Working Paper

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Tesfaye Woldeyohanes, Karl Hughes, Kai Mausch, Judith Oduol

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Abbreviations

CCC	country crop combinations
CIAT	International Center for Tropical Agriculture
CRP	CGIAR Research Program
DC	Dryland Cereal
DIIVA	Diffusion and Impact of Improved Varieties in Africa
DRC	Democratic Republic of Congo
FPVS	farmers participatory varietal selection
GLDC	grain legumes and dryland cereals
HOPE	Harnessing Opportunities for Productivity Enhancement
ICARDA	International Center for Agricultural Research in Dry Areas
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
IV	improved variety
SRF	strategy and result frameworks
SSA	sub-Saharan Africa
TL	tropical legume
TRIVSA	Tracking Improved Varieties in South Asia

Abstract

Like other crop improvement programs, a key prerequisite for the CGIAR Research Program on Grain Legumes and Dryland Cereals (CRP GLDC) to generate large-scale impact is large-scale adoption. Hence, evidencing the breadth and depth of such adoption is both of intrinsic interest and important for estimating downstream impacts, such as improved food and nutritional security, income, resilience, and soil health. While various GLDC adoption studies have been undertaken, a recent effort to systematically review these studies and synthesize the results is lacking. We undertook such a review, identifying 69 studies and 35 independent country crop combinations (CCCs). To generate aggregated and updated estimates of GLDC improved varietal adoption, we devised and applied a procedure to estimate national cropping areas under such varieties and, in turn, the number of adopting households. Estimates derived from household surveys and expert opinion solicitation are treated with higher and lower levels of confidence, respectively. As of 2019, we estimate from higher confidence studies that improved GLDC crops were cultivated on 15.37 million hectares of land by 17.64 million households in CRP GLDC's 13 priority countries. With the inclusion of lower confidence studies, these numbers increase to 32 and 44.64 million, respectively. We are further confident that the program exceeded its adoption target of 8.9 million newly adopting households from 2011, particularly when likely spillovers vis-à-vis non-surveyed areas, non-priority countries, and non-priority crops in priority countries are considered.

Contents

1. Introduction and background

The CGIAR[1] Research Program for Grain Legumes and Dryland Cereals (CRP GLDC) undertakes crop improvement, complementary farm management, and policy research on grain legumes and dryland cereal crops in the semi-arid and sub-humid dryland agro-ecologies of sub-Saharan Africa (SSA) and South Asia. These agro-ecologies are characterized by high levels of poverty, malnutrition, soil degradation, and climate variability, which are key challenges specifically targeted in the CGIAR's Strategy and Result Framework (SRF). CRP GLDC aims to address these challenges by bolstering the productivity, profitability, resilience, and marketability of specific GLDC crops, on which farmers and others within these agro-ecologies significantly depend.

CRP GLDC has committed to achieving an ambitious set of impact targets. These contribute to those of the overall CGIAR system and include:

- 8.9 million farm households to have adopted improved GLDC varieties
- 4.4 million people assisted to exit poverty (50% women)
- 1.2% per year rate of yield increase for GLDC crops
- 12.7 million more people (50% women) assisted to meet minimum dietary energy requirements
- 7.5 million women of reproductive age assisted to meet daily protein dietary requirements
- 4.9 million metric tons of cumulative carbon input to soils from increased GLDC productivity.

1.1 CRP GLDC variety releases

CGIAR has invested significantly in legume and cereal improvement research over the last four decades. This has been through CRP GLDC itself since 2018 and three preceding CGIAR Research Programs (CRPs): Grain Legumes, Dryland Cereals, and Dryland Systems. Direct funding for these CRPs has been augmented by bilaterally funded projects that constitute part of the CRPs, including those supported by the Bill & Melinda Gates Foundation. Key CGIAR research centres involved in the larger research effort associated with GLDC crops include the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (chickpea, groundnut, pigeon pea, millet, and sorghum), the International Institute of Tropical Agriculture (IITA) (cowpea and soybean), the International Center for Tropical Agriculture (CIAT) (common bean), and the International Center for Agricultural Research in Dry Areas (ICARDA) (lentils).

Recent reviews by Varshney et al. (2019) and Walker and Alwang (2015) show that CGIAR legume research has resulted in the release of 322 new varieties in 18 SSA countries alone between 2007 and 2017 (Table 1). Of these, 183 are new common bean varieties, with Ethiopia leading the release of such varieties, followed by Rwanda, the Democratic Republic of Congo (DRC), and Tanzania. New varieties of groundnut, cowpea, and

[1] CGIAR is a global research partnership for a food secure future dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources.

chickpea have also been released in large number. Overall, the trend of varietal release for legume crops has increased more in recent years than in the early 2000s.

Most of these varietal releases were facilitated by bilateral projects, including three Tropical Legume (TL) Projects (Monyo and Varshney, 2016). One report document that 304 improved varieties of legume crops have been developed in 15 countries in Africa, India, and Bangladesh (ICRISAT, 2020). Among South Asian countries, India has released the greatest number of new legume varieties. This includes 16 groundnut, 7 pigeon pea, and 3 chickpea varieties (Varshney et al. 2019).

Table 1: Grain legumes research output in SSA: Varietal releases (2007–2017)

Country	*Chickpea*	*Common bean*	*Cowpea*	*Ground-nut*	*Lentil*	*Pigeon pea*	*Soybean*	*All*
Burundi		18						**18**
Burkina Faso			6					**6**
DRC		22						**22**
Ethiopia	11	28			1			**40**
Ghana			4					**4**
Kenya	9	17				3	7	**36**
Malawi		13		7		3		**23**
Mali			7	9				**16**
Mozambique		8		6		4		**18**
Niger			5	5				**10**
Nigeria			7	3			1	**11**
Senegal				6				**6**
Sudan	1							**1**
Rwanda		25						**25**
Uganda		18		12				**30**
Tanzania	4	21		12		2	2	**41**
Zambia		6				2		**8**
Zimbabwe		7						**7**
All SSA	**25**	**183**	**29**	**60**	**1**	**14**	**10**	**322**

Source: Varshney et al.(2019) and Walker and Alwang (2015)

Unlike legumes, no comparable review of recent varietal releases for dryland cereals has yet been undertaken. However, an ICRISAT-led project, Harnessing Opportunities for Productivity Enhancement (HOPE), documented that 49 cultivars of dryland cereals (25 sorghum, 13 pearl millet, and 11 finger millet) were released between 2009 and 2016 (ICRISAT, n.d.).[2]

1.2 Previous work documenting GLDC adoption

Releasing new crop varieties does not automatically lead to their adoption, particularly among key target groups. Consequently, farming household surveys have been conducted by CGIAR centres and others to ascertain levels of adoption and factors that

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[2] http://exploreit.icrisat.org/profile/Sorghum/193

facilitate and constrain it (Tripp 2011; Pacheco 2014; Walker and Alwang 2015). There have also been several noteworthy attempts to synthesize the results of these studies. One study, for example, by Pachico (2014) reviewed and synthesized the work carried out by over 30 impact assessment and adoption studies conducted in more than 20 countries in Africa.

The Diffusion and Impact of Improved Varieties in Africa (DIIVA) and Tracking Improved Varieties in South Asia (TRIVSA) projects have also documented varietal adoption and diffusion for various crops (including those related to GLDC's mandate) in SSA and South Asia from the period between 1998 and 2010 (Walker and Alwang 2015). This was a large body of work that involved comparing household survey, local informant, and expert opinion approaches to estimating national-level adoption of improved crop varieties.

1.3 Our contribution and approach

Our paper builds on and updates these efforts by reviewing and synthesizing more recent adoption studies and data, while also identifying gaps. We treat the Walker and Alwang (2015) adoption estimates from 2010 to 2014 survey data as our benchmark, and we examine what has changed since and where. However, we treat estimates derived through survey data and expert opinion with higher and lower levels of confidence, respectively, and, consequently, provide two sets of estimates. Noting that adoption is a dynamic process, we estimate current levels based on the latest available data combined with conservative projections, as needed.

1.4 Structure

In the next section, Methods, we describe our hybrid approach of identifying and synthesizing evidence from recent adoption studies, coupled with the use of trends in adoption, to estimate current levels. In Section 3, Results, we review the nature of the adoption studies emanating from our systematic literature search and what they reveal. We then present our estimates of current levels of improved GLDC adoption by crop type and by country following the application of our 'updating' procedure, both in absolute levels and from 2011 onwards (i.e., since beginning of CRP Phase 1). In Section 4, we summarize key findings and present recommendations.

