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MEASURING THE EFFECTIVENESS OF AGRICULTURAL R&D IN SUB-SAHARAN AFRICA FROM THE PERSPECTIVES OF VARIETAL OUTPUT AND ADOPTION

Initial Results from the Diffusion of Improved Varieties in Africa Project

Arega Alene, Yigezu Yigezu, Jupiter Ndjeunga, Ricardo Labarta, Robert Andrade, Aliou Diagne, Rachel Muthoni, Franklin Simtowe, and Tom Walker

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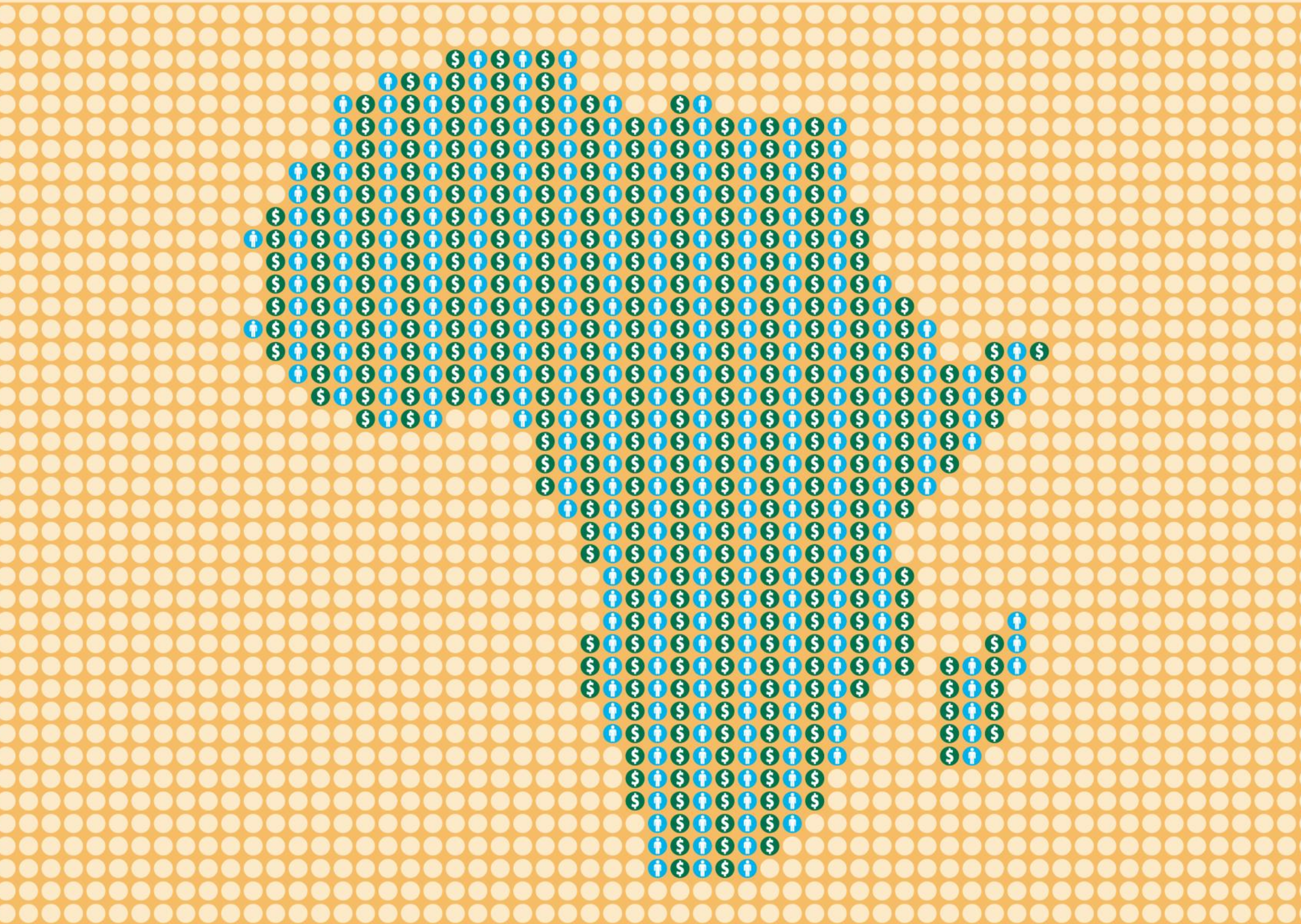
AGRICULTURAL R&D: INVESTING IN AFRICA'S FUTURE
Analyzing Trends, Challenges, and Opportunities



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About the Authors

Arega Alene is an impact assessment economist at the International Institute of Tropical Agriculture (IITA-Malawi); **Yigezu Yigezu** is an applied agricultural economist at the International Center for Agricultural Research in Dry Areas (ICARDA); **Jupiter Ndjeunga** is a principal economist at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT-Niger); **Ricardo Labarta** is a regional economist at the International Potato Center (CIP-Nairobi); **Robert Andrade** is an agricultural economist at the International Centre for Tropical Agriculture (CIAT); **Aliou Diagne** is a program leader and impact assessment economist at AfricaRice; **Rachel Muthoni** is a researcher in CIAT's Pan African Bean Research Alliance; **Franklin Simtowe** is an agricultural economist at ICRISAT-Nairobi; and **Tom Walker** (walkerts@msu.edu) is the Diffusion of Improved Varieties in Africa (DIVA) Project Coordinator and the communicating author for this paper.

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Acronyms and Abbreviations

CCC(s)	commodity by country combination(s)
CGIAR	Consultative Group on International Agricultural Research
DIVA	Diffusion of Improved Varieties in Africa (project)
FTE(s)	full-time equivalent(s)
HYVs	high-yielding varieties
IARC(s)	international agricultural research center(s)
ICARDA	International Center for Agricultural Research in Dry Areas
IITA	International Institute of Tropical Agriculture
MVs	modern varieties
NARS(s)	national agricultural research system(s)
NERICA	New Rice for West Africa
SPIA	Standing Panel on Impact Assessment (of the CGIAR)
SSA	Sub-Saharan Africa

Abstract

Information on varietal output, adoption, and change is critical to measuring and improving the effectiveness of agricultural research in Sub-Saharan Africa. In the late-1990s, modern varieties accounted for only about 20–25 percent of growing area of most primary food crops across SSA. Drawing on initial outcomes from the Diffusion of Improved Varieties in Africa (DIVA) Project's assessment of recent changes in varietal output and adoption, this paper documents considerable dynamism between the late-1990s and 2010 for several crops and many countries. Pairwise comparisons between the two periods for the same crop and country observation are largely characterized by positive change in both the rate of varietal release and the level of farmer adoption. Gains are noteworthy in maize in West and Africa and in cassava in Sub-Saharan Africa in general and in Nigeria in particular. Offsetting these positive developments were findings that two large problems related to varietal adoption and scientific staffing are still unresolved: progress in the uptake of modern coarse cereal and groundnut cultivars in the dominant-producing countries could, at best, be characterized as slow, and small countries continue to overinvest in ineffective agricultural research on small commodities.

