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Patterns of Adoption of Improved Maize Technologies in Ghana

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EXECUTIVE SUMMARY

The average maize yield in Ghana is estimated to be 1.7 metric tons/hectare (MOFA 2009–2011), whereas achievable yields based on on-farm trials are between 4 and 6 tons/hectare. Low adoption of inputs and improved technologies is often cited as the major reason for such a gap. To determine adoption levels and better understand the constraints and incentives for technology adoption, a nationally representative survey of 630 maize farmers in 30 districts in nine regions in Ghana was implemented between November 2012 and February 2013. The study aims to provide up-to-date and rarely collected nationwide data and analysis on the patterns of adoption of improved technologies for maize in Ghana. The latest nationwide adoption study on maize had been done in 1997 (Morris, Tripp, and Dankyi 1998).

The current study generated a number of important findings:

First, fertilizer use is much higher than earlier reports (about half of farmers use fertilizer), although the intensity of use is half the recommended rate (47 kilograms/hectare of nitrogen on average for those who apply, compared with the recommended 90 kilograms/hectare)—and this despite a national subsidy program that encouraged more users and greater rates of application for maize. Half of the nonusers (predominantly in the Forest zone) explained that they did not apply fertilizer because it is not needed as their soil is fertile. Thirty-six percent of maize farmers (predominantly in the Northern Savannah zone) reported a lack of funds or the high cost of fertilizer as the main reasons for nonuse. Plots with fertilizer generate slightly higher or the same yields as those without fertilizer—only in the Northern Savannah zone were the yields between fertilized and unfertilized maize significantly different. When combined with certified seed and herbicide, plots with fertilizer have significantly higher yields (2 tons/hectare more) than those without fertilizer in the Northern Savannah zone, but show no significant difference in other zones. The seemingly more responsive yields to fertilizer use in the Northern Savannah zone can be attributed to lower soil fertility in this zone compared to zones in the South.

Second, herbicide use on maize has become very popular due to the influx of cheap herbicide formulations from China to Ghana. About 73 percent of the maize area received herbicide at an average rate for those who apply of 9.2 liters/hectare, which is higher than the recommended rates. Herbicide use was more prevalent in the South, given a greater prevalence of weeds and higher labor costs. Comparisons with weeding costs suggest that farmers using herbicide have lower costs than those not using herbicide and had to hire more labor for weeding. The pattern and consequences of overuse of herbicide to food safety, environment, and human health will need to be further investigated.

Third, adoption of improved varieties of maize does not seem to have increased since the 1997 survey. Although 61 percent of the maize area was planted with modern varieties, only 15 percent was planted with certified seed (with up to two seasons of seed recycling for open-pollinated varieties). Although the research system has been very active in developing and releasing varieties, a very high weighted-average varietal age (23 years) in Ghana signals that either the research system produces many unneeded varieties that are not solving farmers' binding constraints or the agricultural extension system is unable to disseminate and educate farmers about the net benefits of newer varieties.

A 1992 variety, Obatanpa, is still the predominant variety and has even increased in popularity over the years, while the newer varieties do not seem to have taken off. Plots with Obatanpa have slightly higher yields than those planted with newer open-pollinated varieties. This is the likely reason newer varieties are not able to replace Obatanpa. On the other hand, plots with hybrid varieties have twice the yield of plots with Obatanpa, but hybrids continue to be unpopular and occupy only 3 percent of Ghana's maize area.

Fourth, the adoption of no-tillage practices is very low. This is a surprising result after the much-hailed success of no-tillage technology (no-burn, no-plow, using herbicides, and planting in mulch) in Ghana in the 1990s. Burning and plowing were common practices. Plots that are plowed have significantly higher yield, but plots under slash-and-burn have significantly lower yields. Plots under no-till with mulch or without mulch have significantly lower yields than those not under no-till; and this likely is the main reason of the low popularity of no-tillage technology. The use of nitrogen-fixing crops, such as legumes, for intercropping, crop rotation, or crop relay was limited. Many farmers practice intercropping but with cassava, which is more profitable and more used for home consumption than legumes. The use of mucuna, which was heavily research and promoted in past decades, has not been popular due to the opportunity costs of not being able to plant food crops during the minor cropping season. Continuous cropping was seen in most plots in the Northern Savannah and Transitional zones, fallowing systems are disappearing in the Forest zone, and the overall limited practice of sustainable land management systems puts a lot of stress on the soil.

Fifth, an estimated 53 percent of maize farmers in 1997 had adopted row planting—no increase is seen in row planting in the 2012–13 survey. Whereas the seeding rate seems to be close to recommendations, the actual plant spacing being

followed by farmers and number of seeds per hill seem to differ from recommendations. Only 1 percent of farmers practice germination tests, so it is hard to tell whether the seeding rate, the number of seeds per hill, and plant spacing are optimal. Simple means comparisons of yield suggest that plots planted in rows have significantly higher yields than those not planted in rows, but yields were not different between those farmers who followed and those who did not follow recommendations for maize plant spacing, seeding rates, and seeds per hill.

