ASTI
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Agricultural R&D in West Asia and North Africa

Recent Investment and Capacity Trends

Gert-Jan Stads

MAY 2015

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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 data on agricultural research in low- and middle-income countries. Working with a large network of country-level collaborators, ASTI conducts primary surveys to collect data on funding sources, spending levels and allocations, human resource capacities, and institutional developments from government, higher education, nonprofit, and private for-profit agricultural R&D agencies in about 80 developing countries worldwide.

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, government and higher education institutions, the private sector, and farmers' organizations. IFPRI is a member of the CGIAR Consortium.

About the Author

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Related ASTI Outputs

- ASTI country factsheets, containing a visual, highly accessible presentation of recent institutional, financial, and human resource trends in national agricultural R&D, and featuring a more in-depth analysis of some of the key challenges individual agricultural R&D systems are facing, along with policy options to address these challenges.
- Interactive country pages, available at www.asti.cgiar.org/countries, featuring national agricultural R&D capacity, investment, and institutional indicators and trends.
- ASTI's country benchmarking tool, available at www.asti.cgiar.org/benchmarking/wana, which enables cross-country comparisons and rankings of key ASTI indicators.
- ASTI's data download tool, available at www.asti.cgiar.org/data, containing all of ASTI's regional and country-level data.

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Table of Contents

Acknowledgments

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List of Tables

List of Figures

List of Boxes

List of Acronyms

ACSAD	Center for the Studies of Arid Zones and Dry Lands
AgGDP	agricultural gross domestic product
AOAD	Arab Organization for Agricultural Development
ARC	Agricultural Research Center (Egypt)
ARC	Agricultural Research Corporation (Sudan)
AREA	Agricultural Research and Extension Authority (Yemen)
ARIMNet	Agricultural Research in the Mediterranean Network
ARRC	Animal Resources Research Corporation (Sudan)
ASTI	Agricultural Science and Technology Indicators
CIMMYT	International Maize and Wheat Improvement Center
CNERV	National Livestock and Veterinary Research Center (Mauritania)
CNRADA	National Agricultural Research and Development Center (Mauritania)
CRF	Forestry Research Center (Morocco)
DGALR	Directorate General of Agriculture and Livestock Research (Oman)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FTE	full-time equivalent (researchers)
GDAR	General Directorate of Agricultural Research (Turkey)
IAEA	International Atomic Energy Agency
ICARDA	Institute for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IMROP	Mauritanian Institute of Oceanographic Research and Fisheries (Mauritania)
INRA	National Agricultural Research Institute (Morocco)
INRAA	National Agricultural Research Institute of Algeria
INRH	National Fisheries Research Institute (Morocco)
IRA	Institute for Arid Regions (Tunisia)
IRESA	Agricultural Research and Higher Education Institution (Tunisia)
INSTM	National Institute for Aquatic Science and Technology (Tunisia)
IWWIP	International Winter Wheat Improvement Program
LARI	Lebanon Agricultural Research Institute
NARI(s)	national agricultural research institute(s)
NARS(s)	national agricultural research system(s)
NCARE	National Center for Agricultural Research and Extension (Jordan)
NCARTT	National Center for Agricultural Research and Technology Transfer (Jordan)
PPP	purchasing power parity (exchange rates)
S&T	science and technology
SSA	Africa south of the Sahara
R&D	research and development
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WANA	West Asia and North Africa

1| Introduction

West Asia and North Africa (WANA) is a highly diverse region, encompassing both high-income Gulf countries and a large group of non-oil-producing upper and lower middle-income countries.[1] Nevertheless, these countries share a number of challenges, including loss of agricultural land through rapid population growth, urbanization, or both; progressive exploitation and exhaustion of water resources; land degradation; and the adverse consequences of climate change. Moreover, lack of political stability constitutes a key barrier to food security and economic development in a large number of countries. Importing roughly half of its food needs, WANA is the most food-import-dependent region of the world. The Food and Agriculture Organization of the United Nations (FAO) forecasts that food demand in WANA will grow at a rate of 2.1 percent per year until 2050, while yearly growth in agricultural productivity has averaged just 1.9 percent since the turn of the millennium. If current productivity growth remains unchanged in the next few decades, a widening food gap will emerge that will need to be filled through increased food imports and government-based food-assistance programs. To respond effectively to all of these challenges, agricultural productivity in WANA needs to be accelerated without delay.

Extensive evidence indicates that agricultural research and development (R&D) has had a tremendous impact on agricultural productivity around the world (World Bank 2007; IAASTD 2008). Despite this well-documented evidence, many of WANA's countries continue to underinvest in agricultural R&D. Given the substantial time lag between investing in research and reaping its rewards—which is typically decades, not just years—agricultural research requires a long-term commitment of sufficient levels of sustained funding. For decades, agriculture, including agricultural R&D, was not a political priority in the region. The 2008 global food crisis has changed this to some extent: when food prices rose to record highs, governments across the region realized they could no longer neglect agricultural investment, and they started looking at ways to enhance agricultural productivity.

This report assesses trends in investments and human resource capacity in agricultural R&D in WANA, focusing on developments during 2009–2012.[2] The analysis is based on information from a set of country factsheets prepared by the Agricultural Science and Technology Indicators (ASTI) program of the International Food Policy Research Institute (IFPRI), using comprehensive datasets derived from primary surveys targeting over 300 agencies in 11 countries during 2013–2014. Accounting for about two-thirds of the region's total agricultural gross domestic product (AgGDP), the 11 sample countries do not provide a complete overview of agricultural R&D expenditures and staffing in the region as a whole. Yet, these countries are representative of the region's diversity in terms of income level, country size, and agroclimatic characteristics.[3] As private-sector data were not available in all sample countries, the data presented in this report only include agricultural R&D performed by government and higher education agencies. Data on the contributions of international agricultural R&D agencies operating in the subregion, such as the centers of the CGIAR Consortium, have also been excluded (see Box 1).

BOX 1 | CONTRIBUTIONS TO AGRICULTURAL R&D BY THE PRIVATE SECTOR AND INTERNATIONAL AGENCIES

The role of private-sector agricultural R&D in WANA is difficult to quantify, but is known to be limited or nonexistent in most WANA countries. Private companies typically outsource their R&D to the government and the higher education sectors. In Turkey, about 35 companies (mostly in the food-crop and seed sectors) have only recently begun to conduct limited agricultural R&D in-house. Given inherently high startup costs, most companies lack the resources necessary to recruit full-time researchers, so they engage the services of GDAR or of university-based researchers on a short-term contract basis. Despite having comparatively limited involvement in agricultural R&D to date, private companies do play an important role in releasing new varieties in Turkey.

The CGIAR plays an important role in the region, and the scope of its activities is wide-reaching. One of its centers is headquartered in WANA—the Institute for Agricultural Research in the Dry Areas (ICARDA)—and many others run offices or programs in the region. Many centers have a history of managing regional crop and livestock networks, running regional projects, and collecting and improving germplasm. A good example of successful collaboration between national R&D agencies and CGIAR is the International Winter Wheat Improvement Program (IWWIP), which was established in the mid-1980s and is jointly supported by Turkey, ICARDA, and the International Maize and Wheat Improvement Center (CIMMYT). Various other international organizations, such as the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and the Arab Organization for Agricultural Development (AOAD), conduct or support agricultural research in the WANA region.

2| Policy Context

The quality of political governance differs considerably across the countries of WANA. In 2013 Tunisia was the highest-ranked country in WANA for policy formulation and implementation and overall government effectiveness in the World Bank's Governance Indicators, followed by Morocco and then Jordan (World Bank 2014). Morocco and Tunisia, in particular, are rapidly converging with the European Union (EU) in many areas (as part of the European Neighborhood Policy and deepening preferential trade agreements) and this has brought about some important governance and policy reforms.[4] At the other extreme, Yemen, the lowest ranking WANA country in terms of government effectiveness remains affected by high levels of political instability.