2. Methods

To obtain recent estimates of GLDC varietal adoption, we carried out a systematic review of adoption-related studies conducted between 2007 and 2020, focusing on countries and crops targeted by CRP GLDC. We chose to include studies published after 2006 to capture research carried out under the first phase of the three abovementioned CRPs, as well as the two major bilateral projects, TL and HOPE. In this section, we describe the process followed, as well as our national-level adoption estimation approach.

2.1 Search methods and selection criteria

We relied on three methods to compile post-2006 GLDC adoption evidence: (a) an online search targeting scientific publications and grey literature available online; (b) a search of relevant organizational archives; and (c) direct communication with CRP GLDC scientists for relevant data and reports not yet published online.

For the online search, we used Google Scholar and a string that combined 'adoption' with each of CRP GLDC's target countries and crops as keywords. We retrieved additional grey literature not published online from organizational archives, which included those of ICRISAT, IITA, and CGIAR's Monitoring Evaluation and Learning database. During our validation process and corresponding communications with eight CRP GLDC scientists, we obtained five additional studies unavailable from any of the above.

2.2 Inclusion and exclusion criteria

From our search, we retained papers and other relevant documents that met the following eligibility criteria:

- Focus on one or more of CRP GLDC's target crops. These include seven grain legumes (chickpea, common bean, cowpea, groundnut, lentil, pigeon pea, and soybean) and two dryland cereals (pearl millet and sorghum).
- Focus on one or more of CRP GLDC's 13 target countries: 11 in SSA (Burkina Faso, Ethiopia, Malawi, Mali, Mozambique, Niger, Nigeria, Sudan, Tanzania, Uganda, and Zambia) and 2 in South Asia (India and Myanmar).
- Focus on adoption of one or more of the GLDC improved crop varieties by farmers in the priority countries.
- Timeframe: 2007–2020 to cover the first two phases of the CGIAR's CRPs, as well as research carried out under major bilateral projects.
- Type of publication: adoption and impact studies, including peer-reviewed journal articles, conference papers, working papers, book chapters, and discussion papers that use primary data; and project annual reports and baseline and end-line evaluation reports.
- Only one version of the same study (e.g., only the published paper and not its associated working paper).
- Published in English.

Documents excluded from our review include:

- Studies based on unrepresentative samples, which would, thereby, prevent extrapolation.
- Studies based on experimental or farmer participatory varietal selection (FPVS) trials, as such would be similarly problematic for drawing population-wide inferences.

2.3 Validation

We coded relevant studies and documents meeting the above criteria and tabulated their associated metadata in a spreadsheet. This spreadsheet was shared with key CGIAR scientists involved in GLDC research for validation. They also provided other relevant documents and data not captured in our search process. Through this process, several errors in our captured adoption estimates were identified and corrected (i.e., for cowpea in Nigeria and common bean in Ethiopia).

2.4 Adoption estimation and updating method

Our objective was to use the screened studies and documents as a means of estimating the number of households that have adopted improved GLDC varieties both overall and from 2011 onwards.

However, we encountered four main issues:

- **Varying units**. Many studies do not use 'household' as the main unit for measuring adoption. For example, the area of land under improved varieties measured as a percentage of total area grown vis-à-vis the crop is commonly used. Several other studies also use the percentage of plots under improved varieties or share of improved varieties of seeds used by farmers.
- **Temporal extrapolation challenges**. The estimates associated with the 35 shortlisted studies range from as early as 2010 to as late as 2020. Thus, many estimates do not necessarily reflect current levels of GLDC crop varietal adoption.
- **Geographic extrapolation challenges**. The adoption estimates ascertained from household survey data correspond to the main crop-growing areas or project intervention areas in the target countries. Hence, we could not use these estimates to directly infer adoption at the national level. The DIIVA and TRISVA studies provide national-level estimates, but many of these were derived through a Delphi-informed expert estimation method, rather than survey data (Walker and Alwang, 2015), leading to our fourth issue.
- **Survey data versus expert opinion**. Of our 35 shortlisted studies, 19 are informed by survey data, while the remaining 16 are based on the expert opinion solicitation method used in the DIIVA/TRISVA studies. There is significant variation in the extent to which the resulting expert opinion estimates are consistent with those derived from adoption surveys (Walker and Alwang, 2015). For some crop types, there is reasonable consistency, but this is not the case for others.

Our adoption estimation and updating method addresses these four issues (Figure 1). We began by estimating the national adoption rate (Step 1), particularly for those studies only providing region (or sample area) adoption estimates. Specifically, we multiplied the region-specific estimates by the share of cropping area that this rate applies to (i.e., the cropping area targeted by the study) vis-à-vis the national cropping area. For example, if the share of the study's sampling area represents 75% of the national cropping area, a sample adoption rate of 40% would convert to a national adoption rate of 30% (75% × 40% = 30%). CGIAR centres tend to administer adoption surveys in growing regions where the improved variety was promoted. Consequently, we do not expect adoption rates to be similar in other regions. Indeed, our approach is conservative, as the resulting national estimates assume that no spillovers of the improved varieties to non-surveyed regions has taken place. Consequently, our adoption estimates for the national level likely systematically underestimate actual adoption levels and can, therefore, be treated as 'lower bound' estimates.

Second, we updated our national adoption estimates up to 2019 (the latest available year of FAOSTAT data (FAO, 2020)[3] using the average annual adoption growth rate for each crop (Step 2). For example, for a national adoption rate of 38% in 2016 with an average annual adoption growth rate of 2%, the corresponding 2019 estimate would be 44%. However, adoption growth rates are only reported in some of our shortlisted studies. Out of the 19 higher confidence studies, 12 involved at least two survey rounds. For these, we were able to compute the adoption growth rate, which we used to update our estimates to 2019. For the other studies, we computed the adoption growth rate using changes in yield derived from FAOSTAT data as a proxy. We assume that the adoption growth rate per year is proportional to the long-term average yield growth rate for that crop. We acknowledge the inherent limitations, given that yield is affected by factors other than varietal adoption (e.g., weather and management practices).

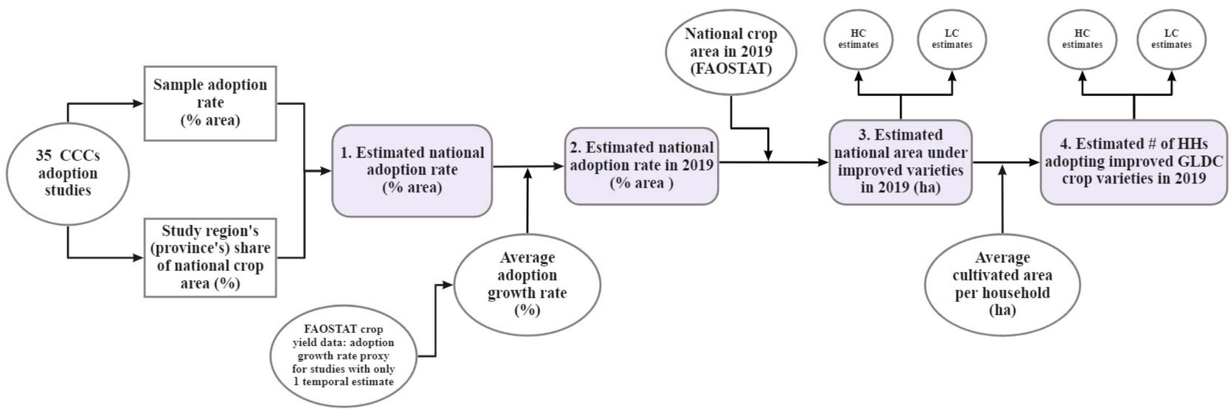

Figure 1. Estimation approach of adoption level at the national level
Notes: CCC = country by crop combination; HC = higher confidence; LC = lower confidence; HH = household

Next, we multiplied our estimated updated national adoption rate by the national area under the crop during the survey period and in 2019 (obtained from FAOSTAT), thereby deriving the estimated number of hectares under the improved variety in question (Step 3). We then we divided these results by data on the average area cultivated per household to derive an estimated number of adopting households (Step 4).[4] Finally, we adjusted for potential double counting by only taking the highest number of households associated with a specific crop in areas where there is geographic overlap in the crop-growing area. This approach is, again, conservative because it assumes that all households in these areas of overlap that adopt the most popular improved GLDC variety also adopt the other improved varieties. This is unlikely to always be the case, thereby resulting in a likely underestimation of total number of households adopting one or more GLDC improved variety.