Finally, several other recommended agronomic practices have limited popularity. The Council of Scientific and Industrial Research and the Ministry of Food and Agriculture recommend particular timing in fertilizer application, but the 2012–13 survey reveals that farmers follow a very different timing of application. The survey offers no clear evidence for why there seems to be a much later application of fertilizer by the majority of farmers and more split applications (up to three to four times) than recommended. Simple means comparisons suggest that plots following the recommendation have the same yield as those not following the recommendation. This will need to be further investigated.

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1. INTRODUCTION

Ghana is widely regarded as an African success story due to its impressive achievements in accelerating growth and reducing poverty and hunger in line with the Millennium Development Goals. Strong agricultural output growth (4.6 percent annually from 1991 to 2009 [Fuglie 2012]) has played an important role in this development. However, much of the growth has been through expansion of cultivated area and not through total-factor-productivity growth, which has averaged only 1.2 percent annually—higher than the African average of 0.5 percent, but well below the global average of 1.8 percent in the 2001–09 period (Fuglie 2012).

Despite these achievements, major technological challenges and yield gaps in Ghana persist. For staple crops such as maize and rice, yields are generally less than half of economically attainable yields (MOFA 2011a). For example, national average yields range between 1.7 metric tons/hectare[1] and 2.5 tons/hectare for maize and rice respectively (MOFA 2009–2011); however, data from different on-station and on-farm trials suggest that yield averages of 4 to 6 tons/hectare for maize and 6 to 8 tons/hectare for paddy rice are achievable (MOFA/CRI/SARI 2005; MOFA n.d.; various annual reports of the Crops Research Institute [CRI] and the Savannah Agricultural Research Institute [SARI]). These figures show a huge gap between actual and achievable yields and, at the same time, a window of opportunity to close that yield gap and increase productivity.

According to many studies and experts, Ghana's slow productivity growth in maize is caused by low adoption of productivity-enhancing technologies, including improved varieties and management practices, and low use of purchased inputs, especially fertilizer. Meanwhile, the studies on technology adoption and impact on maize production in Ghana are outdated. The latest nationwide maize technology adoption and impact study was conducted in 1997 (Morris, Tripp, and Dankyi 1998), and the latest rice technology adoption study used 1998 data based on scientists' opinion (Dalton and Guei 2003). The 2010–12 Diffusion of Improved Crop Varieties in Africa (DIVA) project sought to measure adoption of improved maize and other varieties but relied on scientists' opinions. Such opinions tend to be overestimates or otherwise unreliable, especially in agricultural research and development systems where adoption studies are not done regularly or researchers are not well connected with farmers, extension agents, and other innovation system actors. A review paper by Horna and Nagarajan (2010) highlighted a large knowledge gap in this area and outlined an agenda for further research on seeds, varieties, and improved agricultural technology demand and supply in Ghana.

The present study aims to provide up-to-date nationwide data and analysis on the patterns of adoption of improved technologies for maize production in Ghana. It disaggregates the results by agroecology and farming system to understand differentiated patterns of adoption across such ecologies. We also provide insights into why farmers adopt or do not adopt certain varieties or technological packages promoted by the Council of Scientific and Industrial Research (CSIR) and the Ministry of Food and Agriculture (MOFA), in order to highlight the constraints and opportunities for improving adoption of improved technologies. The paper is the first in a series of papers, and part of a larger project, that assesses the determinants of technology adoption, impact of technologies, and effectiveness of research-and-development investment in Ghana. This first paper focuses on maize, while a second one will be on rice.

The paper focuses on six key technology recommendations of CSIR and MOFA:[2] (1) improved varieties and fresh certified seed used every season, preferably, or at most every three cropping seasons; (2) fertilizer use (rate, method, and timing); (3) zero tillage, with herbicide and planting in mulch; (4) other soil fertility management practices (in the form of intercropping, crop rotation, or crop relay with nitrogen-fixing crops); (5) crop protection with herbicide as the major input; and

[1] Tons referred to in this paper are all in metric tons.

[2] Many more technologies are being developed and promoted, but we focus on the key technological packages for this paper. Among other technology packages and management practices being promoted are timely harvesting; proper storage, including dehusking the maize before storing; and applying chemicals on the stored grain in the storage crib (MOFA/CRI/SARI 2005; MOFA n.d.).