The same dichotomy becomes apparent when looking at science and technology (S&T) policy across WANA's countries. Despite the region's renewed interest in agriculture since 2008, a number of countries still lack functioning policy frameworks needed to fully support agricultural innovation. Of the 11 countries included in ASTI analysis, four do not have official national science, technology, and innovation policies (Table 1), and in several of the countries that do, policies focus on innovation

TABLE 1 | Overview of science and technology policies and agricultural sector plans, selected countries

Country	Does the country have a national science, technology, innovation policy?	Is there an agricultural sector plan, and if so does it include a role for research?
Algeria	Yes, since 1998, but it is not really being adhered to.	The *National Agricultural and Rural Development Program* does not prioritize R&D; however, it does include an R&D capacity strengthening component.
Egypt	Yes, the policy was enacted in 2008; moreover, 2007–2016 has been declared the "Decade for Science and Technology."	Egypt's new *Strategy for Sustainable Agricultural Development towards 2030*, enacted in 2009, is a response to recent global and domestic challenges facing Egypt's agricultural sector. The strategy includes 12 national programs and subprograms, including the *National Program for Agricultural Research, Extension, and Technology Transfer.*
Jordan	Yes, the policy was enacted in 1985.	Jordan has an agricultural policy that includes agricultural R&D, but implementation is weak.
Lebanon	Yes, the policy was enacted in 2006.	The Ministry of Agriculture's Strategic Plan for 2010–2014 did not include R&D; instead, LARI's management board is charged with setting R&D priorities.
Mauritania	Yes, though not a policy per se, but rather a national research and innovation strategy.	Mauritania has a *national agricultural research plan*, but its implementation is highly dependent on donor funding.
Morocco	Yes, though not a policy per se, but rather a national science and technology strategy to 2025.	Agricultural R&D plays a central role in Morocco's 2008 agricultural sector plan.
Oman	Yes, the national science and technology policy was launched in 2011 after the establishment of the Research Council of Oman.	Oman intends to diversify its economy away from oil; the current agricultural sector plan considers the contribution of agricultural and fisheries R&D as vital.
Sudan	No	Sudan has no functioning agricultural sector plan.
Tunisia	Yes, since 1996.	National agricultural priorities are determined in decennial plans, the first of which was implemented in 1999, comprising ten research "domains."
Turkey	Yes, since the 1983 establishment of the Supreme Council for Science and Technology.	Agricultural R&D priorities are embedded within Turkey's agricultural strategy.
Yemen	No	Yemen has no functioning agricultural sector plan; the government's recent *National Agricultural and Food Security Strategy* mainly serves to guide the government in attracting foreign aid projects, some of which include a research component.

Source: Constructed by author using information from qualitative surveys.

at the macro level without offering sufficient guidelines or incentives to individual sectors. Many of WANA's countries have only begun to introduce S&T policies in the past decade or so, making it difficult to evaluate their long-term impact. Nevertheless, at this stage, the existing legislation, regulatory frameworks and policy implementation are thought to be weak in many countries. Underinvestment and noncompliance with certain regional or international targets—such as the minimum R&D investment target of 1 percent of GDP that all African Union member states committed to as part of the Lagos Plan of Action—is widespread and a possible indicator that not all of the region's countries assign sufficient priority to S&T.

National S&T policies and related legal frameworks are typically formulated by ministries overseeing S&T (or similar), whereas agricultural research agencies tend to be administered by ministries of agriculture. Consequently, agriculture-related priorities are not always satisfactorily embedded within national S&T policies, with the result that decisionmaking is fragmented and synergistic coordination among the relevant actors is lacking. Most of the region's countries do, however, have agricultural sector plans (the exceptions being Sudan and Yemen), but the extent to which these plans prioritize agricultural R&D differs widely. The agricultural sector plans of Morocco, Oman, Tunisia, and Turkey have strong agricultural R&D components, but the same cannot be said for the remaining countries in the ASTI sample (Table 1).

Most countries in the region lack policies to stimulate private agricultural R&D and innovation, although Turkey is an important exception in this regard. In 2012, recognizing the potential of privately funded and performed agricultural R&D, Turkey introduced extensive incentives to stimulate investment, including tax and social security–premium exemptions, and the launch of a fund for technology initiatives. As of 2014, additional draft legislation includes tax exemptions on the sale and lease of R&D–driven inventions, and corporate tax exemptions on at least half the income generated by such inventions. In addition, the draft legislation proposes to reduce the minimum number of R&D staff required for companies to be able to take advantage of other legal benefits from 50 to 30 employees. Turkey and the region's other countries still need to take steps to simplify the lengthy administrative procedures associated with registering (and protecting) new varieties, which acts as a major disincentive to private-sector agricultural R&D.

3| Institutional Context

The structure of agricultural R&D in WANA is highly complex, comprising a large number of government, higher education, private sector, and international research agencies (Table 2).

TABLE 2 | Number of agencies conducting agricultural research, 2012

Country	Government	Higher education	Private	Total
Algeria	15	7	0	22
Egypt	29	21	na	50
Jordan	2	7	4	13
Lebanon	2	4	0	6
Mauritania	4	3	1	8
Morocco	5	14	0	19
Oman	3	1	0	4
Sudan	4	28	0	32
Tunisia	12	10	0	22
Turkey	44	43	35	122
Yemen	2	5	0	7

Source: Constructed by author from ASTI (2014–2015).

Notes: ASTI's country pages (available at www.asti.cgiar.org/countries) provide more detail on the agricultural R&D agencies operating in WANA; na = data were not available.

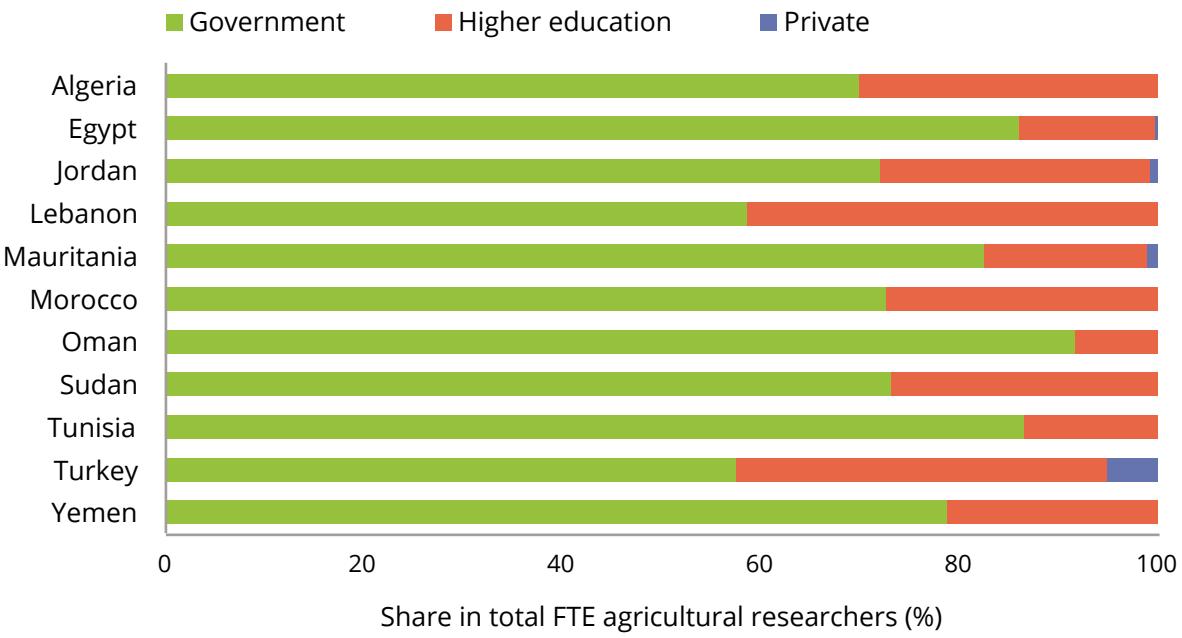
National agricultural research systems (NARSs) in WANA are most commonly anchored by national agricultural research institutes (NARIs), typically complemented by smaller government and higher education agencies and, in some cases, nonprofit and private institutions. NARIs across WANA are structured in one of five ways:

1. as a directorate within a ministry of agriculture or equivalent, such as Oman's Directorate General of Agriculture and Livestock Research (DGALR);
2. as numerous institutes organized under a directorate or center, such as the General Directorate of Agricultural Research (GDAR) in Turkey or the Agricultural Research Center (ARC) in Egypt;
3. as a semiautonomous institute or center under a ministry of agriculture or equivalent, such as Morocco's National Agricultural Research Institute (INRA) or the Lebanon Agricultural Research Institute (LARI);

4. as a semiautonomous institute that oversees all agricultural R&D conducted by the government and higher education sectors, such as Tunisia's Agricultural Research and Higher Education Institution (IRESA); and
5. as multiple agencies focusing on specific agricultural subsectors, such as the combination of Sudan's Agricultural Research Corporation (ARC), which focuses on crops, and its Animal Resources Research Corporation (ARRC), which focuses on livestock.

