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Agricultural Research in Latin America and the Caribbean

A Cross-Country Analysis of Institutions, Investment, and Capacities

Gert-Jan Stads, Nienke Beintema, Sandra Perez, Kathleen Flaherty, and Cesar Falconi

APRIL 2016

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About ASTI

Extensive empirical evidence demonstrates that agricultural research and development (R&D) investments have greatly contributed to economic growth, agricultural development, and poverty reduction in developing regions. Numerous international and regional initiatives emphasize the importance of agricultural R&D to achieving the productivity growth urgently needed to feed expanding populations; reduce poverty levels; and address new challenges, such as those imposed by climate change. Agricultural Science and Technology Indicators (ASTI), led by the International Food Policy Research Institute (IFPRI) and operating within the portfolio of the CGIAR Research Program on Policies, Institutions, and Markets (PIM), contributes to this agenda by collecting, analyzing, and publishing quantitative and qualitative information and trends on funding sources, spending levels and allocations, human resource capacities, and institutional developments in agricultural research in low- and middle-income countries. Working with a large network of country-level collaborators, ASTI conducts primary surveys to collect data from government, higher education, nonprofit, and private for-profit agricultural R&D agencies in around 80 developing countries worldwide. ASTI's scope of activities also includes additional policy-relevant analyses of R&D investments, institutions, and human capacities in order to disseminate greater knowledge and understanding of their impact on agricultural development.

About IFPRI

The International Food Policy Research Institute (IFPRI), established in 1975, provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition. The Institute conducts research, communicates results, optimizes partnerships, and builds capacity to ensure sustainable food production, promote healthy food systems, improve markets and trade, transform agriculture, build resilience, and strengthen institutions and governance. Gender is considered in all of the Institute's work. IFPRI collaborates with partners around the world, including development implementers, public institutions, the private sector, and farmers' organizations. IFPRI is a member of the CGIAR Consortium.

About IDB

The Inter-American Development Bank (IDB) is the leading source of development financing for Latin America and the Caribbean. Established in 1959, IDB supports countries in the region to reduce poverty and inequality, improve health and education, and advance infrastructure. The bank's aim is to achieve development in a sustainable, climate-friendly way. IDB provides loans, grants, and technical assistance; and conducts extensive research. IDB maintains a strong commitment to achieving measurable results and the highest standards of integrity, transparency, and accountability.

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Related ASTI Outputs

- ASTI country factsheets, which contain a visual, highly accessible presentation of recent institutional, financial, and human resource trends in national agricultural R&D. The factsheets also feature a more in-depth analysis of some of the key challenges that individual agricultural R&D systems are currently facing, and policy options to address these challenges.
- Interactive country pages, available at www.asti.cgiar.org/countries, allow users to access detailed investment and human resource trends in agricultural research, and download factsheets and other information.
- ASTI's country benchmarking tool for Latin America and the Caribbean, available at www.asti.cgiar.org/benchmarking/lac, enables cross-country comparisons and rankings of key ASTI indicators.
- ASTI's data download and graphing tool, available at www.asti.cgiar.org/data, allows users to explore in-depth datasets and to filter the data by country and indicator.

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AgGDP	Agricultural gross domestic product
Anacafé	National Coffee Association [Guatemala]
APTA	São Paulo State Agribusiness Technology Agency
ARAP	Aquatic Resources Authority of Panama
ASTI	Agricultural Science and Technology Indicators
CARDI	Caribbean Agricultural Research and Development Institute
CATIE	Agronomic Center for Research and Education [Costa Rica]
CENGICAÑA	Guatemalan Sugarcane Research and Training Center [Guatemala]
Cenicafé	National Coffee Research Center [Colombia]
Cenicaña	Colombian Sugarcane Research Center
Cenipalma	Palm Growers' Research Center [Colombia]
CENIVAM	National Research Center for the Agro-industrialization of Tropical, Medicinal, and Aromatic Plants Species [Colombia]
CIAT	International Center for Tropical Agriculture [CGIAR]
CIMMYT	International Maize and Wheat Improvement Center [CGIAR]
CINCAE	Sugarcane Research Center of Ecuador
CIP	International Potato Center [CGIAR]
CIPRES	Center for Rural and Social Promotion, Research, and Development [Nicaragua]
ColPos	Postgraduate College [Mexico]
CONICET	National Scientific and Technical Research Council [Argentina]
CONICYT	National Commission of Scientific and Technological Research [Chile]
CORBANA	National Banana Corporation [Costa Rica]
Corpoica	Colombian Corporation of Agricultural Research
CTC	Sugarcane Research Center [Brazil]
CURLA	Regional University Center of the Atlantic Coast [Honduras]
DICTA	Agricultural Science and Technology Directorate [Honduras]
Embrapa	Brazilian Agricultural Research Corporation
FHIA	Honduran Agricultural Research Foundation
FIPAH	Foundation for Participatory Research with Honduran Farmers
FTE(s)	Full-time equivalent(s)
ICTA	Agricultural Science and Technology Institute [Guatemala]
IDB	Inter-American Development Bank
IDIAF	Dominican Institute of Agricultural and Forestry Research
IDIAP	Agricultural Research Institute of Panama
IFOP	Fisheries Development Institute [Chile]
IFPRI	International Food Policy Research Institute
IICA	Inter-American Institute for Agricultural Cooperation
IMARPE	Peruvian Marine Research Institute
IMTA	Mexican Water Technology Institute
INBio	National Biodiversity Institute [Costa Rica]
INFOR	Forestry Institute [Chile]
INIA	Agricultural Research Institute [Chile]

List of Acronyms *continued*

INIA	National Agricultural Innovation Institute [Peru]
INIA	National Agricultural Research Institute [Uruguay]
INIA	National Agricultural Research Institute [Venezuela]
INIAF	National Institute for Agricultural and Forestry Research Innovation [Bolivia]
INIAP	National Institute of Agricultural Research [Ecuador]
INIFAP	National Institute for Forestry, Agricultural, and Livestock Research [Mexico]
INIDEP	National Fisheries Research and Development Institute [Argentina]
INP	National Fisheries Institute [Mexico]
INTA	National Institute of Agricultural Technology [Argentina]
INTA	National Institute for Agricultural Innovation and Technology Transfer [Costa Rica]
INTA	Nicaraguan Institute of Agricultural Technology
INVEMAR	Marine and Coastal Research Institute [Colombia]
IPHAE	Institute for Humanities, Agriculture, and Ecology [Bolivia]
IPN	National Polytechnic Institute [Mexico]
IPTA	Paraguayan Institute for Agricultural Technology
ITCR	Technological Institute of Costa Rica
LAC	Latin America and the Caribbean
LAICA	Sugar Industry Association of Costa Rica
MFP	Ministry of Food Production [Trinidad and Tobago]
MNRA	Ministry of Natural Resources and Agriculture [Belize]
MOAF	Ministry of Agriculture and Fisheries [Jamaica]
NARI(s)	National agricultural research institute(s)
PISA	Innovation and Agricultural Services Project [Bolivia]
PPP(s)	Purchasing power parity
PROCIs	Cooperative Technology Development Programs
PUCC	Pontifical Catholic University of Chile
R&D	Research and development
SICTA	Central American Integration System for Agricultural Technology
UAAAN	Autonomous Agricultural University Antonio Narro [Mexico]
UCLA	Centroccidental Lisandro Alvarado University [Venezuela]
UCR	University of Costa Rica
UCV	Central University of Venezuela
UdelaR	University of the Republic [Uruguay]
UNA	National Agricultural University [Honduras]
UNA	National Agrarian University [Nicaragua]
UNA	National University of Asunción [Paraguay]
UNAM	National Autonomous University of Mexico
UNC	National University of Costa Rica
UNC	National University of Colombia
UWI	University of the West Indies

Introduction

Food security will continue to be one of the key global challenges in the coming decades. By the year 2050, the world will need sufficient food to feed 9.7 billion people—up from 7.4 billion in 2015 (UN 2015). Most of this population growth will be concentrated in developing countries, adding severe pressure to their development needs. According to some estimates, agricultural production will need to increase by 50 to 70 percent in order to meet future food demand, and all this will need to happen in a context of accelerating climate change, the effects of which are already being felt in the poorest and most vulnerable countries. Compared with many other regions around the world, Latin America and the Caribbean (LAC) is well placed to scale up its agricultural production and trade. The region's sources of comparative advantage lie, in part, in its abundant water and land resources. LAC's share of global agricultural trade rose from just 8 percent in the mid-1990s to 13 percent in 2015 (OECD and FAO 2015). Brazil, the region's economic engine, is now the world's second-largest supplier of food and agricultural products based on continued productivity improvements in support of fast-growing exports.

Agricultural research has been one of the key factors in increasing agricultural productivity in the region over the past decades, especially in countries like Brazil, Chile, and Uruguay (Nin Pratt et al. 2015). In order to measure, monitor, and benchmark the inputs, outputs, and performance of agricultural research and development (R&D) systems throughout LAC over time, quantitative data are essential. They are an indispensable tool when it comes to assessing the contribution of agricultural R&D to agricultural productivity growth, and economic growth more generally. Such data are also crucial for research managers and policymakers in formulating agricultural research policy and making decisions about strategic planning, priority-setting, monitoring, and evaluation.

This report assesses trends in investments, human resource capacity, and research outputs in agricultural R&D—excluding the private (for-profit) sector—in LAC. It is an update of Stads and Beintema (2009), covering a more complete set of countries and focusing primarily on developments during 2006–2012/2013.[1] The analysis draws largely from a set of country factsheets prepared by Agricultural Science and Technology Indicators (ASTI), which is led by the International Food Policy Research Institute (IFPRI), using comprehensive datasets derived from primary surveys and additional secondary sources targeting close to 700 agencies in 27 LAC countries.

Institutional Overview

The landscape of agricultural R&D in LAC is highly complex, comprising a significant number of government, higher education, nonprofit, private, and international research agencies. Note also that, because data for many private firms are not accessible, the private (for profit) sector is excluded from the analysis in this report. Data on the contributions of international agricultural R&D agencies operating in the region, such as CGIAR, are also excluded (Box 1). Agricultural R&D is defined to include research on crops, livestock, forestry, fisheries, and natural resources, as well as on-farm postharvest research.

In terms of agricultural researcher numbers, the government sector dominates agricultural R&D in more than half of the region's countries for which data were available.[2] For the region as a whole, government agencies employed 55 percent of agricultural researchers in 2012/2013, the higher education sector accounted for 40 percent, and nonprofit agencies for 5 percent (Figure 1). These regional averages mask a considerable degree of cross-country variation, however. In Brazil, the Dominican Republic, Ecuador, Panama, and Venezuela, the government sector employed more than 70 percent of each country's agricultural researchers, whereas in Mexico and Peru, roughly two-thirds of agricultural researchers were employed within higher education agencies. Over time, the higher education sector has steadily gained prominence in agricultural research, especially in Argentina, Bolivia, Costa Rica, Paraguay, and Uruguay. In Colombia and Honduras, the nonprofit sector (mostly comprising producer organizations) plays a particularly important role in agricultural R&D. In these two countries, the sector accounted for roughly 40 percent of the total number of researchers. Underlying these sectoral distributions are institutional structures that vary widely across countries (Table 1).

Agricultural research in Brazil's government sector is conducted at both federal and state levels. The Brazilian Agricultural Research Corporation (Embrapa) is the country's main federal agency, but most states also operate agricultural research agencies focusing on local issues. The vast majority of state-level agricultural R&D is carried out in São Paulo State. Brazil's higher education sector also plays an important role, having about 100 faculties or schools of agricultural sciences that conduct research. The National Institute for Forestry, Agricultural, and Livestock Research (INIFAP), is the main government agency involved in agricultural research in Mexico, but like Brazil a large number of other government agencies conduct research at both state and national levels. In Mexico, however, the majority of agricultural research is carried out by the higher education sector, with more than 100 separate faculties or university units involved in agricultural R&D. The principal public agricultural universities are the Postgraduate College (ColPos), the National Polytechnic Institute (IPN), and the National Autonomous University of Mexico (UNAM). In Argentina, the National Institute of Agricultural Technology (INTA) is the major government agency mandated to conduct both agricultural R&D and

BOX 1 | AN OVERVIEW OF REGIONAL, INTERNATIONAL, AND PRIVATE RESEARCH IN LATIN AMERICA AND THE CARIBBEAN

Regional Research. LAC has a large number of regional organizations that conduct or promote agricultural research. Some LAC countries have well-developed national agricultural research programs and produce technologies and methods applicable in countries elsewhere in the region and in the rest of the world. Cross-country collaboration is cost-effective because countries can more readily capture technology spillovers across geographical and national boundaries.