[3] FAO national crop area data for each crop in the target countries is provided in Appendix A.
[4] The data is obtained from the selected studies and other sources when this not available from the selected studies (see Appendix C)

For Steps 4 and 5, we generated higher and lower confidence estimates. Complementing the findings of Walker (2015), we find that that expert opinion derived adoption estimates are consistently higher than those associated with will follow-up household surveys (cf. Manda et al., 2019; Mwakimata, 2018; Tufa et al., 2019). Therefore, we treated such adoption estimates as less reliable and used them to estimate current levels of varietal adoption only when household survey data were unavailable, thereby leading us to generate two sets of estimates. (See Appendix B for how the shortlisted studies are grouped by level of confidence.)

3. Results

In this section, we first present the results of our search, including a brief description of 69 filtered adoption studies. We then provide a detailed synthesis of the results by target country and crop combination (CCC).

3.1 Description of the selected adoption studies

Our online search returned 203 studies and 17 additional studies were identified through other sources, bringing the total to 220 (Figure 2). Of these, 67 were removed as duplicates and the remaining 153 studies were screened based on their titles and abstracts, which led to 63 studies being dropped. Of the 90 remaining studies, 63 met our inclusion criteria. Our validation process retrieved 6 additional adoption studies from Center scientists, bringing the total to 69. From these, we relied on only 35 CCCs with the latest adoption data to generate our adoption estimates. However, we used the 34 older studies to inform our adoption growth rate computations, as per our modelling approach presented in Section 2.

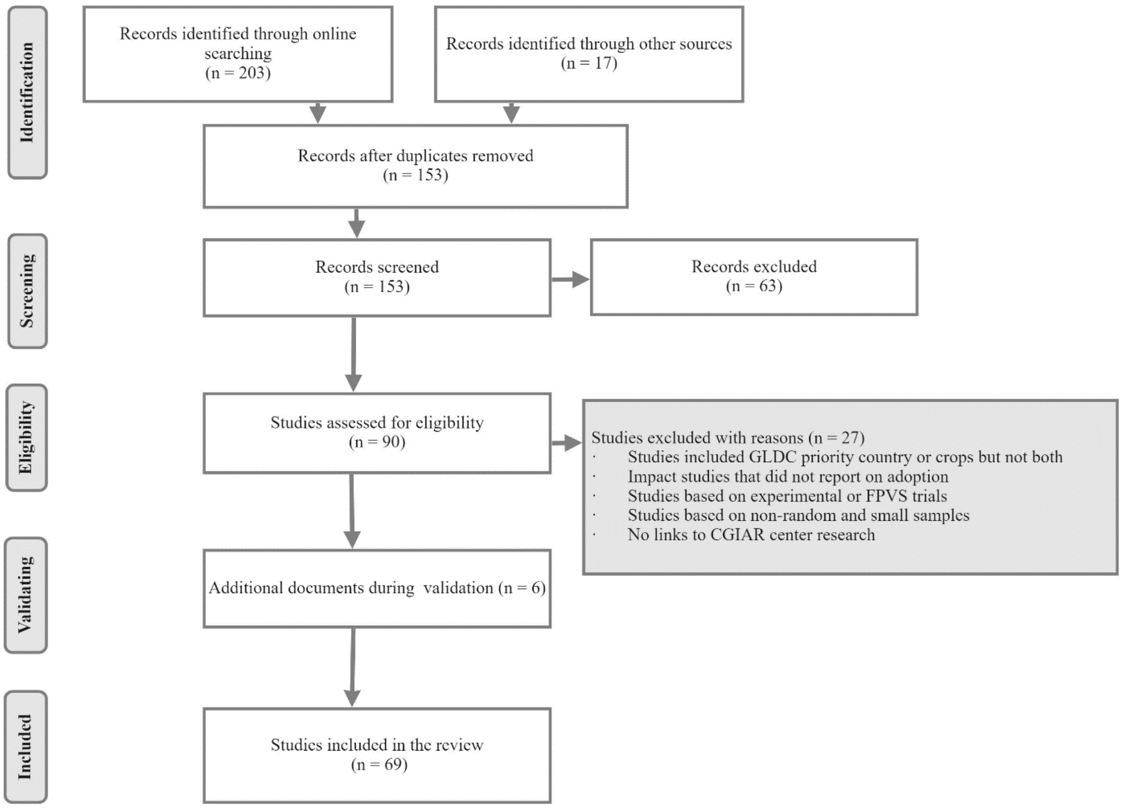

Figure 2. Search and screening process for adoption studies of improved varieties of crops targeted in GLDC
Notes: FPVS = farmers' participatory varietal selection,

Most of the retrieved studies are articles published in peer-reviewed journals and book chapters, followed by research reports of different types (
Figure 3).

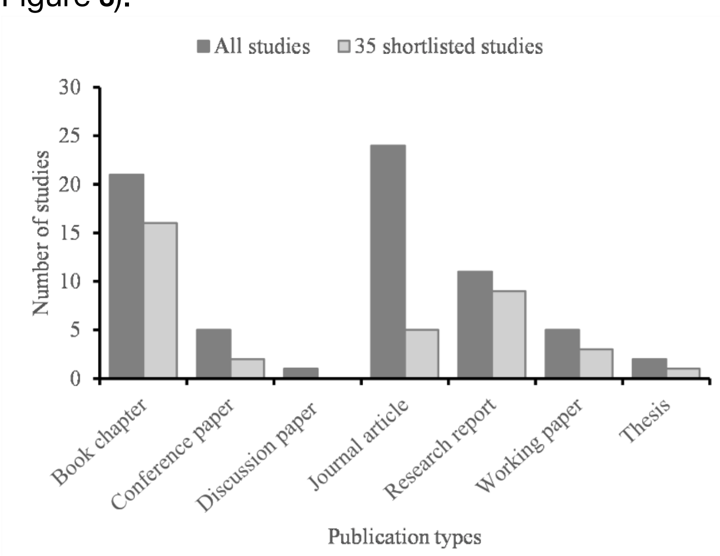

Figure 3. Type of scientific publications reviewed

Figure 4 shows the number of studies across survey years.[5] The year 2010 stands out as it includes projects summarized in Walker and Alwang (2015). Of the 35 studies that form the core basis of our estimates, only 18 are based on household data collected after 2010, revealing a lack of up-to-date information on the level of GLDC crop adoption. This is the rationale for implementing our adoption rate temporal extrapolation approach described in Section 2.

