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Priorities and Opportunities in International Agriculture

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Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
CGD	Center for Global Development
CGIAR	Consultative Group on International Agricultural Research
DFID	Department for International Development
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic information system
IDB	Inter-American Development Bank
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
NGO	Nongovernmental organization
OECD	Organisation for Economic Co-operation and Development
USAID	United States Agency for International Development

Executive Summary

With this paper, we provide an overview of some issues that have major impacts on global agricultural policy and make recommendations for action on both ongoing and emerging trends. Our paper is not exhaustive: we tend to focus mostly on agriculture and forestry (production) per se, and pay relatively little attention to issues such as food safety or nutrition. We similarly do not focus much on trade. We tackle more in depth important issues such as resilience, climate-smart agriculture, the role of smallholders, and others.

We start our paper with an introduction that provides the background and a statistical overview of the key trends, based on analysis of the Food and Agriculture Organization of the United Nations and World Bank data. Although there is no dire crisis and the shock of the middle of the 2000–2010 decade has largely dissipated, we conclude the introduction by identifying continuing reasons for concern.

We then review how development agencies have handled the four issues that seem to dominate agency discourse: intensifying productivity, enhancing the role of the private sector and redefining the role of public policy and expenditure, reducing poverty, and funding research for dealing with climate change, development of marginal lands and other emerging problems. We discuss limits of land and water, possibilities for better use of marginal lands, options for focusing on export agriculture and not just food security narrowly understood as production for domestic consumption, and a need for deepened understanding of technical change and adoption processes.

In the next section, we propose high-level recommendations for policy makers and development agencies that could have the most impact on the issues identified. We propose these courses of action in the current context of a "post–Green Revolution period," when the expansion of food production has slowed and the need to deal with increasingly complex problems has become much clearer. Our recommendations (many of which are interrelated) include the following:

1. Analyze and propose models that assess tradeoffs between incentivizing food production versus incentivizing general value-added and income generation from the sector, for a variety of policy objectives.
2. Create better analysis, modeling, and policy dialogue on use of water resources—especially on issues of pricing, irrigation, and the role of small versus large farmers in water use and management.
3. Study farmer adoption of new technologies or improved complex production systems (e.g., agroforestry and agroforestry/livestock models) that could help them both adapt to emerging climate threats, intensify agriculture without increasing emissions and other forms of externalities, and increase the roles of small farmers in export agriculture.
4. Produce models, based on analysis and modeling, for the development of marginal areas. Carry out policy dialogue and then field experimentation with models.
5. Improve methods of land use planning using modeling and new technologies.
6. In tandem with recommendation 1, explore the degree to which, and support policy dialogue on whether smallholders can benefit from high-valued added export agriculture, even in marginal lands, as opposed to assuming that an optimal role for them is in food production.
7. Continue to improve the research and evidence base for agricultural policy setting, in general, via better modeling and applied political economy.

Finally, we conclude with an appendix that neatly summarizes the strategies and level of emphasis and expertise of 14 agencies on the issues.

Introduction

The agricultural strategies of international development agencies have evolved over the last several decades. In preparing this paper, we reviewed the agricultural strategies or programs of 14 international agencies engaged in agricultural development or policy studies:

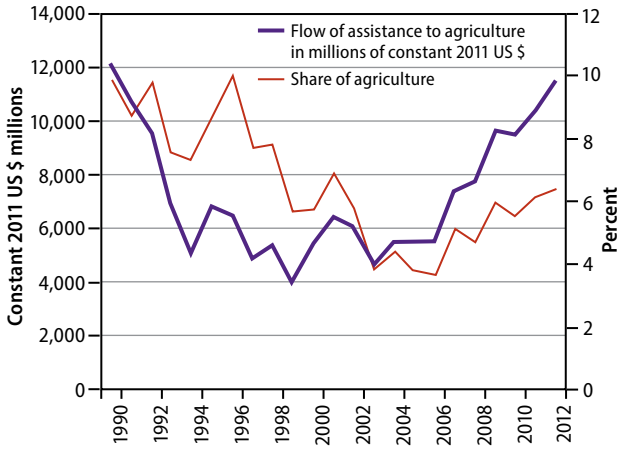
- African Development Bank (AfDB)
- Asian Development Bank (ADB)
- Bill & Melinda Gates Foundation (Gates Foundation)
- Center for Global Development (CGD)
- Chicago Council on Global Affairs (Chicago Council)
- Consultative Group on International Agricultural Research (CGIAR)
- Department for International Development (DFID) of the UK
- Food and Agriculture Organization of the United Nations (FAO)
- Inter-American Development Bank (IDB)
- International Food Policy Research Institute (IFPRI)
- International Fund for Agricultural Development (IFAD)
- Organisation for Economic Co-operation and Development (OECD)
- United States Agency for International Development (USAID)
- World Bank

We chose these agencies because they provide approximately 24 percent of funding to agriculture in developing countries and because, even if they do not grant or lend very much, they have intellectual influence (e.g., IFPRI). In the appendix, we summarize these agencies' agricultural strategies and the main themes or issues these strategies address.

The dominant issues that shape the strategies of these agencies include food security and food production, poverty reduction and welfare of rural households, and the structural transformation of agriculture to enhance economic growth—including the increasing role of the private sector in advancing agricultural productivity. Because of the multidimensionality of agriculture, other issues also have to be addressed to expand the strategic framework of the sector. These issues are the environment, food security, gender, increased productivity, land use, natural resources, nonfarm employment, policy reform, poverty reduction, rural infrastructure, and trade.

Agricultural experts and policy makers debate which priority issues should drive the future course of intervention in agriculture. The debate is gaining wider attention because agricultural systems must transition to meet evolving challenges. In reaction to disruptions in food and financial markets in recent years, a few agencies and donors have urged action improve food security through short-term solutions. This is partially responsible for the recent resurgent interest in agriculture among donors (Figure 1).

Figure 1. Flows and shares of official development assistance to agriculture



Source: OECD DCD–DAC (2016).

Note: This figure represents only concessional assistance and does not include loans from multilateral development banks, such as the World Bank.

The rest of the paper is organized as follows. In what remains of this section, we characterize the food and agriculture issue statistically to provide a better sense of the problems that exist. In the second section, we discuss outstanding issues in the sector, as viewed from the perspective of development agencies' past and current policies, and as they seem to us to emerge from the literature and events of the past decade or

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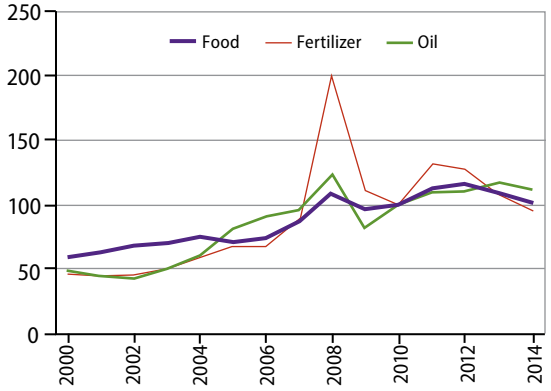
longer. The final section, "Recommendations for Action," summarizes ways that analysts and project implementers could better support improved food and agriculture policy in a changing world.

Statistical Background

Despite sporadic spikes in food prices and agricultural input prices since 2007 (see Figure 2), the main issue in agricultural development is not one of "raw" total agricultural output. Indeed, the worldwide output and average availability of food has increased with few interruptions over the last five decades. However, these averages hide important variations.

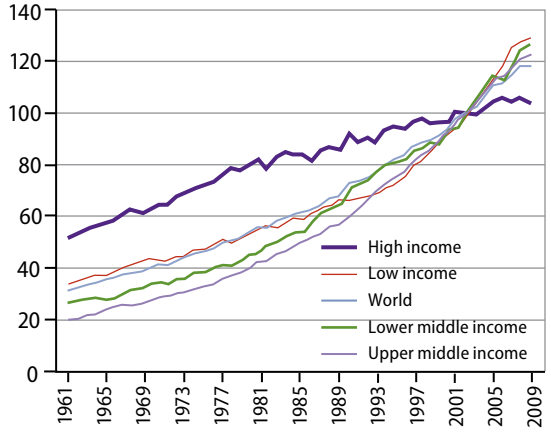
Figure 2. Food, fertilizer, and oil price indices (2000 = 100, constant 2000 US $ values)



Source: World Bank (2016a).

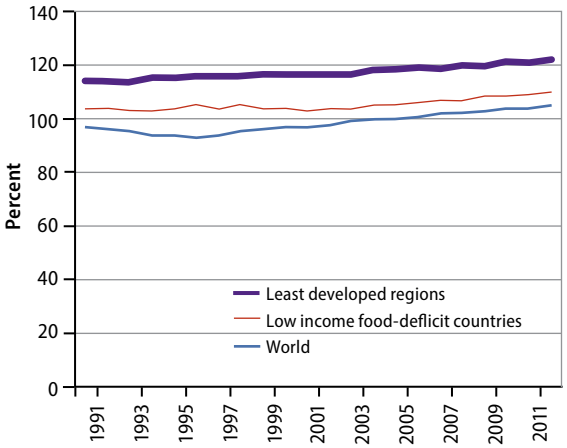
Food production has been growing exponentially around the world in all regions except those with high incomes since the early 1960s, with some occasional peaks and troughs (Figure 3). In addition, food production is roughly sufficient to meet caloric requirements, on average (Figure 4). Even the worst-case group of countries—namely, food-deficit (in the sense of production), low-income countries—were able to import enough food to meet the average caloric requirements of their populations by the early 2000s, and the trend has continued unabated despite the relative crisis of the mid-2000s. Whether imports, often carried out on an emergency basis with public funds, are the best way to address these issues is another important matter.