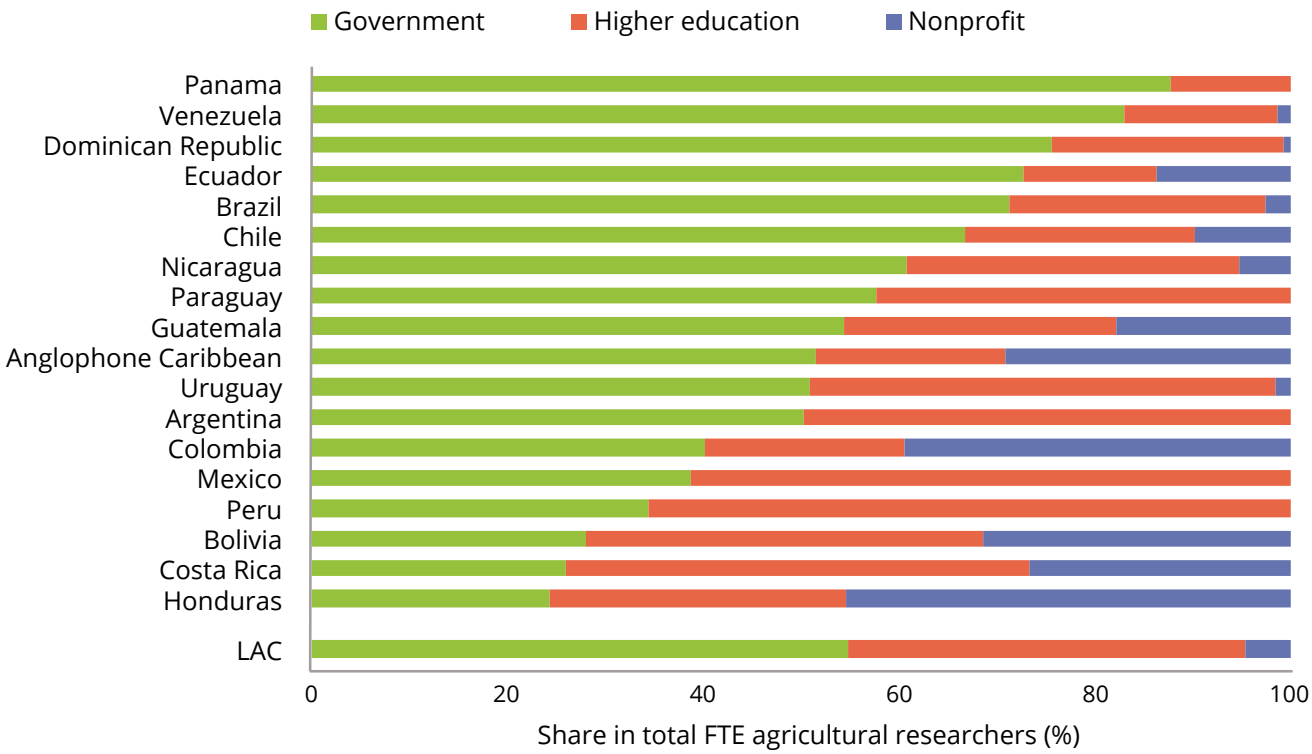
- The Inter-American Institute for Agricultural Cooperation (IICA), headquartered in Costa Rica, plays a useful role in coordinating, promoting, and facilitating sustainable agricultural development in the region. The institute works with all of LAC's countries, as well as a number of CGIAR centers and regional and other organizations.
- The Cooperative Technology Development Programs (PROCIs) comprise a group of subregional mechanisms, each formed by a group of national agricultural research institutes. PROCIs mainly focus on developing and strengthening institutions; designing and coordinating multi-country research projects; and promoting technology transfer. Currently there are four of such programs: PROCISUR (operating in Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay); PROCITROPICOS (covering Brazil, Bolivia, Colombia, Ecuador, Peru, Surinam, and Venezuela); PROCIANDINO (focusing on Bolivia, Colombia, Ecuador, Peru, and Venezuela); and PROCICARIBE (focusing on the Caribbean). The seven Central American countries have a similar system: the Central American Integration System for Agricultural Technology (SICTA).
- The Caribbean Agricultural Research and Development Institute (CARDI) is the main agricultural R&D agency in the Anglophone Caribbean. CARDI members include Antigua and Barbuda, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, and Trinidad and Tobago.
- The Agronomic Center for Research and Education (CATIE) is an autonomous nonprofit institution focusing on agricultural and rural development and natural resource management. Its member states include Bolivia, Colombia, the Dominican Republic, Mexico, Paraguay, Venezuela, and all the countries of Central America.

International Research. The majority of LAC's international research is carried out by the CGIAR Consortium. CGIAR's involvement in the region's agricultural development dates back to the 1960s. Three CGIAR centers are headquartered in LAC: the International Center for Tropical Agriculture (CIAT), in Colombia; the International Maize and Wheat Improvement Center (CIMMYT), in Mexico; and the International Potato Center (CIP), in Peru. In addition, 10 CGIAR centers have established more than 20 regional offices in the region.

Private Research. Private for-profit agricultural research is substantial in LAC compared with other developing regions, such as Africa and the Middle East. Argentina, Brazil, Chile, and Uruguay have particularly advanced agricultural technologies by world standards and have a sophisticated private input supply and postharvest handling and processing systems. Some LAC countries have provided tax breaks for private R&D, and many countries require private involvement in projects funded through competitive funds as a means of promoting the commercial viability of results. Many private firms also outsource their research needs to government agencies or universities, or import technologies from abroad.

Source: Stads and Beintema (2009).

FIGURE 1 | Institutional distribution of agricultural research, 2012/2013



Sources: Constructed by authors from ASTI data and various secondary sources.

Notes: Data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013. FTEs = full-time equivalents; LAC = Latin America and the Caribbean.

extension. Other important government agricultural R&D agencies in Argentina are the National Fisheries Research and Development Institute (INIDEP) and various agencies under the National Scientific and Technical Research Council (CONICET). The higher education sector is also prominent in Argentina, with the principal university involved in agricultural research being the National University of the Littoral, the University of Buenos Aires, the National University of La Plata, and the National University of Central Buenos Aires. The Colombian Corporation of Agricultural Research (Corpoica) is the largest of five government agencies involved in agricultural R&D, but Colombia has a large number of producer organizations that conduct research on a wide range of crops. On the whole, the higher education sector plays a comparatively modest role in agricultural research in Colombia. The dominant government agency in Chile is the Agricultural Research Institute (INIA), although two smaller government agencies focus on fisheries and forestry research. Of the higher education agencies in Chile, most research is undertaken by the University of Chile and the University of Concepción. With the establishment of a number of nongovernmental research centers over the past decade, the nonprofit sector has begun to play an increasingly important role in agricultural research in Chile.

TABLE 1 | The institutional composition of agricultural research in Latin American and Caribbean countries, 2012/2013

Country	Government	Higher Education	Nonprofit
Argentina	• National Institute of Agricultural Technology (INTA): 37% • National Scientific and Technical Research Council (CONICET) : 13%	• National University of the Littoral: 7% • University of Buenos Aires: 5% • National University of La Plata: 4% • National University of Central Buenos Aires: 4%	
Bolivia	• National Institute for Agricultural and Forestry Research Innovation (INIAF): 21% • International Center for Tropical Agriculture (CIAT): 7%	• University of San Simon: 25% • Public University of El Alto: 10%	• Institute for Humanities, Agriculture, and Ecology (IPHAE): 10%
Brazil	• Brazilian Agricultural Research Corporation (Embrapa): 42% • São Paulo State Agribusiness Technology Agency (APTA): 8%	• University of São Paulo: 2%	• Sugarcane Research Center (CTC): 1%
Chile	• Agricultural Research Institute (INIA): 45% • Fisheries Development Institute (IFOP): 15% • Forestry Institute (INFOR): 7%	• University of Chile: 7% • University of Concepción: 6% • Pontifical Catholic University of Chile (PUCC): 3% • Austral University of Chile: 3%	
Anglophone Caribbean	• Ministry of Food Production (Trinidad and Tobago): 17% • Ministry of Agriculture and Fisheries (Jamaica): 10%	• University of the West Indies: 17%	• Caribbean Agricultural Research and Development Institute (CARDI): 24%
Colombia	• Colombian Corporation of Agricultural Research (Corpoica): 29% • Marine and Coastal Research Institute (INVEMAR): 9%	• National University of Colombia (UNC): 5%	• National Coffee Research Center (Cenicafé): 8% • National Research Center for the Industrialization of Tropical, Medicinal, and Aromatic Plants Species (CENIVAM): 8% • Palm Oil Research Center (Cenipalma): 6% • Sugarcane Research Center (Cenicaña): 4%
Costa Rica	• National Institute of Agricultural Innovation and Technology Transfer (INTA): 29%	• University of Costa Rica (UCR): 28% • National University of Costa Rica (UNC): 14% • Technological Institute of Costa Rica (ITCR): 5%	• National Banana Corporation (CORBANA): 9% • National Biodiversity Institute (INBio): 8% • The Sugar Industry Association of Costa Rica (LAICA): 4%
Dominican Republic	• Dominican Institute of Agricultural and Forestry Research (IDIAF): 67%	• Agroforestry University Fernando Arturo de Meriño: 12% • National University Pedro Henríquez Ureña: 10%	
Ecuador	• National Institute of Agricultural Research (INIAP): 73%	• Catholic University of Santiago de Guayaquil: 6%	• Sugarcane Research Center of Ecuador (CINCAE): 6%
Guatemala	• Agricultural Science and Technology Institute (ICTA): 53%	• University of the Valley of Guatemala: 12% • University of San Carlos de Guatemala: 8% • Universidad Rafael Landivar: 8%	• Guatemalan Sugarcane Research and Training Center (CENGICAÑA): 9% • National Coffee Association (Anacafé): 9%
Honduras	• Agricultural Science and Technology Directorate (DICTA): 22%	• National Agricultural University (UNA): 18% • Regional University Center of the Atlantic Coast (CURLA): 8%	• Honduran Agricultural Research Foundation (FHIA): 34% • Foundation for Participatory Research with Honduran Farmers (FIPAH): 8%

TABLE 1 | The institutional composition of agricultural research in Latin American and Caribbean countries, 2012/2013 *(continued)*

Country	Government	Higher Education	Nonprofit
Mexico	• National Institute for Forestry, Agricultural and Livestock Research (INIFAP): 23% • Mexican Water Technology Institute (IMTA): 4% • National Fisheries Institute (INP): 4%	• Postgraduate College (ColPos): 10% • National Polytechnic Institute (IPN): 9% • National Autonomous University of Mexico (UNAM): 5% • Autonomous Agricultural University Antonio Narro (UAAAN): 4%	
Nicaragua	• Nicaraguan Institute of Agricultural Technology (INTA): 61%	• National Agrarian University (UNA): 27%	• Center for Rural and Social Promotion, Research, and Development (CIPRES): 5%
Panama	• Agricultural Research Institute of Panama (IDIAP): 63% • Aquatic Resources Authority of Panama (ARAP): 10%	• University of Panama: 14%	
Paraguay	• Paraguayan Institute of Agricultural Technology (IPTA): 58%	• National University of Asunción (UNA): 42%	
Peru	• National Agricultural Research Institute (INIA): 29% • Peruvian Marine Research Institute (IMARPE): 6%	• National Agricultural University La Molina: 44% • National University of San Marcos: 10% • Alas Peruanas University: 6%	
Uruguay	• National Agricultural Research Institute (INIA): 38%	• University of the Republic (UdelaR): 46%	
Venezuela	• National Agricultural Research Institute (INIA): 83%	• Centroccidental Lisandro Alvarado University (UCLA): 8% • Central University of Venezuela (UCV): 7%	

Source: Constructed by authors from ASTI data.

Notes: For more information on the agricultural R&D agencies operating in the countries of Latin America and the Caribbean, visit www.asti.cgiar.org/countries/lac. Percentages indicate each agency's share of its respective country's total number of agricultural researchers in full-time equivalents. Cuba, El Salvador, Guyana, Haiti, and Surinam are excluded.