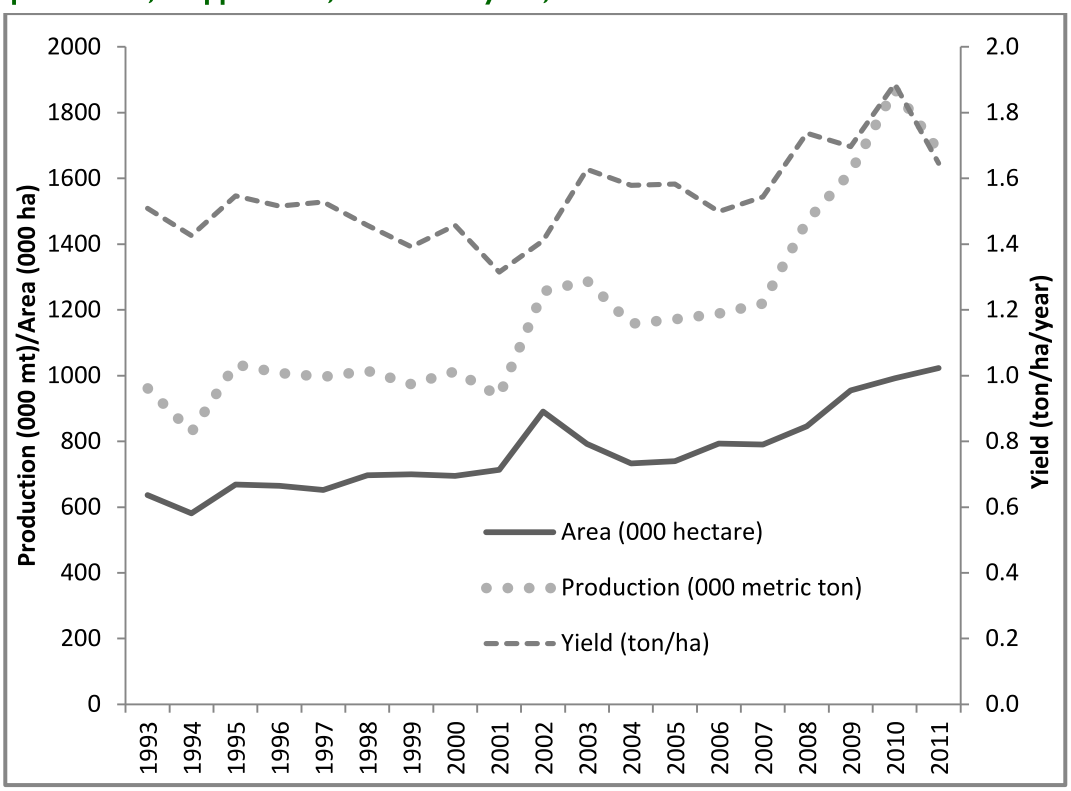
(6) row planting, with proper planting density and spacing. This approach complements earlier studies on maize in Ghana. In the analysis of this survey data, results are compared with those of past studies. This survey on maize technology adoption provides timely and rarely collected feedback on how the technologies CSIR promotes are being used and on farmers' experience with them. This will be useful information for CSIR, MOFA, and other partners working with maize farmers in Ghana on the design of future projects and investments in the maize sector.

The rest of the paper is structured as follows. Section 2 briefly describes the maize sector in Ghana, various maize projects implemented over the years, and the maize research program at CSIR. Section 3 describes the survey used for this study, including the sampling method used and the characteristics of the sample farmers. Sections 4 through 9 present the survey results in terms of adoption level and yield differences structured into (a) varietal and certified seed use; (b) fertilizer use, (c) herbicide use; (d) zero tillage, (e) soil fertility management practices; and (f) planting method and plant density. In all of these sections, the current practices of the studied farmers are compared with the CSIR/MOFA recommendations across agroecological zones. Finally, Section 10 presents a summary of key findings, conclusions, and suggestions for further research.

2. MAIZE SECTOR

Maize is Ghana's most important cereal crop and is grown by the vast majority of rural households. It is widely consumed throughout the country, and it is the second most important staple food in Ghana, next to cassava. Ghana is one of the major maize producers in Africa south of the Sahara, accounting for about 9 percent of the total acreage among surveyed countries in the DIVA project and 7 percent of the total acreage in West and Central Africa (Alene and Mwalughali 2012). In the years 2009 through 2011, maize production in Ghana averaged 1.7 million tons harvested from about 990,000 hectares. Both production (Figure 1) and area cultivated with maize have been increasing over time. Production has been increasing over time slightly faster than area and therefore yield (in tons/hectare). The national average yield was 1.7 tons/hectare/year (MOFA 2009–2011), and this CRI/SARI/IFPRI survey reveals an average yield of 1.2 tons/hectare during the major season in 2012. There is a great opportunity to further increase yield to reach the achievable levels of 4 to 6 tons/hectare based on on-station and on-farm trials.

Figure 1—Maize production, cropped area, and annual yield, 1993–2011



Source: MOFA (1993–2011).

Maize is grown in all regions. In 2011, production was highest in Brong Ahafo, which accounted for 27 percent of national production, followed by Eastern (20 percent), Central (12 percent), Ashanti (12 percent), and Northern (11 percent). Production in these regions is increasing quite fast, especially in Brong Ahafo and other minor-producing regions such as Upper East not included in the earlier 1997 survey by Morris, Tripp, and Dankyi (1998) due to minimal maize production at that time.

The majority of maize produced in Ghana is of the white variety (only a little yellow maize is produced) and is used mainly for human consumption (about 87 percent) (WABS 2008). Per capita consumption continues to grow, increasing, for example, from 38.4 kilograms/head/year in 1980 to 43.8 kilograms/head/year in 2010 to 2011—a 14 percent increase (MOFA 2011a). The majority of maize produced is consumed directly by the farming households (57 percent), and the remaining production is traded either formally or informally (30 percent). A small quantity of maize is produced and used for animal feed in the poultry industry (about 13 percent). Virtually all yellow maize is imported and used for animal feed production (WABS 2008).