Figure 3. Food production index (2004–2006 average = 100)



Source: World Bank (2016b).

Figure 4. Percentage of minimum caloric requirement, by country group



Source: FAOSTAT (2016).

Caloric sufficiency does not tell the whole story, of course. The relatively more expensive foods, such as proteins from animal sources, have also been increasingly available, and steadily so—by about 30 percent in the last 20 years, even in low-income, food-deficit countries. This is largely due to increases in income in these countries, as economic reforms made in the 1980s and 1990s have taken root.

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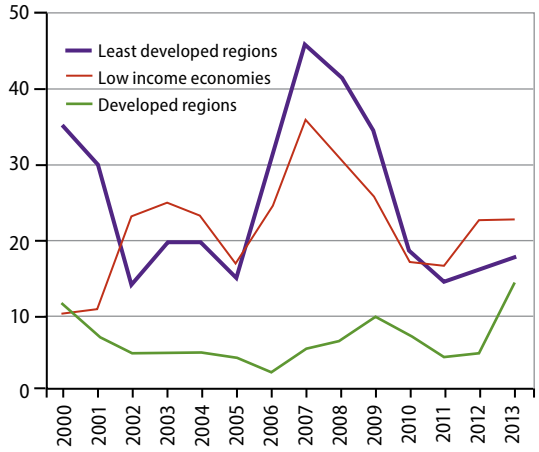
Statistical Dimensions of International Agriculture Problems

As described, the world's agricultural output is sufficient to meet the population's caloric needs on average. However, real problems do exist.

First, wide price volatility creates a poverty-fighting problem. Families living at just above survival or subsistence levels can be sent below those levels by shocks to the agricultural system. They then may have trouble recovering or may do so slowly. Price volatility faced by the countries that can least afford it is six to eight times higher than in the developed regions of the world (Figure 5). This is a much more meaningful—and worrisome—trend than those that pertain to long-term increases in production or availability.

Figure 5. FAO price volatility index (standard deviations of deviations from trend)



Source: FAOSTAT (2016).

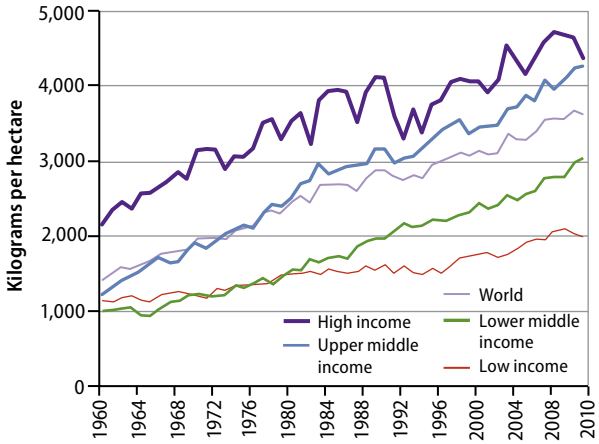
Note: FAO = Food and Agriculture Organization of the United Nations.

A second issue deals with trends in yields and their distribution around the world. As an example, cereal yields since the 1960s have been increasing linearly (Figure 6), whereas demand is increasing exponentially. This means that increases in demand may outpace increases in yields. In addition, these trends are likely an optimistic scenario since yields in other agricultural products such as roots and tubers have not increased as much (see Fischer et al., 2009).

Figure 6 also shows another worrisome issue. In the early 1960s, the cereal yields in developing nations were about 1,000 kg lower than the developed world. Since then, the lower-middle- and upper-middle-income countries have been catching up. However, future increases in yield are limited as more catch-up happens, assuming one takes the (moving) yields in the developed regions as the "practical" maximum at any given time. This means we cannot continue to expect to increase average output by changing the composition of the sources of output (a composition effect): poorer areas growing faster—as the middle-income countries did and increasing the global average.

Finally, the low-income regions are simply not catching up. Despite increases in the 1970s and 2000s, the long-term trends diverge for these countries. If this continues, it adds to why we cannot rely on a composition effect to continue to improve worldwide yields. In addition, while lower-middle-income counties are not falling behind, they are also not catching up. Adoption of improved practices in these poorest regions would have to improve markedly to allow for further increases global yields by relying on the composition effect.

Figure 6. Cereal yields, by income group (kilograms per hectare)



Source: World Bank (2016b).

This brings us to a third issue: the world is reaching the limits of usable land and other resources. This is easier to identify with respect to land, because there are much better data for land than for other resources. It can also easily apply to water and the side effects of agriculture in terms of global warming, reductions in genetic biodiversity, and other byproducts of

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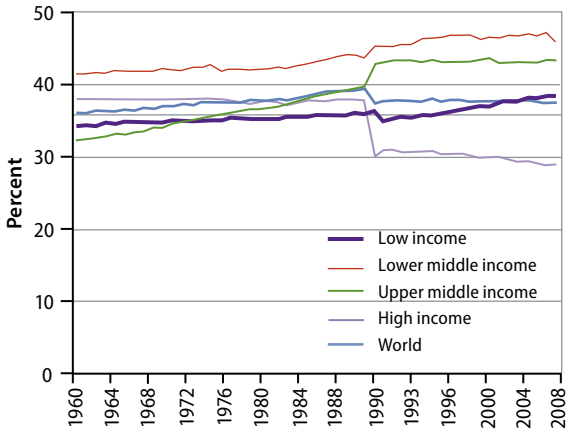
agriculture. Part of the issue is that as income and environmental awareness grow, the demand for use of land for other purposes—such as cities and roads, shopping areas, and other development—increases and competes with agriculture.

The relative stories of long-term land use in the developed versus developing regions of the world is very telling. Figure 7 shows the percentage of land devoted to agriculture by income group. Although the sharp changes in the early 1990s are likely due to data reclassification, the trends before and after that breakpoint are likely valid. As incomes increase, land usage trends away from agriculture. Thus, the last 10 years of data show that use of land for agriculture is either already decreasing or the rate of increase is slowing. Furthermore, because the high-income regions are in the more temperate parts of the world that tend to have better soils or have more capital with which to improve soil conditions and prepare land for agriculture, it seems logical to treat the percentage of land devoted to agriculture in high-income areas in 1960 as a notional limiting benchmark. This suggests that, as incomes continue to rise in the low-income and lower-middle-income countries, the appetite for using land for agriculture will either continue to decline or increase at a slower pace before starting to decline. The same applies to other inputs: citizens and consumers will tend to prefer to use them for purposes other than food and agriculture, such as preserving or even increasing various environmental amenities.

Figure 7. Percentage of land devoted to agriculture, by income group



Source: World Bank (2016b).

A fourth important issue is that despite sufficient average caloric availability, food deficits exist because food distribution among countries—and, among populations within countries—follows income and wealth distribution. The depth of food deficit measures how much caloric availability would have to increase to bring the undernourished up to par, leaving everything else constant. In the least-developed regions of the world, this is approximately equivalent to 200 calories per person (i.e., normalized to the total population), or about 10 percent of the minimum necessary caloric consumption. In the developed world, the figure is 9 calories, or just about 1 percent of the minimum (FAO, 2014). The main correlate of this factor is poverty, and especially rural poverty.

In the past, analysis of poverty as a correlate of malnutrition has been hampered by the lack of data, especially the lack of reliable income or even consumption data. In the last 10 to 15 years, however, researchers have found that constructed asset indices from household surveys such as those by the Demographic and Health Surveys Program are a reasonable way to study the poverty correlates of many social factors. Gwatkin and others (2007) produced a massive number of tables showing the inequality correlates for various indicators and many countries, often with repeated measurements over time. For key poor health and malnutrition indicators, prevalence among the top wealth quintiles was about half of prevalence among the bottom quintile. One of the key conclusions of simulations carried out with the data is strong, "the standard practice of stating health goals in terms of population-wide average rates provides little assurance that the poor will share fully in progress towards them. The poor stand to benefit more from objectives set in distributional terms…" (Gwatkin et al., 2007, p. 12).

The impact of poverty varies depending on the indicator. For example, the prevalence of severe stunting is roughly 66 percent less prevalent in the top wealth quintile than in the bottom one, whereas prevalence of moderate stunting is only about 45 percent less prevalent.

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A fifth issue is key micronutrient deficiency. Using the available data for all of Sub-Saharan Africa as a rough proxy for low-income countries, and applying the median over a whole decade (because data are spotty), 69 percent of children under 5 are anemic, 54 percent of children under 5 have vitamin A deficiency, 29 percent of the population have iodine deficiency, and 54 percent of pregnant women are anemic. Conservatively speaking, the micronutrient nutrition problem would seem to affect half of the population of low-income countries (FAO, 2014).

A final important issue is that we cannot extrapolate the trends we see today into the future. For example, although cereal yields have increased linearly for the last few decades, the rate of change is now decreasing globally (i.e., the second derivative with respect to time is negative), and the average percentage yearly increase is relatively low at about 1.7 percent (see Ray et al., 2012). The World Bank (2007, see Figure 2.12) makes the same point. Land use and other resources seem to be reaching limits, although these limits may be social and economic, in the sense that as incomes rise, populations put increasing value on nonagricultural uses of land and water and perceive the risks due to agriculture's contribution to global warming as more serious.