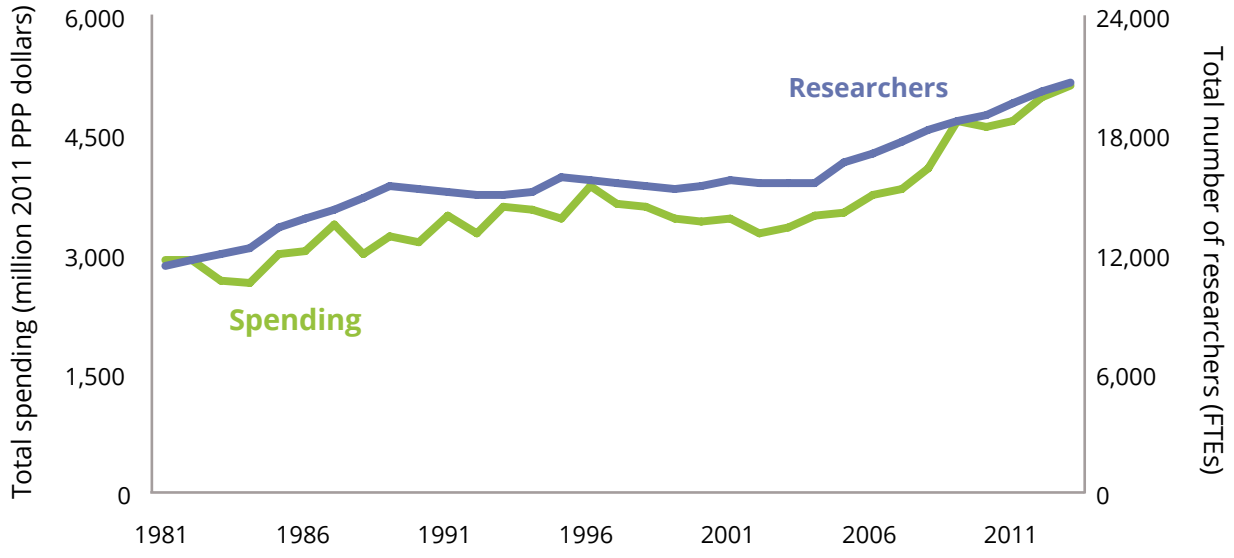
The region's remaining countries have very different agricultural R&D systems. The Dominican Republic, Ecuador, Nicaragua, Panama, Paraguay, and Venezuela, for example, all have a single national agricultural research institute (NARI) employing the vast majority of each country's agricultural research staff, and then a small number of specialist agencies. In contrast, the NARIs in Costa Rica and Uruguay account for only a modest share of national number agricultural researchers, and, instead, the higher education sector fills a stronger role. Agricultural R&D in the Anglophone Caribbean is scattered. With the exceptions of Jamaica and Trinidad and Tobago, the Ministries of Agriculture employ only few agricultural researchers, and most research is implemented by the Caribbean Agricultural Research and Development Institute (CARDI).

Long-Term Spending and Capacity Trends

Agricultural R&D spending in LAC (excluding the private for-profit sector, as previously discussed) was subject to considerable volatility throughout the 1980s and the early 1990s, followed by a period of steady declines until the early 2000s (Figure 2).[3] 2004 marked an important turning point in terms of R&D spending, with overall levels rebounding rapidly. By 2013, the region as a whole spent $5.1 billion on agricultural R&D, in 2011 PPP prices (see Box 2), representing a 75 percent increase over levels recorded in the early 1980s. Total researcher numbers—measured in full time equivalents or FTEs (see Box 2)—followed a similar, but less erratic, pattern characterized by rapid increases in the 1980s, a period of stagnation during 1990–2004, and rapid increases once again thereafter. In 2013, LAC employed close to 20,600 agricultural researchers (in FTEs), nearly twice as many as in the early 1980s.

Unsurprisingly, the regionwide growth in spending and researcher numbers was largely driven by LAC's three largest agricultural research systems: Argentina, Brazil, and Mexico. Throughout the 1981–2013 period, these three countries accounted for

FIGURE 2 | Long-term trends in agricultural researchers and research spending, 1981–2013



Source: Constructed by authors from ASTI data and various secondary sources.

Notes: Data exclude Cuba and Haiti. Data for subperiods were estimated for some countries; data on spending and researcher numbers for Guyana and Surinam were estimated for the entire period by multiplying AgGDP data for these countries with LAC's average intensity ratios over time. AgGDP = agricultural gross domestic product; FTE = full-time equivalent; PPP = purchasing power parity.

BOX 2 | QUANTIFYING AGRICULTURAL R&D SPENDING AND RESEARCHER NUMBERS

Purchasing power parities as the preferred measure of R&D investments

Comparing R&D data is a highly complex process due to important differences in price levels across countries. The largest components of a country's agricultural R&D expenditures are staff salaries and local operating costs, rather than internationally traded capital investments. For example, the wages of a field laborer or a laboratory assistant at a research facility are much lower in Bolivia than they are in any European country; similarly, locally made office furniture in Guatemala will cost a fraction of a similar set of furniture bought in the United States.

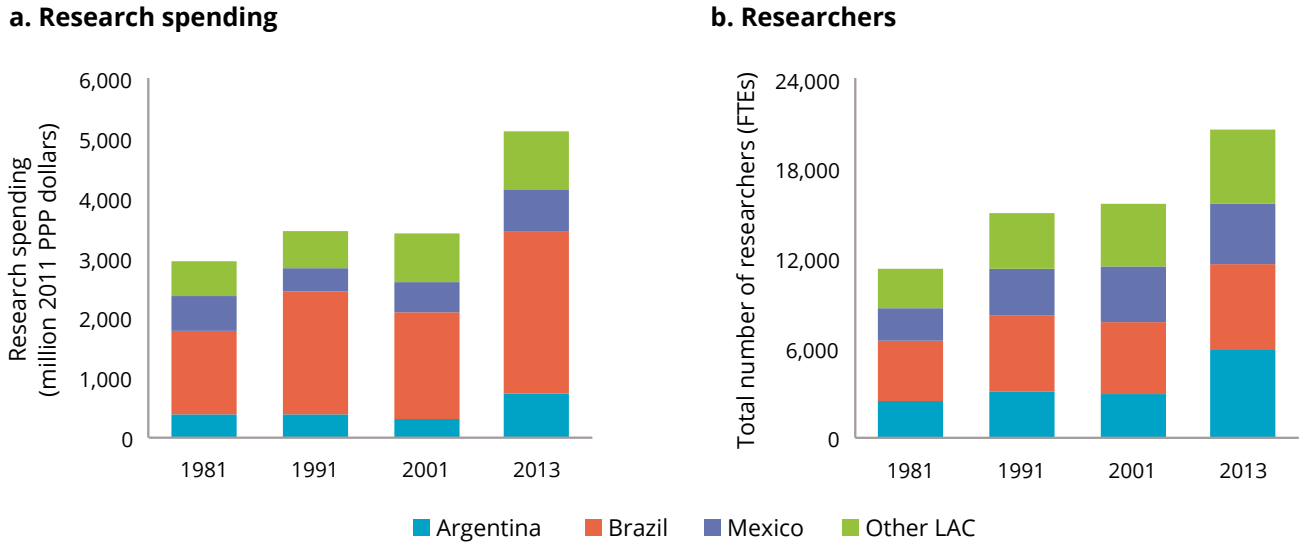
Standard market exchange rates are the logical choice for conversions when measuring financial flows across countries; however, they are far from perfect currency converters for comparing economic data. At present, the preferred conversion method for calculating the relative size of economies, or other economic data such as agricultural R&D spending, is the purchasing power parity (PPP) index. PPPs measure the relative purchasing power of currencies across countries by eliminating national differences in pricing levels for a wide range of goods and services. They are also used to convert current GDP prices in individual countries to a common currency. In addition, PPPs are relatively stable over time, whereas exchange rates fluctuate considerably (for example, the fluctuations in the U.S. dollar–euro rates of recent years).

The concept of full-time equivalent researchers

ASTI bases its calculations of human resource and financial data on full-time equivalents (FTEs), which take into account the proportion of time that researchers spend on R&D activities. University staff members, for example, spend the bulk of their time on nonresearch-related activities, such as teaching, administration, and student supervision, which need to be excluded from research-related resource calculations. As a result, four faculty members estimated to spend 25 percent of their time on research would individually represent 0.25 FTEs and collectively be counted as 1 FTE.

Source: www.asti.cgiar.org/methodology.

FIGURE 3 | Agricultural researchers and research spending in Argentina, Brazil, and Mexico, 1981–2013



Sources: Constructed by authors from ASTI data and various secondary sources.

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a combined total of roughly 80 percent of the region's spending and three-quarters of its agricultural researchers (Figure 3). Given their significant impact on regional trends, these countries warrant individual attention.

Argentina. The total number of agricultural researchers remained relatively stable from the mid-1980s until 2002. Between 2002 and 2013, however, increased government support and a sizable loan from the Inter-American Development Bank (IDB) prompted a large-scale increase in the country's agricultural research spending and capacity.

Brazil. Following a period of strong growth in the 1980s, total researcher capacity fluctuated to some extent during 1990–2004. Capacity growth in more recent years stemmed from increased involvement in agricultural research by the higher education sector and the opening of new Embrapa units in various states, increasing the number of researchers employed at Embrapa by several hundred. As a result, spending levels also increased from 2005 onward.

Mexico. Overall, agricultural researcher numbers have risen since the early 1980s. Declines in research capacity at government agencies in more recent years were largely offset by robust growth within the higher education sector, which was also the main driver of the country's increased spending over time.

Financial Resources

Spending

Unsurprisingly, Brazil is the largest country in LAC in terms of agricultural R&D spending. In 2013, the country spent $2.7 billion on agricultural R&D, representing more than half the region's total spending that year (Table 2).[4] Argentina and Mexico each spent more than $700 million in 2013. Completing the top five countries with the highest levels of investment in agricultural research in 2013 are Colombia ($254 million) and Chile ($186 million). The remaining countries of LAC operate much smaller agricultural research systems, which is reflected in their low shares of regional agricultural R&D spending.

Overall, agricultural R&D spending in LAC grew by 2.7 percent per year during 2009–2013. High growth rates were observed in Argentina, Colombia, Paraguay, and Venezuela whereas spending in countries like Peru actually declined in recent years. Paraguay recorded the highest yearly growth in the region due to the 2010 establishment of the Paraguayan Institute for Agricultural Technology (IPTA). While this is a significant development for the country, it is important to note that the high spending growth is from an extremely small base level, following a sustained period of declining investments in the 1980s and 1990s. In Argentina, growth stemmed from large-scale staff recruitment leading to higher spending on salaries and related expenses following the 2007 establishment of the Ministry of Science and Technology, and the 2009 upgrade of the Secretariat for Agriculture, Livestock, and Fisheries into a ministry. In Colombia, after years of stagnation, the government

increased its support for agricultural R&D, with the 2011 launch of National Research, Development, and Innovation Agenda. Significant reform of the country's national royalty system has also greatly contributed to increased R&D investments in Colombia. Agricultural R&D in Brazil has benefited tremendously from strong

TABLE 2 | Total agricultural research spending, 2006, 2009, and 2012/2013

Country	**Total spending** (million 2011 PPP dollars)			**Share of regional total, 2012/2013 (%)**
	2006	2009	2012/2013	
Argentina	551	579	732	14.3
Bolivia	na	57	59	1.1
Brazil	1,848	2,508	2,704	52.7
Anglophone Caribbean	na	37	37	0.7
Chile	152	190	186	3.6
Colombia	194	190	254	4.9
Costa Rica	33	40	37	0.7
Dominican Republic	27	20	20	0.4
Ecuador	na	na	27	0.5
Guatemala	14	12	16	0.3
Honduras	7	7	8	0.1
Mexico	593	721	710	13.8
Nicaragua	na	na	17	0.3
Panama	12	16	15	0.3
Paraguay	13	20	27	0.5
Peru	na	94	83	1.6
Uruguay	70	65	77	1.5
Venezuela	na	56	86	1.7
Regional total	*3,749*	*4,683*	*5,134*	*100*

Sources: Constructed by authors from ASTI data and various secondary sources.