1. INTRODUCTION

The extent of area planted to improved varieties is often the most important determinant of productivity, food security, and poverty benefits generated by investments in crop genetic research and development (R&D) (Walker and Crissman 1996; Evenson 2003; and Fuglie and Rada 2011). Current knowledge of the diffusion and impact of improved crop varieties is spotty in Sub-Saharan Africa (SSA). In the late-1990s, a global initiative on the impact assessment of varietal change estimated that modern varieties accounted for only about 20–25 percent of growing area of most primary food crops across SSA (Evenson and Gollin 2003a). That baseline is being updated, widened, and deepened in the Diffusion of Improved Varieties in Africa (DIVA) Project, “Measuring and Assessing the Impact of the Diffusion of Improved Crop Varieties in Sub-Saharan Africa,” supported by the Bill and Melinda Gates Foundation.

This substantive and methods-related project is a major building block toward the construction of a routine system for monitoring varietal adoption and impact in SSA. Three main activities drive the work: documenting key performance indicators of crop genetic improvement, collecting nationally representative survey data on varietal adoption, and assessing the impact of varietal change. Seven CGIAR centers and their partners carry out these activities, which are directed and coordinated by the CGIAR Standing Panel on Impact Assessment (SPIA) and administratively organized through Bioversity International.

The three-year project began in 2010. By mid-2011, the bulk of data collection had been completed on the project’s first activity, documenting key performance indicators of crop genetic improvement. This activity consists of the collection and assembly of three databases: (1) historical data on varietal release; (2) recent cross-sectional data on strength of human resources in national agricultural research systems (NARSs), by discipline; and (3) recent cross-sectional data on cultivar-specific levels of adoption elicited from expert panels. The unit of observation for the three data sets is a priority commodity by country combination (CCC).[1]

The project’s results complement the Agricultural Science and Technology Indicators (ASTI) initiative and contribute directly to the ASTI/International Food Policy Research Institute (IFPRI)–Forum for Agricultural Research in Africa (FARA) conference, “Agricultural R&D: Investing in Africa’s Future, Analyzing Trends, Challenges and Opportunities” under theme four: *Measuring and Improving the Effectiveness of R&D Systems.* This paper emphasizes performance monitoring, drawing on preliminary results and initial outcomes from the analysis of the DIVA project’s activity one datasets. The results are based on the first batch of processed and edited data, which are equivalent to more than half the project’s priority CCCs. The earlier data collected in the late-1990s are used as a benchmark.

2. HYPOTHESES AND DATA

The collection and analysis of data on performance indicators in the DIVA Project are guided by 20 hypotheses on varietal output, adoption, and turnover. The strength of NARSs and the use of International agricultural research institute (IARC)–related materials also receive attention in the formulation of hypotheses for testing. Most of these reflect conventional wisdom, estimated trends, and stylized facts in the literature—particularly the analysis contained in the commodity chapters of Evenson and Gollin (2003a). For example, the mean incidence of varietal output over time was expected to continue on an upward trend, as was documented in Evenson and Gollin (2003b); the role of NARSs was hypothesized to continue evolving from the introduction and testing of elite materials, to selecting varietal selection from introduced progenies, to parental crossing and cultivar selection.

[1] There are 104 priority CCCs in the project proposal, which account for about 75 percent of the value of production of 18 food crops covered by the project in SSA. Eleven of the food crops are the same as those covered in the late-1990s initiative. Sixty-five of the priority CCCs are the same for the two periods, offering the potential for a limited time-series analysis.

Several of these hypotheses are implicitly addressed in this paper. They are conditioned by recent changes in the internal and external environment for genetic crop improvement in SSA. Aside from technological advances, the external environment has become more favorable for enhancing the efficiency of crop improvement R&D through more effective macroeconomic policies, such as structural adjustment, and reduced civil conflicts and disturbances (Binswanger-Mkhize and McCalla 2009). The entry of the Bill and Melinda Gates Foundation as a major funder of crop improvement in SSA has breathed life into many national and international programs that were stagnating in the 1990s (Beintema and Stads 2006). On the other hand, donors' increasing reluctance to continue to fund commodity breeding networks and to engage in competitive grant funding for agricultural research was not conducive to leveraging favorable plant-breeding outcomes, which requires long-term stability to achieve sustained progress (Lynam 2010). The above suggests that there is a lot going on in both the external and internal environments and that testing more complex institutional hypotheses, such as the adverse consequences of the demise of materials exchange networks, requires careful data collection combined with textured interpretation.

Appendix A provides information on data coverage in tables that focus on the economic importance of the commodities covered in SSA in the DIVA Project (Appendix Table A1), the level and overlap of CCC coverage between 1998 and 2010 (Appendix Table A2), and the subset of observations by database reported in this initial analysis (Appendix Table A3). The original 11 commodities of the 1998 Initiative are also tracked by the DIVA project. They are described as "Continuing" in Appendix Table A1. In 2006, these same commodities roughly accounted for over 90 percent of the value of production of the 18 food crops included in the DIVA project, which has expanded coverage to six grain legumes (cowpeas, soybeans, faba beans, pigeonpeas, chickpeas, and field peas) and one root crop (sweetpotatoes). With the exception of sorghum and field peas, country coverage within each commodity constituted at least 60 percent of total production in SSA in 2006.[2]

In general, the 1998 data-set is messy because it lacks uniformity in crop coverage across the three databases for barley, lentils, beans, pearl millet, groundnuts, and sorghum. For example, aggregate measures on strength of NARSs are available for 123 CCCs in the 1998 Initiative; in contrast, data on crop release are restricted to about 80 CCCs. Messiness is also attributed to use of literature reviews for millet, groundnuts, and sorghum instead of engaging in interviews and direct data collection, as was carried out for the other crops. For all intents and purposes, the major groundnut- and pearl millet–producing region in West and Central Africa was not covered in the varietal release and adoption databases.

Definitional differences among commodities also erode the value of the 1998 database. Arguably, the most important database pertains to cultivar-specific adoption, and those heterogeneous data—some of which are very fragmentary and others only at the aggregate level of modern varieties as a group—are given for 103 CCCs in 1998 (Appendix Table A2). Nevertheless, there is sufficient coverage to carry out a meaningful comparative analysis between the two periods for 9 of the 11 continuing commodities.

The information in Appendix Tables A1 and A2 provides a context for the CCC submissions arrayed by database in Appendix Table A3 for the purposes of this initial pooled analysis across CG Centers. Priority in CCC selection was assigned to the continuing commodities with countries included in the late-1990s initiative. Coverage in this regard is more than adequate: many of the continuing commodity by country observations are represented for each crop. Indeed, some commodities, such as cassava, potatoes, and rice, have coverage levels that equal or exceed 100 percent for at least one of the

[2] Collaborative work with International Sorghum and Millet (INTSORMIL) Collaborative Research Support Program (CRSP) will bring sorghum in Ethiopia and Sudan into the DIVA Project. Yams, an important multi-species food crop with a limited history of crop genetic improvement, are being addressed by the International Institute of Tropical Agriculture (IITA) using several of the same protocols they are employing for their other mandated crops in the DIVA project. The newest CCC is banana in Uganda, for which Bioversity International is responsible.

three databases.[3] Major exclusions, and hence disappointments, are maize and wheat in Eastern and Southern Africa, which did not have reliable data at the time this paper was written.