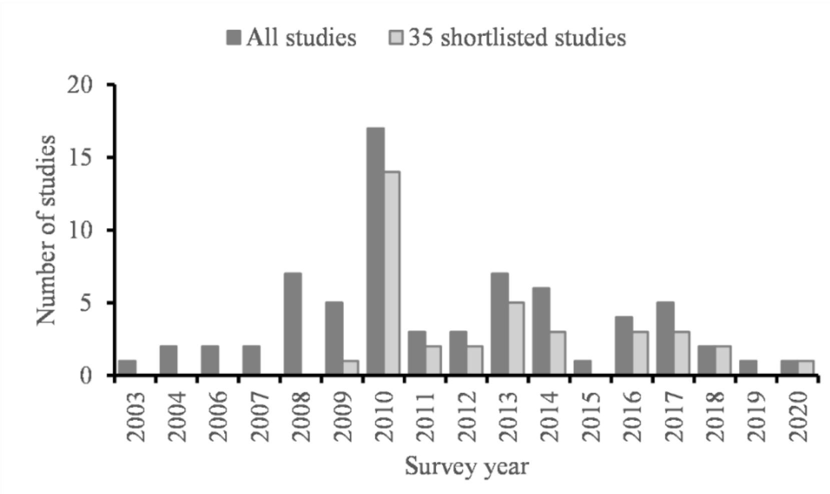

Figure 4. Number of studies per survey year

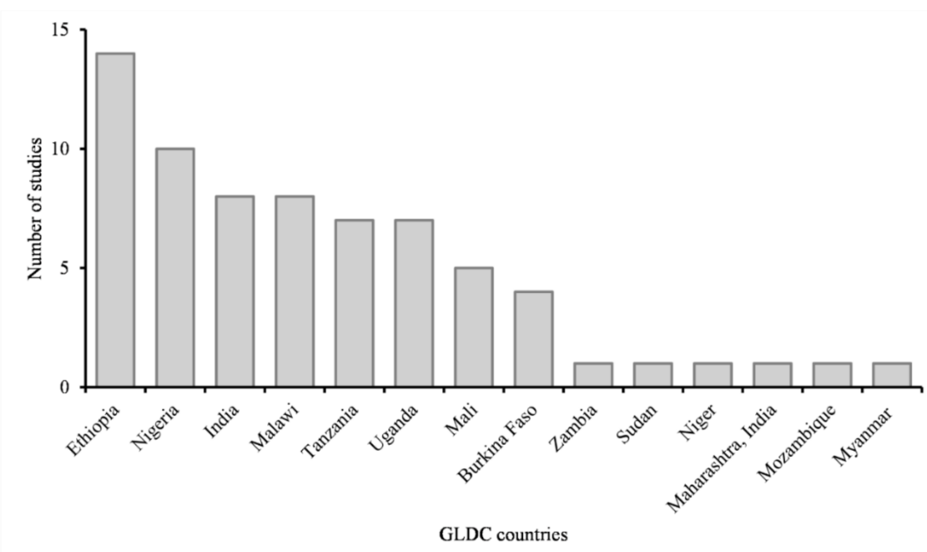

Figure 5 and Figure **6** present the number of adoption studies by CCC. Ethiopia, Nigeria, and Malawi account for the most SSA studies, whereas India dominates the South Asia region. This is partly a reflection of the relatively high number of GLDC crops released in these countries. The highest number of adoption studies pertain to groundnuts (13 studies), while more than five studies were completed for most of the other crops.

[5] Survey year refers to the year data were collected through household surveys and ascertained via expert opinion.

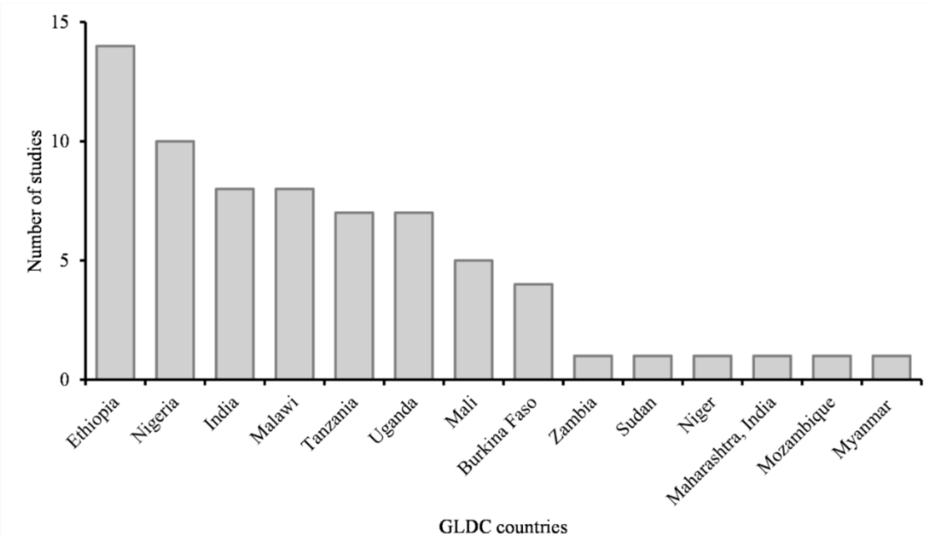

Figure 5. Number of studies by target countries

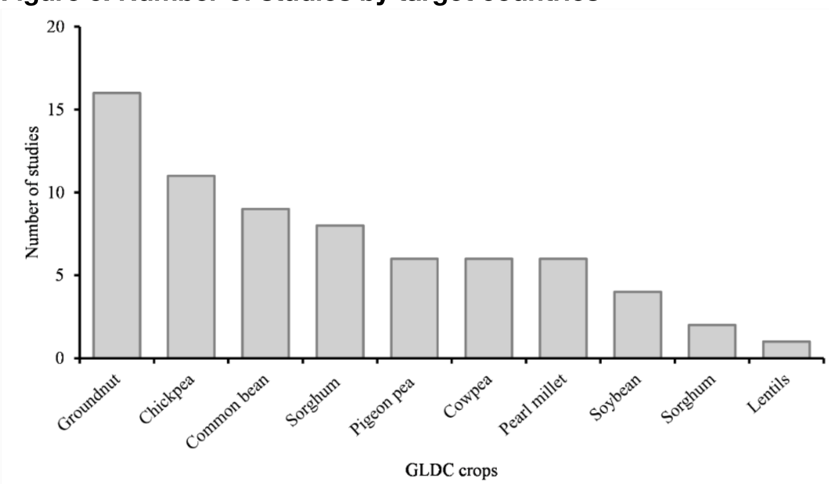

Figure 6. Studies by target GLDC crops

3.2 National-level adoption rate estimates by target crops and country

Figure 7 presents our updated 2019 CCC adoption rate estimates, defined as a percentage of national cropping area (Step 2 in Figure 1). There is large variation across the crops and countries, ranging from as low as 7% for improved millet varieties in Burkina Faso to nearly 100% for chickpea in Myanmar. We indicate which adoption rate estimates are informed by higher confidence studies (i.e., survey data (**)) and those informed by lower confidence studies (i.e., expert opinion (*)).

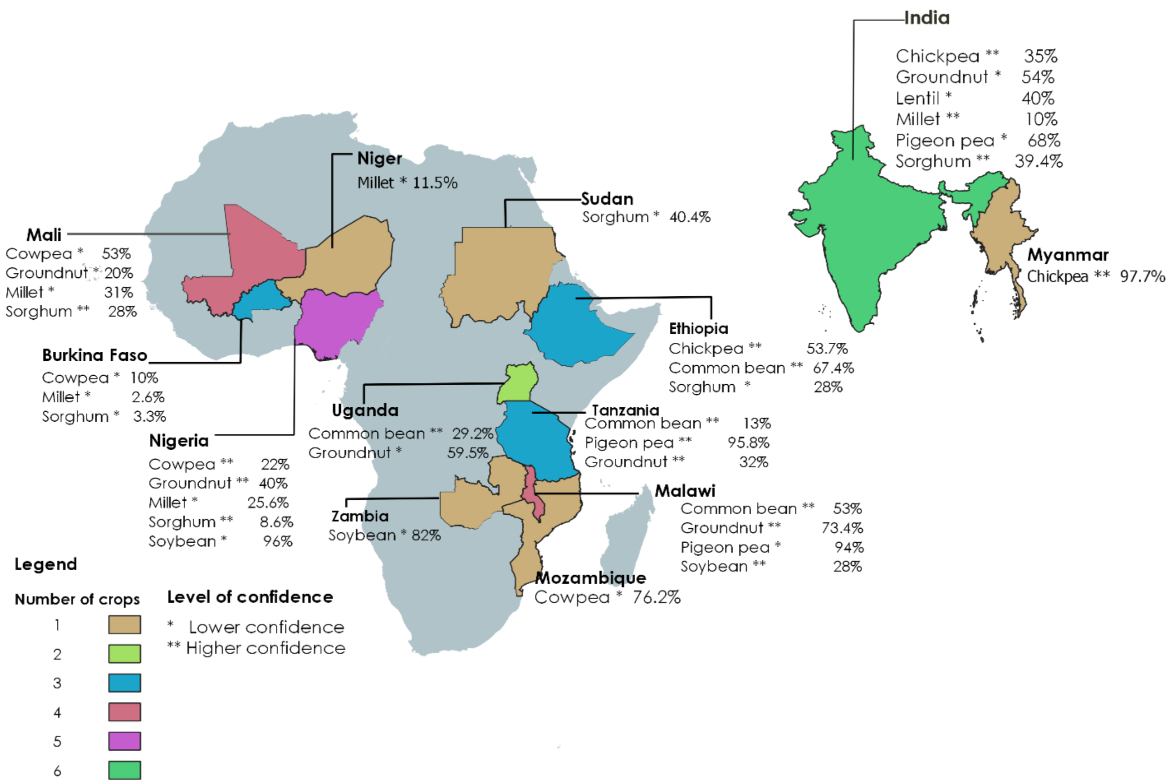

Figure 7. Updated national adoption rate in 2019 (% area) by target countries and crops

From data associated with both the higher and lower confidence studies, we estimate that the adoption rate of GLDC improved varieties has increased considerably over the 2011 to 2019 period (Table 2). On average, we estimate that there was an increase from 37% to 52% for all studies and 30% to 46% for the higher confidence studies. This 15–16% increase in the adoption rate varies across the GLDC crop portfolio. However, there is considerable variation across individual CCCs, ranging from as high as 46% for pigeon pea to as low as 3% for soya bean.

