emissions. Yet because these crops can be grown on different fields, this requirement does not actually require crop rotations. Most farmers are also likely to employ some crop rotations anyway, so the net gain from this requirement is likely limited.

The second greening requirement is that farmers with more than 15 hectares devote at least 5 percent of their land to Ecological Focus Areas as a means to manage agricultural land expansion. Although intended to provide habitat, these areas can include any nitrogen fixing croplands, catch crops, and land lying fallow. In 2015, three quarters of the land declared as Ecological Focus Areas by farmers were deployed in catch crop production, which is basically some kind of short “cover crop” outside the main growing season. Because these production areas are already heavily present on farms, one study concluded that this greening requirement will have only a limited effect on changing farmland uses (Hart, Buckwell, and Baldock 2016).

The third greening requirement consists of two measures to protect permanent grasslands. The first measure states that countries must lose no more than 5 percent of existing permanent grasslands to mitigate land expansion.

However, no country has applied this 5 percent as a limit to individual farmers and it is not clear whether this measure will have a large effect (Hart et al. 2017). The second measure includes an obligation to protect environmentally sensitive grasslands. Countries have responded very differently to this obligation. Ten countries have designated all their grasslands in natural areas as protected, while others have designated as little as 1 percent. Averaged across the EU, however, countries have designated three quarters of all grassland lands, or 7.5 million hectares, as protected (Hart, Buckwell, and Baldock 2016). With stricter definitions, the grassland requirement might help to preserve some soil carbon from conversion. Overall, to date, this requirement does not appear to do much to address climate change or other major environmental challenges.

### ***Conservation in rural development spending***

The third CAP initiative is the inclusion of various conservation activities among the objectives for rural development spending. The 2013 CAP provided six focus areas for rural development including two related to climate change mitigation, enhancing ecosystems and low carbon agriculture and food production.<sup>14</sup> Although all six focus areas are desirable, the focus areas that target economic development have stronger political pull than those that target the environment. However, the EU does require that 30 percent of rural development funding be devoted to land management measures for biodiversity or water and climate change mitigation/adaptation. One review of CAP rural development activities found national plans called for spending 54 percent of rural development funds either on enhancing ecosystems or on a category called climate-resilient agriculture.

The vast majority of rural development funds that were targeted to enhance ecosystems focused on wildlife. However, a review of the plans in 19 countries found that “light green” measures predominated, mostly defined by the sustainable management of a particular cropping or livestock systems. Only a small portion of the enhanced ecosystem funds focused on a specific group, species, habitat, or biodiversity problem (Hart, Buckwell, and Baldock 2016). Although these measurements are not explicitly focused on climate, another study found that at least some spending focused on grassland restoration, peatland preservation, and reducing pesticides or fertilizer, each of which could have potential climate benefits (Jongeneel et al. 2016).

Only a small portion of rural development funds were explicitly identified for climate concerns. In a study of 10 countries, all but one devoted 5 percent or less of rural development funding to climate mitigation, with the tenth devoting 12 percent. These climate mitigation funds were spent primarily for on-farm infrastructure including manure management and forestry activities (Jongeneel et al. 2016).

### **Opportunities for climate change mitigation in Europe and some recent examples of climate change mitigation spending**

Overall, the evidence suggests that while EU conservation conditions and directed spending are likely to have some climate benefits, they appear unlikely at present to contribute significantly to climate abatement. What could these funds support?

How much Europe can and should reduce agricultural emissions has been hotly debated. Modeling studies, employing different approaches and



assumptions, estimate widely varying mitigation potential (Allen and Maréchal 2017; Martineau et al. 2016; Matthews 2016b). Europe is nevertheless moving ahead with a directive that would require reductions in agricultural emissions by 30 percent. However, a variety of complex flexibility provisions may both reduce the actual reduction requirements and allow for controversial credits.

One of the challenges is that European agriculture is already efficient compared to most of the world, so Europe has less technical potential for efficiency gains than do developing countries. Another challenge is the potential for *leakage*. If Europe alone reduces production to reduce emissions, other countries may compensate by producing more.

Nevertheless, countries like Ireland, which has the highest percentage of emissions from agriculture in Europe, have identified large, practical reductions in emissions due to improved livestock practices on grazing (Schulte et al. 2012). Appropriate opportunities also exist to retire some agriculturally unproductive, drained peatlands or reforest some relatively unproductive agricultural lands (although effects on biodiversity will vary greatly with the type of land and whether a plantation or natural forest is reestablished). More broadly, there should be substantial potential to innovate. For example, modeling studies often now find high costs to reduce enteric methane through the established, only somewhat effective feed additives like linseed oil, but there is at least one much more promising new alternative (Hristov et al. 2015b). A focus of Europe should be to incentivize and explore these innovative alternatives.

Some national projections using rural development funds from the EU provide good models. For example, in the UK, farmers work with technical advisers to develop system-wide input reduction programs targeted at farms. Farmers receive payments based on the types of reductions, which are organized by tier (European Network for Rural Development 2017). Farmers then must roll out the program system-wide across the whole farm, document this roll out, and conduct inspections. In France, a program has been developed to reduce the use of pesticides (European Network for Rural Development 2017). Farmers follow the program and keep records to show they are delivering on program goals. At subregional levels, an average use of pesticides is calculated for each crop and participating farmers must reduce their on-farm use of herbicides and pesticides by a proportion calculated each year. Incentive payments are based on the level of reduction, farm records, and inspections.

As in best practice examples in other countries, these programs involve coordinated action among farmers and technical advisors, have clear objectives based on a specific problem, are evidence-based, go beyond mandatory standards, and can deliver clear and verifiable results. They also offer incentive payments based on different levels of performance. Scaling up these kinds of programs would provide excellent uses of agricultural support funding for climate change mitigation.