3. THE SCIENTIFIC STRENGTH OF NATIONAL AGRICULTURAL RESEARCH SYSTEMS

Prologue and Findings from the 1998 Dataset

Investment in scientists is one visible manifestation of the potential effectiveness of agricultural research, including that conducted by both public- and private-sector organizations and universities. Such information on scientific staffing was collected in the 1998 initiative, and it was also gathered in the DIVA Project at the level of the crop improvement program. Information on the scientific strength of NARSs can be a challenging exercise resulting in a multi-institutional query, especially for maize in Southern Africa (Hassan, Mekuria, and Mwangi 2001), where the private sector participates heavily in varietal change. For most food crops, where hybridization is not a commercial possibility, gathering data on full-time equivalent scientists (FTEs) is not a daunting enterprise, but even then there are hurdles to overcome. The crop improvement program needs to be rigorously defined. The definition used in the DIVA project is an inclusive one for research scientists educated at the BSc level and above from diverse disciplines, but exclusive for research. Seed production for extension and related distribution activities are not included.[4]

In the late-1990s dataset, differences in conceptual definitions about inclusivity and exclusivity occurred, as did disparities in the level of aggregation in assembling datasets. Such small differences in substance and process meant that only large transparent results could be adequately detected. Finding several of the same tendencies across crops for a selected country relative to other countries increased confidence that major findings could be derived from the late-1990s dataset in spite of the potential for heterogeneity in the information. The pooled analysis pointed to several relevant findings:

1. Nigeria stood out as a country with consistently low researcher intensity. Indeed, Nigerian farmers appeared to be cursed by some of the lowest readings on researcher intensity ever estimated anywhere in the world. Mean readings of the ratio of FTE scientists to million tonnes of production were 0.1 for cassava, 0.5 for sorghum, 1.7 for rice, 1.8 for pearl millet, and 2.6 for maize, which benefited from some private-sector participation. Nigeria ranked among the lowest in researcher intensity in each of the five commodity groups in which it was a major contributor and figured prominently in the aggregate outcomes for this performance indicator for those same crops.
2. Ethiopia, Kenya, South Africa, and Sudan were characterized by a higher investment in scientific staff than other countries in the dataset. That behavior was reflected in positive and statistically significant estimated country coefficients in an additive effects model regressing total scientists years on production, crops, and countries.
3. Researcher intensity was lower in cassava than in other crops, even when the relatively inferior output value of cassava was factored into the calculation. Although not as extreme as the case of cassava, rice and sorghum also belonged to the set of commodities with lower than expected research intensities.

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[3] IITA, AfricaRice, and International Center for Agricultural Research in Dry Areas (ICARDA) have extended coverage to more countries than was envisaged in the DIVA proposal, and they have submitted some of those additional data for initial analysis.

[4] In general, the definitions are comparable to those used by ASTI (Beintema and Stads 2011), which most likely has more complete coverage of research conducted in agricultural colleges and universities than data elicited by the DIVA Project.

4. Similar to findings from other enquiries (Maredia and Eicher 1995), estimates of researcher intensity decline exponentially as the size of production increases from under 50 thousand to more than 5 million tonnes.
5. Finally, the late-1990s evidence suggested that scientific staff strength exhibited more variation across countries within a crop than across crops within a country.

Initial Results from the 2010 Dataset

Usually for the better, several of the above findings are reversed in the 2010 dataset. Nevertheless, progress in this performance indicator was uneven and difficult to assess in a preliminary analysis. With the exception of pigeon peas, the single observation commodities all refer to Ethiopia, where all programs are characterized by levels of FTE scientists that approach or exceed the median of 5.72 across all crop and country observations (Table 1).

Table 1. Number of full-time equivalent scientists by crop improvement program

Crop improvement program	Number of country observations	Total number of full-time equivalent scientists	Median	Maximum
Barley	1	21.40	21.40	21.40
Beans	10	73.30	5.72	16.75
Cassava	17	138.73	7.20	22.50
Chickpeas	1	8.40	8.40	8.40
Faba beans	1	6.85	6.85	6.85
Groundnuts	8	20.10	2.13	5.00
Lentils	1	5.60	5.60	5.60
Maize (from West and Central Africa)	11	139.10	5.80	77.50
Pearl millet	5	23.42	4.46	7.50
Pigeon peas	1	2.00	2.00	2.00
Potatoes	5	48.30	4.90	21.00
Rice	13	125.00	8.25	15.25
Sorghum	6	24.11	3.48	7.75
Total/total/median/maximum	**80**	**636.31**	**5.72**	**77.50**

Source: Compiled by the authors.

The maximum observation is maize in Nigeria with 77.5 FTE scientists—a five-fold increase on the estimate of about 16 scientists in the 1998 dataset. This sea change reflects an increase in both public- and private-sector investment, a finding that is consistent with Flaherty et al. (2010), who note that since the mid-1990s Nigeria has significantly increased its investment in agricultural research mainly in the form of salary adjustments and infrastructure rehabilitation, but also in the hiring of new FTE scientists.

Relative to other crops, both the median- and maximum-sized scientific cadres for groundnuts seem low. The maximum values for the two coarse cereals, sorghum and pearl millet, are also lower than expected. These crops have proportionally more higher degree-trained scientists than other crops, but groundnuts, sorghum, and pearl millet substantially lag behind other crops in number of BSc-trained researchers focusing activities on them. Beintema and Stads (2011) note that this is a problem common to West Africa with implications for an aging scientific corps.

Estimated researcher intensities are compared across the two time periods in Table 2. Similar to the 1998 estimates, these figures decline exponentially with the size of country production, which is still indexed at 2006 for both periods to determine what is happening in the numerator of this relationship.

Small production sizes drive high estimates of researcher intensity for beans, chickpeas, lentils, and pigeon peas.