Table 2. Overall average adoption rate (% of national cropping area) by GLDC target crop

Crop	Countries		2011 estimates (% area)		2019 estimates (% area)	
	All studies	*HC studies*	*All studies*	*HC studies*	*All studies*	*HC studies*
Grain legumes						
Chickpea	Ethiopia, India, Myanmar	Ethiopia, India, Myanmar	34	34	63	63
Common bean	Ethiopia, Malawi, Tanzania, Uganda	Ethiopia, Malawi, Tanzania, Uganda	30	30	41	41
Cowpea	Burkina Faso, Nigeria Mozambique, Mali	Nigeria	23	17	43	25
Groundnut	India, Malawi, Mali, Nigeria, Tanzania, Uganda	Malawi, Nigeria, Tanzania	38	33	55	50
Lentils	India	India	40	40	59	59
Pigeon pea	India, Malawi, Tanzania	Tanzania	56	50	91	96
Soybean	Malawi, Nigeria, Zambia	Malawi	74	25	64	28
Dryland cereals						
Millet	Burkina Faso, India, Mali, Niger, Nigeria	India, Nigeria	16	18	22	22
Sorghum	Burkina Faso, Ethiopia, India, Mali, Niger, Nigeria, Sudan	India, Mali, Nigeria	22	25	33	34
Overall average			**37**	**30**	**52**	**46**

Notes: HC = higher confidence

3.3 Aggregate area under improved varieties and number of households adopted

In this section, we present our adoption estimates for both the area under improved varieties (Step 3 of Figure 1) and the number of adopting households (Step 4) by country. Estimates by target crops are presented in Appendixes D and E.

Using data from all studies, we estimate that improved GLDC varieties were planted on approximately 32 million hectares of land in 2019 in the 13 target countries (Table 3). This figure is over 15 million when only the higher confidence studies are considered. We further estimate the overall increase in area from 2011 to 2019 to be over 14 million hectares for the set of studies and nearly 7 million hectares for only the higher confidence studies. The largest gains were in the two most populous countries in CRP GLDC's portfolio, India and Nigeria. For the former, there is a considerable difference between the estimates from all studies and the higher confidence studies: 5.4 million and 2.9 million, respectively. Sudan ranks third, but we are only able to offer a lower confidence estimate of 2.2 million hectares. The gains in area for the remaining countries are under 1 million hectares. Ethiopia is the only country where our higher confidence estimate is negative (-67,000 ha), driven by less area devoted to growing improved varieties of common bean (see Appendix F).

Table 3. Estimated national area under improved varieties in 2011 and 2019

Region/country	Estimated area under IV in 2011 ('000 ha)		Estimated area under IV in 2019 ('000 ha)		Additional area under IV ('000 ha)[a]	
	Overall estimates	*Higher confidence*	*Overall estimates*	*Higher confidence*	*Overall estimates*	*Higher confidence*
South Asia	**10,307**	**4,786**	**15,757**	**7,782**	**5,450**	**2,996**
India	10,026	4,505	15,379	7,404	5,353	2,899
Myanmar	281	281	378	378	97	97
Sub-Saharan Africa	**7,566**	**3,621**	**16,251**	**7,588**	**8,685**	**3,967**
Burkina Faso	234	-	417	-	183	-
Ethiopia	542	368	814	301	272	-67
Malawi	388	293	775	528	387	235
Mali	954	372	1,777	544	823	172
Mozambique	11	-	253	-	242	-
Niger	834	-	1,222	-	388	-
Nigeria	2,469	2,198	6,078	5,539	3,609	3,341
Sudan	1,658	-	3,888	-	2,230	-
Tanzania	302	302	518	518	216	216
Uganda	113	88	348	158	235	70
Zambia	61	-	161	-	100	-
Total	**17,874**	**8,407**	**32,008**	**15,370**	**14,135**	**6,963**

Notes: Figures adjusted for potential double counting.

[a] Change in adoption rate from the benchmark is used to calculate additional area under improved varieties (IVs) since 2011, rather than deducting area under IVs in the benchmark from the areas under IVs in 2019. The latter approach is influenced by area change. For example, when area of respective crop in 2019 declined compared to the benchmark, the area under IVs will decline which is not realistic.

As explained by in Section 2, our estimation approach divides our national area estimates for each crop by its associated average household cropping area. Areas of geographic overlap in cropping areas are further identified, with only our highest single crop-specific estimates taken from these areas to adjust for potential double counting. We estimate a slightly lower but comparable increase in the overall number of households that adopted improved GLDC varieties: 12.5 million (Table 4) compared with 14.1 million hectares (Table 3). However, this same difference vis-à-vis our higher confidence estimates is considerably greater: 1.15 million households compared to 6.97 million hectares.

We find that this apparent inconsistency is driven by our estimates for India, which are considerably larger than those of the other countries. For this country, we estimate that there was an approximate 11% drop in the numbers of households growing improved GLDC varieties overall. However, this was not necessarily due to the dis-adoption of improved varieties; indeed, the adoption growth rates are all positive for all GLDC crops targeted for this country (Appendix C). Rather, it is due to a significant decrease in the cropping area devoted to sorghum between the two time periods. Nationally, the area devoted to this crop dropped from 7.4 million to 4.1 million hectares over this period (Charyulu et al., 2016). This, in turn, resulted in a drop in our estimated area devoted to, as well as households cultivating, improved sorghum varieties (see Appendix C and Appendix F). At the same time the adoption of other improved GLDC varieties increased considerably, notably chickpea, which we estimate to have increased by over 500% (Appendix F). While the estimated drop in households cultivating sorghum is considerably greater (2.16 million) compared to the increase in improved chickpea adopting households (0.55 million), the average area per household devoted the former crop is considerably less (0.3 ha) compared with the latter (4.9 ha). This is why our area estimates derived from the higher confidence studies are considerably greater than are those corresponding to our household estimates.

Table 4. Number of households that had adopted improved varieties at the benchmark and updated 2019, aggregated by targeted countries

	Estimated HHs 2011 ('000s)		**Estimated HHs 2019 ('000s)**		**Additional HHs ('000s)**	
Region/country	*Overall estimates*	*Higher confidence*	*Overall estimates*	*Higher confidence*	*Overall estimates*	*Higher confidence*
South Asia	**20,556**	**9,513**	**24,448**	**8,499**	**3,892**	**-1,014**
India	20,391	9,348	24,226	8,277	3,835	-1,071
Myanmar	165	165	222	222	57	57
Sub-Saharan Africa	**11,559**	**6,976**	**20,188**	**9,143**	**8,629**	**2,167**
Burkina Faso	272		515		243	
Ethiopia	592	437	1,771	404	1,172	-33
Malawi	646	456	1,474	979	827	523
Mali	1,165	124	2,467	181	1,302	57
Mozambique	49		1,148		1,099	
Niger	1,668		2,444		776	
Nigeria	5,578	5,262	6,891	6,261	1,313	999
Sudan	754		1,767		1,013	
Tanzania	329	329	660	660	331	331
Uganda	374	368	702	658	328	290
Zambia	132		349		217	
Total	**32,115**	**16,489**	**44,636**	**17,642**	**12,521**	**1,153**

There are several other differences between the cropping area and household adoption estimates. For Ethiopia, Malawi, and Mozambique, our area estimates are considerably lower than those for adopting households. The main explanation is that the average household cropping area for the crops that saw the greatest expansion over the 9-year period are significantly less than 1 ha. In Malawi, for example, our estimated increase in cropping area devoted to improved groundnut varieties is 0.162 million hectares (Appendix F, yet the average household area cultivated for this crop is only 0.3 ha (Appendix C). Hence, the estimate for households is significantly greater than it is for hectares (Appendix G). The same is the case for sorghum in Ethiopia and cowpea in Mozambique.