## BRAZIL

Brazil has emerged as a global agricultural power producing 6 percent of the world's maize, 29 percent of soybeans, 33 percent of coffee, and 41 percent of sugarcane.<sup>15</sup> Public policy over the last 40 years has played a major role in expanding both agricultural area and production. In the 1970s and 1980s, agriculture expanded rapidly across the Cerrado woody savanna and across the

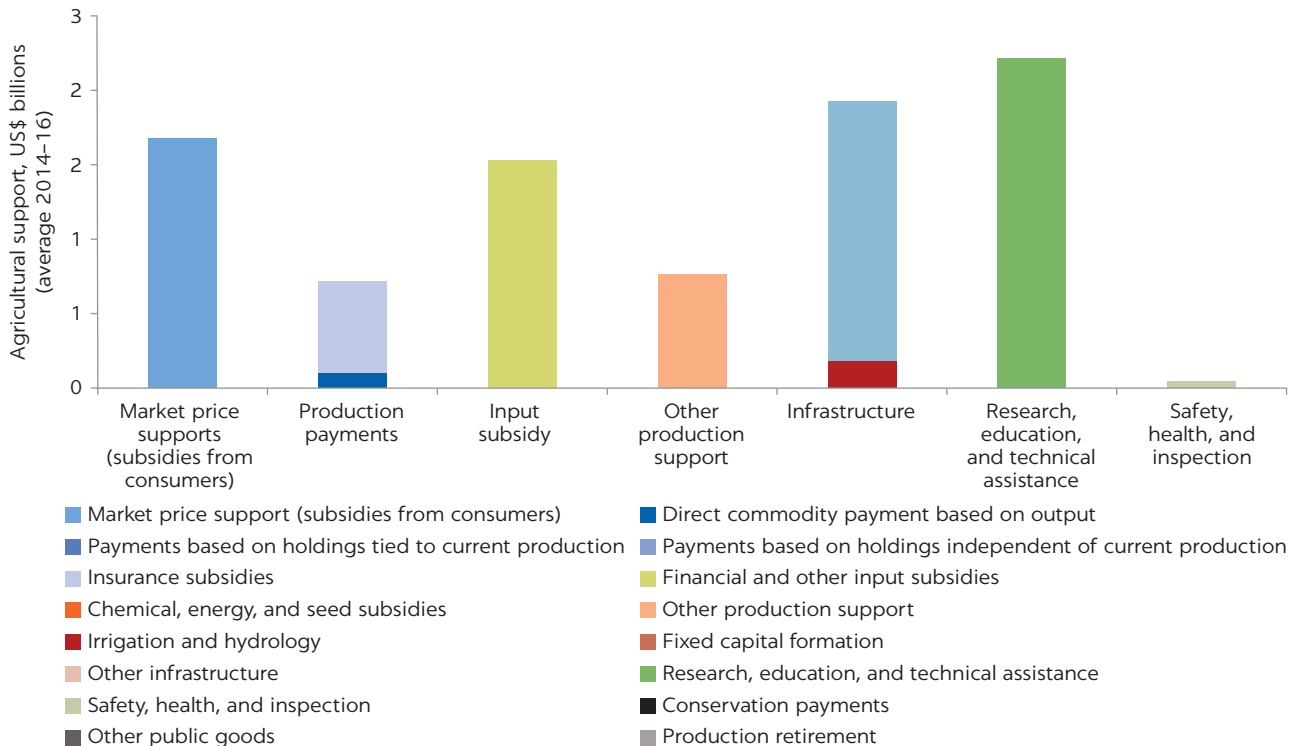
frontiers of the Amazon. This expansion was primarily for cattle ranching, but also for increased production of a range of crops including soybeans. It was driven by a combination of government subsidies for Amazon development, investments in road infrastructure, unclear land tenure, and policies that promoted land speculation by rewarding deforesters with formal land titles (Barreto 2010). These changes enabled Brazil’s agricultural value added to grow from less than US\$5 billion in 1970 to over US\$80 billion today.<sup>16</sup>

Brazil has made impressive efforts in recent years toward climate change mitigation. Suffering large-scale deforestation of the Amazon region, some of Brazil’s recent agricultural support reforms directly address climate change mitigation environmental goals by employing conditionality and compliance to increase production efficiency and to avoid and manage agricultural land expansion.

### Overview of Brazilian agricultural support

Brazil has a wide range of agricultural support programs but its total production support is relatively modest at 10 percent of agricultural value added. Of this amount, approximately 25 percent is directed at improving farm incomes through market price supports or direct farm payments. The remainder is directed at boosting productivity, including 50 percent of overall funding in the form of infrastructure and financial assistance to farmers (mainly low interest loans), and 25 percent for research and technical assistance (figure 4.11). Brazil has directed virtually no funds explicitly to conservation by the OECD categorization used in this report. However, the OECD estimated that about one third of

**FIGURE 4.11**  
**Agricultural support in Brazil, 2014–16**



Source: OECD PSE and GSSE databases.

all support in 2016 was tied to some requirements for compliance with environmental laws or laws protecting other public goods.

Despite the relatively modest levels of support, Brazil operates a broad array of agricultural support programs including price support programs for various crops and livestock products including milk. Annually, Brazil has spent around US\$6 billion for price support over the past decade. These programs, however, have not raised Brazilian food prices much above international prices. In 2016, Brazil's natural average food prices were only 5 percent above international prices. Brazil also provides support for sugar production through a national ethanol program that absorbs roughly 45 percent of Brazilian sugarcane production. This cost is not counted by the OECD.

Since 2006, Brazil has expanded a crop insurance program that offers 35–45 percent subsidies for premium payments. Brazil's dominant large-scale farms have had limited participation because of subsidy ceilings (\$7,550 for livestock and US\$22,650 for crops). As a result, insurance covered only 3.6 percent of the country's agricultural production measured by value in 2014 and subsidy levels were down to US\$126 million (Ministry of Agriculture, Livestock and Food Supply 2016).

## Deforestation and emissions

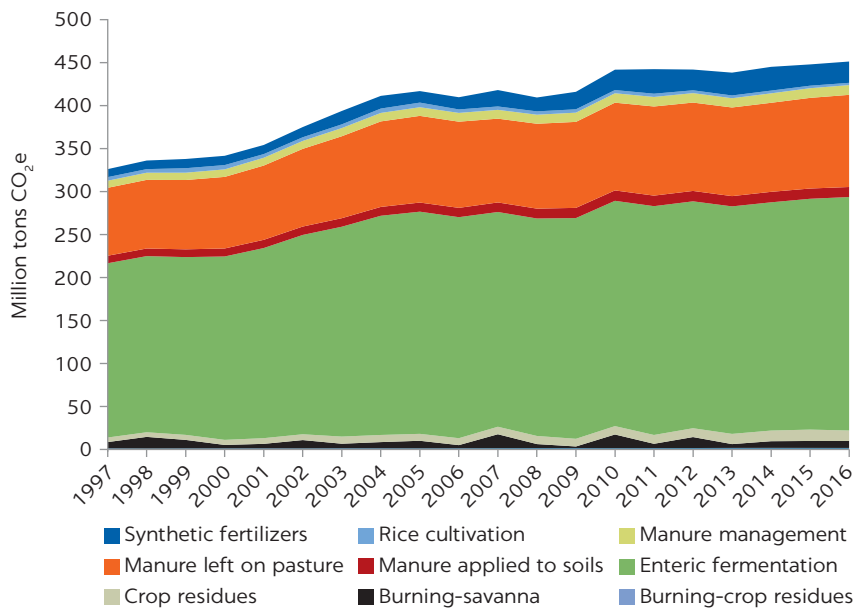
Although Brazil's large agricultural sector generates high levels of emissions from production, Brazil's largest source of emissions is deforestation tied to agricultural expansion (table 4.4). Deforestation averaged 2.3 million hectares per year from 1990 through 2010 (Food and Agriculture Organization 2015). By 2005, Brazil's emissions had risen to 1.9 gigatons CO<sub>2</sub>e/year, 80 percent of which came from agriculture production and land use change (figure 4.12). Deforestation alone generated 57 percent of emissions. Most of the expansion was for low intensity cattle ranching. Cattle pastures today constitute 70 percent of Brazil's 290 million hectares of total agricultural land. Extensive cattle ranching also results in high production emissions. About half of Brazil's emissions from agricultural production—excluding deforestation—come from enteric methane.

