DIIVA stands for the Diffusion and Impact of Improved Varieties in Africa – a project, funded by the Bill & Melinda Gates Foundation, that collected and collated data on improved crop varieties in Africa, south of the Sahara. DIIVA aims to close the knowledge gap on the uptake and turnover of crop varieties that is key to supporting an increase in food production in Africa by informing agricultural researchers about the diffusion of improved varieties. It resulted in three databases on adoption, varietal release, and the scientific strength of breeding programs, organized as a set of 152 crop-country observations (across 20 crops and 30 countries). The DIIVA databases are hosted by the Agricultural Science and Technology Indicators initiative, led by the International Food Policy Research Institute.

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STANDING PANEL ON IMPACT ASSESSMENT

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Adoption of Modern Varieties of Food Crops in Sub-Saharan Africa

Background

In the late 1990s, a global initiative on the impact assessment of crop varietal change estimated that modern varieties (MVs) accounted for about 22% of the growing area of primary food crops across Sub-Saharan Africa (SSA) (Evenson and Gollin, 2003). This baseline has recently been updated, widened, and deepened in the CGIAR's Project Diffusion and Impact of Improved Crop Varieties in Sub-Saharan Africa (DIIVA), supported by the Bill and Melinda Gates Foundation. Seven CGIAR Centers and more than 200 individuals – mainly crop improvement scientists in national programs – participated

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Key messages

- MVs were cultivated on 35% of the area in 20 primary and secondary food crops in SSA in 2010.
- Around 3,500 improved cultivars had been released nationally since 1970; and more than 1,150 improved varieties and hybrids were adopted by farmers in SSA as of 2010.
- About 1,300 full-time equivalent scientists worked in these crop improvement programs in SSA in 2010.
- For ten crops with benchmark data, MV adoption rose from 25% in 1998 to 44% in 2010. This increase was equivalent to an annual gain of 1.45% over the 13-year period.
- The age of MVs in farmers' fields averaged 14 years from their date of release to 2010.

in the DIIVA Project, which was directed and coordinated by the Standing Panel on Impact Assessment (SPIA) of the CGIAR and administrated through Bioversity International.

Key results on adoption from the wide-ranging Synthesis Report titled *Measuring the Effectiveness of Crop Improvement Research in Sub-Saharan Africa from the Perspectives of Varietal Output, Adoption, and Change: 20 Crops, 30 Countries, and 1,150 Cultivars in Farmers' Fields* are presented in this Impact Brief. The annex to the Synthesis Report contains five comprehensive tables where summary data are presented. Databases on scientific capacity, varietal output, and varietal adoption for both 1998 and 2010 are available on the Agricultural Science and Technology Indicators website of the International Food Policy Research Institute at: http://www.asti.cgiar.org/diiva.

Defining MVs and sources of estimates

MVs are defined as improved varieties released after 1970 that are available for adoption because of crop improvement efforts in the public or private sectors. MVs also include 'escapes', products of participatory varietal selection from improved materials, and breeding outputs in countries that do not have a functioning formal release and registry system. Released varieties that are local landraces are not counted as MVs in their country of origin.

Similar to the 13 crop-study chapters in Evenson and Gollin (2003), adoption estimates were mainly generated by eliciting expert opinion (Table 1). Highly focused, nationally representative surveys account for 36 observations: 16 were financed and canvassed by the DIIVA Project; 20 drew on complementary research by other CGIAR Centers and donors, especially AfricaRice's Japan Project.

Table 1.
Source of the national adoption estimates by number of observations

Source	Number
Expert opinion	110
DIIVA adoption survey	16
Non-DIIVA adoption survey	20
Inferred from the literature	5
Seed production and trade	1
Total	**152**

Key results and messages on adoption

Twenty food crops were covered in the DIIVA Project (Table 2). Ten were the same as those reported in Evenson and Gollin (2003). In 2010, the 152 crop-by-country observations accounted for 83% of the area in SSA harvested in the 20 crops.

Levels of MV adoption: The area-weighted grand mean adoption level of improved varieties across the 20 crops is 35% (Table 2). A 35% share in MVs for food crops in SSA in 2010 is roughly the level Asia was at in the early 1970s, Latin America was at in the mid-1980s, and the Middle East and North Africa were at in the early 1990s (FARA, 2006, as cited in Lynam, 2010). The results of 18 comparisons between experts' opinions and nationally representative surveys suggest that this 35% adoption estimate would decline to about 31% if we had had the resources and the capacity to substitute nationally representative surveys for expert opinion panels (as expert opinion tends to slightly overestimate MV adoption rates compared to the nationally representative surveys).