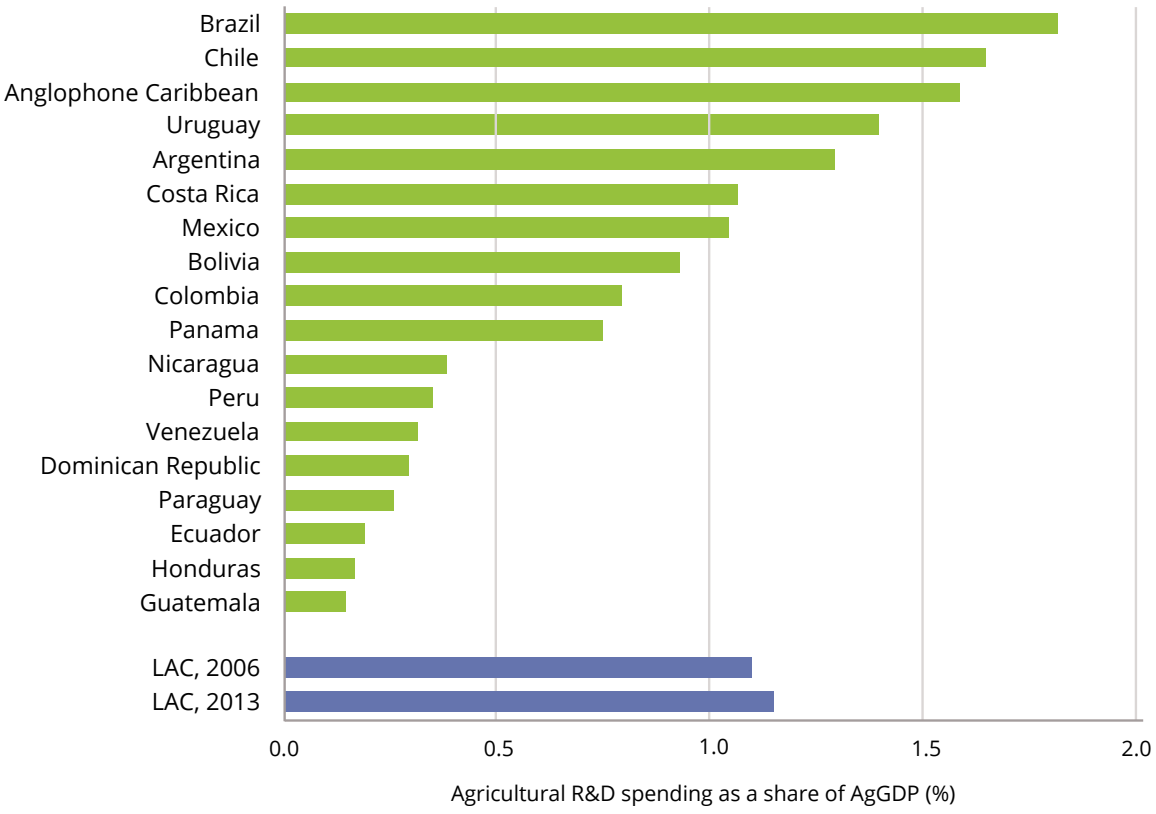
Notes: The regional total excludes Cuba and Haiti but includes Guyana, El Salvador, and Surinam; data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013; na = data were not available; PPP = purchasing power parity.

financial support by the federal and state governments, in an environment of remarkable economic growth since the early 2000s. With the recent economic slowdown, the question will be whether budget cuts may begin to constrain agricultural R&D agencies.

Intensity Ratios

Analyzing absolute levels of research expenditures explains only so much. Another way of comparing the commitment to agricultural R&D investments across countries is to measure total agricultural R&D spending as a percentage of agricultural gross domestic product (AgGDP). International organizations, such as the United Nations, have set minimum agricultural R&D investment targets of at least 1 percent of AgGDP. As of 2013, LAC met this target, investing an average of $1.15 for every $100 of agricultural output (or 1.15 percent), which is slightly higher than the comparable 2006 average of 1.10 percent (Figure 4). Considerable fluctuations in intensity ratios

FIGURE 4 | Agricultural research intensity ratios, 2012/2013



Sources: Constructed by authors from ASTI data; data on AgGDP are from World Bank (2016).

Note: Data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013. AgGDP = agricultural gross domestic product; LAC = Latin America and the Caribbean; R&D = research and development.

at the country or regional level can occur from year to year, which in general follow spending fluctuations at the regional level (see Figure 2).

The regionwide averages mask significant differences across countries. Eight countries (Nicaragua, Peru, Venezuela, Dominican Republic, Paraguay, Ecuador, Honduras, and Guatemala) fall on the low end of the spectrum, spending 0.4 percent or less of their AgGDP on agricultural R&D. In contrast, many of the Southern Cone countries, such as Argentina, Brazil, Chile, and Uruguay, invest well over 1.0 percent of their AgGDP in agricultural R&D. The Anglophone Caribbean, Costa Rica, and Mexico also spent more than 1.0 percent of their agricultural output on agricultural R&D in 2013.

It should be noted that, although intensity ratios provide useful insights into relative investment levels across countries and over time, they fail to take into account the policy and institutional environment within which agricultural research occurs, the broader size and structure of a country's agricultural sector and economy, or qualitative differences in research performance across countries; hence, they should be interpreted in context. A one-size-fits-all investment target for the region is certainly not desirable because countries differ widely in their economic structure and have different investment needs. Some of the caveats of intensity ratios include the following:

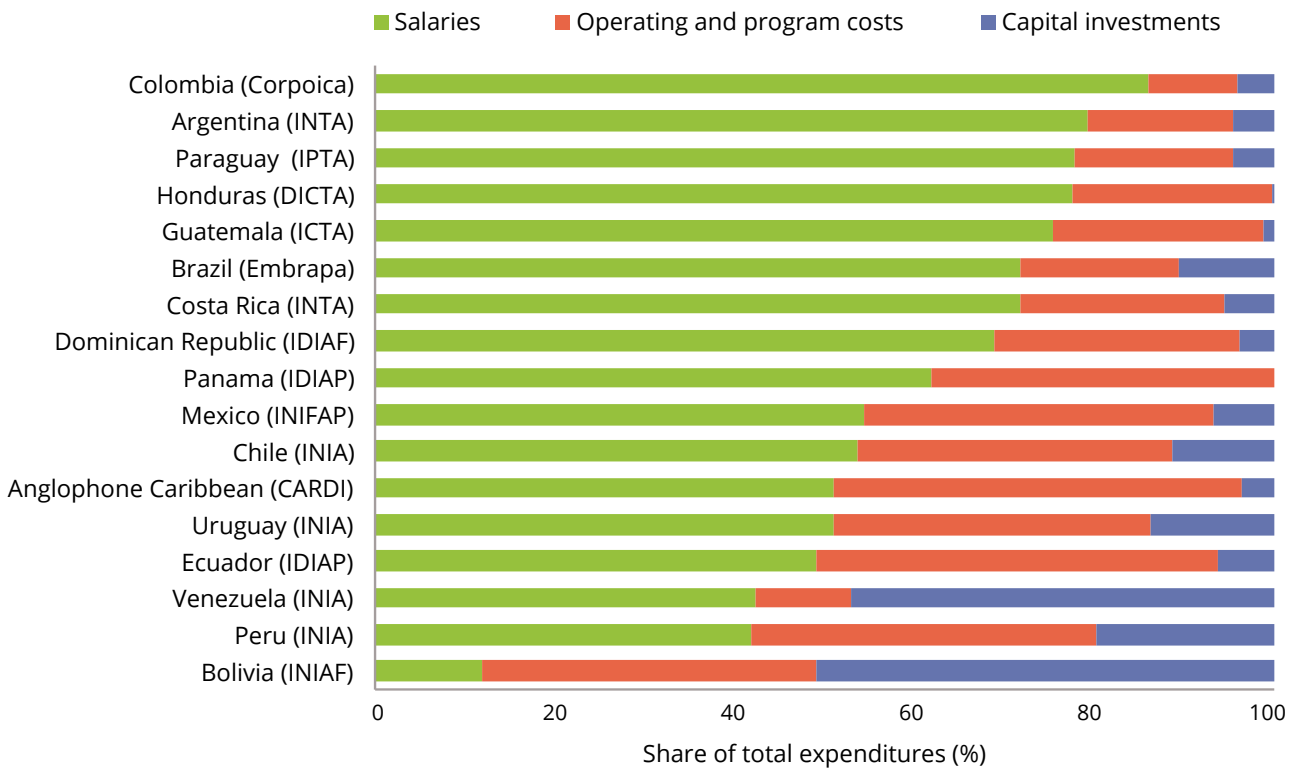
- Small countries, such as the Anglophone Caribbean island states, often have higher intensity ratios based on their inability to take advantage of economies of scale. To be effective, national research systems in small countries need to establish minimum capacities across relevant disciplines and major commodities, regardless of the size of the agricultural sector the system is designed to serve. As a result, they have to spend relatively more than larger countries to achieve the same results.
- Countries can also benefit from spill-ins of the results of research from other countries, rather than conducting their own research. For example, Paraguay has one of the lowest agricultural R&D intensity ratios in the region and relies heavily on technologies generated elsewhere—mainly in Brazil and Argentina.
- It could be argued that official AgGDP data do not fully reflect the importance of agriculture to a country's national economy. For example, investments in food processing, agricultural machinery, or agrochemical research are considerable in Southern Cone countries, but these sectors do not fall under "agriculture" in official GDP classifications and, hence, are not reflected in the country's intensity ratio.
- Finally, increased agricultural R&D intensity ratios do not necessarily reflect an increase in agricultural R&D spending, but could also reflect a drop in agricultural output. AgGDP in Panama, for example, decreased by 17 percent during 2008–2011, so—although the country's research investments remained relatively stable—the country's intensity ratio rose markedly.

Despite these limitations, intensity ratios do show that government support for agricultural R&D in certain LAC countries is too low to sustain viable agricultural R&D programs capable of addressing current and future priorities. This is clearly the case in the Dominican Republic, Ecuador, Paraguay, Peru, and the poorer Central American countries.

Spending Allocation across Cost Categories

A closer look at the composition of agricultural R&D spending by cost category reveals that, in most of the NARIs, salaries and related expenses account for the bulk of agricultural R&D costs (Figure 5). No formula can determine the optimal allocation of agricultural R&D costs across salaries, operating and program costs, and capital investments: this breakdown depends on numerous factors, including country size, agroecological diversity, research mandates, and the composition of staffing. That said, when salary-related expenditures consume more than three-quarters of a

FIGURE 5 | Spending by cost category for the national agricultural research institutes, 2009–2012/2013 average



Sources: Constructed by authors from ASTI data and various secondary sources.

Notes: Data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013. See acronym list for full institute names.

research agency's total budget, a clear imbalance exists, such that too few resources remain to support the costs of operating viable research programs.

Salaries account for more than three-quarters of total spending by the NARIs of Argentina, Guatemala, Honduras, and Paraguay, leaving relatively limited resources to fund the day-to-day costs of conducting research and maintaining and upgrading R&D infrastructure and equipment. During 2006–2013, the salary bill of Argentina's National Institute of Agricultural Technology (INTA) nearly tripled following the recruitment of a significant number of researchers. At the same time, operating costs and capital investments changed little, raising questions about the long-term viability of research programs. A number of countries clearly have insufficient support for the day-to-day operation of research programs, which undoubtedly affects the quality and quantity of research outputs in these countries. For example, due to the recent natural disasters and the global financial crisis, the limited government funding available for agricultural R&D in Anglophone Caribbean countries is allocated to salaries rather than to operating costs or capital investments. As a result, many longstanding research programs had to be eliminated, and a number of laboratory facilities have fallen into disrepair. For the National Institute for Agricultural and Forestry Research Innovation (INIAF) in Bolivia, some of the most immediate infrastructure and equipment challenges are currently being addressed as part of the 2012–2017 Innovation and Agricultural Services Project (PISA), funded by the World Bank and the governments of Bolivia, Denmark, and Switzerland. The project is investing heavily in laboratory equipment, seed processing equipment, and vehicles.