**TABLE 4.4** Estimated Brazilian agricultural production emissions, by category, 2010 and 2050 (million tons CO<sub>2</sub>e)

GLOBAGRI-WRR			FAOSTAT	
CATEGORY	2010	2050	CATEGORY	2010
Enteric emissions	233	358	Enteric emissions	262
Manure management	34	45	Manure management	11
Rice	19	19	Rice	4
Pasture & paddock	52	76	Pasture & paddock	102
Nitrogen	44	65	Synthetic fertilizer	24
Other fertilizers	8	7	Manure applied to soils	12
On-farm energy	24	28	Crop residues	10
Pesticides	8	7	Burning—Crop residues	2
			Burning—Savanna	16
<b>Total</b>	<b>422</b>	<b>606</b>		<b>427</b>

Source: Globagri-WRR and FAOstat.

**FIGURE 4.12**  
**Brazilian agricultural emissions, 1997–2016**



Source: FAOSTAT.

### Opportunities for mitigation and production increases through sustainable cattle intensification

Although most of Brazil's emissions are tied to cattle ranching, its sustainable intensification provides the principal opportunity for mitigation while simultaneously boosting production. Brazil's cattle production expanded largely because of the development of a new variety of brachiaria, an African grass, that can have high productivity if well-managed. But brachiaria needs fertilization and replanting, Embrapa, the national research agencies and progressive ranchers demonstrated the potential of improved management. As estimated by one paper, better fertilization of pasturelands, frequent rotation of cows between paddocks, improved healthcare, and the use of legumes or certain modest crop supplements can increase beef output per hectare several-fold and simultaneously reduce production emissions per kilogram of beef (Cardoso et al. 2016). Other researchers have also estimated high potential for Brazil to dramatically expand agricultural production without clearing more land (Strassburg et al. 2014).

#### ***Policies that link intensification with forest protection***

In various ways, Brazilian policy, including its agricultural programs, has embraced the strategy of linking support for cattle productivity gains to forest protection. In 2004 the government announced a forest protection plan that included new efforts to enforce the forest code. The 2004 forest protection plan explicitly linked that protection to enhanced assistance for livestock intensification. The ABC Climate Plan released in 2010 also focused on such a strategy (Gebara and Thuault 2013). The ABC Plan announced a low-income loan program for sustainable intensification and emphasized the restoration of degraded pastures and increased pasture/forest rotations. The program is expected to avert deforestation and to reduce methane emissions per kilogram of beef.

Although initial uptake was slow, loans totaled US\$250 million per year by 2010/11 (Newton et al. 2016).

In 2008, the federal government also established a policy to deny subsidized government credit to producers in the Amazon biome who could not demonstrate compliance with agricultural laws. From 2008 to 2011, the Brazilian government denied US\$1.4 billion in credits as a result of this policy. A rigorous study demonstrated that this policy was effective in reducing deforestation by cattle ranchers, but was less effective for reducing deforestation by crop farmers (Assunção et al. 2016). Unfortunately, a later study suggested that this policy has been less effective at reducing deforestation on registered properties. In addition to a general lack of enforcement, the policy's satellite monitoring systems cannot identify clearings less than 10 hectares. As a result, farmers did not fear loss of credit for low-level clearing (Azevedo et al. 2017). This subsequent study, however, appears to apply to small scale, additional clearing on existing farms rather than massive clearing of entirely new farms, and improvements in monitoring offer the potential to improve the effectiveness on these farms as well.

Overall, Brazil's policies have had limitations but they have succeeded in reducing deforestation in the Amazon. In 2005, deforestation averaged more than 2 million hectares per year. Within the next 5 years, Amazonian deforestation declined and averaged below one million hectares per year from 2010 to 2015 (Food and Agriculture Organization 2015). In the last few years, deforestation has increased but not to previous levels. Although Brazil continues to experience deforestation, its efforts to link government funding for sustainable intensification with forest protection offer a promising model for climate change mitigation

## INDIA

Indian agriculture must feed a sixth of the world's population based on roughly one tenth of the world's cropland. Since the Green Revolution of the 1970s, India has vastly increased agricultural production and has actually achieved this goal. India has even become a net agricultural exporter by value. By value added, India is the world's second largest agricultural nation after China producing US\$354 billion per year.

Substantial input subsidies for water, electricity, and fertilizer have contributed to this growth. However, input subsidies for nitrogen have dramatically increased emissions and reduced production efficiency through improper application. In an intriguing recent initiative, India has shifted to supporting enhanced efficiency fertilizers in part for financial reasons but which also have the potential to reduce emissions and possibly production.

### Review of agricultural support

Although the OECD does not yet calculate India's total government support for agriculture, that support is large. By one estimate, actual government expenditure was US\$85 billion per year in the early 2010s, which was about 30 percent of agricultural value added (Mustard 2014). Market price supports, which are not included in these figures, are large with price guarantees for sugarcane, cereals, pulses, oilseeds, cotton, tobacco and coconuts among others (Vikaspedia 2018). Only a small fraction of total agricultural support is linked to conservation objectives. Approximately US\$3 billion per year is spent on soil, water conservation, forestry, and wildlife (Mustard 2014).