Table 2. Comparing estimated researcher intensities between 1998 and 2010

	Estimated researcher intensity[a]	
Crop improvement program	**2010**	**1998**
Barley	15.2	na
Beans	33.7	21
Cassava	1.2	3
Chickpeas	37.8	na
Faba beans	12.7	na
Groundnuts	3.9	na
Lentils	61.1	na
Maize (from West and Central Africa)	9.7	10
Pearl millet	1.5	10
Pigeon peas	18.1	na
Potatoes	8.1	22
Rice	10.9	6
Sorghum	1.7	5

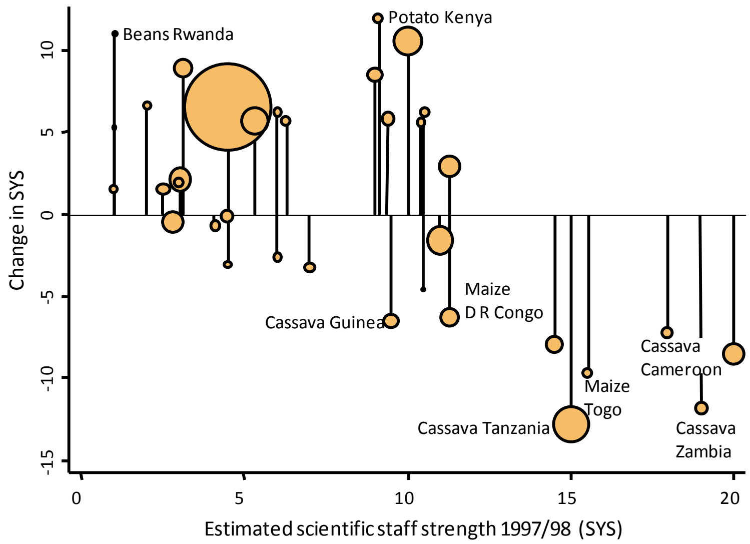
Source: Compiled by the authors.
Notes: na indicates that data were not available in 1998.
[a]Weighted by 2006 production.

The increase in estimated researcher intensity in beans is attributed to a definitional issue. In 1998, scientific staff strength was interpreted narrowly to mean bean breeders who were profiled in a small time-series database for important bean-producing countries in Eastern Africa. Scientific staff strength has definitely increased in some countries such as Rwanda. The decline in potatoes also reflects differences in country coverage to some extent: smaller countries that were covered in 1998 but were not included in 2010. The decline in cassava is real, although this finding could be partially conditioned by aggregation rules used to arrive at total FTE scientists in the 1998 dataset.

With all the above caveats, the reader may be dismayed that not much if anything can be conclusively stated about the comparative information in Table 2. The increase in estimated researcher intensity for rice is the most reliable result in Table 2. Almost all of the same rice-growing countries registered gains in scientific strength.

The first-difference comparison of the overlapping CCC observations in Figure 1 complements the information in Table 2. A small majority of overlapping CCCs increased their scientific staff strength between the two periods. One of these was cassava in Nigeria, which added about six FTE scientists. (The size of the hollow circles reflects the size of production values in 2006; Nigeria's observation for cassava is always the largest circle in these dropline graphs). But, more importantly, several of the largest commodity programs on the right-hand side of Figure 1 suffered through a rationalization process and lost staff. These were mainly concentrated in cassava-growing programs, which explains the decline of researcher intensity for cassava in Table 2. Benin, Tanzania, and Guinea downsized to only two to three FTE scientists per program.

Figure 1. Change in scientific staff strength in food crop improvement programs between 1997/98 and 2009/10



Source: Constructed by authors.
Notes: The change in scientist years (SYs) is on the y axis, and the level of staff strength in 1997/98 is on the x axis. The line shows the direction and extent of change between the two periods. The size of the circle is proportional to the size of estimated value of production for each matching commodity by country observation**.**

Scientific staff strength in a few maize programs also declined over time, but those declines were more than compensated for by Nigeria's dramatic increase in scientific staffing, as was discussed earlier (Table 2). Because it was such an outlier, maize in Nigeria was omitted from Figure 1, which conveys the message that larger crop improvement programs may be highly susceptible to downsizing in times of financial crisis.

Two other issues warrant comment in this discussion. First, the presence of biotechnology or molecular biology is not that visible in the disciplinary allocation of scientist years. Tissue culture is still very much in evidence, but the newer elements of biotechnology are not well-represented in the dataset. Second, the earlier finding that variation across countries contributes more to total variation in scientist years than variation across crops within a country may not stand up to scrutiny with the 2010 dataset. For example, beans seems to be a counterintuitive example with a high allocation of scientists in Tanzania, known for its low investment in agricultural research, and with a low allocation in Kenya, recognized as having invested heavily in agricultural research.

4. VARIETAL OUTPUT

Prologue and Findings from the 1998 Dataset

Varietal release is not a perfect indicator, and in specific cases it may not even be a good measure of varietal output in developing-country agriculture. In some countries, release committees do not meet periodically on a routine basis, both private- and public-sector improved varieties may be available for adoption but may not appear in release registries, and escapes from breeding programs may not be well-identified. Moreover, changes in the release practices over time may give the illusion of increased varietal output when, in fact, its true trajectory has not changed. Nevertheless, absence of release activity is often synonymous with negligible output from plant breeding.

In the 1998 initiative, most CG participants were successful in assembling valid release data for almost all countries, and those data were supplemented by information on so-called informal releases of suspected improved varieties. For maize in Eastern and Southern Africa, release was equated to varietal availability in the market in the late-1990s because of heavy private-sector participation in seed production and distribution. In spite of the inherent difficulties in inferring varietal output from varietal release, such data present a historical benchmark that once carefully consolidated can provide a firm foundation for updates over time.

In the pooled analysis of varietal release in the late-1990s (Walker et al. 2011), relevant findings included:

1. Across all crops, annual releases increased at an accelerating rate from the 1960s to the late-1990s. This positive trend in the rate of release over time is one of the shared findings across the commodity chapters in Evenson and Gollin (2003a). However, beans, cassava, and maize in Eastern and Southern Africa were the only commodity groupings that truly fit the positive-trend stereotype. Varietal output for the other crops peaked in the 1980s and was maintained at roughly the same level in the 1990s.
2. Political instability adversely affected varietal output in some crops in key countries in the 1990s.
3. Some crops were characterized by higher than expected numbers of releases prior to 1975. A few countries could draw on stable lines of research that existed prior to and continued immediately following independence to generate early varietal output. These early positive performers also released substantially more varieties in the period from the mid-1970s to the late-1980s; however, the advantage of an early start vanished in the 1990s. The IARC crop improvement programs were most likely a force that contributed to offsetting differences in initial advantage in research endowments.
4. Across the eight food crops in the study, the higher and more stable release rate in wheat was anticipated. In contrast, the very low release intensity for cassava was unanticipated. Cassava ranked last in average varietal output by a wide margin on any criterion of release intensity. For cassava, the size of country production was not positively correlated with the number of releases. Cassava did have a colonial legacy of genetic research to draw on in the 1960s, but governments were slower to invest in this important staple than in grain crops where technological change was perceived to be more of a reality (Nweke 2009). Other crops, especially rice, have had a substantially richer institutional milieu in the form of national, regional, and international organizations that have been actively involved in promoting crop improvement over the past 50 years in SSA.
5. Release profiles were often punctuated by bursts of activity sandwiched between long periods of inactivity. Most, but not all, extreme cases in release behavior could be explained.

Initial Results from the 2010 dataset

Varietal release outcomes vary markedly across the 13 food crops described in Table 3. Barley, chickpeas, faba beans, and lentils benefited from Ethiopia’s active research and dynamic release policy. As expected, the major staple food crops, cassava and maize in West and Central Africa, had the highest release total, closely followed by beans. But, somewhat unexpectedly, cassava’s total releases in this recent period increased markedly: it summed to about five-sixths of its total releases in the previous 35 years from the mid-1960s to the late-1990s.