A useful but extremely simple view of the likely "collision" between rising demand trends and supply trends can be ascertained by looking first at an equation for demand growth, $dD/D = e\ (dP/P + dI/I)$. In this equation, dD/D is the percentage increase in food demand, e is the income elasticity of demand, dP/P is the rate of growth of population, and dI/I is the rate of growth of per capita income. The growth in supply can be modeled, very roughly, as $dS/S = dL/L + dY/Y$, where dL/L is the percent increase in land usage, and dY/Y is the growth rate of yields. Disaggregating the extrapolation is useful because it alerts us to potential imbalances in the low-income countries (see Table 1).

Table 1. Supply versus demand: a simple extrapolation via an accounting decomposition approach

	Low-Income Countries	World	Source
Demand factors			
Per capita income growth rate	3.7	2.7	Leimbach et al. (n.d.), scenario SSP2, roughly in line with Alexandratos and Bruinsma (2012)
Population growth rate	2.2	0.73	Estimated from World Bank (2016c)
Income elasticity of demand	0.65	0.50	Estimated from Regmi et al. (2001) and Muhammad et al. (2011)
Demand growth rate	3.8	1.7	Income elasticity of demand × (Per capita income growth + Population growth)
Index of demand in approximately 30 years based on index value of 1	3.1	1.7	(1 + Total demand growth rate)^{30}
Supply factors			
Yield growth rate	1.0	0.7	Estimated from quadratic extrapolation of data from World Bank (2016b) and Alexandratos and Bruinsma (2012)
Land area growth rate	0.6	0.1	Estimated from quadratic extrapolation of data from FAO-STAT (2016) and from Alexandratos and Bruinsma (2012)
Supply growth rate	1.7	0.8	Yield growth rate + Land area growth rate
Index of supply in approximately 30 years indexed on 1	1.6	1.3	(1 + Total supply growth rate)^{30}
Growth rate of balance	-2.1	-0.9	Supply growth rate—demand growth rate
"Shortfall" in approximately 30 years[a]	0.9	0.3	(Index of demand and end of period—Index of supply at end of period)/Index of supply at end of period

[a] The word shortfall is in quotation marks because the numbers presented are not a forecast but an extrapolation of trends, the notion is not based on any normative sense of sufficiency, and it does not make any assumptions as to the level of sufficiency in baseline, other than in a definitional market equilibrium sense.

Note: Numbers should be considered approximate and heuristic only. For example, definitions of *low income* vary by source, data on arable land are often only estimates, and yields refer only to cereals. While some of the variables grow only linearly, the growth rates shown are estimated so as to give the same end value as largely linear trends where relevant. Growth rates are useful in conveying the average yearly differences between the yearly changes in key variables, which would be harder to interpret if they were in absolute terms.

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The decomposition using ratios and percentage growth rates, as opposed to absolute units and linear growth, shows where the pressures are coming from, and that the distribution of the pressures is very uneven across countries. For the world as a whole, food production would seem to have to increase by about 70 percent by about 30 years from now according to this simplified approach. Extrapolating supply trends suggest a growth of about 30 percent over those 30 years. The difference between the two equations amounts to a growth rate of -0.9 percentage points per year in a pressure imbalance. For the low-income countries the difference is -2.1 percent, because both population and income would be growing faster there. A 3.8 percent increase in demand from the low-income countries would imply a doubling of demand there in the next 20 or so years. Demand in the upper-middle–income and high-income countries is much more stable because, at their higher levels of income, the income-elasticity of demand is lower, the population is growing very slowly, and income per capita is also growing relatively slowly. Combining the projections of demand in both segments of the global market leads to the forecasted large increases in needed supplies and shows the imbalance between the world's average and the needs in the low-income countries.

This is not meant as a forecast or as doomsday mongering. Our analysis makes the classical Malthusian "error" of ignoring technical change, assumes that income elasticity of demand is fixed, ignores the role of prices, and does not account for the reactions of societies and institutions to events. That is, the equations are not independent of each other, and they ignore other issues. If consumers, because of increases in income, want both more food (or more resource-intensive food) and also want to use water and land for nonagricultural purposes, and now have the income to demand environmental amenities, policy solutions will have to be found—various organizations will have to play a role in finding solutions. So, the contrast between demand and supply is useful only in terms of highlighting the magnitude of technical change (either through discovery or adoption) or responsiveness of prices and consumption patterns that has to be assumed or generated through policy change, research, farmer training, and other efforts.

On the other hand, the model may be too optimistic given climate change. Since the publication of the Fourth Assessment Report (Intergovernmental Panel on Climate Change [IPCC], 2007), researchers have made several efforts to make global climate models more granular to evaluate regional and local impacts of climate-related changes. The performance of agriculture is expected to be hurt by predicted declines in rainfall and temperature increases. Climate change is affecting the reliability and predictability of water availability throughout the world. In arid and semiarid regions, which benefited from investments in irrigation during the Green Revolution, climate risks could upend carefully crafted policies aimed at maximizing yields in agriculturally favored lands (World Bank, 2013, 2014a). If the world warms by 2°C—which may be reached in 20 to 30 years (World Bank, 2013)—this may cause widespread food shortages, unprecedented heat waves, and more intense cyclones.

Projections suggest that climate change will reduce the rate of increase in agricultural productivity. The yields of our most important food, feed, and fiber crops decline precipitously at temperatures much above 30°C (World Bank, 2014a, p.22).

In short, the long-term challenges—such as an increasing global population with more than 800 million people classified as "rural poor" (defined at the $1/day level) but whose incomes (and that of their urban counterparts) are increasing; the degradation and depletion of natural resources, particularly water and suitable cultivable lands; and the impact of climate change—require innovative thinking about sustainable management of both high-potential areas and marginal environments.[1]

[1] For purposes of this review, marginal lands or marginal environments more generally are defined as lands that occupy large areas in the world and, within the limits of current technology, have low inherent productivity for agriculture.

Some Dominant Issues in Agricultural Policy

We now turn to examining the issues as they emerge explicitly from the strategies of the World Bank, FAO, USAID, OECD, IFAD, DFID of the UK, CGD, CGIAR, IFPRI, the Chicago Council, the Gates Foundation, and IDB, ADB and AfDB. The objective of policy makers, development planners, and agricultural and environmental specialists is to employ the reliable policy and technological tools needed to sustain and expand the impressive achievements in agricultural productivity and its contribution to economic growth over the last five decades, and to advance climate-smart agriculture to new frontiers.

Agency strategies and policy often discuss needs somewhat indistinctly from strategies aimed at addressing the needs. Over time, strategies become so entrenched in agency thinking that obstacles to the better use of those strategies start to become issues on their own. For that reason, we discuss a set of issues that comprise both needs and strategies. Four issues in particular dominated much of the thinking over the period from approximately 1960 to about 2000: increasing productivity, enhancing the role of the private sector, reducing poverty, and increasing investment in science and technology. Table 2 summarizes these and other issues of concern. In addition, the Appendix discusses, documents, and ranks the apparent importance of each issue to each donor agency. We describe these as "apparent" because the ranks are assigned based on the depth of concern each agency expresses in policy documents, not necessarily in budget priorities. For example, while it is fashionable to talk about climate-smart agriculture, many development agencies' projects are still largely focused on traditional production issues. Nonetheless, paying attention to the face value of policy attention is useful: (a) agencies can be asked to live up to their claims by governments and civil society, and (b) reality often lags policy statements.

Table 2. Summary of current agency policy concerns

Food security	**Very high**
Institutional and policy reform	**Very high**
Increase productivity	**High overall**
Research, science and technology	High
Extension services	Medium
Diversification toward nonfood crops	Low
Producer organizations	Low
Modernize irrigation	Medium
Livelihood welfare and poverty reduction	**High overall**
Rural organization	Medium
Community-driven development	High
Household income	Medium
Rural infrastructure	**High overall**
Roads	High
Markets	High
Marketing and trade policy	**Medium overall**
Domestic markets and supermarkets for high-value crops	Medium
International trade	Low
Risk management in trade	Low
Natural resources	**High overall**
Water	High
Land	Medium
Forests	Medium
Emissions (air)	High
Nonfarm employment	**Medium**
Land policy and land markets	**Medium**
Gender	**High**
Environmental sercices and climate-smart agriculture	**High**[a]

[a] This is one particular example of where face value policy concern may not be matching budgetary allocations or investments.

Note: See the appendix for a detailed sampling of agencies' policies.

In the sections that follow, we take up an issues-based discussion of the main issues. Note, however, that the organization of these sections does not strictly follow the layout of the table. Our focus tended to select issues of productivity, poverty, and climate-smart agriculture based on our professional judgment of the interest in those issues of the development agencies. Thus, subsequent sections do not take on all of the issues in this table or, when they do, not necessarily sequentially and directly.

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Increasing Productivity

Increasing Food Production

Focusing on food production as a strategic approach has done the most to shape the framework for agricultural development of most agencies. This strategy was initially influenced by the simple model introduced by the pioneers of the Green Revolution and focused on developing scientific tools to narrow the yield gaps of major food crops.

The yield gap is the difference between yield obtained on the farmer's field and yield potential calculated through scientific experiments. A less ambitious notion of a yield gap, which we tend to use in this paper, is the difference between actual yields and those under "best practice" but non-experimental conditions.

Evanson (2004), Hazell (2009), and Pingali (2012) provide detailed evidence of the impact of improved varieties, associated field-tested cultivation practices, and accompanying policy innovations on increasing yields and raising income in many countries. Global rates of adoption of modern varieties and improved production practices are significant, especially in high-potential areas where moisture is adequate, land is fertile, and growing conditions are hospitable.