### Input subsidies and environmental challenge

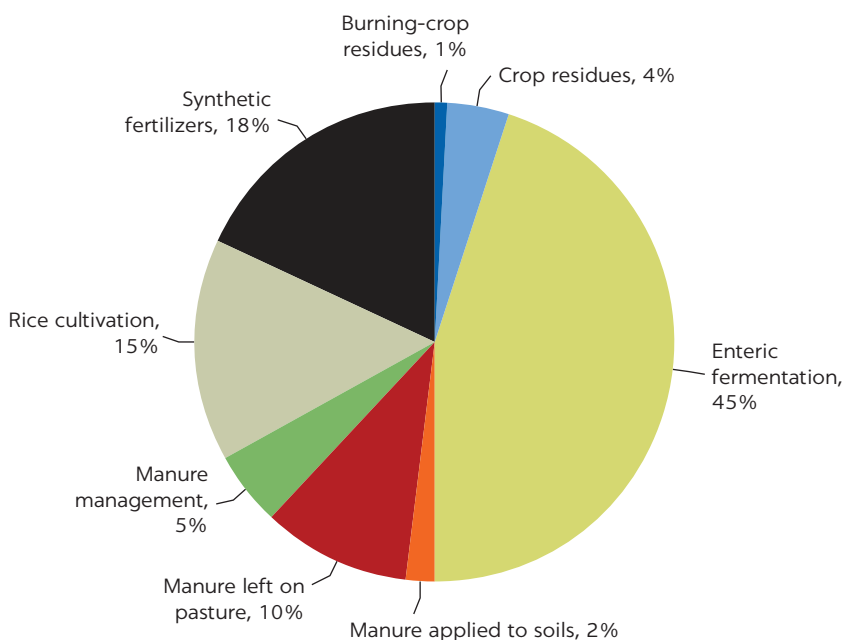
India has achieved its production capacity through a high level of intensification, which relied heavily on government input subsidies for water, power, and, most importantly, fertilizer. Half of India's arable land is irrigated and much produces two crops per year. This irrigation is supported by large electricity subsidies up to US\$12 billion per year as well as by free access to water (Mustard 2014). One challenge is that large portions of Indian groundwater are now overdrawn with groundwater levels declining (Shiao et al. 2015).

Although the heavy use of inputs has helped to hold down land use demands, it has also contributed to high GHG emissions. FAOstat has identified synthetic fertilizer production and use as the largest source of emissions in Indian agriculture aside from enteric fermentation, as shown in figure 4.13.

India's input subsidies have provided strong support for the development of the domestic fertilizer industry since the 1970s (Huang, Gulati, and Gregory 2017a). These fertilizer subsidies have reached as much as US\$15 billion per year (Mustard 2014). In 2015, subsidy costs had reached US\$11.6 billion per year, which is roughly five-fold more than 15 years earlier (Gulati and Banerjee 2015). These subsidies, which support a system of domestic price controls, have resulted in a large gap between global and Indian domestic urea prices. World urea prices were almost four times higher than regulated Indian prices in 2014 (Huang, Gulati, and Gregory 2017a). Government support has allowed dramatic increases in fertilizer production and use over time with average utilization rising from 34 kg per hectare in 1981 to 140 kg per hectare in 2012 (Huang, Gulati, and Gregory 2017a).

The large fertilizer subsidies have contributed to over-application of fertilizer. India's overall nitrogen use efficiency—the percentage of nitrogen

**FIGURE 4.13**  
**Source of Indian agricultural production emissions, 2016**



Source: FAOSTAT.

applied to farm fields that actually goes into the edible portions of crops—is only 30 percent compared to 52 percent in Europe and 68 percent in the United States and Canada (Zhang et al. 2015). Although studies have found that fertilizer subsidies in the early years of the Green Revolution contributed to agricultural growth and poverty reduction, they have found little impact since.

Indian fertilizer subsidies have been inefficient in particular because they more heavily subsidize nitrogen than other nutrient needs resulting in an inefficient balance of fertilizer application (Gulati and Banerjee 2015). Although the recommended nitrogen: phosphorus: potassium ratio (N:P:K ratio) for fertilizer application is around 4:2:1, by 2013/2014 the actually applied ratio in India had risen to roughly to 8:3:1. This ratio has had an adverse, long-term impact on soil fertility resulting in observed reductions in the response of crop yields to increased fertilization (Huang, Gulati, and Gregory 2017a). Reforms have tried to normalize these subsidies, but some reviewers claim that initial efforts have resulted in the opposite effect.<sup>17</sup>

### Enhanced efficiency fertilizer

The general reason that nitrogen use efficiencies are low in agriculture is that nitrogen in forms available for crops tends not to stay around long. If applied in the form of urea, for example, bacteria first convert the nitrogen to ammonia, some of which can escape into the air, before becoming ammonium, which is a form plants can use. Bacteria then convert ammonium into nitrate, which easily runs off with rainwater and also breaks down again in part releasing nitrous oxide, a powerful GHG (Trenkel 2010). If farmers were willing to apply fertilizer every day or week only in the amount needed by plants, the vast majority would be absorbed. Unfortunately, this exact application is impractical.

To overcome this problem, India has promoted the application of compounds that can slow down these conversion processes so that more nitrogen becomes available to crops only when needed (Abalos et al. 2016; Hiroko, Xiaoyuan, and Kazuyuki 2010; Qiao et al. 2015; Trenkel 2010). These compounds, which produce enhanced efficiency fertilizers, can take forms that reduce the capacity of bacteria to push parts of the conversion process. These compounds can also include fertilizer coatings that break down slowly over time and therefore only release nitrogen into the soil in a useable amount over time.

One option is applying a neem oil coating to urea. Neem acts to slow down the release of nitrogen from fertilizer compounds, improving nitrogen use efficiency and potentially boosting crop yields (Prasad et al. 1999). After 2015, at least 75 percent of subsidized urea sales in India must be neem coated.<sup>18</sup> Neem coating has the added advantage of making urea unsuitable for non-agricultural applications. India's Minister for Chemicals and Fertilizer has argued that implementing neem coating for all subsidized fertilizer sales has eliminated the diversion of urea for non-agricultural uses and could help India become fertilizer self-sufficient.<sup>19</sup>

The requirement that increasing quantities of fertilizer be coated with neem is a good start to increasing nitrogen use efficiency. Neem, however, is one of many possible compounds and the responses of different crops under different conditions is highly variable. The next step is a program that analyses these effects, encourages experimentation with more compounds, helps advise farmers on best uses, and ideally creates incentives for the more efficient use of fertilizers.

## SUB-SAHARAN AFRICA

Sub-Saharan Africa (SSA) relies on agriculture for much of its economic output, and for the survival of hundreds of millions of small farmers. Its agriculture is also a surprisingly large source of GHG emissions. Much of governments' agriculture support is going toward input subsidies, particularly for fertilizer. This case study discusses the effects of these subsidies and identifies some priority opportunities for spending that can simultaneously boost productivity and reduce SSA's GHG emissions.

### Agricultural development in Africa

Sub-Saharan Africa produces 8 percent of the world's agriculture by value added. Outside of South Africa, agriculture generated half of the region's GDP in 2015 (Hazell 2017). Between 1960 and 2005, the region's crop yields grew little and cereal yields barely grew at all. At least some of that lack of growth reflected the fact that African governments had substantial net taxation of the agricultural sector through most of this period (World Bank 2007). This lack of agricultural development has contributed to a high level of hunger through limitations of both micro- and macro-nutrients (Von Grebmer et al. 2014). In recent years, productivity has begun to increase. For example, cereal yields grew by 25 percent between 2005 and 2014, and some countries showed sizable growth in value-added per hectare (AGRA 2017).