For Nigeria and to a lesser extent Sudan, the trend is the reverse; the area estimates are significantly larger than the household estimates. For Sudan, the reason is straightforward: The average household area allocated for sorghum is 2.2 ha, resulting in fewer households than hectares. For Nigeria, the situation is more complex, due to the five improved GLDC varieties with differing average household cropping area allocations – several significantly over and several significantly under 1 ha. In short, the reason the area estimates are larger is both due to a greater increase area covered by crops with an average cropping area above 1 ha and adjustments made for potential double counting.

4. Summary and conclusion

Arguably, GLDC is, at its core, a crop improvement program. Improved GLDC varieties have been bred to address specific needs or problems; for example, low productivity, erratic rainfall patterns, recurrent droughts, pest attacks, and emerging trends in consumer demand. These improved crop varieties are then released through national variety release systems, with the expectation that farmers will adopt them and, in turn, experience the associated benefits, particularly when complemented by other interventions, such as extension and market access support. The large-scale adoption of improved GLDC varieties is therefore a key prerequisite for program impact.

Fortunately, efforts by GLDC, its predecessor research programs, and others have invested in carrying out country specific adoption studies and other estimation approaches. Several methods have been used, most notably expert opinion solicitation, representative household-level adoption surveys, and more recently DNA fingerprinting. We capitalized on this investment by systematically searching and screening all relevant studies pertaining to the adoption of improved GLDC crop varieties in the 13 countries targeted by the program. Through this, we identified 35 unique CCCs and 69 relevant studies that target CRP GLDC CCCs.

Unfortunately, we were unable to simply combine the results of these studies to ascertain current levels of adoption. The units in which estimates are reported vary, and data collection for most studies took place several years ago in non-nationally representative survey areas. Moreover, 16 of the 35 studies relied on soliciting expert opinion as the main estimation method, which can be less reliable

Our approach addressed these issues. This involved (a) multiplying the study's adoption rate by the surveyed region's share of the national cropping area to derive a conservative estimate of the national adoption rate at the time of data collection; (b) updating *a* to 2019 using the average adoption growth rate for the crop in question; (c) multiplying *b* by the national cropping area to estimate of the area the improved variety in 2019; and (d) dividing *c* into the average cultivated area per household for the crop in question to derive an estimated number of households growing the improved variety in 2019. We further mitigated the potential for double counting at the household level by conservatively informing our overall household adoption estimates with the highest crop-specific estimates in overlapping national cropping areas. Finally, we treated estimates derived from studies based on household surveys and expert opinion with higher and lower levels of confidence, respectively, thereby generating both overall and higher confidence estimates.

From this, we estimate from both the higher and lower confidence studies that the area under improved GLDC varieties increased by approximately 15% on average across the 13 targeted countries between 2011 and 2019. As of 2019, we estimate from the higher confidence studies that improved GLDC crops were cultivated on 15.37 million hectares of land across 17.64 million households in these same countries. When we include the lower confidence studies, these estimates increase to 32 million hectares and 44.64 million households.

The gain in both area and household-level adoption from 2011 is also significant, but less so for our estimates based on household survey data. From the higher confidence studies, we estimate the gains in cropping area under improved GLDC varieties to be 6.96 million hectares. With the inclusion of lower confidence estimates, this rises to 14.13 million hectares. Our estimates from only the higher confidence studies for the number of adopting households is far lower, standing at 1.53 million. This is primarily driven by a significant reduction in the overall sorghum cropping area in India, but this is not indicative of a drop in the adoption rate of this crop or any other.

With the inclusion of expert opinion-based studies, our estimates of additional households adopting improved GLDC varieties increases considerably to 12.5 million. This estimate exceeds CRP GLDC's adoption target (8.9 million households) by over 40%. Hence, we can be reasonably confident that the program at least met this target, as there would need to be considerable upwards bias among the 16 of the 35 studies relying on expert opinion solicitation and/or our overall estimation approach for this to be otherwise.

Moreover, if we consider likely spillovers of improved GLDC varieties to (a) non-surveyed areas in priority GLDC countries and (b) non-priority countries but where scaling efforts have taken place (e.g., Bangladesh), as well as (c) the diffusion of non-priority GLDC varieties in priority countries (e.g., groundnuts in Zambia and Kenya), our confidence only grows. For example, Mausch et al. (2013) highlight improved groundnut varieties are high adaptable and have diffused far beyond the areas and countries where they were initially released. Similar results have been highlighted for sorghum (Charyulu et al., 2014).

In addition, our approach addresses the potential of double counting by taking only the highest adoption estimate in potential areas of overlap, thereby assuming adopting households adopted all improved varieties in question. In reality, it is unlikely that all households adopted the full set of improved crop varieties in these areas of geographic overlap, thereby resulting in an underestimation of the total number of adopting households.

Despite our confidence that GLDC's overall household adoption target has likely been significantly exceeded, we cannot confidently say by how much; there are too many factors that prevent us from providing precise estimates. We therefore conclude by making three recommendations on how such adoption estimation can be improved. First, continued efforts should be made to improve the accuracy of such estimates. While adoption surveys are likely (at least in general) preferable to soliciting expert opinion, recent studies comparing results obtained from farmer self-reporting and DNA analysis of seed samples obtained from farmers' fields reveal high levels of inconsistency with respect to the former (cf. Jaleta et al., 2020; Maredia et al., 2016). DNA fingerprinting is the only reliable identification method for many crops (Milne et al., 2015).

A second area of improvement is to the frequency of adoption-related surveys. As highlighted above, only 4 of our 35 shortlisted studies are based on data collected from 2018 onwards. This required us to compute adoption growth rates to generate more up-to-date estimates, another potential source of measurement error, given that the average adoption growth rate may vary year by year. Of course, increasing the frequency of adoption-related surveys will increase costs and, therefore, may not be always financially viable. However, recent efforts to include indicators in large-scale efforts, such as the World Bank's Living Standard Measurement Survey, could prove valuable in gaining a deeper and broader understanding of adoption dynamics at a more granular level (Kosmowski et al., 2020).

This leads us to our third and final recommendation: explore ways of increasing the efficiency of reliable adoption estimation approaches. Here, we recommend innovatively integrating such surveys as part of project-related monitoring, evaluation strategies, and even trait-demand appraisal exercises, alongside scaling up efforts to 'piggy back' on nationally representative data collection exercises (Macours et al. 2021).

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Appendix A: National area under GLDC crops in the baseline and 2019 based on FAOSTAT database

Country	Crop	National crop area at the benchmark ('0000 ha)	National area in 2019 ('0000 ha)
Ethiopia	Chickpea	240	209
India	Chickpea	8,522	9,547
Myanmar	Chickpea	333	380
Ethiopia	Common bean	583	281
Malawi	Common bean	307	349
Tanzania	Common bean	738	894
Uganda	Common bean	669	540
Burkina Faso	Cowpea	1,332	1,354
Mali	Cowpea	239	454
Mozambique	Cowpea	99	331
Nigeria	Cowpea	2,860	4,303
India	Groundnut	5,860	4,731
Malawi	Groundnut	308	400
Mali	Groundnut	337	452
Nigeria	Groundnut	2,354	4,303
Tanzania	Groundnut	482	990
Uganda	Groundnut	45	320
India	Lentils	1,341	1,363
Burkina Faso	Millet	1,362	1,177
India	Millet	9,179	8,450
Mali	Millet	1,257	1,990
Niger	Millet	7,253	6,831
Nigeria	Millet	4,364	4,303
India	Pigeon pea	3,466	4,550
Malawi	Pigeon pea	190	263
Tanzania	Pigeon pea	257	87
Burkina Faso	Sorghum	1,983	1,890
Ethiopia	Sorghum	1,835	1,828
India	Sorghum	6,210	4,093
Mali	Sorghum	1,329	1,501
Nigeria	Sorghum	2,860	5,397
Sudan	Sorghum	4,103	6,828
Malawi	Soybean	75	180
Nigeria	Soybean	282	656
Zambia	Soybean	61	196

Appendix B: List of 35 adoption evidence with their level of confidence, by crop and country