The achievements of the Green Revolution were accompanied by a negative trend in investment in agriculture in the 1980s and 1990s. Policy planners and market-oriented economists argued that the basic problems of enhancing agricultural development were adequately addressed and that the sector should be guided by the dynamics of the market. The real prices of wheat, rice, and maize followed a mostly downward trend for decades, as production generally outpaced demand. The downward path was accompanied with moderate fluctuations. The overall downtrend in prices was largely due to the remarkable success of modern agricultural technology adopted by farmers and supportive policies in continually developing and adopting high-yielding varieties (Wright, 2012).

The low commodity prices in the 1980s and 1990s discouraged investors from expanding investment in irrigation, research and extension, and other agricultural institutions, especially credit and market stabilization. As previously described, investment in agriculture by major development agencies declined substantially (see Figure 1) for several years as the World Bank and regional development banks, along with USAID, DFID, Ford Foundation, Rockefeller Foundation, and other donors, shifted resources to other sectors, until the spike in food prices around 2008 (see Figure 5) caught the attention of policy makers.

Economists generally agree that the surge in food prices resulted from a combination of factors. These include higher fertilizer and fuel prices, increased competition for grains to feed livestock and poultry demand from the populations with higher income in middle income countries, diversion of agricultural land for feedstock crops driven by biofuel production, reduction of grain stocks in some OECD countries and China, adverse weather conditions in some countries, reemergence of grain diseases such as wheat rust in major producing countries, and stagnation in investments to increase grain productivity in developing countries. Some of these pressures still exist; others are not so strong. As a result, the price spike has subsided, but the price volatility (see Figure 4) faced by low-income countries remains an issue.

New Frontiers for Increasing Food Production

The outlook for continued technological progress has both positive and negative elements that raise policy concerns. For the major cereals—rice, wheat, and maize—the growth rate of yields in developing countries has slowed since the 1980s (essentially, yields seem to be following a linear—at best—trend in the low-income countries, so that the percentage rate of increase goes down). The easy gains from high use of Green Revolution advances have already been achieved in most regions (recall Figure 5, Fischer et al., 2009). Plant breeders are increasing the yield potential of grain crops by about 1 percent annually, as compared with 3.1 percent in the 1970s and 1980s. Yields of major food crops have leveled off but global figures about advancing yields and improvement conceal regional differences (World Bank, 2007).

Special attention is needed in this area to enhance productivity in large areas where production environments are difficult and for which advances

in well-targeted technological research are needed (recall Figure 5 and the trend for the low-income countries). Historically, a significant part of yield gains has been achieved by narrowing the gap between average farm yields and the experimental yield potential of the crop, or, somewhat equivalently, between the poorer countries and the richer countries (which are typically in more temperate and productive lands, have more capital to invest in improving actual best practice yields toward the experimental optimum, or have a combination of these factors). This may happen up to a point where average farm yields reach about 80 percent of experimental yields—a benchmark that has already been reached in major cereal-producing areas in favorable agricultural lands. Fischer and colleagues (2009) argue that sizable investments in agricultural research and development, such as heat- and drought-tolerant crops suitable to marginal lands and to areas likely to become marginal because of climate change, are needed to advance the frontiers of crop yields to meet growing challenges.

Redefining the Public and Private Sector Roles

New thinking about the role of the public and private sectors is needed to sustain and stabilize the achievements of the Green Revolution to increase food production, enhance rural growth, and reduce poverty (World Bank [2007] is a canonical example but also see King et al. [2012] and Barry & Horsh [2000]). The role of the state in advancing the performance of agriculture has been revisited to better define areas where public policy and investment are needed to protect and enhance public goods and to create healthy economic environments conducive for the private sector to expand investment in agriculture. The increasing income in most developing countries, the expansion of urbanization, changes in lifestyles and food preferences, and globalization of markets and agricultural technologies require serious rethinking about future interventions by the state and the private sector.

During past decades, statism in food production became fashionable. Some countries (even nonsocialist ones) collectivized agriculture, creating top-down "cooperatives" and other forms of direct attempts by the government to enter into production. These practices were not pervasive and did not advance much. More pervasive, however, were deep state interventions in food and crop procurement, often at prices explicitly or implicitly meant to extract surplus from the agricultural sector. Also very pervasive were state-owned or state-sponsored input supply schemes, often subsidized and meant to somewhat make up for the disincentives to agriculture created by state-based low-price procurement, overvalued exchange rates, and other pro-urban policies meant to sustain a forced pace of industrialization.

The conjunction of low output prices, state-based procurement, opaque foreign exchange regimes, and subsidized inputs (including credit at below-market interest rates) created a morass of complex incentives and disincentives that prevented farmers from devoting resources to the activities in which their countries had true comparative advantage. The prices and incentives faced by farmers differed greatly from the "real" prices of goods and services, leading to large-scale resource misallocations. Many of these policies have been dismantled, but further progress could be made.

While the pervasive state role has been rolled back, the private sector has expanded its role in input provision and in quality control of output through much more systematic procurement. In addition, prosocial private or communitarian sector—such as fair trade and other private—policies now also have a role. The role of both for-profit private sector and fair trade and other similar private policies is particularly relevant in the possible use of marginal lands to produce nonfood crops that can sustain livelihoods for poor farmers. But a private role in these segments of the market might require public investment in crop varieties suitable for marginal lands.

In short, the scope for disentangling public, private, and communitarian or social-investor roles is great. Better-informed policy dialogue, based on more evidence, is needed. Work between research scientists and communitarian and social investor nongovernmental organizations (NGOs) and firms would also help. Then, collaboratives that

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bring together the private sector (output buyers and input suppliers), farmers, and philanthropic organizations (such as the Gates Foundation) and official donor agencies, and use the research output, could lead to better use of lands and a better mix of private, social-investor, and farmer energies to improve food production and reduce poverty. All this would not imply a naïve view of the private sector, social investors, or even the communitarian sector as saviors of the situation. In particular, controlling externalities, building or at least financing infrastructure to cope with poverty and inequality, would continue to be strong public roles.

Poverty Reduction

Going Beyond Food Security

An important dimension of agricultural growth is its overall contribution to income and national development, above and beyond its contribution to food production. A broader view includes developing nonfood crops to improve incomes and the capacity to import foods (at the national level) or purchase food (for small farmers). The contribution of agriculture to foreign exchange and national income was a major driver in the pre–Green Revolution era. The production of fiber, beverages, and industrial crops, such as cotton, tea, coffee, rubber, palm oil, and other commodities, dominated world trade and was an essential ingredient for foreign investment in many tropical countries—often under conditions of neocolonialism and marginalization of local farmers, which partly explains why these sorts of crops have received less attention from policy makers concerned with equity.

A left-of-center critique (starting with and exemplified by Lappé [1971]), which sometimes pervades donor agencies and NGOs, has tended to sustain that export crops are inimical to food security and poverty reduction. However, there is nothing inherently neocolonial or anti-equity about the crops as such. In some countries, these crops are a boon to small farmers. In the future, they could be part of a package of noncolonialist solutions to both environmental and income issues by finding packages of export crops (along with inputs) that could be suitable for small farmers, and focusing policy on helping them access inputs and markets.

Although concern for food production and food security should remain a central theme, agricultural growth should take a broad welfare objective to allow the sector to contribute directly to growth and national income, and thereby contribute indirectly but solidly to food security. After all, the same logic that applies to industrial growth applies to growth of nonfood agriculture: some of the countries with greatest food security are industrial countries that grow very little food. The same logic can apply to the production of nonfood agriculture as a means to boost income and thus indirectly impact food security.

Developing countries produce the bulk of major fiber, beverage, and industrial crops. This is especially true in Africa where development agencies have focused on increasing the production of low-value food crops for local consumption, such as sorghum, millet, and cassava, instead of high-value exportable crops. Whether this approach to food security—as opposed to using such lands for nonfood crops that can then support higher incomes and the purchase of food—is a good strategy has not been sufficiently analyzed, and policy making has suffered from lack of evidence.

Limiting the investment needed to improve the productivity of high-value crops that are in increasing demand in world markets reduces the competitiveness of developing countries in these commodities. International trade in high-value fruits and vegetables is expanding rapidly as income rises and associated food habits and dietary practices change in middle-income countries. An example of increased investment in high-value fruits and vegetables is the expansion of the supermarket sector in most countries. While some might see this with some trepidation, it seems as if supermarket investment can enhance the role of the agricultural sector in increasing employment, reducing poverty, and increasing productivity (Reardon & Berdegué, 2002).

An important issue is to assess the competitiveness of traditional food crops or commercial high-value crops cultivated in most developing countries. In

the first case, poverty and hunger could be reduced by allowing farmers to consume more from their land (increased self-sufficiency). This development objective, however, may conceal or retard more promising opportunities for growth. For instance, Kenya would find it increasingly difficult to compete with Europe or the United States in the international maize market. The growing conditions and the institutional capacity needed to support Kenyan farmers are not as favorable as those available to farmers in OECD countries, but small farmers in Kenya competitively produce coffee, tea, and cut flowers for sale in OECD countries. It must also be kept in mind that global trade will increase access to these same commodities in low-income countries, provided that they can compete in the marketplace with other crops for which they truly have a comparative advantage.

The question of crop priorities and diversification for improving agriculture in low-income countries is central and, in effect, not much studied. Supporting a move towards diversification using nonfood crops would require supportive investment in rural infrastructure and rural markets and storage. Establishing development priorities for competitive crops thus goes beyond choosing a winner or which line of products agricultural strategies should bear.

Agricultural Growth and Rural Poverty

The main goal of the development strategies of most development agencies is to reduce poverty among both rural and urban populations. In the past, this was conceptually not separated from strategies for increasing food production. But this has started to shift, and should perhaps shift even more. The strategy for reducing poverty among the rural population has shifted away from advancing agricultural productivity to enhancing rural livelihood through locally designed development projects that are expected to enhance community participation and strengthen ownership by the beneficiaries, providing direct welfare support, creating nonfarm employment, improving the quality of social services in rural areas, and providing other benefits.