The starred crops in Table 2 were included in the 1998 and 2010 benchmarks on MV adoption in SSA. For 61 of the starred crop-by-country observations, reliable inferences can be drawn on progress in MV uptake between the two periods. MV adoption rose from 25% in 1998 to 44% in 2010. This increase was equivalent to an annual gain of 1.45% over the 13-year period.

With the exception of rice and potatoes, all crops experienced an expansion in the use of MVs. Uptake was especially robust in barley, beans, cassava, and maize with adoption levels doubling during the period.

The before-and-after data for the primary staples, maize and cassava, are arrayed in Figure 1 in which the balloons in the droplines are weighted by area in 2010. Maize in the Democratic Republic of the Congo was the only crop-by-country observation to experience a steep decline in the estimated MV adoption rate

Table 2. Adoption of MVs of food crops in SSA in 2010

Crop	Country observations	Total area (ha)	Adopted area (ha)	% MVs
Soybean	14	1,185,306	1,041,923	89.7
Maize–WCA*	11	9,972,479	6,556,762	65.7
Wheat*	1	1,453,820	850,121	62.5
Pigeonpea	3	365,901	182,452	49.9
Maize–ESA*	9	14,695,862	6,470,405	44.0
Cassava*	17	11,035,995	4,376,237	39.7
Rice*	19	6,787,043	2,582,317	38.0
Potato*	5	615,737	211,772	34.4
Barley*	2	970,720	317,597	32.7
Yams	8	4,673,300	1,409,309	30.2
Groundnut*	10	6,356,963	1,854,543	29.2
Bean*	9	2,497,209	723,544	29.0
Sorghum*	8	17,965,926	4,927,345	27.4
Cowpea	18	11,471,533	3,117,621	27.2
Pearl millet*	5	14,089,940	2,552,121	18.1
Chickpea	3	249,632	37,438	15.0
Faba bean	2	614,606	85,806	14.0
Lentil	1	94,946	9,874	10.4
Sweetpotato	5	1,478,086	102,143	6.9
Banana	1	915,877	56,784	6.2
Field pea	1	230,749	3,461	1.5
Total/weighted average	**152**	**107,721,630**	**37,469,577**	**34.78**

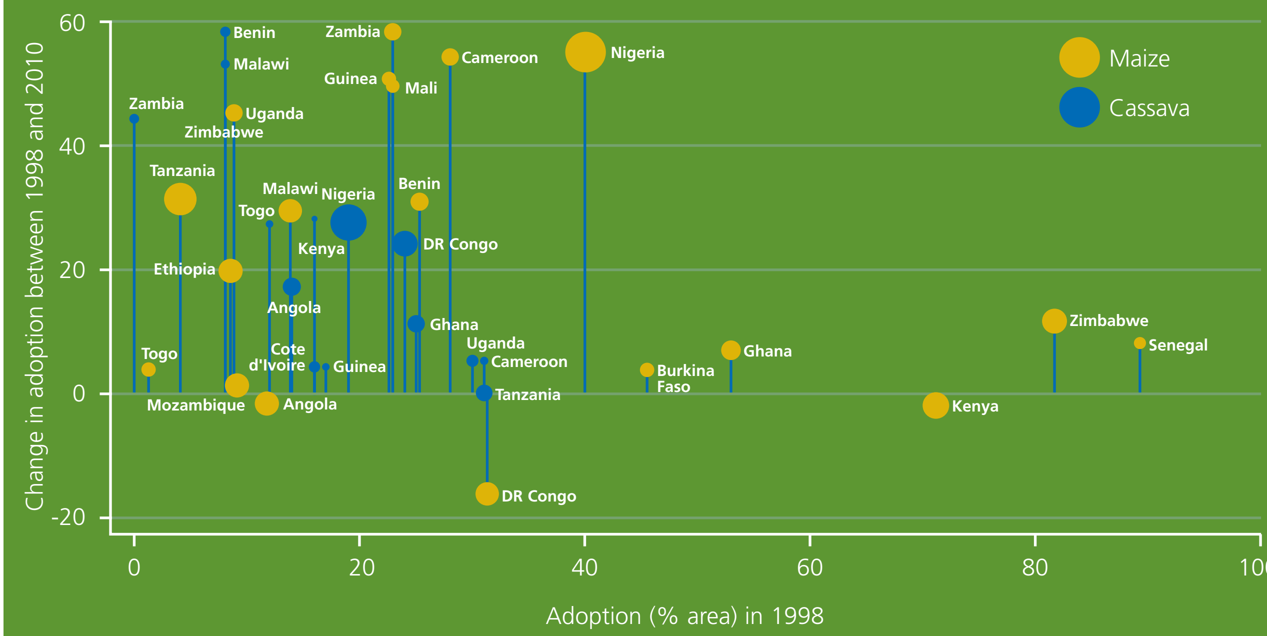
*Crops in both the 1998 and 2010 benchmarks