Crop	Country	Year data ascertained	Method	Level of confidence
Chickpea	Ethiopia	2018	Household survey	High
Chickpea	India	2013	Household survey	High
Chickpea	Myanmar	2018	Household survey	High
Common bean	Ethiopia	2016	Household survey	High
Common bean	Malawi	2013	Household survey	High
Common bean	Uganda	2012	Household survey	High
Common bean	Tanzania	2016	Household survey	High
Cowpea	Nigeria	2017	Household survey	High
Cowpea	Burkina Faso	2010	Expert opinion	Low
Cowpea	Mali	2010	Expert opinion	Low
Cowpea	Mozambique	2010	Expert opinion	Low
Groundnut	Malawi	2011	Household survey	High
Groundnut	Nigeria	2017	Household survey	High
Groundnut	Tanzania	2016	Household survey	High
Groundnut	India	2010	Expert opinion	Low
Groundnut	Mali	2010	Expert opinion	Low
Groundnut	Uganda	2010	Expert opinion	Low
Lentils	India	2014	Mixed	High
Millet	India	2013	Household survey	High
Millet	Nigeria	2020	Household survey	High
Millet	Burkina Faso	2010	Expert opinion	Low
Millet	Mali	2010	Expert opinion	Low
Millet	Niger	2010	Expert opinion	Low
Pigeon pea	Tanzania	2012	Household survey	High
Pigeon pea	India	2010	Expert opinion	Low
Pigeon pea	Malawi	2010	Expert opinion	Low
Sorghum	Nigeria	2010	Household survey	High
Sorghum	India	2013	Household survey	High
Sorghum	Mali	2013	Household survey	High
Sorghum	Burkina Faso	2010	Expert opinion	Low
Sorghum	Ethiopia	2014	Expert opinion	Low
Sorghum	Sudan	2009	Expert opinion	Low
Soybean	Malawi	2017	Household survey	High
Soybean	Nigeria	2009	Expert opinion	Low
Soybean	Zambia	2010	Expert opinion	Low

Appendix C: Parameters used for the calculations: Average crop area per households (ha) and adoption growth rate per year

Country	Crop	Avg. crop area (ha)	Source	Avg. adoption growth rate/year	Adoption growth rate based on FAOSTAT yield change
Ethiopia	Chickpea	0.51	Verkaart et al. (2018)	5.9	3.5
India	Chickpea	4.90	Bantilan et al.(2014)	4.6	1.8
Myanmar	Chickpea	1.70	Boughton et al.(2020)	1.9	-0.5
Ethiopia	Common bean	0.87	Katungi et al.(2010)	1.1	7.0
Malawi	Common bean	0.31	Katungi et al. (2017)		1.1
Tanzania	Common bean	0.60	Katungi et al.(2019)	1.3	7.5
Uganda	Common bean	0.24	Larochelle et al.(2015)		2.3
Burkina Faso	Cowpea	0.9	Joseph et al. (2021)		0.3
Mali	Cowpea	0.5	Kouyate et al. (2021)		0.4
Mozambique	Cowpea	0.2	USAID (2016)		7.2
Nigeria	Cowpea	1.6	Manda et al. (2019)		4.0
India	Groundnut	0.5	*		3.7
Malawi	Groundnut	0.3	Amponsah and Paliwal (2015)	3.8	-0.3
Mali	Groundnut	0.5	*		1.7
Nigeria	Groundnut	1.9	Ahmed et al. (2020)	2.5	-0.8
Tanzania	Groundnut	0.80	Mwakimata (2018)	5.3	-0.3
Uganda	Groundnut	4.3	Shiferaw et al. (2010)	0.5	-3.0
India	Lentil	0.5	*		3.8
Burkina Faso	Millet	0.5	*		0.5
India	Millet	0.8	Charyulu et al. (2017)		1.3
Mali	Millet	0.5	*		1.1
Niger	Millet	0.5	*		0.7
Nigeria	Millet	0.2	Ndjeunga et al. (2011)	3.0	4.8
India	Pigeon pea	0.5	*		1.8
Malawi	Pigeon pea	0.5	*		4.9
Tanzania	Pigeon pea	1.3	Dalton and Regier (2016)	6.6	2.2
Burkina Faso	Sorghum	0.5	*		0.6
Ethiopia	Sorghum	0.3	Cavatassi et al. (2011)		3.7
India	Sorghum	0.3	Charyulu et al.(2016)		0.8
Mali	Sorghum	3.0	Smale et al. (2014)	1.4	2.0
Nigeria	Sorghum	0.2	Ndjeunga et al. (2011)		1.5
Sudan	Sorghum	2.2	Bushara (2016)		2.1
Nigeria	Soybean	0.3	Tufa et al. (2019)		-1.4
Zambia	Soybean	0.9	Kamara et al.(2018)		-2.0
Malawi	Soybean	0.5	TechnoServe (2010)		0.4

Note: For observation with at least two sets of survey data, this is used to calculate adoption growth rate while we used average yield change over the last decade based on FAOSTAT data as proxy for adoption growth rate for the remaining observations. * For crops with no information on average area allocated, 0.5 ha is assumed.

Appendix D: National area and area under improved varieties at the benchmark and updated 2019 for the whole observation, aggregated by targeted crops

Crop	Benchmark national crop area ('000 ha)	Benchmark area under IV ('000 ha)	National crop area in 2019 ('000 ha)	Area under IV in 2019 ('000 ha)	Additional area under IV ('000 ha)
Dryland cereals	**41,735**	**8,229**	**44,287**	**12,832**	**3,988**
Millet	23,415	3,268	22,750	4,714	1,360
Sorghum	18,320	4,961	21,537	8,118	2,627
Grain legumes	**30,980**	**9,913**	**37,133**	**18,944**	**7,156**
Chickpea	9,095	914	10,135	3,772	2,750
Common bean	2,297	590	2,063	648	228
Cowpea	4,530	757	6,443	1,762	618
Groundnut	9,386	4,129	11,196	7,033	2,651
Pigeon pea	3,914	2,580	4,900	4,175	907
Soybean	418	407	1,033	750	-256
Lentils	1,341	536	1,363	804	259
Total	**72,715**	**18,142**	**81,420**	**31,776**	**11,143**

Appendix E: Number of households adopted improved varieties at the benchmark and updated 2019 based on all observations, aggregated by targeted crops

Crop	Number of households adopted at the benchmark	Number of households adopted in 2019	Additional number of households adopted since 2011
Dryland cereals	**19,385**	**26,227**	**7,975**
Millet	8,611	11,091	2,292
Sorghum	10,774	15,136	5,683
Grain legumes	**16,511**	**27,252**	**8,426**
Chickpea	343	1,065	692
Common bean	1,249	1,663	620
Cowpea	752	2,529	1,275
Groundnut	7,405	10,999	4,146
Pigeon pea	1,073	8,250	1,764
Soybean	5,005	1,137	-589
Lentils	684	1,608	518
Total	**35,896**	**53,479**	**16,401**

Appendix F: National area under improved varieties at the benchmark and updated 2019, by targeted countries and crops

Country	Area under IV in 2011 ('000 ha)		Area under IV in 2019 ('000 ha)	
	Overall estimates	*Higher confidence*	*Overall estimates*	*Higher confidence*
Burkina Faso	**234**	**-**	**417**	
Millet	35	-	79	
Sorghum	65	-	166	
Cowpea	133	-	172	
Ethiopia	**542**	**368**	**814**	**301**
Sorghum	174	-	513	-
Chickpea	28	28	112	112
Common Bean	340	340	189	189
India	**10,026**	**4,505**	**15,379**	**7,404**
Millet	918	918	1,493	1,493
Sorghum	2,446	2,446	1,798	1,798
Chickpea	605	605	3,309	3,309
Groundnut	3,164	-	4,131	-
Pigeonpea	2,357	-	3,844	-
Lentils	536	536	804	804
Malawi	**388**	**293**	**775**	**528**
Common Bean	141	141	184	184
Groundnut	132	132	294	294
Pigeonpea	95	-	247	-
Soybean	19	19	50	50
Mali	**954**	**372**	**1,777**	**544**
Millet	390	-	818	
Sorghum	372	372	544	544
Cowpea	127	-	258	-
Groundnut	66	-	158	-
Mozambique	**11**	-	**253**	-
Cowpea	11	-	253	-
Myanmar	**281**	**281**	378	**378**
Chickpea	281	281	378	378
Niger	**834**	-	1,222	-
Millet	834	-	1,222	-
Nigeria	**2,469**	**2,198**	**6,078**	**5,539**
Millet	1,091	1,091	1,102	1,102
Sorghum	246	246	1,210	1,210
Cowpea	275	275	1,284	1,284
Groundnut	587	587	1,944	1,944
Soybean	271	-	539	-
Sudan	**1,658**	-	**3,888**	-
Sorghum	1,658	-	3,888	-
Tanzania	**302**	**302**	**518**	**518**
Common Bean	20	20	117	117
Groundnut	154	154	317	317
Pigeonpea	128	128	84	84
Uganda	**113**	**88**	**348**	**158**
Common Bean	88	88	158	158
Groundnut	25	-	190	-
Zambia	**61**	-	**161**	-
Soybean	61	-	161	-
Grand Total	**17,874**	**8,407**	**32,007**	**15,370**