This approach allows for decentralizing the funding of local initiatives. IFAD, DFID, the World Bank, USAID, and the Gates Foundation, along with several international development agencies, have increased funding for rural development issues such as nutrition and health, women's issues, and rural child care. Funds allocated to centrally driven agricultural development, in the classical sense of increasing yields and production, were reduced in the 1990s with the understanding that community enterprises and local initiatives for village-level investment would allocate such decentralized rural development or community-based development funds according to their local priorities, which could include nonfarm employment and interventions aimed at directly improving rural welfare. However, Mansuri and Rao (2013) question the effectiveness of community-driven development.

Partly as a result of such efforts and partly because increasing productivity itself has helped, rural poverty is on the decline in many areas.[2] A large share of the gains has been due to better wages and lower prices, though these effects took time. In addition, the benefits were not confined to those immediately below the poverty line (Ravallion, 2009). More studies and demonstration projects are needed to assess the impact of community-driven development and livelihood projects that can simultaneously increase local food supplies and sustain growth in rural communities, thus addressing both production and welfare. However, there is debate about whether smallholders can effectively transit to becoming commercially successful, the degree to which food production can be a poverty-fighting strategy, and whether more direct welfare or income-development strategies (including help with outflow from the sector) are needed (see, e.g., Collier & Dercon, 2014).

[2] There is great unevenness around the world in terms of rural poverty reduction, with Asia and particularly China often dominating the picture. For a useful summary of overall reduction, but caution as to unevenness, see IFAD (2011).

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Investments in Science and Technology for New Issues

The issues discussed above represent the "classical" concerns of most donor agencies or development partners. In recent years, some newer issues have come to the forefront, even though the classical issues are not all addressed.

Limits of Land and Water

The scope for extracting value through further expansion of favorable agricultural lands is narrowing and is geographically possible only in parts of South America and sub-Saharan Africa (FAO, 2011). (Sustainable intensification, as an option, is discussed in the section "Farming Models for the Future" on page 13.) The past strategy, aimed at investing in high-input agriculture on the most suitable and high-potential lands for cropping, is reaching its limits in most other parts of the world. This underscores the urgency of any future strategy to look for opportunities to extract more economic value from marginal agricultural lands. The scarcity of good agricultural land has also resulted in so-called land grabs, by which companies or individuals typically from wealthy countries have purchased rights to land in poorer areas and then limited the ability of local farmers to use the land to produce food. This issue has been highlighted in the technical and popular press and is a manifestation of the competition for resources and its unfortunate consequences. (See judicial review brought against DFID for its alleged support of Ethiopia's villagization program as described in George [2013] and Human Rights Watch [2014].)

Alexandratos and Bruinsma (2012) present data to support the argument that trying to make the food production system sustainable using past strategies is not possible. They cast doubt on the possibility of business as usual—that is, using high levels of external inputs in agricultural production, increasing the share of livestock in total output, expanding cultivated land through reliable irrigation, and transporting products over long distances. They argue that resource constraints for agricultural production are becoming more stringent, while growth of yields is slowing down. This is a primary reason why officials in donor agencies and other opinion makers fear that world food production may not be enough to feed a growing population and ensure food security for all. Countries in many regions in the world have reached their limits in terms of expanding production either into high-potential areas or through expansion of irrigation.

The scarcity of land and water resources requires new paradigms for extracting value from marginal lands and arid and semiarid parts of the world (Alexandratos & Bruinsma, 2012). Their findings confirm an earlier presentation by the 2030 Water Resources Group (2009). Meeting competing demands for water will be a considerable challenge, but it is possible to close the growing gap between water supply and demand through investment in innovative water management systems and modern water technologies. The challenges of meeting the water needs to sustain irrigation in major regions of the world will require intensive investment in efficient field water technology, water policy, and water management, and in agricultural diversification for crops with low water demand. The challenges of water scarcity and irrigation will intensify as other sectors—such as urban areas, industry, and energy generation—increase competition for water resources, a natural outcome of population and income growth.

Effect of Climate Change on Productivity

As noted earlier, climate change will likely make the yield and productivity increases of the past half century unsustainable. The expected increased frequency and intensity of extreme weather events, such as droughts, floods, and cyclones, as well as pest threats will likely have the most important impact. At the regional level, the effects could be more pronounced. Crop mixes and crop yields will likely change.

Agricultural practices also have a negative impact on climate due to mismanagement of natural resources, deforestation, and ranching, which increases the emission of greenhouse gases. Recent modeling of the potential impact of climate change on agriculture

reveals that farming systems' performance—including crops and grazing land—might increase in the higher latitudes, mainly in temperate zones. Agricultural productivity in the countries in the lower latitudes may subsequently shrink to a level that can no longer sustain local food supplies. In addition, fishery resources could suffer from higher sea temperatures, and low-lying coastal areas will suffer from saltwater intrusion that could make irrigation and drinking water unusable.

Thus, developing means to both mitigate and reduce the impact of agriculture on climate change and reduce impact of climate change on agriculture, and increase the resilience of various systems to climate change, must continue to receive a great deal of attention.

Several CGIAR centers have expanded their search for new tools to address challenges caused by increasing resource scarcity compounded by climate change and the impact on productivity of major food crops. IFPRI's Global Food Policy Report provides important guidelines about a future course of action toward sustaining productivity and improved nutrition and food security. It projects a rise in food prices for most cereals and meat, reversing long-established downward trends that would have implications for the status of food and nutrition available to the poor (Marble & Fritschel, 2014).

Another important IFPRI study on food security attempts to address the challenges of climate change and increasing scarcity of land and water. This study provides a better understanding of future benefits from alternative agricultural technologies and assesses future scenarios for the potential benefits of these technologies on yield growth and production, food security, food demand, and agricultural trade. The study is based on several models designed to explore the impact of 11 alternative technologies, including land and soil treatments, water harvesting, drip irrigation, modern varieties, minimum tillage, and others (Rosegrant et al., 2014).

Farming Models for the Future: Innovations for Marginal Lands and Sustainability of Traditionally Productive Lands

Studies are under way to assess the possibility of reducing resource and environmental degradation, as well as improving economic growth and poverty reduction, through well-managed investments in marginal areas. In addition, creative thinking is needed to improve the livelihood of more than 800 million poor farmers who continue to cultivate resource-poor areas in many countries with inadequate technology to enhance productivity. Reports from Alexandratos and Bruinsma (2012), the World Bank (2007), and CGIAR (2000) provide useful insights on how to design a strategy to utilize marginal environments in developing countries. The strategy highlights the role of marginal lands in complementing efforts to reduce poverty, increasing the efficient use of natural resources for food and livestock, innovating with technologies for environmental services, and advancing opportunities to improve the livelihood of the millions of rural families trying to earn a living in these zones.

These three reports reviewed the status of global marginal agricultural lands, which are currently used for agriculture, grazing, or agroforestry (1.8 billion hectares). Such areas typically encompass mountains and tropical and subtropical lowlands or plateaus with poor soils and low fertility, with low-quality and limited quantities of irrigation water and unstable rainfall. The main suggestions in these studies include mainstreaming work to improve niche commodities suitable for marginal areas such as forestry, agroforestry, and fisheries, but with added emphasis on breeding drought- and heat-tolerant varieties, working on integrated soil nutrient and water balances and utilization, and other more environmentally friendly approaches to agricultural intensification and improvement.

Traditionally, strategies advanced by policy makers are based on the evidence that although investing in less-favored lands might have a greater direct economic impact on the poor living in those areas, investments in high-potential areas give higher net economic and social returns (compared to a

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targeted program of investments in marginal areas). The logic behind this argument has been that investments in high-potential areas generate more agricultural output and higher economic growth at lower investment cost than in less-favored areas. Faster economic growth leads to more employment and higher wages nationally, and greater agricultural output leads to lower food prices. Both would provide "trickle-down" economic benefits to the poor. For example, less-favored areas would benefit from cheaper food, increased market opportunities for growth, and new opportunities for workers to migrate to more productive jobs in the high-potential areas and in towns. Under this scenario, fewer people would try to live in less-favored lands, and this would help reduce environmental degradation and increase per capita earnings (Fan & Hazell, 2001; Pender & Hazell, 2000).

Two IFPRI studies challenge this traditional wisdom and present a well-reasoned case for investing in marginal areas (Fan & Hazell, 2001; Pender & Hazell, 2000). Marginal areas usually have a comparative advantage in some types of agricultural production, livestock rearing, or nonfarm activities. The diversity of situations in these marginal areas can leverage their unique comparative advantages to alleviate rural poverty, enhance the environment, and sustain balanced interactions among important elements of natural resources, such as land and water, with appropriate infrastructure and policies.

Based on these studies, creative models are being advanced to develop farming in marginal areas. The emerging markets for ecosystem or environmental services in marginal lands can significantly contribute to farm income, while investors fulfill their corporate social responsibility/global commons objectives through social and environmentally friendly investments. Ecosystem and environmental services present an innovative approach for creating markets for environmental amenities. They offer opportunities for agricultural producers, particularly those on marginal lands, to diversify away from traditional systems and increasingly move toward farming systems that use resources in such a way that valuable societal or environmental output or services are supplied.