between 1998 and 2010. Gains in the uptake of maize hybrids were significant in Zambia and Malawi. Hybrids also played an important role in Ethiopia. Increases in the West African countries and in Tanzania and Uganda were almost entirely fueled by the spread of improved open pollinated varieties. In general, the cassava-growing countries were characterized by lower adoption levels in 1998 than the maize-producing countries but, aside from Tanzania, every cassava-producing country registered an increase in the uptake of improved varieties in 2010.

Low investment causes low adoption: In Table 2, about two-thirds of the crops are characterized by below-average adoption. Banana in Uganda, field pea in Ethiopia, sweetpotato in East and Southern Africa (ESA), and yams in West and Central Africa (WCA), owe their low ranking in the table to scant varietal output in the 1970s and 1980s when investment in the improvement of these crops was negligible.

Groundnut, sorghum, and pearl millet similarly show lower than average MV adoption outcomes in Table 2. They are produced extensively in the Sahelian, Sudanian, and Guinean zones of West Africa. Relative to the size of their production, these crops fit the profile of commodities starved of scientific resources as they are characterized by the lowest estimated research

Figure 1. Change in the estimated level of adoption of improved maize and cassava cultivars between 1997/98 and 2009/10.



intensities of the 20 crops in the DIIVA Project. The ageing profile of crop improvement scientists in West Africa was also documented as an increasingly critical problem.

Lagging countries, agroecologies and sub-species: The majority of crops in Table 2 have at least one country lagging behind in adoption, with some countries showing less uptake of MVs on multiple food crops. For example, Angola and Mozambique are the two countries in southern Africa where the adoption of MVs is low for all primary and secondary food crops. For some crops, leveraging adoption in one country is key to significant progress e.g. cowpea in Niger. For other crops, enhancing the prospects of adoption in just one agroecology of a single country would make a difference e.g. rice in the rain-fed lowlands of Madagascar. Meanwhile in Ethiopia, MVs of spring bread wheat are approaching full adoption in contrast to the negligible adoption of MVs of durum wheat.

Other contributors to low adoption outcomes: Political instability and civil war have diminished adoption prospects and even resulted in significant disadoption of MVs in some crop-by-country observations. In potato, for example, the greater uptake of improved clones in Ethiopia and Kenya has not compensated for a sharp downturn in the use of improved materials in Rwanda since the 1994 Genocide that devastated both the potato improvement program at the Ruhengeri Station, the hub of the International Potato Center's activities in the Great Lakes Region, and Rwanda's previously effective seed program. In rice, civil war in Sierra Leone similarly led to the demise of the Rokupr station, an historically and regionally important source of improved rice varieties adapted to the difficult mangrove agroecology. Stiff competition from 'older' improved varieties that were selected during colonial rule has contributed to the low adoption of groundnut MVs in West Africa. An inadequate seed supply in Ethiopia partially explains the limited adoption of chickpea and lentil MVs to small areas where extension projects were active. Pursuit of a varietal ideal that subsequently turned into a blind alley also delayed varietal output of the improved sorghum cultivars that are now satisfying farmers' preferences in West Africa.

Relevance of genetic materials related to the CGIAR: The analysis of cultivar-specific information underscores the importance of the CGIAR Centers in supplying material to, and sharing it from, the national agricultural research systems (NARS): about 65% of varietal adoption originated in CGIAR-related materials. Moreover, CGIAR Centers' contribution for 10 of the 20 crops was above 80%. For most crops, the Centers' share in adoption was substantially higher than their share in varietal output.