Maize Programs

The Ghana Grains Development Project (GGDP), which ended in 1997, was the last large long-term program focusing on the maize sector. According to Morris, Tripp, and Dankyi's (1998) impact assessment, GGDP had a number of notable successes. Several varieties were developed and disseminated under the project; several agronomic practices were evaluated; production guides were produced; and a heavy investment was made in the extension and dissemination of improved technologies. Obatanpa, a quality protein maize developed through the project, has become widely popular in Ghana and in other countries in Africa south of the Sahara. At the same time, several farm demonstrations were conducted to test and promote modern varieties under the Sasakawa Global 2000 program. One of the focus technology packages tested and promoted under Sasakawa Global 2000 was the zero-tillage package, involving no plowing, the use of herbicide in land preparation, and planting in mulch. In the 1990s, CRI and Sasakawa Global 2000 collaborated with Monsanto, which conducted various testing and farm demonstrations on this zero-tillage technology.

Aimed at continuing what GGDP started, the Food Crops Development Project (FCDP) was implemented in eight districts in various regions that funded field trials, production manuals, extension, input provision, and processing. Manu, Fialor, and Issahaku's (2012) study of 130 maize-producing households in Ejura, one of FCDP's focus districts, shows that FCDP has provided greater access to credit, provided information about improved technologies, increased maize output, and improved food security compared with preproject levels. Several smaller projects have been implemented focusing mainly on seed multiplication of maize and other crops (Annex 1).

Maize Breeding and Research

Most of the activities by the national research institutes in relation to maize are in varietal improvement and testing. Several trials on agronomic practices have also been conducted, mainly under GGDP and FCDP, on improved land preparation, row planting, fertilizer use, herbicide use, pest and disease control, and water management, among others. However, agronomic research has been limited since those two large programs ended.

IMPROVED VARIETIES

Twenty-seven improved varieties have been released since the 1960s (Table 1). Varietal improvement and testing done by CRI and SARI focus on high yield, protein content (that is, quality protein maize [QPM]), tolerance to pests and disease (mainly blight, rust, streak, and stem borers), *Striga* resistance, kernel type, lodging resistance, and early maturity. Maize breeding is being carried out on normal maize and QPM. The emphasis in the past decade has been on developing open-pollinated varieties (OPVs) and hybrids. As maize is a major staple cereal, the development of micronutrient-dense (iron, zinc, and provitamin A) QPM for enhanced nutrition is emphasized. The major sources of germplasm were the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture; and CRI and SARI scientists conduct genetic improvement through crosses.

The most popular variety is Obatanpa. It was released as a medium-maturing open-pollinated QPM variety in 1992, but it is still by far the most popular variety. It was adapted to the growing conditions in the lowland tropics and has been adopted extensively in Ghana and many other African countries (Sallah et al. 2003). Obatanpa accounted for about 96 percent of certified seed production from 2001 to 2011—about 2,500 tons in 2011 (3,466 tons average in 2009 through 2011) (Annex

2). Given 0.95 million hectares cropped nationwide and an average seed rate of 20 kilograms/hectare, the annual certified seed production of Obatanpa could cover 18 percent of the maize-cropped area with fresh seeds every year.