Table 3. Performance in varietal release, 1998–2009/10

Crop	Number of country observations	Total releases	Annual average release rate		Number of releases per country program	
			Simple	Weighted	Maximum	Minimum
Barley	1	30	2.30	2.30	30	30
Beans	9	99	0.85	0.93	24	2
Cassava	17	172	0.78	0.99	21	0
Chickpeas	1	13	1.00	1.00	13	13
Faba beans	1	14	1.07	1.07	14	14
Groundnuts	9	36	0.39	0.28	10	1
Lentils	1	5	0.38	0.38	5	5
Maize (from West and Central Africa)	11	104	0.77	1.71	38	0
Pearl millet	5	5	0.17	0.19	6	0
Pigeonpeas	2	8	0.31	0.34	6	2
Potatoes	5	40	0.61	0.76	20	0
Rice	7	24	0.26	0.47	12	0
Sorghum	7	11	0.63	0.36	46	0
Total	**76**	**560**	–	–	–	–

Source: Compiled by the authors.

Almost all major food crops with the exception of pearl millet were characterized by one or more countries with 10 or more releases from 1998 to 2009/10. Nigeria was very active in releasing an average of three varieties annually during the period. For reasons that are not transparent, Mali had either a very active or lax release policy in sorghum. By the same token, most commodities contained one or more countries with zero releases during the period.

Because the size of production varies considerably across countries, the weighted annual average rate is a better guide to release performance than a simple average. The crops with five or more observations have release rates that range from a high of 1.71 in maize in West and Central Africa, to a low of 0.19 in pearl millet (Table 3). Although release does not imply instantaneous availability, this disparity in varietal release suggests that maize farmers had many more varietal options in the recent past than pearl millet farmers in West and Central Africa. Were Mali excluded, the sorghum varietal release rate would fall to 0.19. Groundnuts, sorghum, and pearl millet all appear to have low numbers of scientists and, what is more certain, low numbers of releases per unit area or per unit of production.

Rice's entry of 0.47 for a weighted average release rate is the most surprising estimate (Table 3). The increase in scientific staffing documented in the previous section, and the introduction of the New Rice for West Africa (NERICA) varieties during this period, should have resulted in higher release rates.

Indeed, with the exception of rice, the period from the late-1990s to 2010 was marked by considerable dynamism in varietal release (Table 4). Substantial progress was made in varietal release, especially for maize in West and Central Africa, which seems to have fully recovered from a depressed rate of output in the 1990s. During this period, hybrids from mainly public-sector in-bred lines became increasingly available for planting (Alene et al. 2009). Quality Protein Maize (QPM) has also increased the release potential in maize in West and Central Africa. Both sources of these materials have generated spill-over varieties shared by several countries in the region.

Table 4. Estimated weighted annual national release rates by crop, 1974–1997/08, the 1990s, and 1998–2009/10

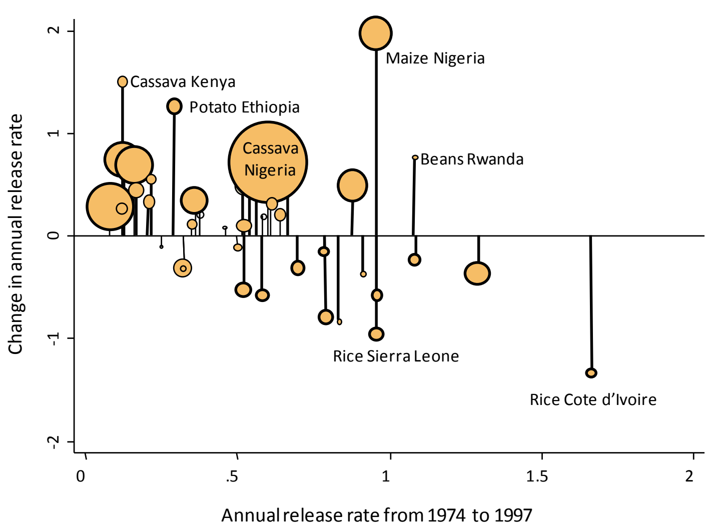
Crop	1974–1997/08	The 1990s	1998–2009/10
Beans	0.53	0.96	0.93
Cassava	0.50	0.68	0.99
Maize (from Eastern and Southern Africa)	1.47	3.33	na
Maize (from West and Central Africa)	0.77	0.40	1.71
Potatoes	0.33	0.41	0.76
Rice	1.20	1.41	0.47
Wheat	2.08	2.55	na

Source: Compiled by authors.
Note: na indicates that data were not available.

Pair-wise comparisons tell the same story. The 43 pair-wise comparisons between the two time periods showed that the simple annual average release rate increased by about 30 percent, from 0.56 in the earlier period from 1975 to 1997/98, to 0.73 in the recent period from 1998 to 2009/10. The estimated mean weighted annual release rate roughly doubled from 0.58 to 1.02 between the two periods. When the early to mid-1990s (1990–1997/98) release rates are compared with the recent period, the estimated mean simple annual release rate was actually higher, at 0.83, but the weighted annual release rate was substantially lower, at 0.69, in the 1990s. The weighted evidence suggests that larger producing countries in the overlapping set were more productive in generating varietal output in the most recent period than in the earlier periods. Like much of aggregate agricultural statistics in Sub-Saharan Africa, this result is partially driven by the dynamism documented in Nigeria primarily in maize and secondarily in cassava.

The majority of observations and the bulk of production displayed a positive change in weighted average varietal release (Figure 2). Aside from the already noted performance of maize in Nigeria, cassava in Kenya, potatoes in Ethiopia, and beans in Rwanda were crop and country combinations that were characterized by sharply increasing release rates compared to the 1970s, 1980s, and 1990s. Of these, Rwanda's upturn in releases is perhaps the easiest to understand. Rwanda's scientific staffing and varietal-output trajectories in beans, potatoes, and other important field crops were severely affected by the 1994 genocide.

Figure 2. Change in estimated annual release rates between 1974–97/98 and 1997/98–2009/10



Source: Constructed by authors.

The downward droplines in Figure 2 also shed light on one possible cause for rice's lower than expected release rate in Tables 3 and 4: political instability and civil war in Côte d'Ivoire and Sierra Leone in the recent past. Côte d'Ivoire was very active in rice releases in the 1990s, and, in the 1980s, Sierra Leone released many varieties tailored for, but not limited to, the mangrove production agroecology in West Africa. Varieties from its historically important Rokpurh Rice Research Station have figured prominently in technology-specific impact assessments (Adesina and Zinnah 1993; Edwin and Masters 1998).