While there have been ongoing internal reorganizations over the past decade, the institutional structure of agricultural R&D in most WANA countries has remained largely unchanged. Notable exceptions include Oman, Jordan, and Tunisia. In 2006, the Government of Oman consolidated numerous isolated entities under an agriculture and livestock directorate and a fisheries directorate. One year later, Jordan's main agricultural research agency at that time (the National Center for Agricultural Research and Technology Transfer [NCARTT]) was merged with the country's agricultural extension department to form the National Center for Agricultural Research and Extension (NCARE). In Tunisia, the National Institute for Aquatic Science and Technology (INSTM) and Institute for Arid Regions (IRA) were the country's last agricultural R&D agencies to be transferred to the IRESA umbrella in 2008, bringing them closer to the constituents they serve. Egypt's research centers are currently being consolidated under the Ministry of Scientific Research's Supreme Council of Scientific Research Centers and Institutes, with the goal of harmonizing the activities being conducted.

FIGURE 1 | Institutional distribution of agricultural research, 2012



Source: Constructed by author from ASTI (2014–2015).

Notes: Data for Mauritania are for 2011. Private-sector data for Egypt were not available, but companies like Imtenan, Pioneer, Sekam, and Technogreen are all known to conduct a limited amount of agricultural R&D in Egypt. FTE = full-time equivalent.

The government sector continues to dominate agricultural R&D in all countries for which data were available. Government agencies accounted for between 57 percent (Turkey) and 92 percent (Oman) of the total number of agricultural researchers in the sample (Figure 1). The role of the higher education sector has gradually risen in recent years based on an increase in the number of higher education agencies, both through the creation of new universities and of new departments and faculties within existing universities. Still, many of these universities and faculties employ only a handful of full-time agricultural researchers. This has led to an increased fragmentation of NARSs in certain cases, such as in Sudan, and a potential shift away from the applied research needs of farmers (typically the responsibility of national agricultural research institutes) to more specialized basic research (typically the role of universities).

4| Financial Resources

Expenditures

Agricultural R&D spending levels differ broadly across the 11 sample countries. In accordance with international standards (ASTI 2015a), ASTI presents spending data in purchasing power parity (PPP) dollars (see Box 2), which measure the relative purchasing power of currencies across countries by eliminating national differences in price levels. Egypt ranked highest in agricultural R&D spending: In 2012, the country

BOX 2 | PURCHASING POWER PARITY EXCHANGE RATES 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 Egypt than they are in any European country; similarly, locally made office furniture in Morocco 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 for comparing economic data. When calculating economic data, such as agricultural R&D spending across countries, the preferred method 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. PPPs are also used to convert local 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).

Using market exchange rates to calculate agricultural R&D spending in WANA would result in a completely different picture. When expressed in U.S. dollars, for example, Turkey's agricultural R&D spending in 2012 would be the region's largest (more than three-times larger than Egypt's).

spent 471 million PPP dollars (in 2005 prices) on agricultural R&D (Table 3). Turkey and Morocco ranked second and third, spending 406 million and 131 million, respectively, on agricultural R&D that year.

TABLE 3 | Total agricultural R&D spending, 2009 and 2012

Country	Total spending, 2009 (in million 2005 PPP dollars)	Total spending, 2012 (in million 2005 PPP dollars)	Spending as a share of AgGDP (%), 2012
Algeria	68.6	81.7	0.21
Egypt	379.3	471.0	0.44
Jordan	34.0	32.3	1.84
Lebanon	21.7	34.1	0.95
Mauritania	11.2	8.9	0.80
Morocco	127.4	131.2	0.49
Oman	81.4	97.0	6.51
Sudan	52.4	30.0	0.19
Tunisia	49.4	55.9	0.64
Turkey	407.5	406.3	0.51
Yemen	47.6	34.5	0.56

Source: Constructed by author from ASTI (2014–2015).

Notes: ASTI's country pages (available at www.asti.cgiar.org/countries) provide more detail on the agricultural R&D agencies operating in WANA; na = data were not available.

Total agricultural R&D spending in the 11 sample countries grew by just 8 percent on average in inflation-adjusted terms during 2009–2012. Lebanon reported the highest growth during this period (more than 50 percent), but this was mostly due to investments in infrastructure and equipment after years of neglect. Algeria and Egypt also reported relatively large increases in their agricultural R&D spending, but in both cases the increases were driven by (retroactive) salary-related increases. In Oman, a sharp increase in oil revenues in 2010—just when the government was revising its Eighth Five-Year Plan (2011–2015)—prompted a considerable increase in government funding to agricultural R&D. In contrast, Sudan and Yemen recorded sharp declines in their agricultural R&D spending levels during 2009–2012. In Sudan, the decrease can be attributed to decreased oil revenues due to the 2011 attainment of independence by South Sudan. Despite this considerable reduction in funding levels, early indications suggest that agricultural R&D expenditures in Sudan have risen since 2013. Falling investment levels in Yemen can largely be attributed to political instability.

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 share of AgGDP. This relative measure goes beyond absolute agricultural R&D spending levels to indicate the "intensity" of research investments. International and regional organizations, like the United Nations and the African Union, have called for minimum agricultural R&D investment targets of at least 1 percent of AgGDP, but as of 2012 only 2 of the 11 sample countries in WANA had reached that target (Table 3). Most of the countries invested between 0.5 to 1.0 percent of their AgGDP in agricultural R&D that year. Algeria and Sudan seriously underinvest in agricultural R&D, each spending just 0.2 percent of their AgGDP on agricultural research, which is clearly insufficient given the important role that agriculture plays in their economies. In contrast, Oman's 2012 intensity ratio reached 6.5 percent, one of the highest shares in the world.

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. For these reasons they need to be interpreted carefully, within the context of national circumstances. A one-size-fits-all investment target for the region is certainly not desirable given that structural economic differences call for different investment strategies. Guidelines for the interpretation of intensity ratios include the following:

- Small countries often have higher intensity ratios based on an inability to take advantage of economies of scale. To be effective, national research systems in small countries need to establish minimum-level capacities across relevant disciplines and major commodities, regardless of the size of the agricultural sector they serve. Establishing this critical mass generally means spending more relative to larger countries to achieve the same results.
- Many countries in WANA have an arid climate and hence smaller agricultural sectors compared with their tropical neighbors. The smaller the country's AgGDP, the higher its agricultural R&D intensity ratio.
- A case can be made that AgGDP levels only partially indicate the importance of agriculture to a national economy. For example, Turkey invests significantly in research relating to agrochemicals and food processing, but these fields are not classified as "agriculture" by the World Bank and hence are not reflected in the country's intensity ratio.

Despite these limitations, intensity ratios do show that support for agricultural R&D in certain countries of WANA is too low to sustain viable agricultural R&D programs capable of addressing current and future priorities. In many of the sample countries, a significant majority of R&D funding is allocated to staff salaries, leaving comparatively small shares to support the actual day-to-day costs of running research programs.