Table 1—Improved maize varieties developed and promoted by CRI and SARI

Name of variety	Year of *formal* release	Origin (institute)	Maturity period (days)	Potential (tons/ hectare)	Selected characteristics
Mex 17 Early	1961	CIMMYT	90–105		Earliness, resistance to lodging
Comp 4	1972	CIMMYT	120		High yield, lodging resistant
Comp W	1972	CRI/CIMMYT	120		Yield, kernel type, tolerance to pests/diseases (blight, rust, streak, and stem borers), lodging resistance
Golden Crystal	1972	CRI/CIMMYT	105–110	4.6	Yield, suitable for poultry
Laposta	1972	CIMMYT	120		High yield, lodging resistant
Aburotia	1983	CRI/CIMMYT	105–110	3.5	High yield
Dobidi	1984	CIMMYT	120	5.5	High yield, lodging resistant
Kawanzie	1984	CIMMYT	90–95	4.6	Earliness
Safita – 2	1984	CIMMYT	90–95	3.5	Earliness
Okomasa	1988	IITA/CIMMYT	120	5.5	High yield, streak resistance
Abeleehi	1990	IITA/CIMMYT	105–110	4.6	Yield, streak resistance
Dorke SR	1992	IITA/CIMMYT	95	3.8	Yield, kernel type, tolerance to pests/diseases (blight, rust, streak, and stem borers), lodging resistance
Obatanpa	1992	IITA/CIMMYT	105	4.6	Yield, quality protein maize, kernel type, tolerance to pests and diseases (blight, rust, streak, stem borer), lodging resistant
Mamaba (hybrid)	1996	CIMMYT	105	6.0–7.0	High yield, drought tolerant (hybrid), lodges heavily in certain conditions
Cida-ba (hybrid)	1997	CIMMYT	110	6.0–7.0	High yield, protein content (hybrid)
Dada-ba (hybrid)	1997	CIMMYT	110	6.0–7.0	High yield, protein content (hybrid)
Dodzi	1997	IITA	80–85	3.5	Extra early, open pollinated
Aziga (yellow)	2007	CIMMYT	110	4.7	High yield, QPM, good for poultry and livestock industry, contains carotene which imparts yellow color to egg yolk, similar to Golden Jubilee except that it is more flint/dent type (better for storage and more resistant to weevil attack)
Akposoe	2007	CIMMYT/IITA	80–85	3.5	Extra early, QPM, DT, excellent taste when boiled or roasted
Etubi (hybrid)	2007	CIMMYT	105–110	6.5–7.0	QPM hybrid, DT, lodging tolerance (an advantage for Mamaba)
Golden Jubilee (yellow)	2007	CIMMYT	105–110	5.0	High yield, QPM, cross of white Obatanpa and a yellow QPM, good for poultry and livestock industry, contains carotene which imparts yellow color to egg yolk
Aburohemaa	2010	IITA	90	5.0	DT, *Striga* tolerant, QPM; all 2010 varieties are drought resistant and mature early, were suitable for the forest and coastal zones, as well as that of Northern and Sudan savannah zones.
Enibi (hybrid)	2010	CIMMYT/IITA	110	6.5	QPM hybrid, DT, lodging resistant
Abontem	2010	IITA	75–80	5.0	DT, *Striga* tolerant, QPM
Omankwa	2010	IITA	90	4.7	DT, *Striga* tolerant; QPM
Aseda	2012		110–115	6.7	Hybrid white, DT, very good for domestic purposes
Opeaburoo	2012		110–115	7.5	Hybrid white, DT
Tintim	2012		110–115	7.9	Hybrid white, DT
Nwanwa	2012		110–115	7.9	Hybrid yellow, suitable for human, poultry, livestock consumption
Odomfo	2012		110–115	6.5	Hybrid yellow, suitable for human, poultry, livestock consumption
Honampa	2012		110–115	5.2	Open-pollinated variety, yellow, source of provitamin A

Source: Compiled from DIVA project raw data; MOFA/CRI/SARI (2005); and personal communication with scientists in the Council of Scientific and Industrial Research.

CIMMYT = International Maize and Wheat Improvement Center; CRI = Crops Research Institute; SARI = Savannah Agricultural Research Institute; IITA = International Institute of Tropical Agriculture; QPM = quality protein maize; DT = drought tolerant.

Four varieties were released in 1997: three of them were high-yield, QPM hybrids (Mamaba, Cida-ba, and Dada-ba), and the other was an extra-early-maturing OPV (Dodzi). Four varieties were again released in 2007: two were high-yield, QPM, open-pollinated yellow maize varieties (Aziga and Golden Jubilee); one was an extra-early maturing, QPM, drought-tolerant variety (Akposoe); and the other was a QPM, drought-tolerant hybrid variety (Etubi). In 2010, another set of four varieties was released: three drought-tolerant, *Striga*-tolerant, QPM OPVs and one drought-tolerant, QPM hybrid (Enibi). In total, five hybrid varieties were developed and released by CRI and SARI, namely, Mamaba, Cida-ba, Dada-ba, Etubi, and Enibi. In 2012, six varieties were officially released: five hybrids and one OPV with provitamin A.

Private companies have also begun promoting hybrid maize varieties in Ghana. Wienco has been promoting Pannar varieties. In 2012, eight private seed companies signed a memorandum of understanding with CRI for the production of foundation and certified hybrid seeds. Under this arrangement, CRI will provide breeder seeds, training and supervision to the seed companies.

CERTIFIED SEED

CSIR and MOFA recommend buying fresh seed from a certified source every season. CSIR trials have shown that certified seed has higher germination rates and higher yields than farmer-saved seed. For example, in 2005, certified Obatanpa seed afforded a 7 to 9 percent higher yield than farmer-saved seed in Kwadaso and Ejura experimental plots (CRI 2005). If farmers cannot buy fresh seed, OPVs can be recycled for up to two seasons (three seasons of planting in total). Hybrid seed have to be bought fresh for every season. CSIR and MOFA also recommend buying fresh Obatanpa seed every season to maintain its nutritional value, but if that is not possible among farmers the seed can be recycled for up to two seasons (three seasons of planting in total); and the seed to be stored for the next cropping season must be selected from the middle of the plot to minimize crossing.

FERTILIZER USE

Recommended rates of fertilizer application depend on the agroecological zone, soil type, and cropping history. Table 2 presents recommended rates by zone and cropping history. According to Morris, Tripp, and Dankyi (1998), numerous trials were conducted under GGDP to derive these recommendations. Split application is recommended. Compound fertilizer (for example, NPK 15-15-15 or NPK 20-20-0) is recommended, and the starter fertilizer should be applied about 5 centimeters away from the hills at planting, and if not possible, just after germination (one to two weeks after planting). Sulfate of ammonia (N21 S24) or compound fertilizer (NPK 20-20-0 or NPK 20-20-20) is recommended as a side-dress applied four to five weeks after planting at the soil surface (except for sloping fields). Urea (N45) can also be used but needs to be buried in the soil for maximum benefit. Urea loses its nutrients easily, and if stored or sealed improperly for a year, it would not retain any nutrients.