Market forces: The role of the market in stimulating MV adoption is inferred from the high ranking of the more commercially oriented soybean, maize, and wheat crops (Table 2). In the DIIVA Project, bean MVs showed a substantially higher uptake in Ethiopia than MVs for any other grain legume, presumably because Ethiopia has developed a vibrant export industry for haricot beans. The location of pigeonpea in the top half of Table 2 also benefited from a cash-crop orientation. Kenya, Malawi, and Tanzania have a commercial demand for higher-yielding medium-duration varieties that are well adapted to the countries' bi-modal seasonal rainfall.

Commercial orientation has led to positive adoption outcomes, but it has not translated into increased varietal turnover of improved varieties. The leading soybean varieties in farmers' fields in Nigeria date from the early 1990s. The dominant maize hybrid in Kenya was released in the mid-1980s. Across the 20 crops, the weighted average age of improved varieties in farmers' fields was 14 years since release. Improved varieties in farmers' fields today are not getting any younger for most crops and countries. The potential of biotechnology to increase varietal turnover through techniques such as Marker-Assisted Selection is still largely unfulfilled.

Wide adaptability: Although so-called 'mega-varieties' that are adopted on millions of hectares in SSA were not documented in the DIIVA Project, the high incidence of spillover varieties that were adopted in multiple countries pointed to wide adaptability in most crops. Researchers from the International Institute of Tropical Agriculture were able to describe in detail the occurrences of spillovers in adoption for four of their five mandated crops. TMS 30573 occupies a sizeable area planted with cassava in Nigeria and Uganda; and, to a lesser extent, is also cultivated in Benin, Côte d'Ivoire, Guinea, and Kenya. In cowpea, IT82E-32, IT81D-1137 and VITA-7 fit the description of spillover varieties that are attractive to farmers because they embrace multiple attributes, featuring high yield potential, good disease tolerance, and short duration. In maize, Obatanpa (derived from quality protein maize materials) and TZEE-Y are popular varieties that have crossed over the borders of several countries in WCA. Two improved soybean varieties are also widely cultivated in the region.

Groundnut seems to be the exception to the finding that the prevalence of spillover varieties is more common in WCA than in ESA. In four of the five groundnut study countries in ESA, rosette-resistant ICGV-SM 90704 and drought-tolerant ICGV 83708 ranked first or second in the adoption of improved varieties.

Finally, New Rice for Africa (NERICA) 1 is presently cultivated in five of the 12 rice-producing countries. Earlier, BG 90-2 from Sri Lanka was a commonly introduced cultivar that was released by the majority of rice-producing countries in WCA and later became popular in some.

Stability and instability: Stability and instability figure prominently in the discussion of adoption results. Staying the course in crop improvement usually led to desirable outcomes. Most adopted cassava varieties in Figure 2 trace their origins from breeding populations that were developed in the early 1960s; the first improved clones were released in Nigeria in the mid-1980s.

Instability in varietal output was noted for almost all crops and countries. Short bursts in varietal releases were sandwiched between long periods of inactivity. Shortfalls in the funding of CGIAR crop improvement programs contributed to instability in varietal output. Some CGIAR Centers lost more than 50% of their scientific capacity from the mid-1990s to the early 2000s.

Implications and challenges

The results of the DIIVA Project show that it is possible to establish a comprehensive benchmark on the diffusion of MVs in SSA for a relatively small quantity of resources. Extrapolating past performance to the future suggests a target of around 50% MV adoption by 2020.

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Expert opinion may still be the only cost-effective option for arriving at reasonable adoption estimates for SSA, which is characterized by multiple food crops in diverse country settings. However, expert opinion could not provide reliable cultivar-specific estimates when private-sector hybrids were widely adopted, aggressive relief and technology transfer efforts markedly increased availability and perceived adoption, and when civil war affected varietal adoption. Structuring panels with wider institutional participation and at a lower level of spatial disaggregation was recommended by most CGIAR Center participants.

Surveys are also not optimal when varietal identification by farmers is fuzzy or extremely location-specific. Identification of improved cassava clones in southwestern Nigeria represented the extreme case in which field appraisal corraborated by expert judgment was needed. Investing in pilot studies with DNA fingerprinting remains a priority for improving varietal identification.

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