### Emission challenges in Sub-Saharan African agriculture

A variety of analyses suggest that SSA is likely to experience serious challenges due to climate change. Temperature increases are likely to reduce yields of cereals such as maize and wheat, which are sensitive to heat (Nelson and Stathers 2009; Schlenker and Lobell 2010; Shi and Tao 2014). Some important cash crops such as coffee and cocoa will also become unsuitable in parts of areas currently under cultivation (Bunn et al. 2015; Schroth et al. 2016). The continent already experiences high rainfall variability. Further increases in drought and more variable rainfall present serious problems. One study projects greater than 20 percent declines in the length of growing seasons in much of SSA (Thornton et al. 2011). Sub-Saharan Africa is also a major source of emissions from agriculture. Africa's current emissions total 606 gigatons as calculated by the Globagri-WWW model. The vast majority of those (383 million tons) are enteric emissions (table 4.5).

The region's contributions to emissions are likely to become larger. According to UN average estimates, the Sub-Saharan population is likely to grow from 880 million in 2010 to 2.2 billion in 2050 and is expected to keep growing rapidly thereafter.<sup>20</sup> The Globagri-WRR projection to 2050 assumes good yield growth similar to that projected by the FAO. This projection more than doubles yields of most major crops from 2006 to 2050. The projections assume that the region will continue to import roughly 20 percent of its staple calories. Even so, annual production emissions grow to more than 1 billion tons in 2050 under the Globagri-WRR model.

Of even greater significance, the Globagri-WRR projection to 2050 estimates that agricultural area will expand by more than 200 million hectares, including 100 million hectares of cropland. That expansion will cause emissions from land



**TABLE 4.5 Estimated Sub-Saharan African agricultural production emissions excluding emissions from land use change, by category, 2010 and 2050 (million tons CO<sub>2</sub>e)**

GLOBAGRI-WRR			FAOSTAT	
CATEGORY	2010	2050	CATEGORY	2010
Enteric emissions	383	629	Enteric emissions	239
Manure management	51	89	Manure management	15
Rice	53	86	Rice	23
Pasture & paddock	69	114	Pasture & paddock	170
Nitrogen	28	96	Synthetic fertilizer	10
Other fertilizers	2	2	Manure applied to soils	7
On-farm energy	18	37	Crop residues	10
Pesticides	3	3	Burning—Crop residues	3
			Burning—Savanna	148
<b>Total</b>	<b>606</b>	<b>1,057</b>		<b>477</b>

Source: Globagri-WRR and FAOSTAT.

use change to average 2.1 billion tons annually from 2010 to 2050. If true, the combined emissions from African agriculture production and land use change would themselves equal one seventh of the world's allowable emissions by 2050 while the region's agriculture would still likely contribute only a small fraction of 1 percent of global GDP.

These numbers indicate the large, shared global interest in boosting the productive of SSA agriculture, and the close relationship of that productivity to mitigation.

### Agricultural support—Input subsidies

Recognizing the importance of agricultural development in reducing poverty, eliminating hunger, and promoting economic development, African governments collectively expressed a goal to increase their support for agriculture to 10 percent of public expenditures in 2003 (African Union 2003). Spending in many but not all African countries has now exceeded this level.

Economic arguments for agricultural support in Africa have some support. As summarized by (Dorward, Hazell, and Poulton 2008), many poor African farmers are caught in a low-productivity poverty trap. Because input use and productivity are low, farmers need to focus on staple crops to survive. This stifles crop and income diversification. The result is a vicious cycle of: (1) unstable food prices; (2) dis-incentivized investment in surplus staple production; (3) decreased consumer willingness to rely on markets for staple foods; and (4) limited opportunities to escape from low productivity subsistence staple cultivation. Proponents argue, as summarized critically in (Gautam 2015), that by addressing these four issues, support can create a virtuous cycle in which higher agricultural productivity boosts income, lowers food prices, and reduces poverty by providing the capital and security for farmers to invest more and pursue more balanced and higher income agricultural opportunities

A critical question is how best to provide this support. Today and for much of the last several decades, a large proportion of support for agriculture has come

in the form of input subsidies, particularly for fertilizer. Input subsidies have a long history in Africa. They were mostly phased out by 1995 as a result of a general consensus that costs exceeded benefits. Widespread structural adjustments for highly indebted governments also led to reductions in subsidy levels. Countries began to resurrect input subsidy programs after 2005 in part in response to improved fiscal situations after loan forgiveness. The perceived success of input support projects in Malawi and the global food crisis in 2008 also contributed to increased input support. In response, the World Bank and others promoted a concept of smart subsidies, which would: (1) promote private sector fertilizer markets; (2) focus on farmers with currently low but potentially profitable use of fertilizers; (3) contribute to a “wider sector strategy that recognizes the importance of supplying complementary inputs, strengthening output markets, and appropriately sequencing interventions”; and (4) execute an exit strategy (Morris, Ronchi, and Rohrbach 2011).

As shown in table 4.6, across 10 countries studied in the region, total input subsidies varied from 20 percent to 26 percent of agricultural spending from 2011 through 2014.<sup>24</sup> In three countries, input subsidies reached 40 percent or more in at least one of these years. Fertilizer subsidies alone reached US\$1.2 billion in 2012 (Jayne and Rashid 2013). These are conservative estimates because they do not count state-level fertilizer subsidies in Nigeria that may contribute roughly US\$800 million per year. These public expenditures on input subsidy programs obviously diminish funds available for other purposes.

Economists have now had the chance to study the effects of these input subsidies programs (Jayne et al. 2018). Research has found some increases in yields and incomes for those farmers who receive subsidies. Research has also found two limitations to these increases. First, subsidy funding tends to flow disproportionately to larger and more politically connected farms. Second, subsidized fertilizer often crowds out commercial market purchases of fertilizers so the net increase in yields is far smaller than the amount of subsidized fertilizer would suggest. There is little evidence that these input support programs are reducing poverty and food prices or even contributing much to yield gains in the case of Malawi.

Perhaps most significantly, the real-world yield response to increased fertilizer has been much lower than field tests had projected. Experience has highlighted the fundamental challenges with soil quality throughout much of SSA. These challenges include low PH, sandy soils, and low soil carbon. In fact, evidence suggests that African soils are losing soil carbon. This loss of soil carbon is part due to the depletion and mining of nitrogen, but also due to that fact that low yields and demands for crop residues lead to limited return of carbon back to the soil (Tittonell and Giller 2013). In addition to poor soil quality, limitations in other agronomic practices and the effects of pests and disease also reduce the results of increased fertilizer use (Tittonell and Giller 2013).