The World Bank, in partnership with several donors, is promoting such diversification through the BioCarbon Fund (World Bank, 2013, 2014a, 2014b).[3] The fund works with two other carbon funds: the Prototype Carbon Fund for energy-related projects and the Community Development Fund, which concentrates on small-scale energy and biocarbon projects in the least-developed countries. These initiatives are direct results from the Kyoto Protocol. The BioCarbon Fund will finance two types of activities: (1) reforesting of deforested or degraded land through small-scale reforestation, community forest management, agroforestry, and other methods; and (2) activities such as rehabilitating grazing lands, increasing soil carbon storage, and establishing wider landscape management plans. Unlike conventional commodity crops, these new global environmental commodities and services (e.g., carbon sequestration, preserving native biodiversity, biodiesel production, watershed protection, aquifer protection, mitigation of drought risks through income diversification) have the potential to generate revenues for farmers without the need for costly harvesting, processing, or transport to markets.

A key issue is to explore the trade-off between production of environmental services and food security. The move toward biofuels, and even the subsidies of alcohol produced from sugarcane and maize, were well-intentioned attempts to use land to provide environmental services. But the consequences were not sufficiently explored via serious modeling. What turned out to be foreseeable consequences (e.g., nutrient runoff, destruction of wetlands) were not sufficiently taken into account, and thus were either unforeseen in practice or not heeded because of insufficient modeling analysis and policy debate or dialogue.

[3] Since its creation in 2004, the BioCarbon Fund has allocated resources to projects that transform landscapes and directly benefit poor farmers. It was the first carbon fund established in the world to focus on land use. Housed within the Carbon Finance Unit of the World Bank, the BioCarbon Fund is a public–private-sector initiative mobilizing financing to help develop projects that sequester or conserve carbon in forest and agro-ecosystems. It has been a pioneer in this sector, developing the infrastructure needed to pilot transactions and paving the way for the growing land-use carbon market established to date.

The debate about developing marginal areas revolves around three complementary options: (1) enhance the contribution of these areas toward mitigating climate change by developing special models for environmental services; (2) develop niche crops or farming systems suitable for these areas, such as tree crops and industrial crops; and (3) develop technologies for improving food crops to feed the rural poor households residing in these areas. An important dimension in this debate is the scale of adoption of any of these options among the farming communities cultivating marginal areas. The large diversity of marginal lands requires new development models suitable to local conditions. There is no simple formula for designing a unified strategy for the highly heterogeneous marginal areas because the causes of marginality differ from place to place.

In spite of these new initiatives to cultivate marginal areas into climate-related options, some governments would not be able to use environmental services to justify sufficient transfer of expenditures to provide alternative income for the poor residing in these areas. In addition, some growers may be unwilling to retire land for nontraditional income, seeing it as a risk due to undemonstrated, credible benefits and slower return on investment.

Agriculture in many countries is in a state of transition to meet evolving challenges. Much has been written about maximizing return on investment in high-potential world regions where moisture is adequate, land fertile, and institutions well developed. Detailed evidence has been provided about increasing yields and productivity as the results of adopting improved varieties, associated field-tested cultivation practices, and accompanying policy innovations and community participation and decentralization, which raised income from farming operations in several countries. But more research and investment are needed.

Many countries have limited their scope for production to well-endowed and high-potential areas for agriculture. The current body of knowledge about such issues is limited. Further investment is needed in analytical work and modeling to maximize return on investment in marginal regions in developing countries where moisture is inadequate, soils poor, and institutions not fully developed in terms of research and extension and markets. Special studies are needed to study and assess the suitability of the marginal areas for diversified production systems, including tree crops, forestry, livestock, and environmental services. Important dimensions of such research should address policy innovations, the role of the private sector and community participation, and decentralization of investment in these areas.

Adoption of Farming Models and Associated Technologies

Despite decades of study and extensive research on barriers to adopting new farming models, the drivers of adoption either are still not well understood or not acted upon (Jack, 2013). This will be especially problematic for the relatively complex techniques aimed at helping increase incomes from marginal lands or mitigate or adapt to climate change. It will continue to be important to better understand the main factors influencing the adoption of new farming models and associated technologies rather than determine which specific particular technologies, such as a new rice or wheat, should be adopted. There is also a need for protocols to measure and verify the benefits of adopted technology and best management practices.

Small farmers are not only dealing with more complex ecosystem pressures. They are likely to be different from big farmers as well as more different from each other than big farmers are from other big farmers. Small-scale complex systems differ from each other more than large-scale monocropping and intensive feedlots systems differ from each other. Thus, small farmers require more specialized research and extension adapted to their more particular circumstances.

This issue is important because agricultural experts in both public and private institutions emphasize the growing interest and support for improvement of conventional and molecular breeding, as well as molecular genetic modification, to adapt our existing food crops to increasing temperatures, decreased

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water availability in some places and flooding in others, rising salinity, and changing pathogen and insect threats. Another important dimension to modern cultivation is increasing crops' nitrogen uptake and use efficiency, because nitrogenous compounds in fertilizers are major contributors to waterway eutrophication and greenhouse gas emissions. It may be difficult to push current crops to perform as well as they do now at higher temperatures and with less water and other inputs. It will take new approaches, new methods, and new technology—indeed, perhaps even new crops and new agricultural systems (Federoff et al., 2010).

Recommendations for Action

The previous discussion identified the main issues guiding intervention in the agricultural sector by key international development agencies. Some of these issues—such as achieving food security and poverty reduction, sustaining and enhancing the productivity of small farmers, and assisting in building and strengthening institutions and reforming policies—have defined the development objectives of most donor agencies. Some of these issues are persistent but could benefit from new thinking and approaches or from developing highly specific approaches for them. The first two subsections below deal with analytical work on specific issues; the third subsection deals with overall analytical and policy support work; and the fourth subsection deals with pilot projects and implementation opportunities. The recommendations do not derive from an analysis of particular papers or research projects and their presumed deficiency, but from the authors' overall sense of which of the issues in the foregoing sections require support of various kinds.

High-Leverage Actions on Persistent Issues

Design Studies to Compare Food Crops Versus Export Crops

Policy makers in Africa and elsewhere would benefit from well-designed studies to assess the trade-offs between producing low-value food crops and high-value export crops. Further studies and policy dialogue could elaborate on the impact of shifting priority of crop production on food security in Africa. Questions to focus on include: Will farmers in Africa benefit from this shift? Could the economy of concerned countries rely on arbitraging export of industrial crops for importing food crops where needed? Will exports generate enough foreign exchange to import food commodities? What are the income-distribution impacts, and the impacts on food affordability for the poor?

Studies of trade-offs could lead to better assessment of the interplay between increasing farmers' income (from industrial crops) and attaining food security either through investing in local production or imports from international markets. Related questions include: Is there a need to change current investment strategies to enhance the contribution of agriculture to economic growth, especially in Africa? How can one combine that, if at all, with the intensified use of marginal lands by supporting or tweaking various agroforestry/livestock systems? How do we model all this?

Study the Response to Scarce Water Resources

Another area of concern is the use of increasingly scarce water resources for the production of low-value food crops. Ongoing studies on water productivity and crop productivity have not provided clear signals to guide policy makers toward efficient policy and managerial tools for allocating water for high social and economic returns. An overriding issue here is to study how farmers select crops to maximize the returns of water as a precious input, especially in dry areas. A related issue is to study how to understand farmers' willingness to adopt new technologies designed to conserve land and water resources where use of such technologies is initially slow to produce measurable results. Another area for further study is the increasing use of treated waste water for agriculture, and the costs and benefits of its recovery and use. Factoring in better use of water rights (e.g., interbasin transfer), through markets, communities, and public action, is another important area for researchers to study. As water needs expand with urbanization, a new dimension of study is the interaction between the urban and agricultural sectors and the need for guidelines for allocating water to them.

Review Farmer Adoption of New Technologies Needed to Mitigate Emerging Threats

Adoption studies have traditionally focused on how farmers have adopted innovations in agronomy or in improved seeds or pesticides to address easily identified diseases or insects, or relatively simple yield and production problems. (To call the adoption of, say, dwarf varieties, a "simple" problem is not to minimize the great achievement that this was. But the "new" tasks are more daunting.) Future challenges related to climate change and marginalization of resources will require expanding the scope of the adoption process and how farmers perceive these problems and their solutions. This is now overlaid on the adoption studies of the Green Revolution types of improvements—an area itself imperfectly understood (e.g., as in Prokopy et al., 2008; Prokopy et al., 2015). One could build on adoption studies by bringing in expertise on modeling, evaluation, and the extensive research that has been done in the health field to determine what precipitates behavior change.

High-Leverage Action on Emerging Areas

Several issues mentioned in this paper deserve increasing studies by international development agencies. Empirical knowledge on these topics could guide policy planning and investment related to these issues.

Consider Development of Marginal Areas

Marginal lands are being transformed into productive zones through investments in irrigation in the semiarid zones of India and Africa, or improved land management and watershed development on the Loess Plateau in northwest China. There is scope to restore and improve the use of these regions for innovative farming systems adaptable to the marginal resources of topography, water, and soils. Limited studies and assessments have been carried out to guide policy formation and investment and development of these regions, which cover large tracts of land in many developing countries.

More analytical work and modeling are needed to assess the suitability of marginal lands for traditional crops to reduce poverty, new farming systems to enhance the contribution of agriculture to environmental services, or niche crops and trees that could accomplish both poverty reduction and production of environmental services. Advances in information technology including geographic information systems (GIS) provide time-series data on the conditions of productive and marginal lands of the world. The application of new modeling techniques using GIS and other technologies to monitor the state of natural resources, crop coverage, forestry, and grazing lands would provide policy makers in developing countries with timely information about the status of these resources. Models are needed to update knowledge about trends in water quality and the state of water resources, both surface and ground water, to guide short- and long-term allocation policies.