Table 2—Recommended rates of fertilizer application

Zone and cropping history	Starter fertilizer (in 50 kg bag/acre)	Sidedress (in 50 kg bag/acre)	Nutrient equivalent (kg/ha)*		
			N	P	K
Coastal Savannah and Northern Savannah zones					
Land fallowed for 5 or more years	1	1	45	19	19
Land fallowed for less than 5 years or continuously cropped	2	2	90	38	38
Land is continuously cropped + hybrid	3	3	134	56	56
Forest and Transitional zones					
Land fallowed for 5 or more years	0	0	0	0	0
Land fallowed for less than 5 years	1	1	45	19	19
Land is continuously cropped	2	2	90	38	38
Land is continuously cropped + hybrid	3	3	134	56	56

Source: MOFA/CRI/SARI (2005).

Note: kg = kilogram; ha = hectare; N = nitrogen; P = phosphorus; K = potassium.
* Assuming NPK 15-15-15 as the starter fertilizer and sulfate of ammonia as the side-dress. NPK 20-20-0 can also be used as starter fertilizer (with the same intensity) and urea as side-dress (half the intensity of sulfate of ammonia).

CROP PROTECTION

The general rule is to keep maize plots free from weeds especially during the first 30 days of planting. CSIR and MOFA recommend the use of herbicide before and after planting. Glyphosate (for example, Roundup or Roundup Turbo) is a systemic herbicide and is recommended for actively growing weeds two weeks before planting. Examples of formulations of herbicides that have been tested and are available in Ghana are Roundup (360 grams/liter of glyphosate) and Roundup Turbo (450 grams/liter glyphosate). If the grassy weeds are standing tall, they should be slashed down to about 30 centimeters and allow for regrowth before glyphosate is applied. Recommended application is 2.5 to 4 liters of glyphosate (depending on the strength of its formulation) per 15-liter knapsack sprayer to spray a hectare. A second application is also recommended with lasso-atrazine to the soil immediately after planting. The recommended rate is about 4 liters of lasso-atrazine per 15-liter sprayer per hectare. It kills weed seeds that have yet to germinate or have just germinated. If both glyphosate and lasso-atrazine are applied well, there may be no need for any hand-weeding until harvest (MOFA/CRI/SARI 2005). If weeds emerge after planting, it is recommended to apply 1 liter per hectare of Gramoxone or adjust the rate for other available formulations (MOFA/CRI/SARI 2005).

Striga, a parasitic weed common in Ghana, cannot be controlled by chemical, and the recommended controls are (1) rotation with nonsusceptible crops (such as cotton, groundnut, and soybean varieties such as Janguma and Quarshie) to stimulate suicidal germination of *Striga* seedlings; (2) fertilizer application because well-fertilized maize is less affected by *Striga* than an unfertilized crop (a 20 percent urea solution can be applied directly to the *Striga* seedling); and (3) use of *Striga*-resistant varieties. Stem borer, a major insect affecting maize plots, can be controlled by combining pesticide application and cultural practices, such as not planting during the minor season if the plot is heavily infested during the major season or clearing nearby grass to minimize crop loss from stem borers. Streak virus is a major disease affecting maize plots and can be controlled by planting streak-resistant varieties.

ZERO TILLAGE

In the 1980s, research to adapt zero tillage, or no-till, with mulch as a sustainable alternative to slash-and-burn was initiated by CRI in conjunction with the International Maize and Wheat Improvement Center, Monsanto, and Sasakawa Global 2000. Zero tillage, or no-till, is a management practice that involves no plowing (no disturbance of the soil), no burning, using herbicide during land preparation, and planting into mulch. Experimental yield data of no-tillage practices (in the Ashanti, Brong Ahafo, and Central regions) ranged from 4.55 to 7.5 tons/hectare (mean 6.05 tons/hectare) compared with a range of 2.9 to 4.5 tons/hectare (mean of 3.25 tons/hectare) for slash-and-burn (CRI 1999).

OTHER SOIL FERTILITY MANAGEMENT PRACTICES

In addition to organic and inorganic fertilizer use and no-till practices, several soil fertility management practices are being recommended including maize-legume rotation, maize-mucuna relay, and maize-legume intercropping. Legumes such as mucuna, cowpea, groundnut, and Bambara nut, if grown at recommended planting densities and other recommended practices, may add 20 to 90 kilograms/hectare of nitrogen to the soil for use by the succeeding maize crop (MOFA/CRI/SARI 2005). A particular on-station trial in Ejura in 2001 concluded that mucuna, a nonfood legume, produced the highest yield on subsequent maize production, compared with food legumes (soybean, cowpea, and groundnuts) as cover crops and natural (weedy) fallow plots (CRI 2001). Other experiments concluded that improved maize-cowpea intercrop systems increase yield by 20 percent (when early-maturing cowpea varieties are used) and 60 percent (when medium-maturing cowpea is used) over sole crops (MOFA/CRI/SARI 2005).