5. VARIETAL ADOPTION

Prologue and Findings from the 1998 Dataset

In the DIVA project, the estimates of improved cultivar specific adoption are arrived at via expert opinion complemented by other sources, such as adoption surveys and data on seed sales where available. Taking cassava as an example, teams of economists visited all the countries and held structured consultations/interviews (for example, with the adoption questionnaire disaggregated by recommendation domain to minimize the inherent subjectivity) with experts/variety release bodies and reviewed NARS reports and other literature relating to variety release, adoption, and staffing. This strategy, together with a guidelines document, enabled them to adopt and apply a common definition across crops and countries. Working with the national programs also meant that they could subject expert opinions on adoption to peer reviews and triangulation.[5]

The main methods issue in measuring improved varietal adoption accurately centers around the treatment of older landrace materials that are often purified and released as improved varieties following limited selection in their country of origin. Although these varieties have utility, their additional benefit is usually small—they represent a very limited type of varietal change. Including them in the set of modern varieties (MVs) can be justified in specific contexts, but, in general, their inclusion can result in substantially inflated levels of MV adoption when, in reality, only limited varietal change has taken place. For example, in the late-1990s, the adoption level fell by 40–50 percent in the upland-rice producing agroecology of Nigeria, Côte d'Ivoire, and Sierra Leone when purified traditional varieties released in the 1960s and 1970s were excluded from the tabulations (Dalton and Guei 2003). Changes in decisionmaking on exclusion or inclusion can result in abrupt upward or downward shifts in adoption levels. Estimates of varietal turnover, such as weighted mean age from release, are useful in detecting cases where these older vintage materials can make a difference in adoption rates.

The uptake of high-yielding varieties (HYVs) of wheat, especially those planted in spring bread wheat, was very high and approached 100 percent in most countries, with the exception of Ethiopia where local landraces dominate durum wheat production (Table 5) (Heisey and Lantican 2000). Modern varieties or rice and potatoes also accounted for a sizable share of area, approaching or exceeding 50 percent. Between a third to two-fifth of maize-growing area was planted in improved open-pollinated varieties (OPVs) and hybrids.

[5] Expert opinion estimates are being validated in nationally representative diffusion surveys conducted in 2011 in Ethiopia, Nigeria, Mali, Rwanda, Tanzania, and Uganda. A smaller DIVA–related project, Tracking Improved Varieties in South Asia (TRIVSA) is also carrying out similar methods-research on adoption estimates elicited via expert opinion vis-à-vis those from nationally representative adoption survey. Early results of that work for rice in East India (in Orissa) do not point to systematic biases in relying on expert opinion when the experts know the crop and the production environment well.

Table 5. Results of improved varietal adoption by crop from the late-1990s dataset

Commodity	Improved cultivars (% estimated adoption)	Coverage (% of total area in SSA)	Improved cultivars: lower bound assumption (% adoption)
Wheat	66	85	56
Potato	56	68	44
Rice	45	57	25
Maize (from West and Central Africa)	37	94	35
Maize (from East and Southern Africa)	36	90	34
Cassava	22	83	18
Sorghum	23	54	13
Beans[a]	15	67	10
Barley	11	90	10
Groundnut	30	6	2
Pearl Millet	19	10	2
Lentils	0	80	0

Source: Compiled by authors.
a. International agricultural research institutes only.

Coverage in the late-1990s global initiative ranged from a paltry 6 percent in groundnuts in SSA, to a hefty 94 percent in maize in West and Central Africa. Conservatively assuming that the omitted countries were characterized by negligible adoption–which is more than a distinct possibility–results in the lower bound estimate of MV adoption presented in the third column of Table 5. Interpreting the estimate in the second column as the upper bound, and the fourth column as the lower bound, gives an adoption interval that is tight for maize and cassava and wide for groundnuts and pearl millet. Hence, the adoption level for groundnuts could have been as low as 2 percent or as high as 30 percent.

Initial Results from the 2010 Dataset

From the pooled analysis of the 1998 dataset, the main source of uncertainty revolved around the level of MV adoption in groundnuts, pearl millet, and sorghum in their heaviest production region, West and Central Africa. Broader coverage of these crops in the DIVA Project shows that the 2010 estimates fall within the adoption interval derived from the 1998 dataset (Table 6). Groundnuts are at the upper range of that interval; sorghum is near the lower bound, and pearl millet is roughly in the middle. Although MV adoption is somewhat higher in Eastern and Southern Africa, particularly for groundnuts, weighted average diffusion levels are low for the three crops. Because coverage in the 1990s dataset was spatially selective, drawing inferences on progress is riddled with speculation. In contrast, it can more firmly be stated that the use of MVs in barley have roughly doubled from 10 to 20 percent, because Ethiopia dominates production and is included in both time periods.

Table 6. Preliminary results on adoption of modern varieties by crop from the 2010 dataset

Crop	Number of observations	Estimate of modern variety adoption (% area)
Barley	2	22
Beans	7	32
Cassava	17	39
Chickpeas	3	20
Faba beans	3	14
Groundnuts	9	22
Lentils	2	10
Maize (from West and Central Africa)	11	67
Pearl Millet	5	17
Pigeon peas	2	34
Potatoes	5	59
Sorghum	7	14

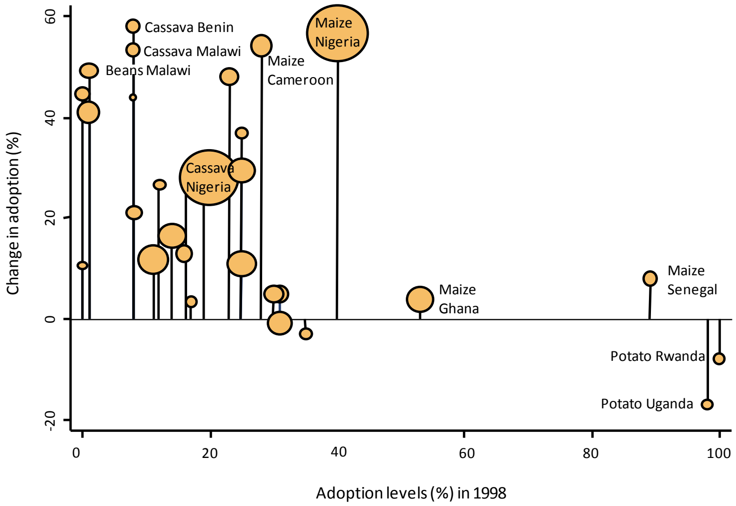
Source: Compiled by authors.

MVs of maize in West and Central Africa, cassava, and beans have made substantial gains during the recent period (Table 6). Foremost among these is maize, where progress can be called nothing short of spectacular, with an annual linear increase approaching 3 percent over the 13-year period. Nigeria is driving these results with an adoption level approaching 100 percent, but adoption is also high to moderately high in several other countries, such as Senegal where full adoption of MVs is becoming a reality (Alene et al. 2009). Senegal is an extreme case where the adoption of improved varieties of one cereal approaches 100 percent, but the diffusion of modern cultivars in a main oilseed (and cash crop) and in other important cereals is negligible.