Land Use Planning

Advances in socioeconomic and geographic mapping, combined with modeling, could provide planners with updated models of the changing socioeconomic and physical conditions in select regions. These tools can be used to guide policy decisions about intervening in poverty reduction and land use planning. Various government agencies and nongovernmental organizations could help explore and develop these analytical tools for concerned development agencies to articulate policies and strategies needed to invest in marginal areas with a special emphasis on tracking changes in socioeconomic standards and land use patterns, and assess niche crops and associated farming systems suitable for the repercussions of climate change.

Enhanced Diversification of Agriculture Beyond Food Crops: Focus on Small Farmers

The review identified promising areas for growth for small farmers who produce commodities increasingly needed in world market, such as coffee, tea, cocoa, cotton, palm oil, and rubber. Because development strategies have concentrated on food security and poverty reduction, these commodities have received little attention from government or donor agencies in terms of policy analysis, technology development, and advances in data and information systems for markets, trade and processing services. The private sector has been the main driver of change in these commodities.

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Studies have confirmed the valuable contribution these commodities could provide to foreign investment and income earnings and employment throughout the value chain. There is ample scope to help producing countries shift from being suppliers of raw material to producers of finished products, which adds economic opportunities through the value chain. Several issues require further studies such as how expanding investment in value-added activities could increase rural employment, enhance nonfarm income, and improve understanding of how a typology of farmers—small, medium, and large farmers in both marginal and productive areas—approach and adopt or reject alternative farming options and crop choices and the socioeconomic factors that influence their decisions.

Analytical and Policy Reform Support Work

Donor Support to Evidence-Based Policy Debate on Persistent Issues: Modeling and Evidence-Based Policy Dialogue

Aside from possible research in the areas noted above, donors can support evidence-based debate by interacting with countries to improve modeling and process skills. Donor staff and NGOs (consulting firms, think tanks) should keep current with the debate-guiding strategies related to these issues to avoid duplication. They can also develop, where possible, innovative frameworks of analysis and modeling to update and guide policy development and associated intervention related to these issues: trade-offs between assisting small farmers to produce crops for export or food crops for local consumption; alternative management practices and crop choices of scarce water resources to agriculture; new models for water allocation among competing sectors (urban, industrial, and energy); and alternative cropping and agroforestry/livestock systems for sustainable intensification of production on marginal lands.

There are opportunities for donors to assist in crafting development strategies by designing analytical tools to assess why farmers do what they do and to understand important economic and social factors that facilitate choices and improve capabilities and comparative advantages. The assessment should also include studies of alternative policy options and investment opportunities that could guide allocation of resources to enhance diversification or specialization in promising commodities. Areas to consider range from the dynamics of international markets and associated policies that affect supply and demand to evolving technologies in production and processing that influence competitiveness and growth.

Donors and NGOs should develop and promote a scientific framework to guide responsive policies to address the interplay between agriculture and salient issues, such as climate change or food security and poverty reduction. As mentioned earlier, the relationship between agriculture and climate change requires thoughtful analysis because, as IPCC (2007) and other studies have argued, climate change will affect productivity and certain agricultural practices add to the emission of greenhouse gases. Donors are funding many activities to monitor the impact of various sectors (e.g., energy, urban, housing, agriculture, transport) on climate change. These reports provide little guidance to scientifically shape actions needed to reduce the negative interplay between agriculture and climate change. The food and agriculture sector would benefit from innovative activities to build reliable models for intervention. The controversial debate about converting food commodities such as maize, soya, and sugar into biofuel—causing spikes in food prices—indicates that more work is needed to expand our understanding of these issues through comprehensive modeling of the intervening factors between climate change and agriculture to guide policy formation, incentives, and future investment in the sector.

Ongoing modeling and analysis of poverty issues also ought not to be neglected. In spite of worldwide reduction in rural poverty, there are many unsolved problems in particular countries and areas. The interplay among resilience, poverty, and the potential use of marginal lands for intensification are issues that are poorly understood and on which countries require guidance. These analytical voids are too important to be left without adequate scientific guidance. Donors and NGOs can develop this knowledge by advancing modeling as a tool for guiding policy design and policy option.

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Appendix. Priority Ranking of Major Development Agencies' Strategies

This appendix presents a summary of the intersection between 11 primary international agricultural issues and 14 donor agencies (listed below) that provide funds for agricultural projects. We rated the various issues and policy priorities among the 14 agencies reviewed. The agencies were chosen because they provide approximately 24 percent of the funding to developing country agriculture and because, even if they do not grant or lend very much, they have intellectual influence (e.g., the International Food Policy Research Institute).

Each agency is assigned a rank of 1 (minimal involvement) through 5 (major support and interest) for its level of support for or involvement with each issue. The rankings are accompanied by a brief description of the agencies' activities, focus, and scope on the issues under discussion.

We based the table on our judgments and relied mostly on written documentation that may be, in some cases, a little dated, and hence cannot be taken to be totally representative of the agencies' priorities. While some agencies, such as the World Bank, IFAD, and FAO, update their strategies regularly to adapt to emerging issues, others do not. The table does give a general sense of which issues have received the most attention in the last few years across a large and diverse set of agencies. Also, there is a conflation of issues and policy approaches in the table, so the table does not focus only on the underlying problems. That is because the implementation of certain policy solutions is itself seen as a strategic issue within donor agencies.

The 14 international agencies and abbreviated forms of their names are as follows:

- African Development Bank (AfDB)
- Asian Development Bank (ADB)
- The Bill & Melinda Gates Foundation (Gates Foundation)
- Center for Global Development (CGD)
- The Chicago Council on Global Affairs (Chicago Council)
- Consultative Group on International Agricultural Research (CGIAR)
- Department for International Development (DFID) of the UK
- United Nations Food and Agriculture Organization (FAO)
- Inter-American Development Bank (IDB)
- International Food Policy Research Institute (IFPRI)
- International Fund for Agricultural Development (IFAD)
- Organisation for Economic Co-operation and Development (OECD)
- United States Agency for International Development (USAID)
- The World Bank

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Major issues ranked by importance to international agricultural development organizations

Rank[a]	Agency	Description
Environmental Issues		
5	World Bank	Increasing emphasis on impact of climate change on agriculture and natural resources. Finance adaptation, mitigation, and agricultural investment in carbon funds.
5	OECD	Focus on climate change studies, adaptation and mitigation strategies, and innovative agricultural practices.
5	CGIAR	Increasing attention to policy implications. Finance special research program on climate change studies and adaptation of food crops.
5	The Gates Foundation	Provide funds for a wide range of environmental programs and climate studies.
4	FAO	Conduct studies on climate change and options for climate-smart agriculture.
4	IDB, AfDB, ADB	Support environmental components in most investment projects and fund and participate in international projects for environment and climate change.
3	DFID	Support policy formulation to help countries design suitable action plans. Limited analytical work at country or regional levels to identify specific course of action.
2	CGD	Increasing attention to impact assessment.
2	IFAD	Impact of climate change on productivity but no special strategy for adaptation or mitigation.
2	USAID	Support studies on climate change.
Food Security		
5	The Gates Foundation	High in global support for analytical work and high in granting operations at country and regional levels.
5	FAO	High in global analytical work and high in country-level policy and discussion.
5	IFAD	High in global analytical work and high in country-level policy and discussion.
5	IFPRI	Priority attention to food security and nutrition and related policy analysis.
5	World Bank	Implement food security grants on behalf of multidonor funds to select countries in Africa and South Asia.
5	CGIAR	Research agenda highly focused on food security.
4	DFID	High on country-level investment in select regions and high-priority countries in Africa and South Asia.
3	IDB, AfDB, ADB	Overall strategy similar to the World Bank but limited analytical work. High in building international partnerships.
3	World Bank	Global- and country-level analytical work and sector studies. International partnerships. Investment policy dialogue.
3	IDB, AfDB, ADB	Low on country-level studies and support.
2	USAID	Implicit in overall strategy. No analytical work. High in building international partnerships.
2	DFID	Overall strategy for agricultural development. Limited country-level analytical work. High in building international partnerships.
2	OECD	High in global-level analytical work. Limited country-level sector studies and international partnerships but low in investment portfolio and in policy dialogue at country level.
1	The Chicago Council	Global-level analytical work to build international partnerships but limited engagement or operational work.
1	CGD	Limited work on food security and related policy studies.
1	USAID	Low on country-level studies and support.