The challenge with soil quality contributes to the arguments to rebuild soil carbon as a means of increasing yields and the benefits of added fertilizer. One recent careful study has shown that increasing soil carbon up to 2 percent, which many African soils lack, increases yields (Oldfield, Bradford, and Wood 2019). To improve soil quality, one school of thought has promoted “conservation agriculture,” which focuses on no-till or reduced tillage agriculture, the retention of crop residues to keep the soil covered, and crop rotations preferably including legumes to help fix nitrogen. Yet, scientists now disagree both about the potential of conservation agriculture to boost yields, (Erenstein 2010; Hobbs 2007;

**TABLE 4.6** Input subsidy programs and broader agricultural sector spending, 2011–14

COUNTRY	YEAR	ISP COST (MILLION US\$)		THOUSANDS OF TONS OF ISP FERTILIZER DISTRIBUTED	PUBLIC EXPENDITURE ON AGRICULTURE (MILLION US\$)	ISP COST AS PERCENT SHARE OF PUBLIC AG. SPENDING [= (B/D)*100]
		OFFICIAL SOURCE	SECONDARY DATA			
		(A)	(B)	(C)	(D)	(E)
<b>Mali</b>	2011	n.a.	44	173	213	21
	2012	n.a.	17	65	195	9
	2013	n.a.	20	75	204	10
	2014	n.a.	18	84	199	9
<b>Burkina Faso</b>	2011	n.a.	25	25	291	9
	2012	n.a.	35	36	310	11
	2013	n.a.	47	51	351	13
	2014	n.a.	49	51	358	14
<b>Ghana</b>	2011	53	63	176	148	42
	2012	64	75	174	141	53
	2013	33	47	167	149	32
	2014	0	0	0	109	0
<b>Senegal</b>	2011	n.a.	47	54	182	26
	2012	n.a.	37	41	374	10
	2013	n.a.	30	36	368	8
	2014	n.a.	36	43	390	9
<b>Nigeria</b>	2011	n.a.	81	264	817	10
	2012	n.a.	92	249	788	12
	2013	n.a.	96	264	802	12
	2014	n.a.	86	256	795	11
<b>TARGETED SUBSIDY PROGRAMS</b>						
<b>Kenya</b>	2011	15	40	57	356	11
	2012	n.a.	64	68	386	17
	2013	n.a.	70	81	444	16
	2014	n.a.	77	112	479	16
<b>Malawi</b>	2011	127	106	149	345	31
	2012	151	77	177	355	22
	2013	207	95	213	350	27
	2014	168	157	208	352	45
<b>Tanzania</b>	2011	94	40	110	349	12
	2012	76	53	126	326	16
	2013	n.a.	46	105	338	14
	2014	n.a.	43	112	332	13
<b>Zambia</b>	2011	184	120	182	613	20
	2012	166	134	184	325	41
	2013	113	84	188	376	22
	2014	n.a.	81	208	407	20

continued

TABLE 4.6, *continued*

COUNTRY	YEAR	ISP COST (MILLION US\$)		THOUSANDS OF TONS OF ISP FERTILIZER DISTRIBUTED	PUBLIC EXPENDITURE ON AGRICULTURE (MILLION US\$)	ISP COST AS PERCENT SHARE OF PUBLIC AG. SPENDING [= (B/D)*100]
		OFFICIAL SOURCE	SECONDARY DATA			
		(A)	(B)	(C)	(D)	(E)
<b>ETHIOPIA'S PROGRAM (NOT CONSIDERED A "SUBSIDY" PROGRAM BY THE ETHIOPIAN GOVERNMENT)</b>						
<b>Ethiopia</b>	2011	n.a.	289 (62)	551	530	54.5 (11.6)
	2012	n.a.	449 (60)	633	771	58.2 (7.8)
	2013	n.a.	289 (43)	449	850	34.0 (5.0)
	2014	n.a.	307 (48)	597	937	32.8 (5.1)
<b>TOTAL ACROSS 10 COUNTRIES</b>						
<b>Total</b>	2011	n.a.	854 (627)	1,741	3,844	22.2 (16.3)
	2012	n.a.	1,033 (644)	1,753	3,971	26.0 (16.2)
	2013	n.a.	825 (578)	1,629	4,232	19.5 (13.7)
	2014	n.a.	853 (594)	1,671	4,358	19.6 (13.6)

Source: Jayne et al. 2018.

Note: n.a. = not applicable.

Powlson et al. 2014); (Palm et al. 2014), and about its practicality for African farmers because of the increased need for herbicides and competing demands for residues as animal feeds (Giller et al. 2015; Magnan, Larson, and Taylor 2012; Valbuena et al. 2012). Effects on yields are variable, (Pittelkow et al. 2014), resulting in adoption mainly in particularly arid areas (Arslan et al. 2014).

Alternative methods of building soil carbon include agroforestry and manure. However, these alternatives do not always fit farmers' resource conditions and are not always economical when adopted. Manure provides a good example. The fundamental challenge is that quantities are limited, and it would take many hectares of grazing to produce the manure necessary to fertilize one hectare of cropland (Tittonell and Giller 2013). For example, one report estimates that providing enough nitrogen to produce even two tons of maize would require a grazing area of 14–42 hectares of miombo woodland (Swift et al. 1989). Where agroforestry techniques involve taking land out of production for a few years to grow trees for eventual mulching, they also require that farmers contribute substantial labor and absorb the costs of not producing food on that land for a few years, which has proven to be a major obstacle to adoption (Smith et al. 2016; Snapp, Mafongoya, and Waddington 1998).

An overarching challenge is that there are many feedback effects that require addressing multiple problems simultaneously. For example, the benefits of inputs are low unless farmers put in additional efforts to do high quality weeding, planting and other agronomic practices, but the returns to those efforts are low without the ability to afford higher quality inputs. Low crop yields lead to low production of residues, which means less carbon to add back to soils. Low use of nitrogen means farming soils for nitrogen, but without available nitrogen soils will not build carbon and in fact will lose the nitrogen they have (van Groenigen et al. 2017). In addition, adding a carbon source to soils without adding more nitrogen might not increase yields initially because that carbon can immobilize whatever nitrogen would be added or become available.

The experience indicates that governments are still looking for effective models to build crop productivity on depleted soils. One option might be subsidizing reclamation of small portions of fields initially, and then extending those

efforts across more of the fields over time. Support could include not merely methods to increase carbon uptake but also adequate fertilizer to stabilize the carbon in soils. Such concentrated efforts might rebuild soils sufficiently fast to generate quick economic returns to farmers through higher yields.