Improved clones of cassava have also turned in a solid performance during the recent period. Their annual rate of uptake since the late-1990s is higher than 1.0 percent in several countries. Beans are a case where the information is fuzzier because only limited information on IARC–related adoption was available in the 1990s dataset. Because of mixed planting of improved and local varieties together, reliable adoption estimation in beans can be fraught with difficulties. Nonetheless, it is also likely that improved bean cultivars approached or surpassed a 1-percent linear rate of growth in adopted area since the late-1990s.

The performance in MV adoption for the overlapping observations was overwhelmingly positive from the levels estimated in 1998 (Figure 3). Inspection of the overlapping observations with information on adoption in both periods can also shed light on the characteristics of adoption for the positive outliers. Nine observations approached or exceeded a change level of 40 percent (Figure 3). These include four from maize (Cameroon, Mali, Nigeria, and Togo), four from cassava (Benin, Malawi, Zambia, and Zimbabwe), one from beans (Malawi), and one from potatoes (Ethiopia). Inspecting the weighted average age profiles in these countries suggests that seven of these high-adoption cases have a good representation of recently released and introduced materials in the cultivar-specific composition of improved adopted varieties.

Figure 3. **Change in the estimated level of adoption of improved varieties between 1997/98 and 2009/10**



Source: Constructed by authors.

In contrast, cassava in Benin and Malawi are dominated by older landrace materials that should have figured more prominently in the 1998 dataset if they were regarded as improved varieties. On average, released varieties that farmers were planting in these two countries were about 20 years from their date of release; the dominant cassava variety in Malawi is a landrace cultivar that is 30 years old. Adoption of these varieties was likely underestimated in the 1998 initiative; therefore, the magnitude of the abrupt increase in adoption could be questioned. In an effort to define levels of varietal adoption more precisely, data on adoption and release lists can be combined to arrive at a more textured understanding of differences in adoption by type of material.

In closing, the dropline observations in Figure 3 show very few, if any, real cases of disadoption. This is an unexpected finding because the ending of fertilizer subsidies is frequently mentioned as a motivation for reversion to local varieties. The evidence for disadoption is sparse, particularly for maize in West and Central Africa, which is the most intensive user of fertilizer of the studied commodities.

6. SUMMARIZING AND INTERPRETING EMERGING FINDINGS

The presentation of the emerging evidence on performance indicators on crop improvement R&D from the DIVA Project is a frustrating paper to read because the analysis is preliminary and commodity coverage is incomplete. Only about 70 percent of the observations were available for analysis when the paper was revised; no new information was reported for maize and wheat in Eastern and Southern Africa. Moreover, measuring progress between the 1998 and 2009/10 was plagued by caveats that reflected differences in definition and in country coverage that, in turn, blurred comparative understanding. In spite of these sources of frustration, this initial analysis is nonetheless informative, and sheds light on the emerging character of varietal output, adoption, and change in Sub-Saharan Africa.

The results on scientific input in crop improvement in terms of the number of FTE scientists were mixed and, in general, inconclusive. If anything, the negatives outweighed the positives. On the plus side of the ledger, Nigeria displayed gains in researcher intensity (in scientists per unit of production) across several important food crops, particularly maize. This dynamism substantially elevated Nigeria from the lowest mean level of researcher intensity among all country and commodity observations in the late-1990s, to an average level of researcher intensity in 2010. All rice-producing countries also showed increases in researcher intensity between the two time periods.

Programs that ranked lower in researcher intensity mostly registered gains in scientific staff strength by 2009/10. Those overlapping observations that ranked higher in the earlier period all lost ground in the later period—that is, high levels of intensity (above 10 scientists per million tonnes of production) could not be maintained over time. This finding reinforces conventional wisdom that efforts to markedly increase scientific staff strength in particular programs and commodities, although perhaps worthwhile, are not sustainable over time.

Offsetting these positive developments were findings that two large potential problems related to scientific staffing and the efficiency of crop improvement R&D are still unresolved. The small country/small commodity conundrum is still transparent and unchanged in comparing the cross-sectional evidence on researcher intensity for the two periods. Less traded food crops, such as cassava, pearl millet, and sorghum, are characterized by substantially lower levels of researcher intensity than other crops. Low levels of researcher intensity are still endemic to several crop improvement programs, including a smallholder cash crop like groundnuts in West and Central Africa.

Although such problems were very much in evidence in the database on scientific staffing, human resource investment in biotechnology was not. Biotechnology-related areas were not well-represented in the disciplinary composition of most of the NARS crop improvement programs. Realized investment pertained mainly to the traditional area of tissue culture in vegetatively propagated crops. Few if any new released varieties could yet be attributed to marker-assisted selection. In other words, the downstream, adaptive character of NARS crop improvement programs is still their most visible aspect in the recent period.

In contrast to the volatile and ambiguous conclusions on scientific staffing, the positive developments in the recent past outnumber the negative ones for varietal output and adoption. Consistent with expectations, the mean rate of release has increased secularly over time. Part of this increase is likely to be explained by more liberal release procedures, but increased varietal output is also attributed to greater availability of elite materials ready for release. More intense release activity took place in cassava and maize programs in West and Central Africa. These same programs were also characterized by dynamism in improved cultivar adoption, which increased in all commodities and in over 90 percent of the overlapping observations from 1998 to 2009/10. The results thus far suggest that the estimated linear growth rate in modern variety adoption averaged across all CCCs and weighted by area should exceed 1.0 percent per annum for the period 1998–2009/10.

By 2009/10 and assuming that the results for maize in East and Southern Africa will be similar to those for maize in West and Central Africa, the food crops grown in SSA can be stratified into four groups based on their levels of adoption. The low adoption group (with less than 25 percent of total area in improved varieties) includes groundnuts, pearl millet, sorghum, barley, chickpeas, faba beans, lentils, sweetpotatoes, yams, and durum wheat. Few if any countries in this group are (or will be) characterized by adoption rates of over 50 percent for varieties released since 1980 when all the project data are available for analysis. Several crops, such as sweetpotatoes and yams, have not been recipients of long-term investments in crop improvement. Others, such as groundnuts, pearl millet, and sorghum, in spite of their current low scores on researcher intensity, have received considerable attention from a plant breeding perspective over time. Their adoption performance should at least approach or exceed that of cassava produced in the same countries, but it has not.

The output and adoption performance criteria underscore the need for an assessment of strategy to determine whether conducting business in the same way is a blind alley or will result in positive outcomes with the expected easing in the future of present constraints on these crops. For example, ICRISAT sorghum breeders in West Africa are emphasizing the hybridization of elite local Guinean populations within a framework of farmer participatory selection. This is a significant departure from the Center’s regional breeding strategy from the 1970s to the 1990s, and it will be interesting to see if commitment to this approach will translate into improved adoption outcomes.

For the high adoption group consisting of spring bread wheat, potatoes, and soybeans, most countries have attained or are approaching 100 percent adoption. In terms of performance indicators, attention now shifts to varietal turnover: how fast are newer improved cultivars replacing earlier released varieties and hybrids. Evidence on varietal turnover was not presented in this paper, but the available estimates point to no significant improvement in this performance criterion. Age estimates from the date of release in both 1998 and 2009/10 do not seem to be significantly different: most fall in the range of 10–20 years for weighted average age of improved cultivars.