Funding Sources

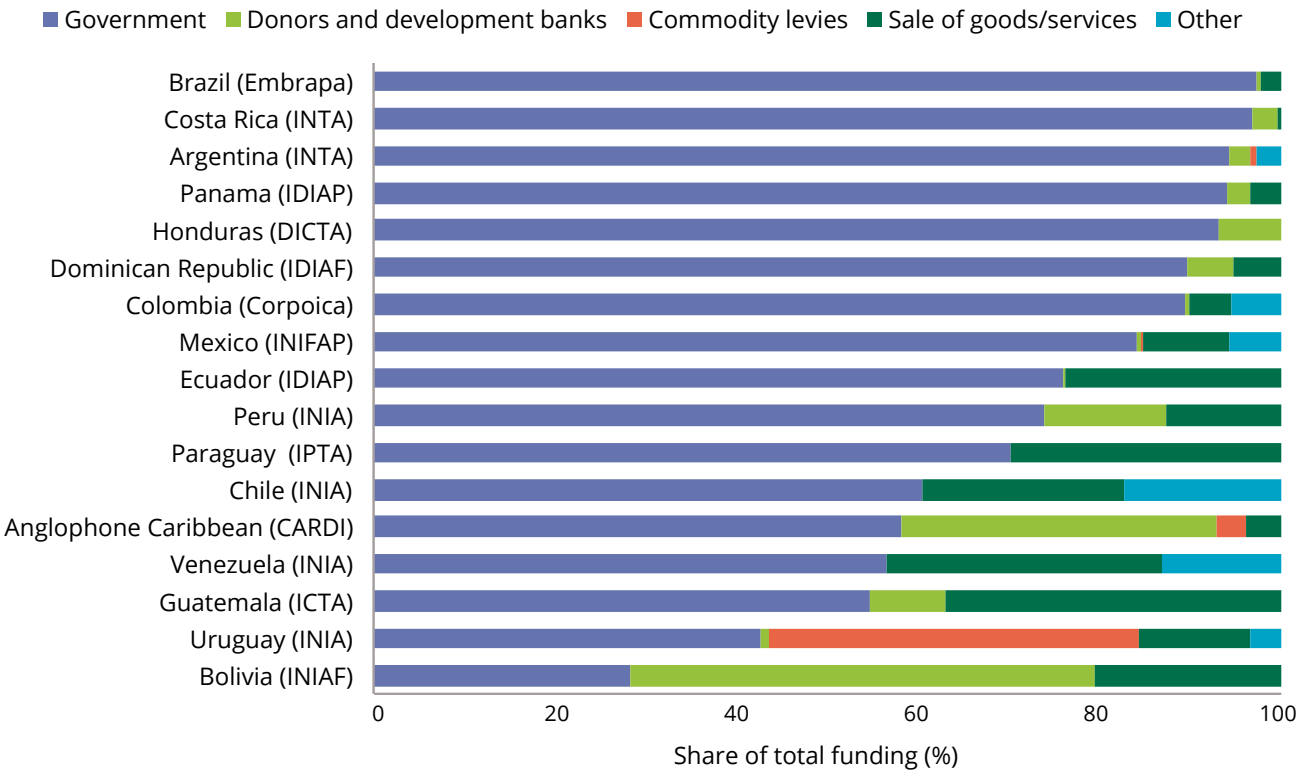
Funding for agricultural R&D in LAC is derived from a variety of sources, including national governments, donors, development banks, producer organizations, and the private sector, along with revenues generated internally through the sale of goods and services. Governments are by far the dominant source of funding for the region's NARIs (Figure 6). Of the total funding received by national institutes in Argentina, Brazil, Costa Rica, the Dominican Republic, Honduras, and Panama, 90 percent or more was derived from government contributions.

Government funding can be disbursed to agricultural R&D agencies through a variety of channels. In some countries, payment of staff salaries is made directly by the Ministry of Finance, whereas operating and capital costs are the responsibility of the ministry of agriculture or another ministry overseeing agricultural research. Most countries have a ministry of science and technology that allocates research funding through one or more science funds, either competitively or through direct budget allocations. Competitive funds can be a useful means of promoting research priorities; increasing the participation of the private and academic sectors in the performance of research; and developing linkages among government, academic, and private research agencies. Competitive funds tend to increase the flexibility of research programs, but they often favor short-term, applied research at the expense

of more basic, longer term research and, hence, have the potential run counter to national research priorities. Starting in the 1980s, Chile was one of the first Latin American countries to introduce competitive funding mechanisms for agricultural R&D. The country currently has several funds in operation with substantial financial support from the government. In many other LAC countries, competitive funding mechanisms have gained prominence, both in terms of size and scope, but the day-to-day management of these funds and the optimal allocation of funds across agencies can pose challenges. In Ecuador, for instance, bureaucratic approval procedures and constantly changing requirements create a major disincentive for researchers to apply for this type of funding, whereas in Argentina, the bulk of available funds are awarded to experienced researchers based in central provinces, creating an obstacle for agencies in more remote provinces that lack a critical mass of qualified research staff able to craft proposals.

Donors and development banks play a comparatively small role in funding agricultural R&D in LAC compared with Africa south of the Sahara and certain countries in Asia-Pacific. Of all LAC countries, Bolivia is by far the most dependent on

FIGURE 6 | Relative shares of research funding for the national agricultural research institutes, 2009–2012/2013 average



Source: Constructed by authors from ASTI data.

Notes: Data for Nicaragua were not available; data for Central America and the Caribbean are for 2009–2012; data for South America and Mexico are for 2009–2013, except for Ecuador (2010–2013), Paraguay (2011–2013), and Venezuela (2013). See acronym list for full institute names.

this type of funding. As previously mentioned, PISA is an important project intended to strengthen INIAF's institutional underpinnings, as well as its capacity to undertake effective research, technical assistance, and certified seed distribution. PISA also supports the development of an information and monitoring system to strengthen the impact of INIAF's activities and enhance its ability to measure and demonstrate its contribution to the country's agricultural added-value in the long-term.

A valuable means by which research agencies can increase their funding is conducting research on a contract basis (for example, for the private sector) and through the commercial sale of research outputs, such as seed. This source of funding has become increasingly important in a number of LAC countries. Institutes in many countries have autonomy in the use of the revenues they generate internally, but for some—such as Ecuador's National Institute of Agricultural Research (INIAP)—these revenues are returned to the Treasury, eliminating the incentive for researchers to pursue this revenue stream.

A number of LAC countries have instituted R&D funding mechanisms that impose a tax on the value of agricultural production or exports, or both. Colombia is one of the most advanced countries in this regard. Its three main producer organizations—the National Coffee Research Center (Cenicafé), Colombian Sugarcane Research Center (Cenicaña), and Palm Growers' Research Center (Cenipalma)—fund more than three-quarters of their research using this mechanism. Countries like Costa Rica, Guatemala, and Honduras also fund research through commodity taxes, mainly on the production of coffee and sugar. Uruguay's principal government agency, National Agricultural Research Institute (INIA), has a unique funding structure in that it receives the proceeds of a commodity tax on the total value of the sale of the country's agricultural commodities; in addition, the national government provides quarterly counterpart funding in direct proportion to the funds generated by the tax.

Human Resources

Research Capacity by Number and Share of Agricultural Researchers

The region employed close to 20,600 agricultural researchers (in FTEs) in 2012/2013 (Table 3). The three largest countries—Brazil (5,869 FTEs), Argentina (5,825 FTEs), and Mexico (3,967 FTEs)—accounted for 76 percent of these researchers. Colombia and Chile accounted for 5 and 3 percent, respectively, and the remaining 20 countries collectively accounted for the balance (15 percent).

The total number of agricultural researchers in LAC grew by 2.6 percent per year during 2009–2012/2013. Growth was particularly high in Argentina, the Dominican Republic, Honduras, and Paraguay. In Argentina, agricultural researcher numbers doubled during 2006–2013, although the vast majority of recruits were junior researchers with limited qualifications and experience. In Mexico, recent declines

in the number of researchers employed at government agencies (mostly due to retirement) were offset by increased researcher numbers in the higher education sector, leading to a shift in the institutional composition of research in that country. In Brazil, recent growth in researcher numbers was predominantly driven by growth in researcher capacity in the higher education sector.

TABLE 3 | Total number of agricultural researchers, 2006, 2009 and 2012/2013

Country	Total researchers (FTEs)			Share of regional total, 2012/2013 (%)
	2006	2009	2012/2013	
Argentina	3,830	4,948	5,825	28.3
Bolivia	na	192	190	0.9
Brazil	5,359	5,262	5,869	28.5
Anglophone Caribbean	na	178	189	0.9
Chile	665	671	716	3.5
Colombia	1,045	1,072	1,103	5.4
Costa Rica	253	259	242	1.2
Dominican Republic	131	195	200	1.0
Ecuador	na	98	149	0.7
Guatemala	120	112	142	0.7
Honduras	69	67	88	0.4
Mexico	3,724	3,946	3,967	19.3
Nicaragua	na	na	131	0.6
Panama	149	132	133	0.6
Paraguay	131	154	210	1.0
Peru	na	298	339	1.6
Uruguay	377	369	372	1.8
Venezuela	na	407	503	2.4
Regional total	*17,107*	*18,643*	*20,580*	*100*

Sources: Constructed by author from ASTI data and various secondary sources.

Notes: The regional total excludes Cuba and Haiti but includes Guyana, El Salvador, and Surinam; data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013; na = data were not available; FTEs = full-time equivalents.

Composition of Agricultural Researchers by Qualification Level

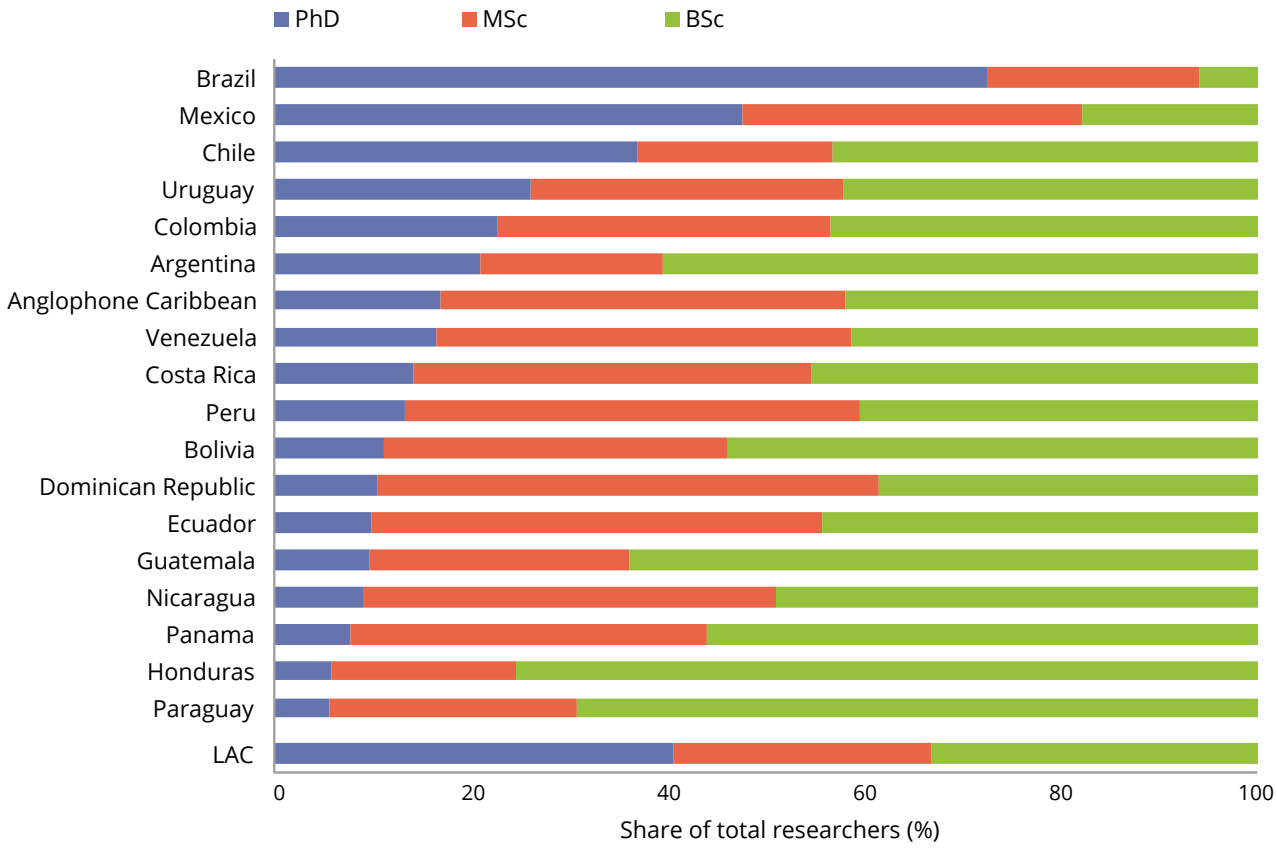
Looking at the breakdown of agricultural researchers by academic qualifications reveals that, with the exception of Brazil, most of the region's capacity growth during 2006–2013 was among researchers with BSc degrees only. In Argentina, for example, the number of BSc-qualified agricultural researchers rose from nearly 1,800 FTEs in 2006 to more than 4,200 in 2013. The number of MSc- and PhD-qualified researchers increased at a similar pace, but from much smaller base levels. Integrating this large pool of junior researchers into existing structures and projects, and providing the necessary training and guidance, has presented a challenge. Chile, Colombia, Ecuador, and Venezuela also recruited considerable numbers of researchers qualified to the BSc level during this period.