Allocation of Expenditures across Cost Categories

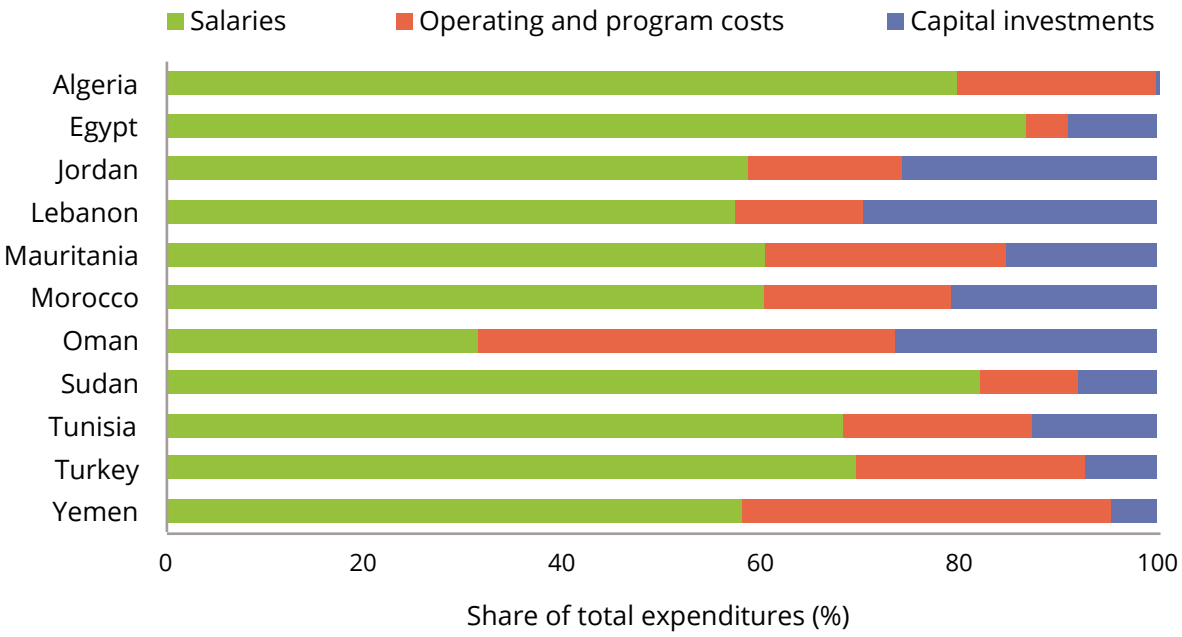
A closer look at the composition of agricultural R&D spending by cost category reveals that in most of the sample countries staff salaries account for the bulk of agricultural R&D expenditures. No formula can determine the optimal allocation of agricultural R&D spending across salaries, operating and program costs, and capital investments: it 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 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 accounted for more than 80 percent of total expenditures by the national agricultural research institutes of Algeria, Egypt, and Sudan during 2009–2012 (Figure 2). This is an enormous proportion, especially considering Algeria's and Sudan's extremely low intensity ratios, as previously mentioned. In Egypt, close to 90 percent of ARC's total spending is allocated to salary-related expenses, leaving very limited resources to fund the day-to-day costs of conducting research and maintaining and upgrading R&D infrastructure and equipment. In the past, donors played a considerable role in funding these types of expenditures, but the 2011 revolution led to a substantial decline in donor contributions. The day-to-day operation of research programs is clearly underfunded in Jordan and Lebanon as well, which understandably impacts the quality and quantity of research outputs in these countries. In Jordan, many long-standing research programs were eliminated following recent budget cuts. In Lebanon, greater investments in laboratories, inputs, and information and communications technologies are urgently needed. Oman, the only high-income country included in the sample, clearly stands out. Oman not only has a much higher agricultural R&D intensity ratio, but also spends a considerably larger share of its budget on nonsalary-related costs.

Funding Sources

Funding for agricultural R&D in WANA is derived from a variety of sources, including national governments, donors, development banks, producer organizations, and the private sector, along with internally generated revenues through the sale of goods and services. Governments are by far the most important source of funding for agricultural R&D in the region (Figure 3). Government funding can reach an agricultural R&D agency through a variety of channels. In some countries, staff salaries are directly disbursed by the Ministry of Finance, while operating and capital costs are disbursed by the Ministry of Agriculture or equivalent. Most countries in the region have a Ministry of Science and Technology that allocates research funding through one or more science funds, either competitively or through direct budget allocations. Regional competitive funds, which are common in Africa south of the Sahara (SSA) and Latin America, do not exist in WANA. The EU-supported Agricultural Research in the Mediterranean Network (ARIMNet) fulfills a similar role in countries around the Mediterranean. ARIMNet aims to promote and enhance coordination of agricultural

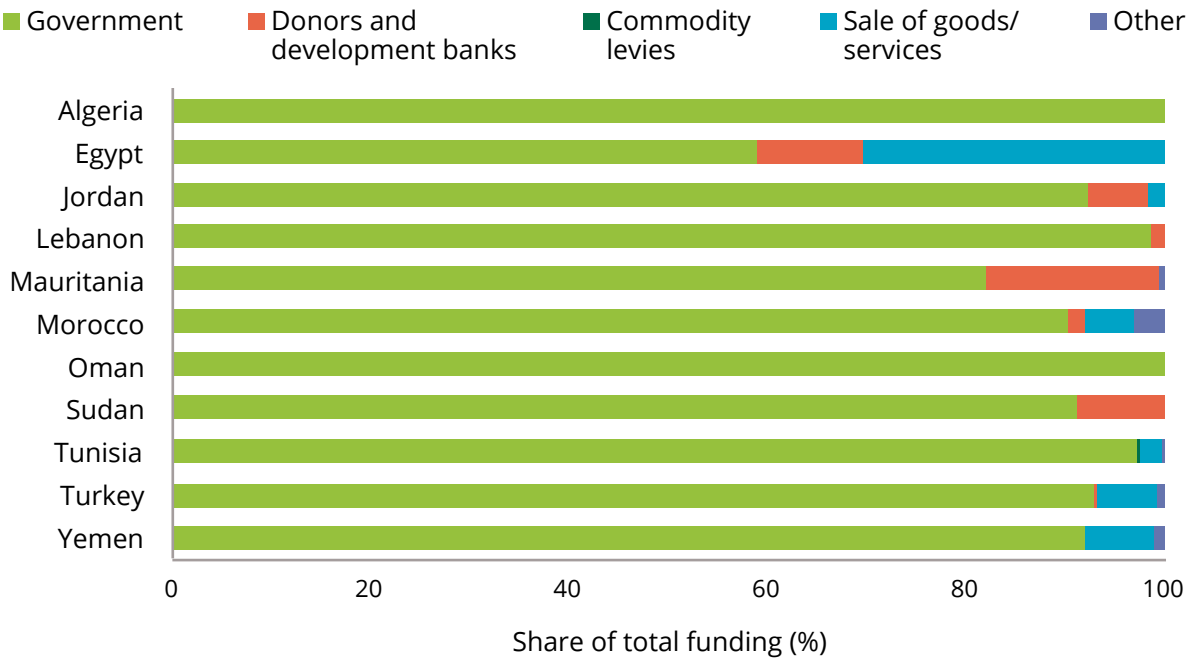
FIGURE 2 | Spending by cost category for the main government agencies, 2009–2012



Source: Constructed by author from ASTI (2014–2015).

Notes: Shares are based on averages for the 2009–2012 period (and in the case of Mauritania, 2009–2011). Data for each country include the following entities: Algeria = INRAA; Egypt = ARC; Lebanon = LARI; Mauritania = IMROP, CNERV, and CNRADA; Morocco = INRA, INRH, and CRF; Oman = DGALR; Sudan = ARC; Tunisia = all government agencies under IRESA; Turkey = all agencies under GDAR; and Yemen = AREA. See the acronym list for the full names of each agency.

FIGURE 3 | Relative shares of research funding for the main government agencies, 2009–2012



Source: Constructed by author from ASTI (2014–2015).

Notes: Shares are based on averages for the 2009–2012 period (and 2009–2011 in the case of Mauritania). Data for each country include the following entities: Algeria = INRAA; Egypt = ARC; Jordan = NCARE; Lebanon = LARI; Mauritania = IMROP, CNERV, and CNRADA; Morocco = INRA, INRH, and CRF; Oman = DGALR; Sudan = ARC; Tunisia = all government agencies under IRESA; Turkey = all agencies under GDAR; and Yemen = AREA. See the acronym list for the full names of each agency.

research programs and improve local cooperation. It funds research programs in member countries on a competitive basis.

Donors and development banks play a relatively small role in funding agricultural R&D in WANA compared with other developing regions around the world, such as SSA and Central America. The EU and individual EU countries are WANA's main agricultural R&D donors. The United States Agency for International Development (USAID) also plays a key role in certain countries. Additional funding is provided by international organizations and funds, including the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), FAO, the International Atomic Energy Agency (IAEA), ICARDA, the International Fund for Agricultural Development (IFAD), the United Nations Development Programme (UNDP), and others.