### Support for livestock intensification

Another major opportunity for climate change mitigation in agriculture focuses on improvements in the livestock sector, which is the largest source of Africa's agricultural production emissions. Kenya's smallholder dairy efforts provide a good example of how targeted input subsidies have provided large opportunities for smallholders, improved agriculture and helped to reduce GHG emissions-intensity simultaneously. A program to help farmers adopt zero-grazing practices by bringing forage to animals greatly increased yields from 1980 to 1992. As of 2000, farmers with 3 or fewer cows produced 80 percent of Kenya's milk. Further, smallholders have captured a steadily rising market share. Today, some 600,000 small farmers operating 1–3 dairy cows produce 60 percent of Kenya's milk (Odero-Waitituh 2017). The Kenyan dairy sector today delivers 6–8 percent of Kenya's GDP primarily through smallholders (Odero-Waitituh 2017).

While progress in the Kenyan dairy sector has been far from uniform, average cattle productivity has improved significantly over time reaching over 2,000 liters per year by 2012 (Kenyan Ministry of Agriculture, Livestock, and Fisheries 2013). The Government of Kenya continues to partner with international donors to support dairy sector development. Kenya currently partners with IFAD through a US\$20 million smallholder dairy commercialization program (IFAD 2015). The main strategies for intensification of milk production have been the improvement of livestock breeds and the adoption of zero-grazing feed strategies using fodder crops such as napier grass, which can be grown at high yields in difficult places.

### NOTES

1. This funding includes not just national government funding, but state funding as well. The data is compiled by the Economic Research Service at the U.S. Department of Agriculture (USDA) and is available at <https://www.ers.usda.gov/data-products/agricultural-research-funding-in-the-public-and-private-sectors/>.
2. Budget authority differs from the spending tracked by OECD. The U.S. Congress gives government agencies an authority to spend money, but not all that money may be spent in that year. For example, conservation programs are typically administered through contracts that last over many years. The numbers quoted here track the budgetary authority and therefore differ from the OECD account.
3. A U.S. conservation group has collected data on uses of conservation programs and made it available online at <https://conservation.ewg.org/eqip.php?fips=00000&regionname=theUnitedStates>.
4. Cf. <https://conservation.ewg.org/csp.php?fips=00000&regionname=theUnitedStates>. By 2007, contracts that had been entered using better targeting criteria in the middle 1990s were already expiring.
5. Fact sheets on each state program are listed at [https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/2017/crep\\_delaware\\_jan2017.pdf](https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/2017/crep_delaware_jan2017.pdf).
6. The eligible list includes agricultural or forestry associations, farmer cooperatives or other groups of producers, state or local governments, American Indian tribes, municipal water treatment entities, water and irrigation districts, conservation-driven nongovernmental organizations and institutions of higher education.

7. The project is the Midwest Agriculture Water Quality Partnership.
8. The plan had other reductions under the influence of U.S. Department of Agriculture related to the forestry sector, energy production, and consumption supplied by rural utilities. The reductions purely from the agricultural sector were 35–49 million tons (CO<sub>2</sub>e) with the difference based entirely on carbon sequestration levels.
9. <https://www.ers.usda.gov/topics/natural-resources-environment/climate-change/agriculture-and-climate-change/>.
10. These emissions are taken from FAOSTAT for 2014 except that emissions from nitrogen use and production are taken from ( Zhang et al. 2013) because FAOSTAT does not incorporate emissions from synthetic fertilizer production, which are exceptionally high in China and therefore important.
11. IFPRI ASTI Website, <https://www.asti.cgiar.org/china> (last accessed August 28, 2018).
12. A large secondary review of the literature by the Center for International Forestry Research (CIFOR) (Rodriguez et al. 2016) concluded: “A skewed temporal and geographic distribution of the examined studies limits the generalizability of the results, though the evidence base confirms a substantial increase in forest cover and associated carbon stocks linked to reallocation of sloping agricultural land to forest. To some degree, soil erosion has been controlled and flood risk reduced at local scales. Meanwhile household incomes have increased and rural employment has readjusted towards off-farm sectors. However, some studies also indicate instances of diminished food security and increasing social inequality. Finally, several studies indicate suboptimal regional or localized trade-offs among specific ecosystem services, including carbon sequestration vs. water discharge rates, flood control vs. riparian soil replacement, and forest productivity vs. biodiversity.”
13. UK Rural Payments Agency Guide to cross compliance in England: 2016 (6 January 2016), <https://www.gov.uk/guidance/guide-to-cross-compliance-in-england-2016/gaec-1-establishment-of-buffer-strips-along-watercourses>.
14. In fact, the CAP authorized seven areas of focus, but countries only selected six:
  - (1) Fostering knowledge transfer in agriculture and forestry, focused on promoting human capital and smart networking; fostering innovation and the knowledge base; and strengthening the links between the sectors and research and development.
  - (2) Enhancing competitiveness of all types of agriculture and enhancing farm viability, with a focus on: restructuring of farms facing major structural problems, with a low degree of market participation, and farms in need of agricultural diversification; also facilitating generational renewal in the agricultural sector.
  - (3) Promoting food chain organization and risk management in agriculture: integrating primary producers into the food chain through quality schemes, promotion in local markets and short supply chains, producer groups and inter-sectoral organizations.
  - (4) Preserving and enhancing ecosystems dependent on agriculture: preserving biodiversity and landscapes; improving water and soil management.
  - (5) Promoting resource efficiency and the transition to a low carbon economy in the agriculture and food sectors, increasing efficiency in water use; energy use; supply and use of wastes, residues and other non-food raw material for the bio-economy; reducing nitrous oxide and methane emissions from agriculture; and fostering carbon sequestration in agriculture and forestry.
  - (6) Realizing the jobs potential and the development of rural areas, facilitating diversification and job creation; promoting social inclusion and poverty reduction; and fostering local development in rural areas.
15. FAOSTAT data for 2016.
16. World Bank Data (constant dollars), <https://data.worldbank.org/indicator/NV.AGR.TOTL.CD?locations=BR>.
17. <http://www.gktoday.in/nutrient-based-subsidy-scheme/> <http://www.livemint.com/Opinion/XCCJwEzwbzwyWFYfK1wRdO/Indias-flawed-fertilizer-policy.html>.
18. [http://www.business-standard.com/article/economy-policy/neem-coated-truth-urea-policy-isn-t-a-game-changer-116021601168\\_1.html](http://www.business-standard.com/article/economy-policy/neem-coated-truth-urea-policy-isn-t-a-game-changer-116021601168_1.html).
19. <https://www.financialexpress.com/opinion/neem-coated-urea-why-is-narendra-modi-govt-waiting-for-5-years-to-make-india-self-sufficient-in-fertilisers/454215/>.
20. <http://worldpopulationreview.com/continents/sub-saharan-africa-population/>.
21. This table was generated for this report by one of the co-authors and has also been published in (Jayne et al. 2018).