A minimum number of PhD-qualified scientists is considered necessary for effectively conceiving, managing, and executing high-quality research; for communicating with policymakers, donors, and other stakeholders, both locally and through regional and international forums; and for increasing an institute's chances of securing competitive funding. Most countries for which long-term time-series data were available have expanded their pool of PhD-qualified agricultural researchers since 2006. Exceptions are Costa Rica, Honduras, and Panama where the number of PhD-qualified researchers employed remained fairly stagnant. Researchers in Brazil and Mexico are by far the most highly qualified among LAC countries. In 2013, close to three-quarters of Brazil's and half of Mexico's agricultural researchers were trained to the PhD level (Figure 7). In fact, 72 percent of the region's PhD-qualified researchers were employed in just these two countries. At Embrapa in Brazil, in addition to an emphasis on training existing staff and recruiting researchers with PhD degrees, many of its retiring scientists held MSc or BSc degrees. As a result, from 2006 to 2013, the number of PhD-qualified researchers employed at Embrapa rose by 36 percent while the number qualified to the MSc- and BSc-level declined by more than half. Generally, technical support staff at Brazilian agricultural research agencies are highly qualified as well, often holding MSc degrees and sometimes even PhD degrees. In contrast, many other countries lack the critical mass of PhD-qualified researchers needed to enable their research systems to have a tangible impact on agricultural productivity growth and poverty reduction. Several national agricultural research systems employ too few PhD-qualified researchers for agricultural research to have a substantial impact on agricultural growth: Bolivia (21 FTEs), Dominican Republic (21 FTEs), Ecuador (14 FTEs), Guatemala (14 FTEs), Honduras (5 FTEs), Nicaragua (12 FTEs), Panama (10 FTEs), and Paraguay (11 FTEs). Providing training for researchers to the PhD level is an inherently expensive, time-consuming process, often taking decades. Most of LAC's smaller countries lack in-country PhD programs in agricultural and veterinary sciences, so researchers intending to further their careers need to secure (scarce) scholarships to undertake PhD degree training abroad.

A number of the region's countries have recently established (or are in the process of establishing) mechanisms to address some of their most pressing capacity

constraints. In Argentina, Colombia, and Peru national programs were established to attract highly qualified researchers working abroad to return home. Corpoica in Colombia, for example, hopes to attract 225 PhD-qualified researchers back home by 2018. Chile has invested heavily in postgraduate training for its agricultural scientists, both in-country and abroad. Nevertheless, the country's agricultural R&D agencies lack the ability to employ all of these highly qualified researchers as they complete their degrees—INIA, for example, has been hindered by recruitment restrictions. In order to avoid having the supply of highly qualified researchers exceed agricultural R&D systems' capacity to employ them, it is crucial that training and recruitment needs are carefully assessed, planned, and coordinated. Chile's National Commission of Scientific and Technological Research (CONICYT) is currently exploring options to secure overseas employment for some of the most promising PhD graduates, enabling them to gain valuable research experience until Chile is in a position to employ them at home.

FIGURE 7 | Distribution of researchers by qualification level, 2012/2013



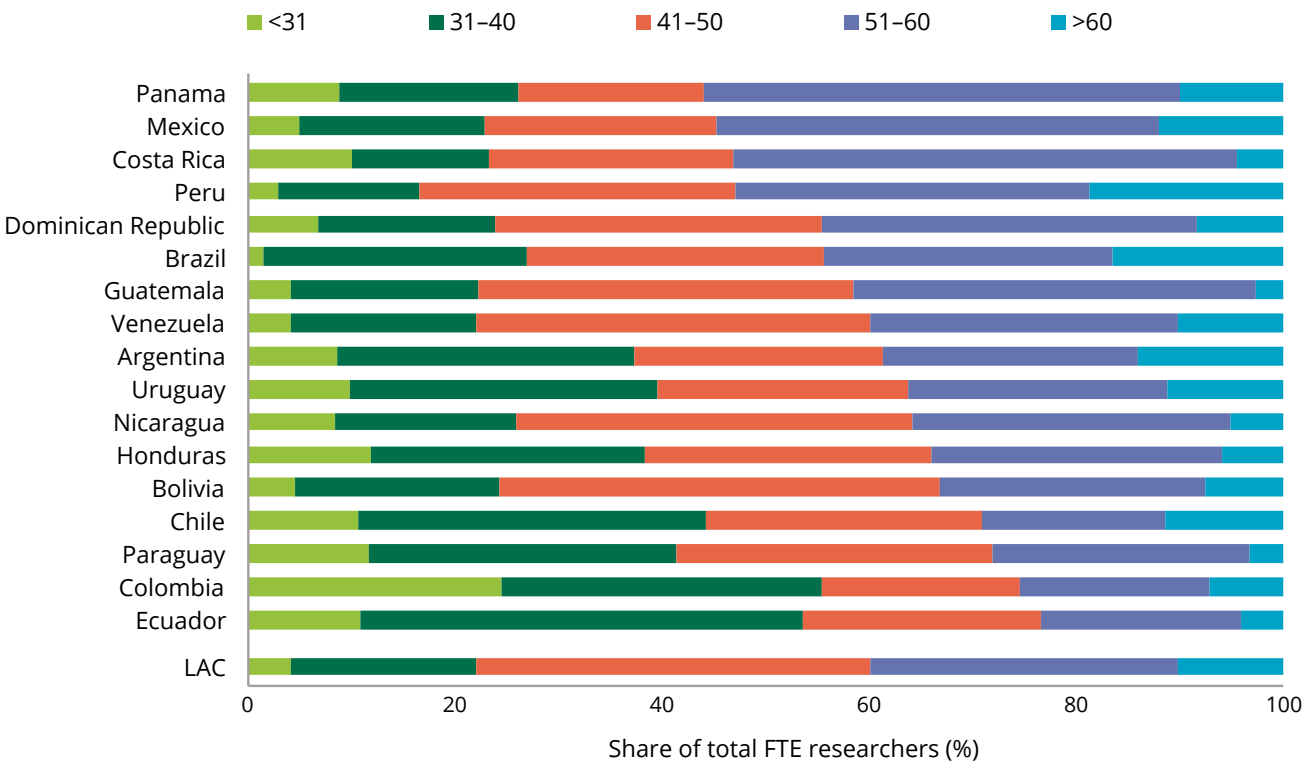
Sources: Constructed by authors from ASTI data.

Notes: Data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013. LAC = Latin America and the Caribbean.

Composition of Agricultural Researchers by Age

Overall, 40 percent of the region's agricultural researchers are in their 50s or 60s (Figure 8). Given that the official retirement age in most countries is 60 or 65 years, a significant number of senior researchers are set to retire in the short to medium term. This situation is most severe in Guatemala, Panama, and Peru, where more than 70 percent of PhD-qualified agricultural researchers are more than 50 years old (Figure 9). Mexico has recently lost a considerable number of highly experienced researchers with PhD degrees following two consecutive voluntary retirement schemes, coupled with years of limited recruitment. Fifty-five percent of the country's remaining researchers with PhD degrees are currently in their 50s, highlighting the urgent need for succession strategies. Throughout LAC, many agencies will be left without the critical mass of experienced, PhD-qualified researchers needed to lead research programs and mentor and train junior staff. Without adequate succession strategies and training, significant knowledge gaps will emerge, raising concerns about the quality of future research outputs.

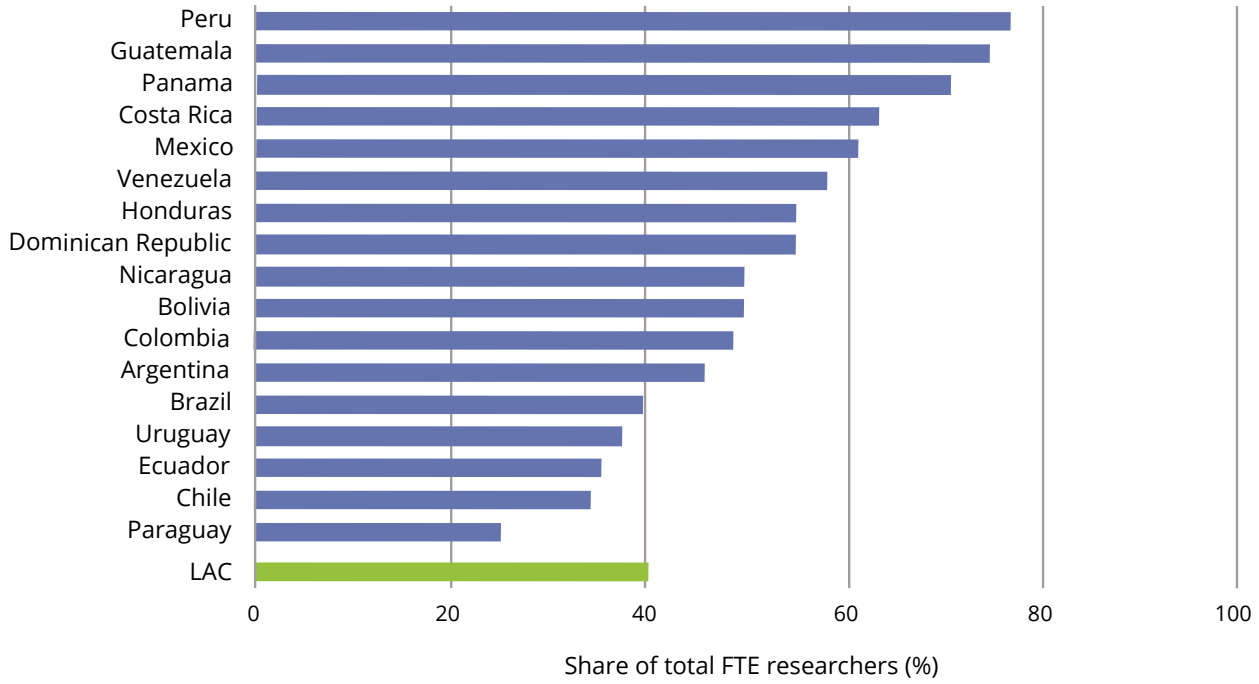
FIGURE 8 | Distribution of agricultural researchers by age bracket, 2012/2013



Source: Constructed by authors from ASTI data.

Notes: Data for the Anglophone Caribbean were not available; data for Central America are for 2012; data for South America and Mexico are for 2013. Data for Ecuador exclude the nonprofit sector; data for Paraguay exclude the higher education sector. FTEs = full-time equivalents; LAC = Latin America and the Caribbean.

FIGURE 9 | Share of PhD-qualified researchers over 50 years of age, 2012/2013



Sources: Constructed by authors from ASTI data.

Notes: Data for the Anglophone Caribbean were not available; data for Central America are for 2012; data for South America and Mexico are for 2013. Data for Ecuador exclude the nonprofit sector; data for Paraguay exclude the higher education sector. FTEs = full-time equivalents; LAC = Latin America and the Caribbean.

In contrast, Colombia employs the youngest pool of agricultural among LAC countries. This can largely be explained by the important role that producer organizations play in that country's national agricultural research. Producer organizations typically employ much younger pools of researchers, although in recent years Corpoica has increased its recruitment of young researchers as well. Chile, Paraguay, and Uruguay also have a much younger pool of agricultural researchers compared with most other LAC countries.