Research agencies can increase their funding by commercializing their outputs. Some agricultural R&D agencies in WANA, such as those in Egypt, manage to derive a considerable share of their total funding through the sale of seed and vaccinations, and services such as laboratory tests and technical assistance. However, not all agricultural research agencies can keep the resources they generate internally. All funds raised through the sale of goods and services by NCARE in Jordan, for example, are channeled back to the Treasury, creating a disincentive for the center to diversify its funding.

5| Human Resources

Researchers

Egypt's agricultural R&D system is among the world's largest in terms of human resource capacity. As of 2012, Egypt employed more than 8,400 full-time equivalent (FTE) agricultural researchers, three-quarters of whom were employed at ARC (Table 4). Turkey also has a large agricultural R&D system, employing over 3,000 FTE researchers in 2012. The remaining sample countries have much smaller NARSs. Algeria, Morocco, Sudan, Tunisia, and Yemen each employed between 500 and 1,000 agricultural FTEs in 2012, while the systems in Jordan, Lebanon, and Oman each employed between 200 and 300 FTEs. Mauritania has a very small agricultural R&D system (63 FTEs in 2011) and hence lacks the critical mass of scientists needed to have a tangible impact.

On a positive note, the number of agricultural researchers grew in all sample countries during 2009–2012, either modestly, as in Jordan and Sudan, or more considerably, as in Egypt and Lebanon. Egypt's agricultural R&D system added nearly 2,000 FTE researchers during 2009–2012 as a result of the Ministry of Agriculture's Sustainable Agricultural Development Strategy towards 2030, which emphasizes

human resource development in agricultural R&D and extension. Growth in Lebanon occurred following a sustained period of recruitment restrictions and subsequent capacity losses.

Comparing FTE researcher numbers with the economically active agricultural population provides an indicator of the relative concentration of agricultural R&D capacity across countries (Figure 4). Very large differences were observed across the sample countries. Algeria, Mauritania, Morocco, and Sudan employ relatively few agricultural researchers when taking into account the number of people economically engaged in agriculture. Egypt, Jordan, and Lebanon, on the other hand, employ very high numbers of researchers per farmer. With the exception of Mauritania, ratios of researchers per 100,000 farmers have increased in all countries in recent years. Although these ratios provide useful insights, their limitations should be noted given that they take neither the qualification levels nor the experience of researchers into consideration.

TABLE 4 | Total number of agricultural researchers, 2009 and 2012

Country	Total researchers, 2009 (in full-time equivalents)	Total researchers, 2012 (in full-time equivalents)	Researchers per 100,000 farmers, 2012
Algeria	510.3	593.4	17.6
Egypt	6,490.3	8,419.7	133.3
Jordan	268.7	272.3	228.8
Lebanon	130.1	209.2	747.1
Mauritania	48.9	62.9	8.3
Morocco	520.7	556.3	19.0
Oman	193.3	243.6	63.6
Sudan	925.3	932.8	13.0
Tunisia	431.5	541.6	66.1
Turkey	2,581.8	3,009.4	38.5
Yemen	486.8	526.7	23.8

Source: Constructed by author from ASTI (2014–2015) and, for data on farmers, FAO (2015).
Note: Mauritania data are for 2009 and 2011.

BOX 3 | THE CONCEPT OF FULL-TIME EQUIVALENT RESEARCHERS

ASTI bases its calculations of human resource and financial data on full-time equivalent staffing, or FTEs, which take into account the proportion of time 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 one FTE.

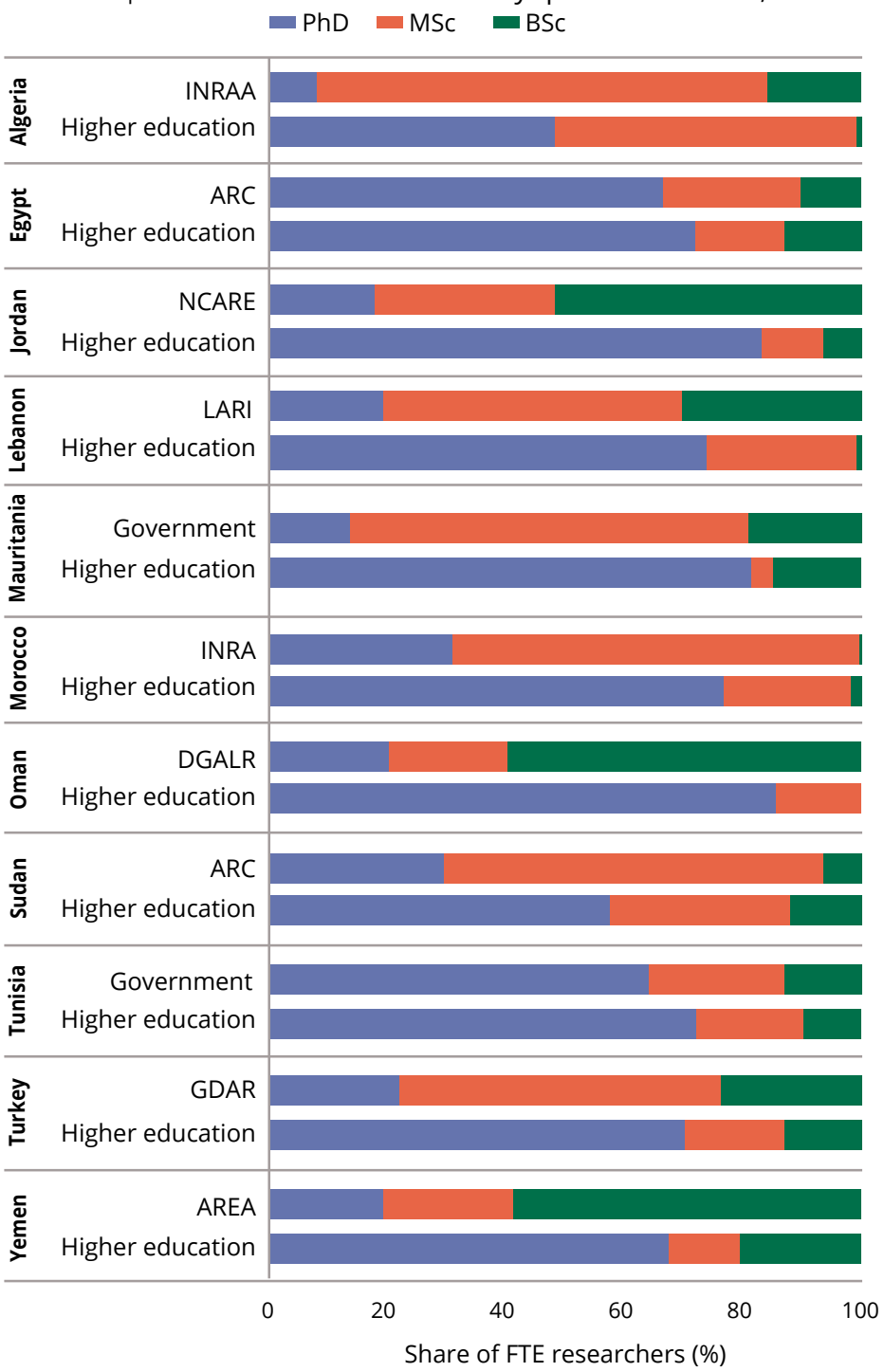
Researcher Qualification Levels

A minimum number of PhD-qualified scientists is generally considered fundamental to the conception, execution, and management of high-quality research; to effective communication 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. The sample countries of WANA don't all offer adequate PhD training, however. Lebanese universities currently offer no PhD-level agricultural science programs, while PhD training in Oman has only been possible since 2009, when Sultan Qaboos University began PhD programs in crop sciences, soil and water management, food science and nutrition, and marine sciences and fisheries. The majority of agricultural researchers in the other countries, especially the younger ones, hold PhD degrees from local universities.

Egypt employs close to 5,700 PhD-qualified agricultural researchers (in FTEs), more than the rest of Africa combined. Many, however, question the quality of local PhD training compared with international standards, citing that Egyptian PhDs are too easily awarded. It is encouraging that the Egyptian government has recognized these issues and taken steps to improve the situation by laying the foundation for a new education system through legislative reform, institutional restructuring, and the establishment of independent quality-assurance mechanisms and monitoring systems. Still, it will remain challenging to attract and maintain a qualified pool of agricultural researchers without competitive remuneration.