PLANT DENSITY, SPACING, AND ROW PLANTING

Plant configuration recommendations—specifically on plant density, seeds per hill, spacing, timing, and planting in lines—were developed in Ghana based on extensive on-station and on-farm trials mainly under GGDP. Trials concluded that lodging increases with higher plant density and greater interplant competition, or a planting density of about 56,000 to 76,000 plants per hectare (based on two-seeds-per-hill planting) or approximately 20 kilograms of seed per hectare. Farmers had been used to planting as many as five seeds per hill, and researchers examined the effect of number of seeds per hill at different plant densities in several on-station trials. Yields fell only slightly when surviving plants per hill increased from one to two, but the decline became more rapid when the number exceeded two per hill, especially at low plant densities. Depending on the germination test, planting two seeds per hill is recommended for those with an 85 to 100 percent germination rate and three seeds per hill for a 70 to 84 percent germination rate; it is recommended to get better seeds if the germination rate is lower than 70 percent.

The recommendations emphasized planting in rows to help farmers calibrate plant population densities and achieve plant spatial arrangements that facilitate subsequent crop management operations, such as weeding and applying fertilizer. Two methods for line planting were demonstrated. The first involved the use of ropes, and although a number of farmers were able to use this method, it involved extra expense and was difficult on fields with many tree stumps. An alternative method was developed using a series of three poles that farmers could sight along in a straight line. With a little practice, farmers found that they could use sighting poles efficiently. In addition to stressing the importance of row planting, the recommendations also focused on reducing the distances between rows and holes, which were expressed in terms of the length of the cutlass that most farmers use for planting: 75 to 90 centimeters between rows or lines (depending on the variety) (about 1.5 of a cutlass length) and 40 centimeters (two-thirds of a cutlass length) between plants within rows or lines.

3. DATA AND METHODS

This study uses data from a survey of 630 maize farmers in 30 districts in nine regions in Ghana. This survey was implemented from November 2012 to February 2013 by CRI, SARI, and the International Food Policy Research Institute (IFPRI). Annex 3 lists the sample districts, the number of sample farmers interviewed in each district, and the production, cropped, and yield data of each sample district.

Sampling Method

The survey used three-stage, clustered, and randomized sampling procedure. First, a proportional probability sampling of districts was done, giving more weight to those with higher maize production, and the final list of sample districts was done in a randomized procedure. That was followed by a random selection of enumeration areas (EAs) in each of the sample districts using the same classifications and boundaries as the census and the Ghana Living Standards Survey. Finally, a random selection of farmers was made in each of the sample EAs.

Thirty districts were selected based on the list of maize-producing districts (districts with more than 3,000 hectares of maize production, 2009–11 average) (Annex 3). The sampling frame represents 92 percent of total hectares planted with maize in Ghana during 2009–11. Proportional probability sampling was used to select the sample districts (that is, districts with a larger production area of maize were given a higher probability of being selected). The selected districts represent 40 percent of the total maize production area (and 39 percent of the total production in tons or 37 percent of total acreage) in Ghana in 2009–11. For each sample district, three EAs were randomly selected, and seven farmers were randomly selected from the sample villages (stratified by gender). A maize farmer is defined as one who managed and decided on a maize plot during the major season of 2012 (with a minimum of 0.5 acres, or 0.2 hectare, of maize area to be included in the list of maize farmers). A list of all maize farmers in sample EAs was compiled including both female and male farmers and large, medium, and small farmers. The list was arranged by gender and plot size (that is, gender and plot size were used for implied stratification in the sampling process). The total sample is 630 maize farmers, of which 78 percent are male and 22 percent are female. Fifteen farmers reported cultivating and managing two maize plots, and therefore, the dataset includes 645 maize plots that are used for analysis.

Description of Sample Farmers and Plots

The average maize plot size in the sample is 1.6 hectares, ranging from 0.2 to 12 hectares per farmer (Table 3). The largest average maize plot sizes are in the Transitional and Northern Savannah zones. Farmers in Northern Ghana have larger plot sizes than those in Southern Ghana, and female-managed maize plots are relatively smaller than male-managed plots in both Northern and Southern Ghana. Only 2 percent of plots (from the Northern Savannah and Forest zones) were under a special project, credit scheme, or block farm (government input provision through credit).

Table 3—Number of sample farmers and characteristics of sample maize farmers and plots

Agroeco-logical zone	No. of sample farmers	Plot size (ha)*	% of maize sold*	Female (%)	Age*	Educ. years*	Married (%)	Native (%)	HH size*	Crop income (% to total income)*	Total farm land (ha)*
Forest	294	1.4	77	20	46	8	88	53	8	86	3.7
Transitional	147	1.8	83	26	43	7	88	54	8	87	2.6
Northern Savannah	126	1.8	49	22	42	3	93	89	13	73	3.5
Coastal Savannah	63	1.3	71	15	47	6	90	83	8	88	3.2
Total	**630**	**1.6**	**72**	**21**	**44**	**7**	**89**	**63**	**9**	**84**	**3.4**

Source of raw data: CRI/SARI/IFPRI survey (November 2012–February 2013).
Note: ha = hectare; HH = household.
* Average; other columns (except 1) are in proportion to total farmers in each zone.