Female Participation in Agricultural Research

Female researchers, professors, and senior managers offer different insights from their male counterparts, and their input provides an important perspective in addressing the unique and pressing challenges of female farmers in the region. Consequently, it is important that agricultural R&D agencies employ a balance of male and female researchers. The overall share of female agricultural researchers is higher in LAC (36 percent in 2013) than in other developing regions, such as Africa south of the Sahara (22 percent in 2011), South Asia (20 percent in 2011/2012), and West Asia and North Africa (34 percent in 2012) (Beintema and Stads 2014; Stads

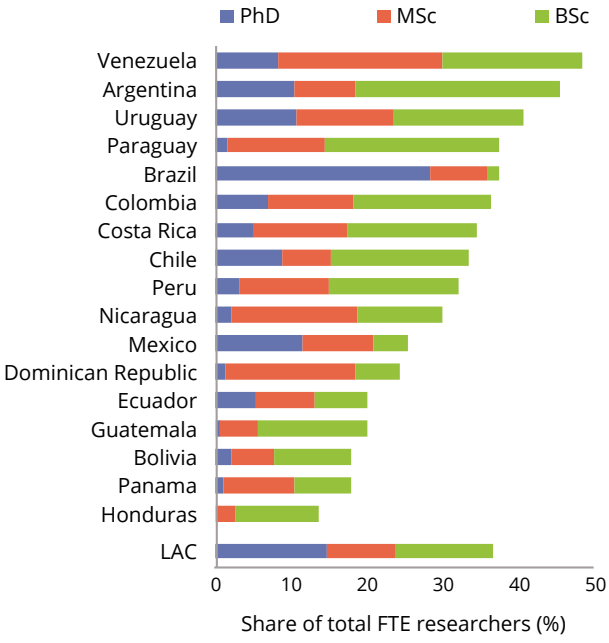
2015a and 2015b). In countries like Venezuela (48 percent), Argentina (44 percent), and Uruguay (40 percent), women are well represented at agricultural research agencies (Figure 10a), but in countries like Bolivia, Honduras, and Panama shares of female researchers remain quite low (between 14 and 18 percent).

Over time, women's involvement in agricultural R&D has steadily risen throughout LAC, which is a positive development. In 10 of the 11 countries for which historical data on the gender balance were available, the share of female agricultural researchers was higher in 2012/2013 than in 2006 (Figure 10b). Growth was highest in Costa Rica, which managed to expand its share of female agricultural researchers from 21 percent in 2006 to 34 percent in 2013. Chile and Guatemala recorded increases of 6–7 percent points during the timeframe. In a number of countries, women also hold higher level research and management positions, but the vast majority of these positions in most countries are still held by men.

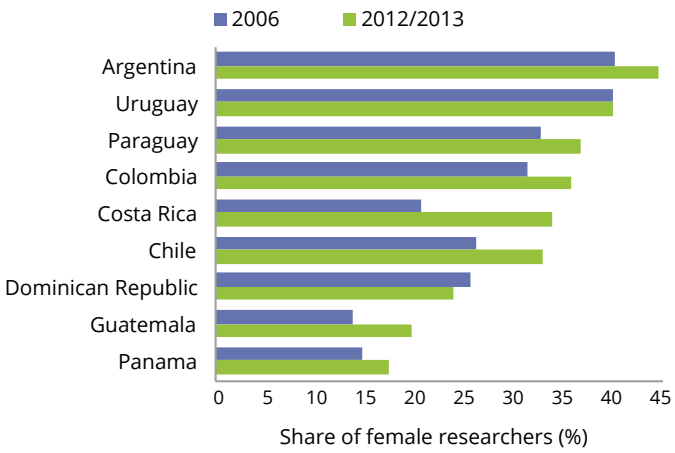
In contrast to many other developing regions around the world, where female agricultural researchers tend to have lower average qualification levels than their male counterparts, no gap in qualification levels is apparent between male and female agricultural researchers in LAC. On average, 36 percent of PhD-qualified researchers

FIGURE 10 | Female participation in agricultural R&D

a. Overall share of female researchers and distribution by qualification level, 2012/2013



b. Change in share of female researchers in selected countries, 2006 and 2012/2013



Sources: Constructed by authors from ASTI data.

Note: Data for the Anglophone Caribbean were not available; data for Central America are for 2012; data for South America and Mexico are for 2013. Data for Ecuador exclude the nonprofit sector. FTEs = full-time equivalents; LAC = Latin America and the Caribbean.

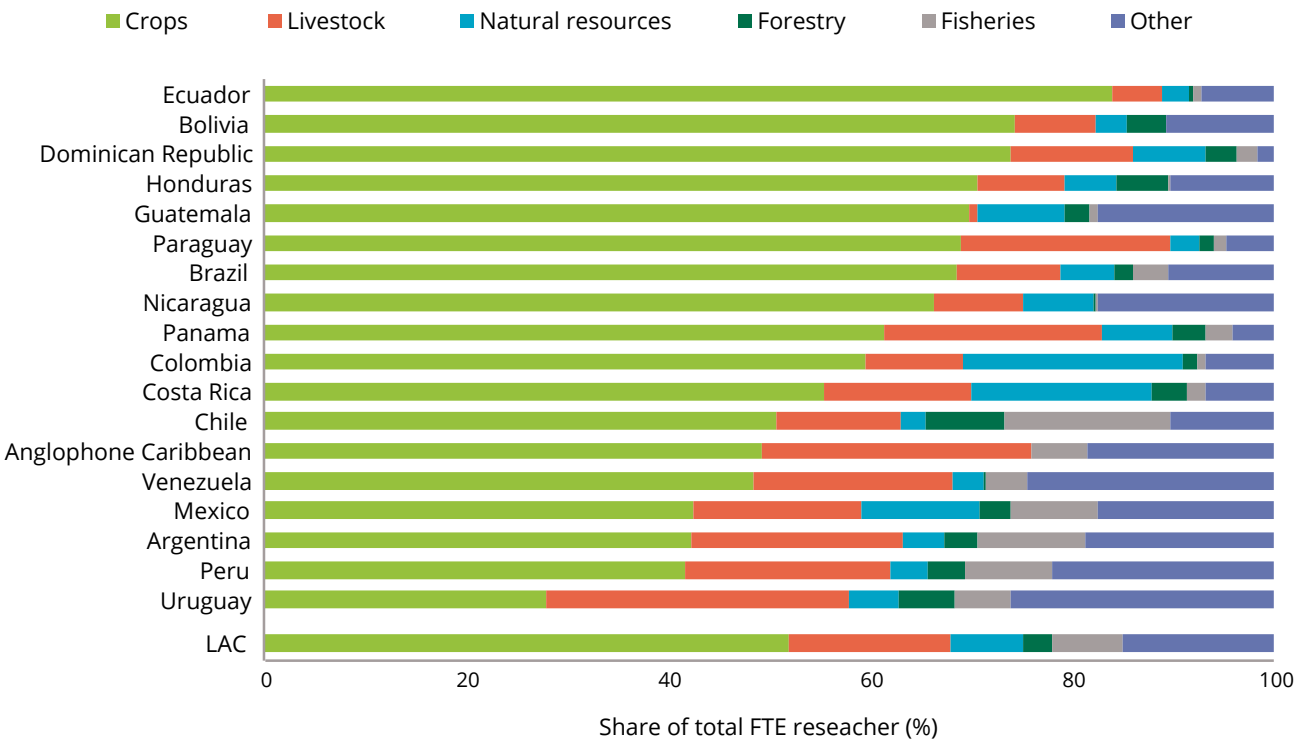
in LAC are women. This regionwide average masks some important cross-country differences. In the Dominican Republic, Guatemala, and Honduras, for example, women are two to three times less likely to hold PhD degrees than their male colleagues. In contrast, in Argentina and Venezuela, the overall share of female researchers with PhD degrees was actually higher than the comparable share of male researchers.

Research Focus

Governments and agricultural research agencies across LAC are limited in their choice of options of how to allocate scare resources. It is important, however, that they allocate sufficient resources to the right types of research and on the right commodities for agricultural R&D to have lasting effects on productivity growth and poverty reduction. ASTI collected detailed information on the allocation of FTE researchers across commodity areas.

In 2013, more than half of all FTE researchers in the 18-country sample conducted crop research, whereas 17 percent undertook livestock research (Figure 11). Natural resources and fisheries research accounted for 7 percent each. The

FIGURE 11 | Focus of agricultural research by country, 2012/2013



Sources: Constructed by authors from ASTI data.

Notes: Data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013; data for the Anglophone Caribbean only include CARDI. FTEs = full-time equivalents; LAC = Latin America and the Caribbean.

remaining researchers focused on forestry or other areas. Crop research accounted for 70 percent or more of time spent on agricultural research in Bolivia, the Dominican Republic, Ecuador, Honduras, and Guatemala. Uruguay stands out among LAC countries in that its focus on livestock research (30 percent) is higher than its focus on crop research (28 percent). Fisheries research was relatively important in Chile (16 percent) and Argentina (11 percent), whereas natural resources research played a prominent role in Colombia (22 percent), Costa Rica (18 percent), and Mexico (12 percent).

The most researched crops include cereals and horticultural crops. Understandably, some fundamental differences in the focus of crop research exist between countries (Table 4). Researchers in the region's tropical countries focus more on bananas, coffee, and sugar, while their colleagues in Southern Cone countries focus more on wheat, soybeans, and grapes.

TABLE 4 | Major crops under research by country, 2012/2013

Country	Major crop items
Argentina	Fruit (14%), vegetables (11%), soybeans (8%), wheat (7%), and maize (6%)
Bolivia	Quinoa (17%), wheat (13%), potatoes (13%), maize (8%), fruit (7%), and vegetables (5%)
Brazil	Fruit (21%), soybeans (10%), maize (9%), beans (7%), rice (6%), cotton (6%), vegetables (5%), and cassava (5%)
Anglophone Caribbean	Tubers (64%), vegetables (8%), and fruit (4%)
Chile	Fruit (31%), wheat (21%), potatoes (13%), and rice (11%)
Colombia	Coffee (15%), fruit (17%), oil palm (14%), sugar (9%), and cocoa (7%)
Costa Rica	Bananas and plantains (20%), other fruit (18%), rice (11%), coffee (6%), sugar (6%), tomatoes (5%), and potatoes (5%)
Dominican Republic	Fruit (21%), rice (18%), other vegetables (14%), cocoa (12%), coffee (9%), beans (8%), and cassava (5%)
Ecuador	Cocoa (23%), sugar (16%), bananas and plantains (9%), maize (9%), potatoes (9%), and rice (9%)
Guatemala	Maize (12%), beans (19%), coffee (13%), potatoes (13%), sugar (13%), and rice (8%)
Honduras	Maize (13%), beans (11%), fruit (10%), tomatoes (10%), other vegetables (8%), cocoa (7%), coffee (5%), and potatoes (5%)
Mexico	Maize (19%), fruit (12%), beans (8%), chilies and peppers (7%), flowers and ornamentals (6%), and wheat (6%)
Nicaragua	Maize (23%), beans (19%), sorghum (13%), rice (10%), coffee (5%), potatoes (6%), tomatoes (7%), and cassava (5%)
Panama	Rice (36%), maize (14%), potatoes (7%), beans (7%), oil palm (7%), bananas and plantains (6%), and coffee (5%)
Paraguay	Wheat (19%), soybeans (16%), cotton (13%), fruit (11%), maize (9%), other vegetables (7%), sugar (7%), and beans (5%)
Peru	Potatoes (12%), beans (9%), quinoa (8%), maize (8%), fruit (8%), coffee (6%), and cocoa (5%)
Uruguay	Fruit (25%), rice (17%), soybeans (14%), other cereals (11%), sweet potatoes (7%), wheat (7%), and sorghum (5%)
Venezuela	Rice (14%), maize (12%), cocoa (9%), coffee (7%), fruit (6%), tomatoes (6%), beans (5%), and other vegetables (5%)

Source: Constructed by authors from ASTI data.

Note: Major crops include those that are the focus of at least 5 percent of all crop researchers. Data for Central America and the Caribbean are for 2012; data for South America and Mexico are for 2013; data for the Anglophone Caribbean only include CARDI.

Conclusion and Policy Implications

Well-developed national agricultural research systems and adequate levels of investment and human resource capacity are prerequisites for the attainment of agricultural productivity growth, food security, and poverty reduction. Throughout LAC, success in achieving these objectives is intrinsically dependent on sufficient and stable financial resources for agricultural R&D and on the development of adequate human resource and institutional capacity.

Agricultural research spending and capacity in LAC have grown progressively since the turn of the millennium, but this regionwide growth masks considerable differences across countries. On the one hand, the region is home to Brazil, which outperforms every other country with its highly qualified research staff and world class research infrastructure and outputs. Argentina, Colombia, Costa Rica, Mexico, and Uruguay also have relatively well-developed agricultural research systems, but many other countries—especially the Central American countries, Caribbean island nations, and poorer Andean countries—are increasingly falling behind in terms of infrastructure, investment levels, and capacity.