On average, agricultural researchers employed at government agencies across WANA hold much lower qualification levels than their university-based counterparts (Figure 4). The disparity in the official status of government-based scientists (as civil servants) and university scientists (as teachers/researchers) prevents government agencies in many countries from offering the competitive salaries and benefits needed to attract, motivate, and retain staff. This has provoked the departure of many well-qualified, young researchers in favor of better conditions at universities in a large number of countries, including Algeria, Jordan, Lebanon, and until recently Oman. In January 2014, the Omani government closed the 25–50 percent salary gap between the country's agricultural R&D agencies in the government and

FIGURE 4 | Distribution of researchers by qualification level, 2012



Sources: Constructed by author from ASTI (2014–2015).
Notes: Data for Mauritania are for 2011 and include CNERV, CNRADA, and IMROP. Data for Tunisia include all government and higher education agencies under IRESA. See the acronym list for the full names of each agency.

higher education sectors to institute greater equality, thereby allowing government agencies to compete in recruiting and retaining agricultural researchers. In Turkey, government agencies under the GDAR umbrella remain severely challenged

in retaining PhD-qualified researchers because promotional opportunities are nonexistent beyond the "associate professor" level. The lack of opportunity for career advancement within GDAR has driven many of its senior researchers into the higher education or private sectors, despite GDAR's superior research infrastructure and equipment.

Interestingly, the status, remuneration, and incentive inequities between the government and higher education sectors that characterize most of the countries in WANA are nonexistent in Egypt and Tunisia. As a result, no significant differences were observed in average qualification levels between government- and university-based researchers in these two countries. Status and salary differences within countries are only one part of the problem, however; differences across countries are also driving staff turnover. In recent years, there has been a considerable exodus of talented and highly qualified professors and researchers from countries like Egypt, Jordan, and Lebanon toward the Gulf and other high-income countries, considerably weakening local capacity.

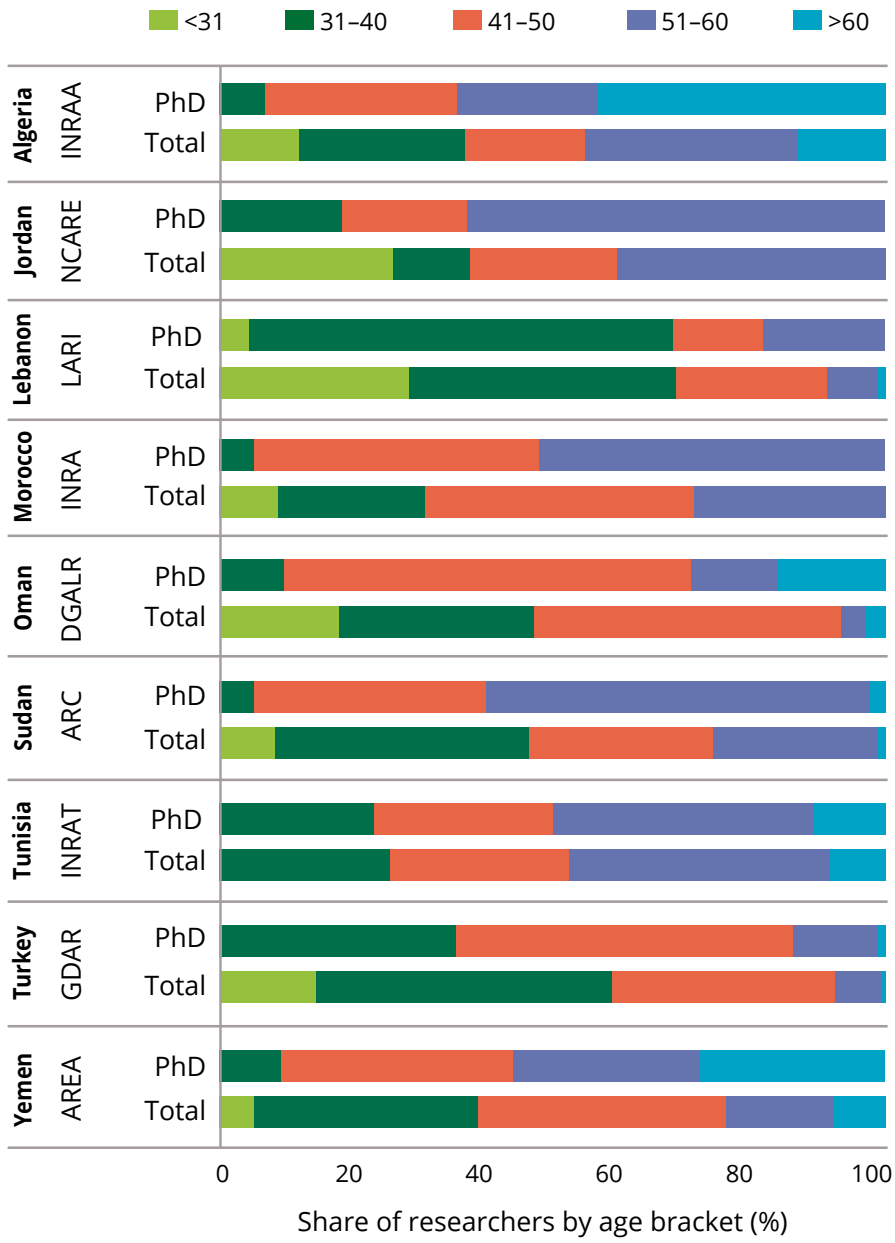
Despite all this, in 10 of the 11 WANA sample countries the number of PhD-qualified researchers increased in absolute terms during 2009–2012 (the exception being Jordan). Moreover, most of the capacity increases in the region described above occurred at the MSc and PhD level, rather than the BSc level, indicating that average qualification levels among the agricultural researchers in the sample countries have improved over time.

Staff Turnover and Aging

Despite the improvements described in the previous section, a large number of the sample countries of WANA are facing challenges when it comes to maintaining a critical mass of PhD-qualified researchers. Over the past decade, Morocco lost a considerable number of highly experienced researchers with PhD degrees following two consecutive voluntary-retirement schemes, coupled with limited recruitment. As of 2012, close to two-thirds of Morocco's remaining PhD-qualified agricultural researchers were 50 years or older and nearing the retirement age. The national agricultural research institutes of Algeria, Jordan, Sudan, Tunisia, and Yemen are facing similar challenges, with more than half their PhD-qualified researchers being 50 years or older (Figure 5). Given that the official retirement age in most countries is 60 to 65 years, a very large number of highly experienced researchers will be retiring in the short to medium term. Without adequate succession strategies and training, this will create significant knowledge gaps and concerns about the quality of future research outputs. Although the average age of university-based agricultural researchers is generally lower than researchers in the government sector, the staff aging problem is not exclusive to the government sector. In Morocco, for example, at the Agronomy and Veterinary Institute Hassan II, the country's main agricultural university, more than 90 percent of PhD-qualified researchers (and two-thirds of MSc-qualified researchers) are in their 50s or 60s.

Lebanon and Turkey employ a much younger pool of agricultural researchers compared with most other countries in the region. As previously mentioned,

FIGURE 5 | Distribution of researchers by age bracket, 2012



Source: Constructed by author from ASTI (2014–2015).

Notes: Data on the age of researchers were not available for Egypt. Mauritania is excluded because it doesn't have a NARI. The official retirement age for agricultural researchers is 60 years in Algeria and Oman; 64 years in Lebanon; and 65 years in Mauritania, Sudan, Tunisia, and Turkey. In Egypt it is 60 years for researchers employed at government agencies, but there is no fixed retirement age for those employed at higher education agencies. In Jordan the retirement age is 55 years for women 60 years for men. In Morocco it is 60 years for researchers at government agencies and 65 years for researchers at higher education agencies. In Yemen, it is 60 years by age and 65 years by service. See the acronym list for the full names of each agency.

following a sustained period of recruitment restrictions, LARI obtained approval to hire new researchers, most of whom are young and inexperienced. As of 2012, 70 percent of LARI's researchers were in their 20s or 30s and in need of considerable training and mentoring to progress in their careers.