Appendix G: Number of households adopted improved varieties at the benchmark and updated 2019, by targeted countries and crops

	Number of adopting HH at Benchmark		Number of adopting HHs in 2019	
Country	*Overall estimates*	*Higher confidence*	*Overall estimates*	*Higher confidence*
Burkina Faso	**272**	-	**515**	-
Cowpea	141	-	183	-
Millet	71$^{\not\subset}$	-	157$^{\not\subset}$	-
Sorghum	131$^{\subset}$	-	332$^{\subset}$	-
Ethiopia	**591**	**437**	**1,771**	**405**
Chickpea	46	46	168	187
Common bean	391$^{\not\subset}$	391	218$^{\not\subset}$	218
Sorghum	545$^{\subset}$	-	1,603$^{\subset}$	-
India	**20,391**	**9,348**	**24,226**	**8,277**
Chickpea	123	123	675	675
Groundnut	6,329	-	8,261	-
Millet	1,133$^{\not\subset}$	1,133$^{\not\subset}$	1,844$^{\not\subset}$	1,844$^{\not\subset}$
Pigeon pea	4,714	-	7,688	-
Sorghum	8,152$^{\subset}$	8,152$^{\subset}$	5,993$^{\subset}$	5,993$^{\subset}$
Lentils	1,073	1,073	1,608	1,608
Malawi	**646**	**456**	**1,473**	**979**
Common bean	456$^{\subset}$	456$^{\subset}$	593$^{\not\subset}$	593$^{\not\subset}$
Groundnut	442$^{\not\subset}$	442$^{\not\subset}$	979$^{\subset}$	979$^{\subset}$
Pigeon pea	190	-	495	-
Soybean	235$^{\not\subset}$	59$^{\not\subset}$	157$^{\not\subset}$	157$^{\not\subset}$
Mali	**1,165**	**124**	**2,467**	**181**
Cowpea	253	-	515	
Groundnut	132	-	315	
Millet	779$^{\subset}$	-	1,636$^{\subset}$	
Sorghum	124$^{\not\subset}$	124	181$^{\not\subset}$	181
Mozambique	**49**	-	**1,148**	-
Cowpea	49	-	1,148	-
Myanmar	**165**	**165**	**222**	**222**
Chickpea	165	165	222	222
Niger	**1,668**	**-**	**2,443**	**-**
Millet	1,668	-	2,443	-
Nigeria	**5,578**	**5,262**	**6,891**	**6,261**
Cowpea	174$^{\not\subset}$	174$^{\not\subset}$	813$^{\not\subset}$	813$^{\not\subset}$
Groundnut	302$^{\subset}$	302$^{\subset}$	1,002$^{\subset}$	1,002$^{\subset}$
Millet	4,959$^{\subset}$	4,959$^{\subset}$	5,010$^{\not\subset}$	5,010$^{\not\subset}$
Sorghum	1,069$^{\not\subset}$	1,069$^{\not\subset}$	5,259$^{\subset}$	5,259$^{\subset}$
Soybean	317	**-**	630	-
Sudan	**754**	**-**	**1,767**	**-**
Sorghum	754	-	1,767	-
Tanzania	**329**	**329**	**660**	**660**
Common bean	34	34	196	196
Groundnut	194	194	398	398
Pigeon pea	101	101	66	66
Uganda	**374**	**368**	**702**	**658**
Common bean	368	368	658	658
Groundnut	6	-	45	-
Zambia	**132**	**-**	**349**	-
Soybean	132	-	349	**-**
Grand Total	**32,115**	**16,489**	**44,636**	**17,624**

Note: To mitigate potential double counting, only highest estimates maintained for country estimates where cropping areas overlap. ⊂ denote included estimates; ⊄ denote excluded estimate

Appendix H: National area and area under improved varieties at the benchmark and updated 2019 based on higher confidence evidence, aggregated by targeted crops

Crop	Benchmark national crop area ('000 ha)	Benchmark area under IV ('000 ha)	National crop area in 2019 ('000 ha)	Area under IV in 2019 ('000 ha)	Additional area under IV ('000 ha)
Dryland cereals	**23,942**	**5,072**	**23,744**	**6,147**	**1,730**
Millet	13,543	2,009	12,753	2,596	675
Sorghum	10,398	3,064	10,991	3,551	1,055
Grain legumes	**19,069**	**3,603**	**23,825**	**8,992**	**4,487**
Chickpea	9,095	914	10,135	3,772	2,750
Common bean	2,297	590	2,063	648	228
Cowpea	2,860	486	4,303	1,080	348
Groundnut	3,144	874	5,693	2,554	991
Pigeon pea	257	128	87	84	40
Soybean	75	75	180	50	-130
Lentils	1,341	536	1,363	804	259
Total	**43,011**	**8,676**	**47,568**	**15,139**	**6,217**

Appendix I: The benchmark, extrapolated adoption estimates and incremental change from 2010

Country	Crop	Survey year	National adoption rate (% area)	Adoption rate at the benchmark	Updated adoption rate in 2019 (% area)	Change in adoption (% area)
Ethiopia	Chickpea	2018	11.5	11.5	53.7	42.2
India	Chickpea	2013	7.1	7.1	34.7	27.6
Myanmar	Chickpea	2018	97.7	84.4	99.6	15.2
Ethiopia	Common bean	2016	64.0	58.4	67.4	9.0
Malawi	Common bean	2013	46.0	46.0	52.7	6.7
Tanzania	Common bean	2016	9.2	2.7	13.1	10.4
Uganda	Common bean	2012	13.2	13.2	29.2	16.0
Burkina Faso	Cowpea	2010	10.0	10.0	12.7	2.7
Mali	Cowpea	2010	53.0	53.0	56.7	3.7
Mozambique	Cowpea	2010	11.0	11.0	76.2	65.2
Nigeria	Cowpea	2017	21.8	17.0	25.1	8.1
India	Groundnut	2010	54.0	54.0	87.3	33.3
Malawi	Groundnut	2011	43.0	43.0	73.4	30.4
Mali	Groundnut	2010	19.6	19.6	34.8	15.2
Nigeria	Groundnut	2017	40.1	24.9	45.2	20.2
Tanzania	Groundnut	2016	16.0	32.1	32.0	-0.1
Uganda	Groundnut	2010	55.0	55.0	59.5	4.5
India	Lentil	2014	40.0	40.0	59.0	19.0
Burkina Faso	Millet	2010	2.6	2.6	6.7	4.1
India	Millet	2013	10.0	10.0	17.7	7.7
Mali	Millet	2010	31.1	31.0	41.1	10.1
Niger	Millet	2010	11.5	11.5	17.9	6.4
Nigeria	Millet	2020	25.6	25.0	25.6	0.6
India	Pigeon pea	2010	68.0	68.0	84.5	16.5
Malawi	Pigeon pea	2010	50.0	50.0	93.9	43.9
Tanzania	Pigeon pea	2012	49.6	49.6	95.8	46.2
Burkina Faso	Sorghum	2010	3.3	3.3	8.8	5.5
Ethiopia	Sorghum	2014	9.5	9.5	28.1	18.6
India	Sorghum	2013	39.4	39.4	43.9	4.5
Mali	Sorghum	2013	28.0	28.0	36.2	8.2
Nigeria	Sorghum	2010	8.6	8.6	22.4	13.8
Sudan	Sorghum	2009	40.4	40.4	56.9	16.5
Nigeria	Soybean	2009	27.2	100	28	-72.1
Zambia	Soybean	2010	96.0	96.0	82.1	-13.9
Malawi	Soybean	2017	100.0	100.0	81.9	-18

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