Despite these large cross-country differences, all LAC countries face common challenges. Economic inequality remains deep-rooted, with the majority of the rural poor depending on agriculture as their main source of income and employment. Additionally, climate change is having demonstrable adverse impacts on agriculture across the region. Given the critical role of agricultural research in addressing these and other challenges, stable and sustainable levels of funding are key to securing strategic programs of effective research that yield increased agricultural productivity.

Governments will also need to provide the necessary policy environment to stimulate cooperation among their countries' agricultural R&D agencies in order to maximize synergies and efficiencies in the use of the limited resources available to universities and government agencies. Further integration of R&D at the regional level is indispensable too, so that countries with weak agricultural research systems can benefit from the gains made in countries with more developed systems. Continued support to and growth of regional bodies, networks, and mechanisms will help effectively define, implement, and fund a regional research agenda targeting issues of common interest.

Given the immense diversity of the region's countries in economic, social, and environmental terms, as well as the large differences in the quality of agricultural research systems across countries, the implications for potential policy interventions to address key institutional, human capacity, and financial challenges differ broadly by country. ASTI's series of country factsheets for LAC, listed at the end of this report and available on ASTI's website (www.asti.cgiar.org/lac), provides more detail on these national challenges and their policy implications.

Appendix A. Overview of Agricultural Research in Anglophone Caribbean

Anglophone Caribbean countries employed 189 agricultural researchers (in FTEs) and spent $36.7 million combined on agricultural research in 2012 (Table A1). In addition, at the subregional level, CARDI headquarters and two nonprofit agencies employed 27 researchers (in FTEs) and spent $3.8 million on agricultural research that year.

Agricultural research is primarily conducted in Jamaica and Trinidad and Tobago at the agricultural ministries and the campuses of the University of the West Indies

TABLE A1 | Number of agricultural researchers (FTEs) at the subregional and national levels in Anglophone Caribbean, 2012

Country/subregion	CARDI	UWI	Government	Higher education	Nonprofit	Total
Antigua and Barbuda	0.5	—	7.0	—	—	7.5
Barbados	0.7	2.2	7.0	—	—	9.9
Belize	1.0	—	4.5	0.5	6.6	12.6
Dominica	3.0	—	—	—	—	3.0
Grenada	0.3	—	1.5	—	—	1.8
Jamaica	16.0	5.0	41.1	—	—	62.1
St. Kitts and Nevis	1.0	—	0.1	3.4	—	4.5
St. Lucia	1.4	—	—	0.8	—	2.2
St. Vincent and the Grenadines	0.5	—	2.0	—	—	2.5
Trinidad and Tobago	5.0	29.2	48.2	0.6	—	83.0
Subtotal	*29.4*	*36.4*	*111.4*	*5.3*	*6.6*	*189.1*
Subregional level	22.4	—	—	—	4.6	27.0
Total	*51.8*	*36.4*	*111.4*	*5.3*	*11.2*	*216.1*

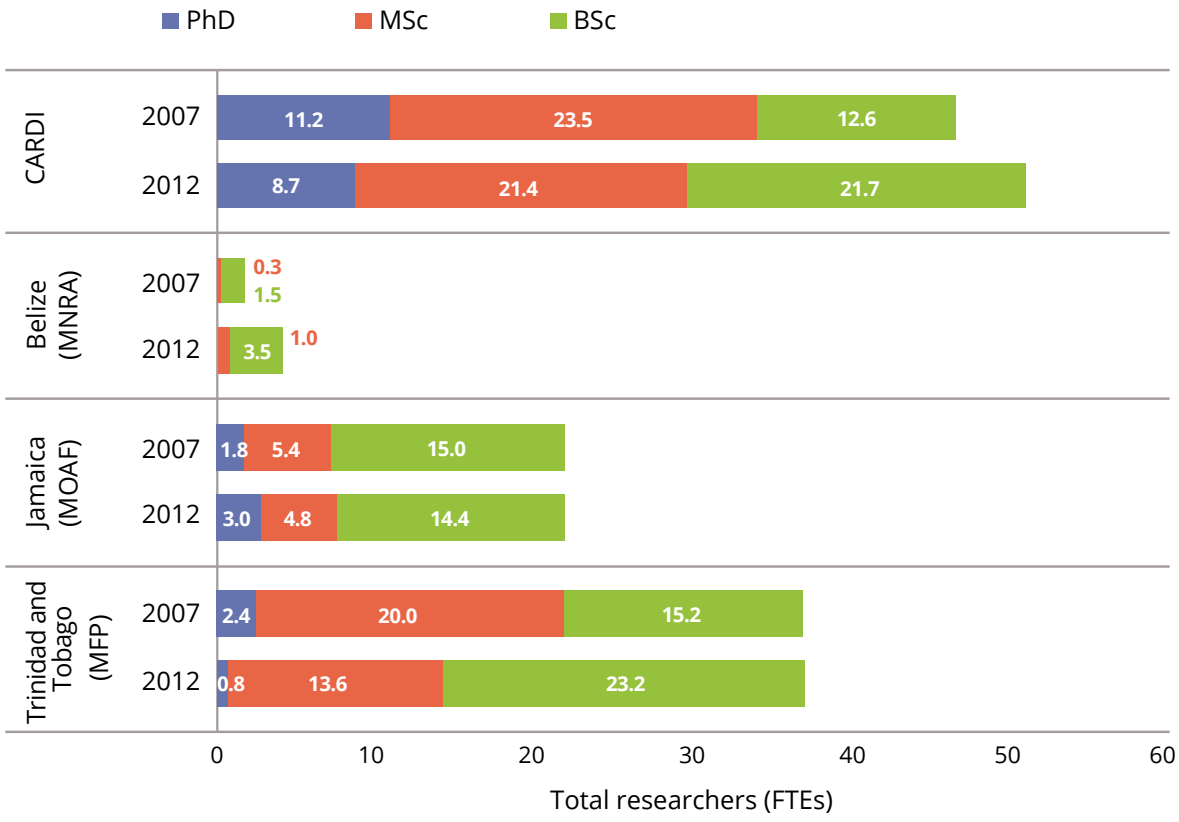
Source: Flaherty et al. (2015).

Notes: The subregional level includes CARDI's headquarters and two other subregional nonprofit agencies. CARDI = Caribbean Agricultural Research and Development Institute; UWI = University of the West Indies.

(UWI) and by the subregional agency CARDI. Most countries in the subregion employed fewer than 10 agricultural researchers (in FTEs) and spent less than $2 million on agricultural R&D in 2012.

CARDI employs the highest number of PhD-qualified researchers (in FTEs), although the majority of its researchers are only qualified to the BSc and MSc levels (Figure A1). As of 2012, the largest national government agencies in the subregion—located in Belize, Jamaica, and Trinidad and Tobago—employed between 0 and 3

FIGURE A1 | Agricultural researchers by degree at CARDI and selected ministries, 2007 and 2012



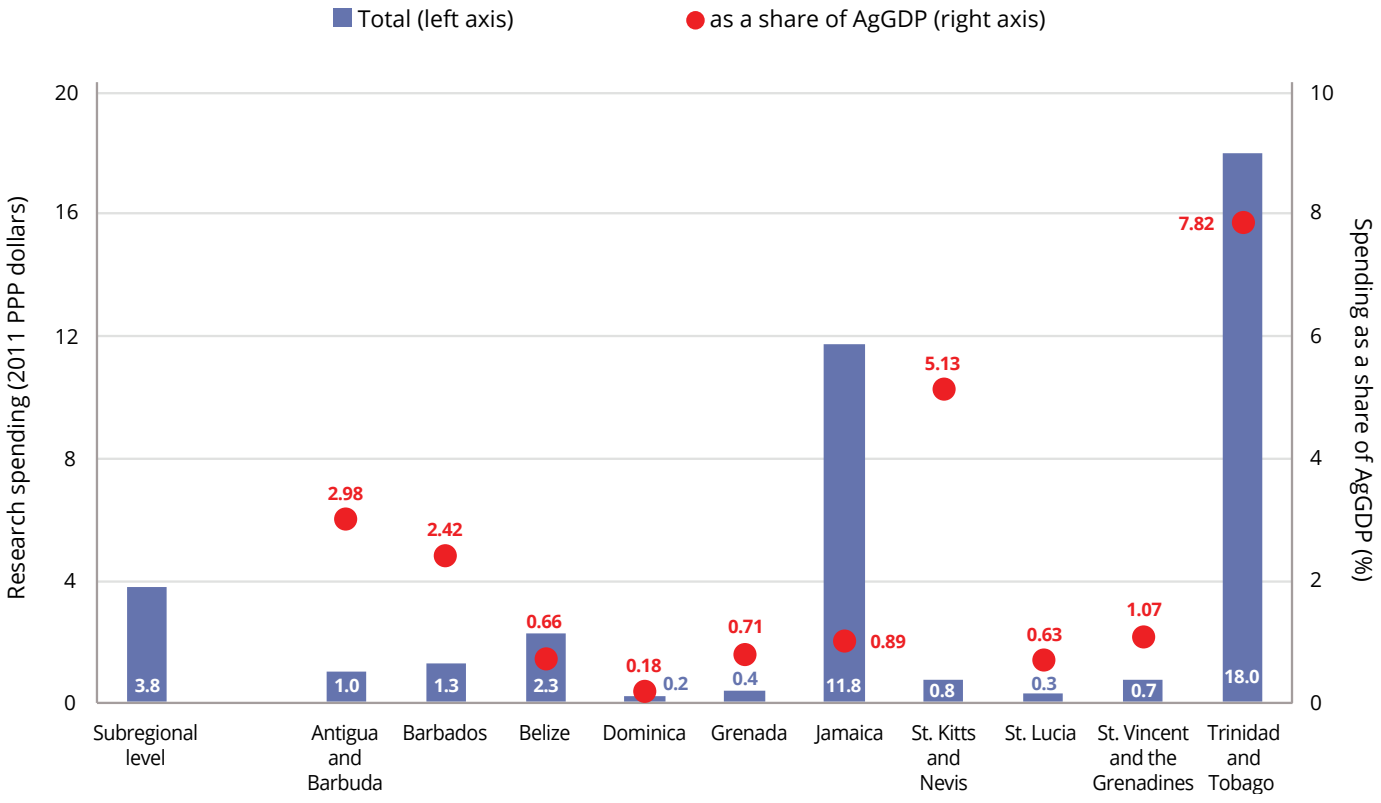
Source: Flaherty et al. (2015).

Notes: CARDI = Caribbean Agricultural Research and Development Institute; MNRA = Ministry of Natural Resources and Agriculture; MOAF = Ministry of Agriculture and Fisheries; MFP = Ministry of Food Production.

FTE researchers with PhD degrees; more than half the researchers at these agencies only held BSc degrees.

Although Jamaica's agricultural GDP was almost six times larger than Trinidad and Tobago's in 2012, it spent considerably less on agricultural R&D (Figure A2). Jamaica's low spending as a share of agricultural GDP (0.89 percent) reflects this difference. The high intensity ratios recorded in Antigua and Barbuda, Barbados, St. Kitts and Nevis, and Trinidad and Tobago are not unusual given their high-income status and small agricultural sectors.

FIGURE A2 | National government and subregional spending on agricultural R&D and as a share of AgGDP, 2012



Source: Flaherty et al. (2015).

Notes: Subregional level spending includes CARDI's headquarters and two other subregional nonpro it agencies. CARDI's country-based research stations are included in each country's national spending; UWI campuses are included under national rather than subregional spending; AgGDP = agricultural gross domestic product; CARDI = Caribbean Agricultural Research and Development Institute; PPP = purchasing power parity.

Notes

1| Note that for the countries of Central America and the Caribbean, 2012 is the latest year for which ASTI data are available, whereas for the countries of South America and Mexico, 2013 is the latest year for which these data are available.

2| In the context of this report, the Caribbean refers to the whole subregion, whereas Anglophone Caribbean only includes Antigua and Barbuda, Barbados, Belize, Dominica, Grenada, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, and Trinidad and Tobago. Note also that these 10 countries are treated as a single entity in the analyses presented (see Appendix A for an overview of their agricultural research and spending levels).

3| Stads and Beintema (2009) provide a detailed description of historical developments across the region's agricultural R&D institutions.

4| Note that the financial data in this report are presented in 2011 PPP dollars; for more information, see Box 2.

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