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Major issues ranked by importance to international agricultural development organizations *(continued)*

Rank[a]	Agency	Description
Gender		
5	USAID	Encourage women experts to lead in agriculture and rural activities.
5	OECD	Cross-cutting theme in all interventions.
5	The Gates Foundation	Strong support for investment in schemes for women entrepreneurs. Facilitate opportunities for increasing participation of women in development projects.
5	CGIAR	Allocate special agenda teams in all research programs.
4	IDB, AfDB, ADB	Increasing emphasis on development project and financing of schemes for women in rural areas.
4	IFAD	Cross-cutting theme in all activities.
4	FAO	Special program for enhancing women's contributions to agriculture.
4	World Bank	Cross-cutting issue for all activities.
3	DFID	Emphasis on gender issues with a plan of action for how to expand support for women in rural in rural development.
Increase Productivity: Research & science and technology, extension services, diversification toward non-food crops, producer organizations, modernize irrigation		
5	DFID	Strong support to science and technology.
5	USAID	Strong support to science and technology.
5	FAO	Strong emphasis on increasing the efficiency of production of food crops and monitoring supply and demand.
5	IDB, AfDB, ADB	Strong support to science and technology.
5	IFAD	Strong emphasis on increasing the efficiency of production of food crops for small farmers.
5	The Gates Foundation	Strong emphasis on increasing the efficiency of production of food crops and monitoring supply and demand.
5	USAID	Strong support for the CGIAR.
5	IDB, AfDB, ADB	Strong support for the CGIAR.
5	DFID	Strong support for the CGIAR.
5	CGIAR	Research programs designed to increase productivity of more than 16 commodities of essential food crops and develop new technologies and assess adoption of innovations.
4	OECD	High in investment for research and development.
4	World Bank	High in investment for R&D in general with special focus on food crops with strong support for the
4	The Gates Foundation	High in investment for R&D in general with special focus on food crops with strong support for the
4	DFID	Increase support for non-food crops and support small farmers. Increased specialization in high-value crops and export commodities.
4	IFAD	Regional research organizations, especially in Africa. Support producer organizations and local civil society.
4	IFAD	Support the CGIAR.
4	OECD	Special focus on food crops with strong support for the CGIAR.
3	The Gates Foundation	Increasing support for producers' organizations.
3	CGD	More emphasis on science and technology in general.
3	IFAD	Support for small farmers commodities beyond food crops.
3	OECD	Increasing support for producers' organizations.
3	World Bank	Increasing support for producers' organizations.
2	CGD	Limited work on productivity.
1	DFID	Support research and extension and for producers organizations in select countries.
1	IDB, AfDB, ADB	Limited support for research and extension and for producers organizations.
1	CGIAR	No work on non-food crops.

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Major issues ranked by importance to international agricultural development organizations *(continued)*

Rank[a]	Agency	Description
Increase Productivity: Research & science and technology, extension services, diversification toward non-food crops, producer organizations, modernize irrigation *(continued)*		
1	OECD	Limited analysis of non-food crops and commercialization. Limited analytical work of diversification toward export commodities and how OECD countries can facilitate trade in tropical commodities.
1	OECD	Limited investment or analytical work or policy discussion at country level.
1	USAID	Limited support for research and extension and for producers organizations.
1	World Bank	Limited investment or analytical work or policy discussion on non-food crops.
1	The Gates Foundation	Support grants for, and investment in, analytical work of policy discussion. Limited work on non-food crops.
Land Use		
5	World Bank	Conduct studies on land policies and markets and assess impact of international investment in land markets for large-scale farming.
4	FAO	Collect and update data on markets and international investment in large-scale farming.
3	IDB, AfDB, ADB	Prepare country studies on land issues in selected countries. Limited investment in land markets.
2	IFAD	Little involvement in land studies except in supporting poor and landless labor.
2	The Gates Foundation	Provide grant funds to studying land issues such as registration and rights and titling in select regions.
1	The Chicago Council	Limited studies about land markets and international investment in agricultural lands.
Natural Resources		
5	CGIAR	Substantial resources to develop and test technology adoption for natural resources.
4	The Gates Foundation	Provides funds and supports studies on water and soil and provides grants for small projects in select rural communities in Africa and South Asia.
4	IDB, AfDB, ADB	Provide substantial resources for sustainable management of natural resources both in terms of studies and in investment operations.
4	IFAD	High priority for natural resources and managing water scarcity, especially in marginal lands where poor communities live.
4	OECD	High support for sustainable management of natural resources especially in Africa and Latin America.
4	World Bank	Strong emphasis on studies of investment in natural resources.
3	FAO	Conduct studies on status of land and water at global and regional levels.
3	USAID	Support resources, especially water, in selected regions.
3	World Bank	Emphasis on international partnerships in forestry and water management.
2	OECD	Support for sustainable management of natural resources to a limited extent in South Asia.
2	OECD	Limited support for national-level forestry programs but strong support for international partnerships in forestry management.
1	IFAD	Limited engagement in forestry.
1	CGD	Limited work.
Nonfarm Employment		
4	IDB, AfDB, ADB	Provide finance for employment schemes and in rural areas and conduct studies on local and regional labor markets for agriculture and other sectors.
4	World Bank	Support studies along with financial schemes to create nonfarm enterprises. Increase income among rural poor.
4	OECD	Strong support for growth in nonfarm activities to absorb labor from rural areas. Also support investment in value-added agriculture industry to create agriculture-related employment where possible.
3	The Gates Foundation	Provide financing for employment schemes along with studies on local labor markets to facilitate economic mobility for the rural population in select countries.

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Major issues ranked by importance to international agricultural development organizations *(continued)*

Rank[a]	Agency	Description
Nonfarm Employment		
3	IFAD	Attention to growing needs to find alternative employment for rural poor outside the agricultural sector.
2	FAO	Conduct studies on job opportunities outside agriculture.
2	USAID	Support rural poor in exiting the farm sector to increase income among rural poor.
1	CGIAR	Only IFPRI works on this issue. Other centers are not engaged in this issue.
Policy Issues		
5	The Gates Foundation	Support institution building and policy studies on the future outlook for agriculture and food supplies in the medium and long term.
5	World Bank	Support policy reform in producer prices. Reform in incentives and subsidies to producers. Support public and informal institutions and civil society engaged in agriculture and rural development.
5	CGIAR	Provide support for institution building and capacity enhancement and training.
5	IFPRI	Conduct extensive analytical work on institution and policy reform.
4	FAO	Support capacity building and conduct policy studies related to a variety of agriculture issues.
4	OECD	High on all aspects of intervention.
4	DFID	High on institution building, especially informal institutions and civil society.
4	USAID	Support capacity building and training of policy makers and managers and assist in policy adjustment
3	OECD	Strong emphasis on informal institutions and civil society. Limited support for private sector and cautious support for public institutions.
3	IFAD	Support for capacity building and institution development.
3	DFID	Limited on policy reform at country level. Support international partnerships in institution building through trust fund.
2	CGD	Limited focus on institutions with one paper on reform of FAO.
Poverty Reduction		
5	IDB, AfDB, ADB	ADB and AfDB allocate substantial resources to welfare and livelihood operations.
5	The Gates Foundation	Support for initiatives in livelihood operations; provide support to multisector operations, including health, food, and nutrition and nonfarm enterprises. Concerned with the welfare of small farmers and the rural poor.
5	World Bank	Increasing emphasis on community-driven agenda including non-agricultural enterprises for rural development. Support local institutions and community participation in setting policies and priority investment in social services including health and nutrition.
5	DFID	Strong emphasis on welfare and livelihood for small farmers and high-priority support for rural communities to exit from agriculture where needed. Support social services such as health and education and development of local enterprises.
4	OECD	Strong support for social organization and decentralization of rural development activities. High on non-formal organizations and civil society engagement in mobilizing action for agricultural and rural
4	IFAD	Target increase in farm income as essential tool to improve livelihood.
4	CGIAR	Priority attention to rural livelihood within the context of improved productivity.
3	IDB, AfDB, ADB	IDB supports investment in education and health for the rural poor and finances community-driven development.
3	FAO	Conduct studies on local agricultural issues that are critical to the rural development agenda.
3	IFAD	Support small farmers' initiatives and facilitate community-driven development in selected areas.
2	CGD	Limited work on issues related to livelihood of rural communities.

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Major issues ranked by importance to international agricultural development organizations *(continued)*

Rank[a]	Agency	Description
Rural Infrastructure		
5	World Bank	High priority to link rural communities to markets.
5	IDB, AfDB, ADB	Heavy investment in rural roads and markets and water schemes.
5	The Gates Foundation	Support substantial investment in rural infrastructure.
4	IFAD	Priority to rural assets serving small farmers, especially roads and markets.
4	OECD	High on supporting rural assets, especially roads and water supplies and markets.
4	USAID	Provide support on select countries within agreed program assistance to enhance domestic markets.
3	FAO	Supportive studies on priority rural infrastructure and locally relevant design.
3	World Bank	Conduct assessment of needs for rural infrastructure.
2	CGIAR	Only studies on rural infrastructure.
1	DFID	Emphasis on social assets with limited support for infrastructure.
Trade Issues		
5	OECD	Support studies on international trade and investment environment for the private sector and risk management studies to assess option for producers and marketers.
4	FAO	Monitor changes in competitiveness of domestic and international markets. Study options for crop insurance and risk management.
4	DFID	Support for the private sector through liberalization and financial incentives.
4	USAID	Support market development. Reform in trade and encourage risk management and crop insurance schemes.
4	World Bank	Support modernization of markets and reform market policies and price support to producers. Increasing search for initiative needed to enhance value chains for local supermarkets and risk management and crop insurance schemes.
4	DFID	Invest in facilitating trade for domestic markets through modernization of market infrastructure.
3	IDB, AfDB, ADB	Support country-level investment in modernizing market facilities and support trade studies in their respective regions, and provide technical assistance to select countries in these areas.
3	The Gates Foundation	Support modernization of markets and finance studies on trade issues both domestic and
3	The Chicago Council	Limited number of studies on international trade in agriculture.
3	CGIAR	Limited number of CGIAR centers focus on markets and trade of food grains.
3	DFID	Conduct studies on market development and trade reform.
3	IFAD	Support for local markets.
3	OECD	Conduct studies on local markets and trade.
2	OECD	Limited follow-up policy discussion with national agencies or investment in trade reform at the national level.
2	CGD	Limited work and few studies.
1	IFAD	Limited engagement in trade policy or analytical work on commodity trade or risk management.

[a] In some cases an issue may receive two rankings within the same agency. This is because an agency's policy or approach on the issue may be multifaceted. The ranking reflects the depth or dedication with which the policy or approach in the "Description" column is being implemented as of the time the policy statements were issued.

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