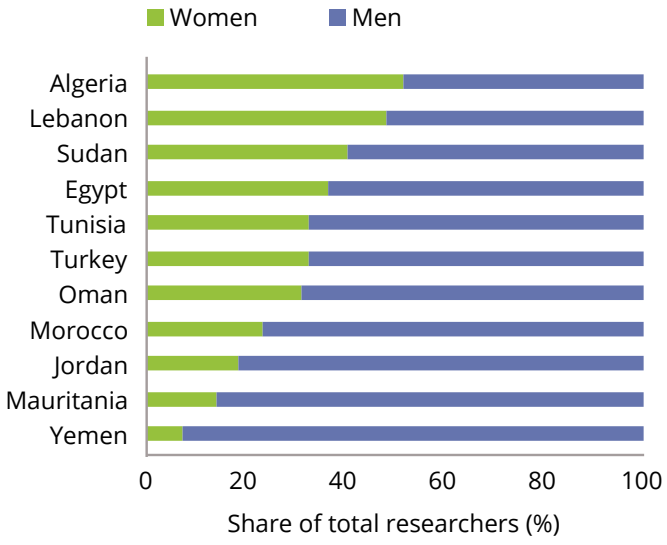
Participation by Women

Over the past two decades, women's participation in agriculture has increased significantly in WANA as large numbers of men have migrated to Gulf countries in search of nonagricultural employment, leaving women at home to manage farms. Between 1990 and 2011, the share of women in the total agricultural labor force across WANA increased from 34 to 45 percent (FAO 2011). 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 sufficiently high shares of female agricultural researchers.

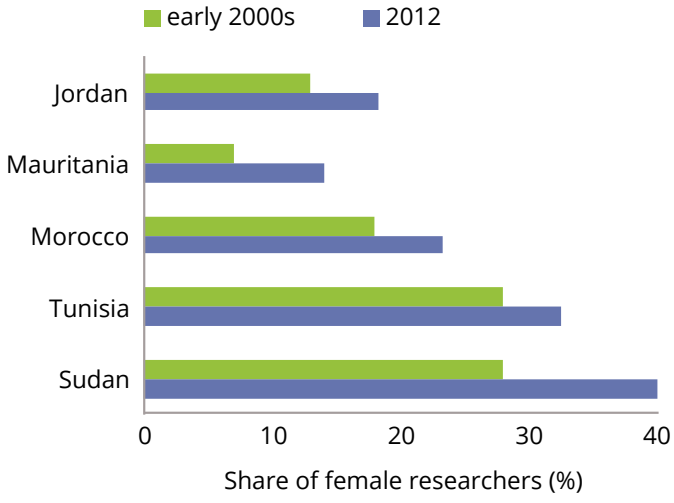
Nearly one-third of all agricultural researchers in the 11 sample countries in 2012 were female, which is higher than the average for SSA (22 percent in 2011) and for most countries in South Asia. Women constitute significant shares of agricultural researchers in countries like Algeria (51 percent), Lebanon (48 percent), and Sudan (40 percent); however, in countries like Jordan (18 percent), Mauritania (14 percent), and Yemen (7 percent), shares of female researchers remain very low (Figure 6a).

FIGURE 6 | Female participation in agricultural R&D

a. Share of female researchers, 2012



b. Change in the share of female researchers in selected countries, early 2000s–2012



Source: Constructed by author from ASTI (various years).

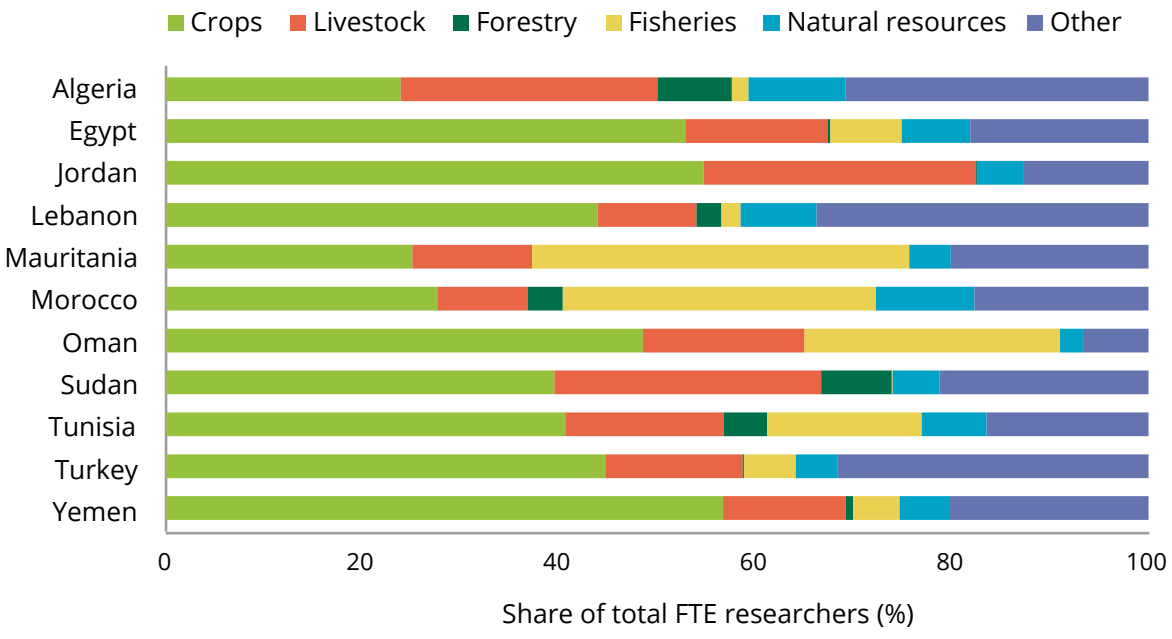
Notes: Data for Sudan are for 2000; data for Mauritania are for 2001 (and 2011); data for Morocco and Tunisia are for 2002; data for Jordan are for 2003.

A positive development, however, is the trend toward increasing shares of female researchers. In all the sample countries for which historical gender data were available, the share of female agricultural researchers has increased by at least 5 percentage points since the turn of the millennium (Figure 6b). The increase was greatest in Sudan (12 percentage points), but Mauritania also doubled its share of female researchers from 7 percent in 2001 to 14 percent in 2012. Nonetheless, in most countries, the majority of high-level research and management positions are still held by men. An important exception is Lebanon, where (as of 2012) three out of four deans of agricultural faculties were female.

Research Focus

Governments and agricultural research agencies across WANA are limited in their choice of options when it comes to allocating scare resources. It is important, however, that they earmark sufficient resources to key priorities and commodities of national (and regional) significance if agricultural R&D is to have a lasting impact on productivity growth and poverty reduction. ASTI collected detailed information on the allocation of researchers across commodity areas. Roughly half of the time of researchers in Egypt, Jordan, Oman, and Yemen was spent on crops (Figure 7). Researchers in Algeria, Mauritania, and Morocco, on the other hand, spent less than a quarter of their time on crop research. The most researched crops in WANA include wheat, fruits, vegetables, and olives (Table 5). Livestock research accounted for between 10 and 30 percent of FTE researchers in the 11 sample countries. Fisheries research plays a particularly important role in Mauritania, Morocco, and Oman.

FIGURE 7 | Researcher focus by major commodity area, 2012



Source: Constructed by author from ASTI (2014–2015).
Note: Mauritania data are for 2011.

TABLE 5 | Research focus of crop scientists by major crop item, 2012

Country	Major crop items
Algeria	Wheat (30%), other cereals (17%), chickpeas (10%), other pulses (6%), olives (6%), fruits (6%), other oil-bearing crops (5%), beans (5%)
Egypt	Fruits (15%), wheat (11%), vegetables (11%), maize (6%), cotton (5%), rice (5%)
Jordan	Vegetables (38%), olives (17%), medicinal plans (17%), wheat (10%), barley (7%), fruits (7%)
Lebanon	Wheat (18%), fruits (17%), olives (11%), potatoes (10%), medicinal plants (7%), vegetables (6%), almonds (6%), barley (5%)
Mauritania	Rice (40%), wheat (13%), vegetables (10%), sorghum (7%), fruits (5%)
Morocco	Wheat (17%), other fruits (15%), olives (13%), citrus fruits (12%), medicinal plants (10%), vegetables (5%)
Sudan	Sorghum (14%), fruits (12%), wheat (11%), vegetables (10%), beans (6%), cotton (6%)
Tunisia	Olives (20%), vegetables (14%), fruits (12%), barley (10%), pulses (10%), wheat (9%)
Turkey	Fruits (26%), wheat (11%), vegetables (9%), maize (7%), olives (6%), oil-bearing crops (6%)
Yemen	Wheat (25%), fruits (20%), vegetables (12%), pulses (7%), barley (5%), maize (5%), sorghum (5%), other cereals (6%)

Source: Constructed by author from ASTI (2014–2015).