Another adoption group pertains to maize in both East and Southern Africa and West and Central Africa. Improved varieties and hybrids now account for over 50 percent of total area in both regions, but widespread variation in modern variety adoption exists across countries. At one extreme, there's Togo, DR Congo, and Mozambique with less than 15 percent MV adoption; at the other end of the spectrum, there's Kenya, Nigeria, and Senegal, where MV adoption surpasses 75 percent and, in some cases, approaches 95–100 percent. For the first subset of countries, maize is like any other crop stuck in a low-level equilibrium adoption trap. For the second subset, maize, with bright prospects for hybridization and private-sector involvement, may be unlike any other crop. The poster country for this second subgroup is Senegal, where MV adoption levels are less than 20 percent for groundnuts and more than 95 percent for maize. For the remaining countries, tradeoffs between characteristic demands from and effort allocated to subregions within the country are likely to be sharp.

The other intermediate MV adoption group contains cassava, rice, beans, and cowpeas. Like maize, the overall estimate of adoption is near or exceeds 50 percent, but, unlike maize, no country approaches full adoption when a modern variety is more rigorously defined as being developed after 1980. Successes in some agroecologies suggests that the breeding strategy is on the right track, but more location-specific problems in low potential zones have thwarted adoption of rice MVs. Positive but incomplete adoption outcomes also indicate that a low multiplication ratio for cassava, beans, and cowpeas may be a strong but not insurmountable deterrent to success.

The above taxonomy of modern variety adoption may not be that useful in translating estimates of monitoring performance into viable recommendations for improving crop genetic R&D; however, it is suggestive of the potential utility of the DIVA–generated data, which requires contextual development to result in practical use. Literally, there is a story to tell for each of the commodity by country observations. The CG Center participants and their partners will flesh out many of the details in their commodity-level reports on these performance indicators. Knitting these stories together to generate a realistic scenario of what is happening in MV adoption in SSA will take place in mid-2012. The data are slated for public distribution by August 2012. Providing public access to the data is the optimal way to ensure that performance estimates ultimately influence decisionmaking on crop genetic R&D in SSA. Making the data available to the public will also help to identify egregious errors of omission and commission that require correction to generate a reliable benchmark, especially for cultivar-specific adoption data that lie at the heart of the DIVA Project and that, from the perspective of monitoring adoption, should be updated at a 5–10 year interval.

Attention in the second half of the Project now shifts (a) to determining how well expert opinion on improved cultivar adoption matches national diffusion estimates and (b) to assessing the impact of varietal change. Coming up with reasonable estimates for changes in net benefits with varietal replacement in the predominantly rainfed agriculture of SSA will likely be the most challenging component of impact assessment and is also the area that most complements the adoption estimates of varietal change. These initial results also highlight numerous puzzles and paradoxes, both small and large, that warrant plausible explanations. They range from simple inquiries into reasons for bursts of activity in varietal release and for abrupt increases in adoption, to more nuanced analyses of how some programs can lose scientific staff and yet still manage to increase varietal output. Coming up with plausible reasons for such issues that beg perplexing questions is the next and most difficult step in this exercise.

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APPENDIX A. DATA COVERAGE

Appendix Table A1. Sub-Saharan African commodity by country combination coverage in the DIVA Project, 2010

Commodity	Description	Countries (number)	Share of production (%)
Cowpeas	New	5	91
Faba beans	New	3	91
Barley	Continuing	3	91
Rice	Continuing	10	89
Wheat	Continuing	5	86
Cassava	Continuing	11	84
Millet	Continuing	5	80
Lentils	Continuing	3	80
Beans	Continuing	10	77
Chickpeas	New	3	77
Maize	Continuing	18	76
Pigeonpeas	New	3	71
Sweetpotatoes	New	6	69
Potatoes	Continuing	5	65
Soybean	New	1	64
Groundnut	Continuing	10	61
Field peas	New	1	46
Sorghum	Continuing	7	32

Source: Compiled by authors.

Appendix Table A2. Comparing 1998 and 2010 coverage of commodity by country combinations for continuing commodities

Commodity	2010	1998	Overlapping in 1998 and 2010	New in 2010	Covered in 1998 but not in 2010
Maize	18	22	17	1	5
Cassava	11	19	11	0	8
Rice	10	7	7	3	0
Beans	10	7	7	3	0
Groundnut	10	9	4	6	5
Sorghum	7	14	5	2	9
Wheat	5	5	5	0	0
Potato	5	8	4	1	4
Pearl millet	5	9	1	4	8
Barley	3	1	1	2	0
Lentils	3	2	2	1	0
Total	**87**	**103**	**64**	**23**	**39**

Source: Compiled by authors.

Appendix Table A3. Number of country observations in the initial analysis of the 2010 dataset for the cross-sectional and time-series analyses

	Total number of observations			Pairwise comparisons		
Crop	Staff strength	Varietal release	Varietal adoption	Staff strength	Varietal release	Varietal adoption
Barley	1	1	2	–	–	1
Beans	10	9	7	6	9	3
Cassava	17	17	17	13	14	13
Chickpeas	1	1	3	–	–	–
Faba beans	1	1	3	–	–	–
Groundnuts	8	9	9	–	–	–
Lentils	1	1	2	–	–	1
Maize (from West and Central Africa)	11	11	11	9	9	7
Pearl millet	5	5	5	–	–	–
Pigeon peas	1	2	2	–	–	–
Potatoes	5	5	5	4	4	4
Rice	13	7		4	7	–
Sorghum	6	7	7	–	–	–
Total	**80**	**76**	**73**	**36**	**43**	**29**

Source: Compiled by authors.

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www.ifpri.org

FORUM FOR AGRICULTURAL RESEARCH IN AFRICA

PMB CT 173 | Accra, Ghana
Tel: +233.302.772823
Fax: +233.302.773676 | Email: info@fara-africa.org
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The Agricultural Science and Technology Indicators (ASTI) initiative compiles, analyzes, and publishes data on levels and trends in agricultural R&D investments, capacities, and institutional arrangements in developing countries. ASTI is managed by the International Food Policy Research Institute (IFPRI) and involves collaborative alliances with many national and regional R&D agencies.

Jointly convened by ASTI/IFPRI and the Forum for Agricultural Research in Africa (FARA), the conference, "Agricultural R&D—Investing in Africa's Future: Analyzing Trends, Challenges, and Opportunities," brought together experts and stakeholders from the region to contribute their expertise for the purpose of distilling new insights and creating synergies to expand the current knowledge base. The themes under focus were (1) why African governments under invest in agricultural R&D; (2) how human resource capacity in agricultural R&D can be developed and sustained; (3) how institutional structures can be aligned and rationalized to support agricultural R&D; and (4) how the effectiveness of agricultural R&D systems can be measured and improved.

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