# 5 Conclusion and Key Takeaways

The review of literature and the six case studies suggests that the US\$600 billion of annual governmental support for agriculture in the OECD database contributes only modestly to the related objectives of boosting crop yields and mitigating climate change. Whether analyzed by support for general services versus farm payments or by conservation spending alone, only a limited portion of support funds are moving climate change mitigation forward. In addition, most support is flowing to larger and wealthier farms—both on a country basis and within countries—reducing the likelihood that this support enables smallholder farmers to boost productivity by avoiding poverty traps.

There are also some promising developments. The portion of subsidies that are most market-distorting has declined. Less distortion will likely contribute to agricultural productivity in the long run although regional differences in productivity may not necessarily reduce the GHG effects of agriculture across the globe. Although environmental conditionality for agricultural support has not been onerous and has not been fully designed to avoid agricultural expansion, such conditionality has been growing. Several countries are currently moving to integrate farm support payments into coordinated projects that hold the most promise for advancing environmental objectives including climate change mitigation.

To advance the process, this paper offers the following recommendations.

- *Focus on mitigation:* Climate mitigation includes boosting the productivity of the use of land and increasing efficiency in the use of natural resources, and then using these gains to avoid agricultural expansion into forests and savannas. Mitigation strategies offer opportunities for win-win solutions, but imposing constraints on land expansion will face political challenges. Agricultural funding to support productivity gains can only succeed to mitigate emissions if it is linked explicitly or implicitly to laws that protect native carbon.
- *Advance land retirement and restoration of marginal agricultural lands:* The land area used for agriculture has the potential to decline in some countries, which can help offset expansion elsewhere in the world. As shown in the China case study, retirement of marginally productive lands can potentially reshape the landscape. Combining land retirement with the restoration of native habitats is critical to obtaining both carbon and biodiversity goals.

- *Redirect market price supports:* The most challenging support to redirect is the support that comes from consumers through higher prices as a result of market price supports. There appears to be no plausible mechanism to make market price support assist climate mitigation. When countries cut their market price support, however, they often increase their direct spending as compensation as illustrated in the Europe Union case study. This method of compensation might provide a path for redirecting these market price supports toward climate change mitigation.
- *Condition aid on land use protections:* As long as farm payments remain a staple of government policy, climate mitigation requires that this aid come with the condition of not clearing new land. At a minimum, governments should not make farm payments available to farming on new land. In Africa, where some land expansion seems inevitable, there might be a justification for relaxing this conditionality, but only if plans are in place to direct that expansion to minimize the release of carbon and other environmental costs.
- *Use graduated payments:* As the U.S. and European case studies illustrate, the use of minimum environmental standards for conditionality is likely to lead to low environmental conditions. By contrast, programs that are specifically designed to achieve environmental outcomes tend to create a system of graduated payments that rewarding farmers for increasingly better performance. Graduated payments also have the potential to encourage innovation to the extent that governments that can find ways to condition payments on performance rather than implementation of specific technologies. For these reasons, systems of graduated payments are more likely to achieve public goods and promote climate change mitigation.
- *Use support to enhance innovation:* Many farm management measures exist to reduce emissions, and many of them have potential productivity gains. Yet, innovation is critical to deal with climate change both because the magnitude of the challenges require new solutions and because those solutions must become self-sustaining to survive over the long-term. A prime rationale for any subsidy can be the promotion of new technologies that have the potential to become self-sustaining once adopted by a critical mass of users. Performance-based projects, which require the measurement of progress, also favor innovation.
- *Combine support with legal requirements:* One way to use agricultural support for climate change mitigation is to require that farms meet certain climate requirements while providing the financial support to implement them. This approach has certain merits. It gives farmers incentives to try to develop the most cost-effective ways of meeting environmental goals. It avoids a situation in which farmers claim they will not employ a practice unless compensated even though they actually would or could. This approach reduces the likelihood of leakage because other farms will not be able to avoid meeting environmental standards. Finally, it avoids the risk that dollars spent on encouraging voluntary measures will be wasted because farmers decide to abandon them.
- *Incorporate support into integrated projects:* Solving complex challenges requires a range of coordinated actions, rigorous progress monitoring, regular implementation adjustments, and iterative improvements. These actions require that assistance be targeted based on data-driven analysis and supported by ongoing research and development. Providing support for



coordination, monitoring, and analysis not only enables more environmental progress, but provides synergies in the measurement of improvements in production and income. It is no accident that the United States focused upon coordination and research when it put together a plan to reduce agricultural GHG emissions. China's simultaneous improvements in nitrogen use efficiency and yields provides another example. Using competitive procedures to award support encourages innovative ideas and reduces the risk of favoritism.

These kinds of reforms to agricultural support programs would be appropriate for climate negotiations and international collaboration. Many countries have identified changes in agricultural management or reduction in land use change as important parts of their independent, national commitments as part of the Paris climate accord. Assuring that these commitments are backed by adequate financing is an appropriate inquiry and area for global action. Countries can also learn from each other on best practices for reforming agricultural support to support climate change mitigation. Further analytical work by the World Bank, particularly work that focuses in detail on possible reform models, could call attention to the needs and opportunities, increase public understanding, and provide useful guidance to national governments.

In the countries analyzed in this report, government support already reaches almost one third of the value added by agricultural production. Reforming the focus and delivery of this support could assist the effort to stabilize the climate.



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ECO-AUDIT

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Agriculture generates roughly one-quarter of global greenhouse gas emissions. By 2050, without major mitigation efforts, agricultural emissions are likely to reach levels that would make meeting global climate targets practically unachievable. Meanwhile, countries that produce two-thirds of the world's agricultural output provided US\$600 billion per year in agricultural financial support, on average, from 2014 to 2016. By evaluating these support programs, both overall and with six case studies, this report finds that many governments have moved to make their farm support less likely to distort what farmers produce; but only a modest portion of programs support environmental objectives, and even fewer support the mitigation of climate change.

Of US\$300 billion in direct spending, only 9 percent explicitly supports conservation, while another 12 percent supports research and technical assistance. Instances in which receiving government funding is contingent upon supporting environmental objectives provide models on which to build but so far have produced only modest environmental benefits. Because crop and pasture yields need to grow dramatically to avoid more deforestation and other conversion of native habitats, mitigation priorities include help for farmers to boost yields and livestock productivity. Yet to avoid inadvertently encouraging more conversion, this aid must be conditioned on the protection of forests and other native areas.

Overall, climate-oriented support for agriculture should have as a guiding principle increasing the efficient use of land and other natural resources. Incentive programs should be structured so that they offer graduated payments for higher climate performance. Governments should also prioritize coordinated projects across multiple producers to explore critically needed innovations in farm management, and should support those projects with research and technical assistance.