Notes: Major crops include those that are the focus of at least 5 percent of all crop researchers. Mauritania data are for 2011; Oman data were unavailable.

In smaller WANA countries, like Jordan, Lebanon, and Oman, very few crop varieties are generated in-country. Most are bred by ICARDA and ACSAD, and tested and adapted locally by NARIs. The research focus of agricultural R&D agencies across WANA has increasingly shifted toward product development and food processing in recent years. Moreover, given looming chronic water shortages and the fact that agriculture accounts for the lion's share of the region's water consumption, improving agricultural water use efficiency is also becoming a major research priority across WANA. The main thematic areas covered by researchers in this area include irrigation techniques and water management practices, water resource development, and the health and environmental impacts of water quality.

6| Policy Implications

Well-developed NARSs and adequate levels of investment and human resource capacity are prerequisites to the attainment of agricultural productivity growth, food security, and poverty reduction. WANA is a highly diverse region when it comes to agricultural research: On the one hand, it is home to countries like Turkey with relatively well-staffed and well-funded research institutes producing world class research. On the other hand, the region includes countries like Sudan and Yemen that grossly underinvest in research and are severely challenged by outdated equipment and facilities that impede the conduct of productive research and compromise the number and quality of research outputs. Throughout the region, success in achieving future agricultural productivity growth is intrinsically dependent on sufficient and stable financial resources for agricultural R&D and the development of adequate human resource and institutional capacity. Governments need to translate the political support to agriculture that has emerged since the global food crisis into a clear set of policy directives if the many challenges facing agricultural R&D systems in the region are to be addressed. Taking into account the various challenges related to agricultural R&D funding, human capacity, outputs, and institutional structure highlighted in this report, policy implications for the region's national governments are indicated across key areas, as is outlined below.

- **Governments must address underinvestment in agricultural R&D and take the necessary policy steps to diversify funding sources**

Despite increased allocations to agricultural research by a number of national governments in WANA in recent years, agricultural R&D spending in most of the sample countries during 2009–2012 remained below the levels required to sustain their agricultural sectors' needs. The majority of the countries invested less than 1 percent of their AgGDP in agricultural research (the minimum investment target proclaimed by international and regional organizations, such as the United Nations and African Union). Some countries that have increased their expenditures substantially in recent years, such as Egypt, have directed most of the funds toward (much-needed) salary increases, rather than actual research programs. In many countries in the region, nonsalary-related expenditures account for an insufficient share of total R&D expenditures to support viable research programs. National governments urgently need to address this underinvestment if they are to secure a strategic program of effective research activities that yields increased agricultural productivity.

Compared with other developing regions around the world, agricultural R&D funding in WANA is extremely dependent on government sources. In order to stimulate diversification, the region's governments need to develop strategies and mechanisms to raising additional funding in other ways, such as through donor contributions, private-sector participation, or the sale of goods and services. The private sector is currently the least developed source of sustainable financing for agricultural R&D in WANA (its funding potential remains largely untapped in most countries). Cultivating private funding requires that national governments provide a more enabling policy environment through tax incentives, protection of intellectual property rights, and regulatory reforms to encourage the spill-in of international technologies.

- **Governments must invest in training and capacity building and remove status and salary discrepancies between government- and university-based researchers.**

Few national agricultural research institutes in WANA have autonomous status in setting their own financial, human resource, or operating policies, which limits their ability to diversify their funding sources, offer competitive salaries and working conditions, and generally maximize efficiency levels. Growing concern exists regarding the lack of human resource capacity in agricultural R&D to respond effectively to the challenges facing the agricultural sectors of the region's countries, which include water scarcity and the loss of agricultural land. The majority of PhD-qualified researchers will retire in the next decade in numerous countries. R&D agencies therefore need to develop systematic human resource strategies without delay, incorporating existing and anticipated skills gaps and training needs. The successful implementation of such strategies will require both political and financial support. National governments must expand their investments in agricultural higher education to allow universities to increase the number and size of their MSc and PhD programs—or establish such programs in countries were MSc and PhD programs are still lacking—and to improve the curricula of existing programs. In addition to degree-level training, NARIs should involve present and past tenured researchers in mentoring their younger colleagues. In some countries, this may involve increasing the official retirement age of researchers (as Sudan has recently done), or instituting some form of flexible working arrangements for retired researchers. Developing incentives to create a more conducive work environment for agricultural researchers is also crucial. In a large number of countries, significant discrepancies exist in the remuneration, working conditions, and incentives offered to researchers employed at NARIs compared with their university-based colleagues. These inequities need to be eliminated or overcome to enable NARIs to attract, retain, and motivate well-qualified researchers.

▶ Governments must develop long-term national agricultural research policy agendas and provide stronger institutional, financial, and infrastructural support to NARIs

A critical area needing urgent attention is the development of strong, national agricultural research policy agendas, together with the necessary expertise to support these agendas long term. It is also essential that governments strengthen the institutional, financial, and infrastructural foundations of agricultural R&D agencies so they can more effectively address farm productivity challenges. Strengthening the planning capacity at the research program level is crucial to the overall effectiveness of R&D agencies. Many agricultural R&D agencies currently lack efficient administration systems and practices needed to more effectively monitor progress and inform strategic decisionmaking.

Governments will also need to provide the necessary policy environment to stimulate cooperation among the country's agricultural R&D agencies in order to maximize synergies and efficiencies in the use of the scarce resources available to universities and government agencies. In addition, governments must take action to ensure that improved varieties and technologies released by agricultural R&D agencies are disseminated to and adopted by farmers. This involves strengthening extension agencies and more clearly delineating the roles of NARIs and extension agencies to actively promote cooperation. Gender considerations also need to be taken into account in terms of identifying gender-specific research needs, designing training programs, and determining criteria for technology development and adaptation.

▶ Governments must strengthen research linkages at the regional and international level

Political integration across the countries of WANA is not very strong because many leaders are reluctant to give up control to supranational bodies. Compared with other regions around the developing world, regional integration of agricultural research in WANA is relatively weak. The impact of agricultural R&D does not stop at national borders, however. Synergies can be taken advantage of in the development of new knowledge and technologies across multiple countries willing to cooperate and provide the necessary resources. For a region like WANA, which comprises numerous small countries or countries with small agricultural sectors, this kind of strategy would maximize the use of limited resources. The fact that WANA countries are currently facing numerous common challenges—such as climate change, water scarcity, and rapid population growth—the region as a whole could benefit tremendously from a more integrated approach to agricultural R&D. Governments will therefore need to establish political and institutional mechanisms to enhance regional integration and support regional bodies and networks in defining, implementing, and funding a regional research agenda targeting issues of common interest.

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Notes

1| Note that there is no uniform definition of the countries that comprise WANA; for the purpose of this study, the region is defined to include Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, the United Arab Emirates, and Yemen.

2| ASTI is mandated to collect financial and human resource data from agricultural R&D agencies in low- and middle-income countries. In this case, however, Oman (a high-income country) was included to facilitate the construction of a representative sample. The remaining 10 low- and middle-income countries account for about three quarters of the combined agricultural GDP of the region's low- and middle-income countries.

3| Agricultural R&D is defined to include research on crops, livestock, forestry, fisheries, and natural resources, as well as on-farm postharvest research.

4| The European Neighborhood Policy was developed in 2004, with the objective of avoiding the emergence of new dividing lines between the enlarged EU and its neighbors. Within this policy, the EU offers its neighbors a privileged relationship, building upon a mutual commitment to common values (democracy and human rights, rule of law, good governance, market economy principles and sustainable development).

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