About 72 percent of maize harvests were sold on average. The highest average proportion of harvest sold was 83 percent in the Transitional zone, followed by the Forest zone (77 percent of harvest sold), and then the Coastal Savannah zone (71 percent); the lowest was in the Northern Savannah zone (49 percent). Whereas maize is mainly a commercial crop in the Transitional, Forest, and Coastal Savannah zones, it is grown both for food consumption and as a cash crop in the Northern Savannah zone. These percentages are much higher than the estimate by WABS (2008) that only 43 percent of national production is traded, mainly in informal markets (see Table 1 above). It may be that maize is increasingly being commercialized over the years, or it is an indication of the difficulties of estimating at an aggregate or national level.

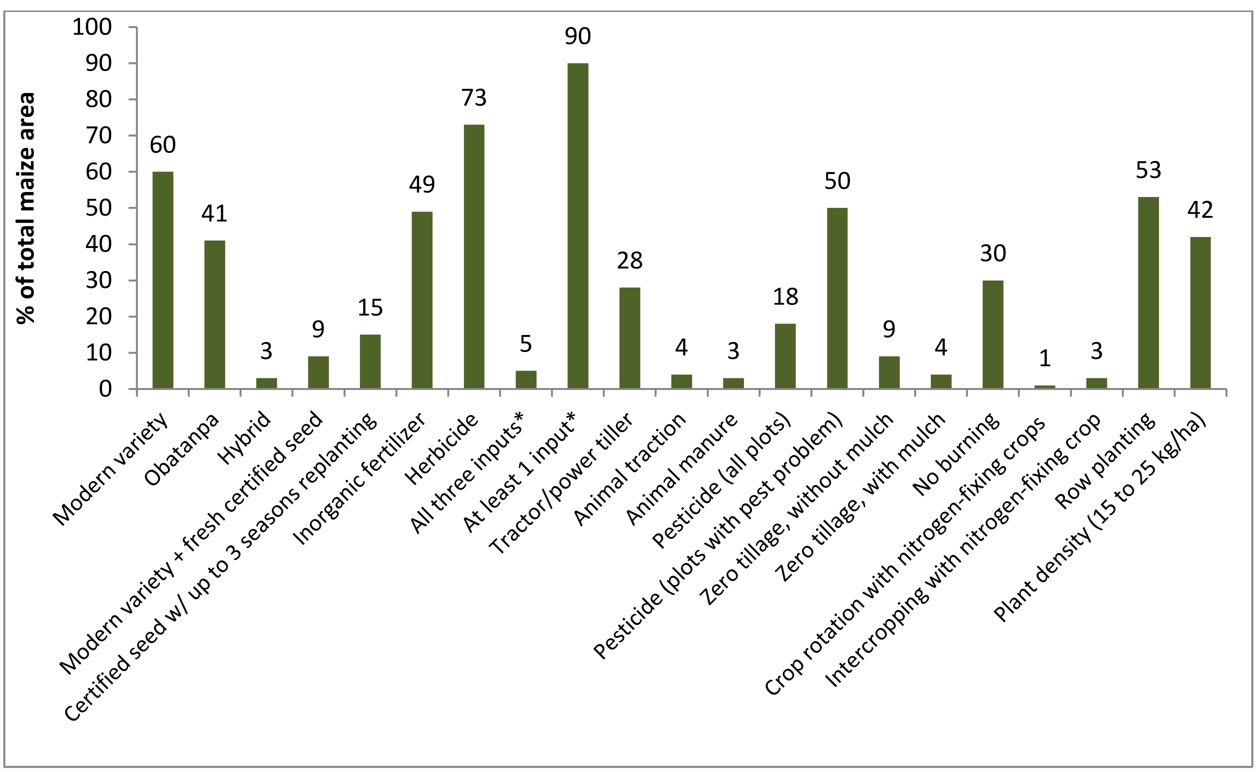
Eighty-four percent of income among maize farmers comes from sales of all crops, indicating that they depend heavily on agriculture for income generation. More land is devoted to cocoa and other tree crops in the Forest zone, whereas more land is available for field crops in the Northern Savannah zone. Total land cultivated with both tree and field crops averages 3.4 hectares per farmer. It is highest in the Forest zone (mainly because of the tree crops) and Northern Savannah zone (mainly due to more plots and wider land available for cultivation).

About 21 percent of maize farmers in the sample are female, and the majority of the sample maize farmers (89 percent) are married. The average age of the sample maize farmer is 44 years, whereas the average number of years of education is seven. Most maize farmers have primary education; the next largest group consists of those without formal education, which is followed by those with secondary education. About 63 percent are native to their current community, and 37 percent are reported to be settlers originating from other communities. The sample maize farmer household size is nine members.

4. IMPROVED VARIETIES AND CERTIFIED SEED

Figure 2 presents the rates of input use and adoption of main recommended agronomic practices among maize farmers during the major season of 2012. Sixty percent of maize area was planted with modern varieties during that major season. That figure is slightly higher than both the DIVA project estimate of 57 percent (Alene and Mwalughali 2012) and the estimate of 54 percent in 1997 by Morris, Tripp, and Dankyi (1998). This shows a little improvement in the efforts to disseminate modern varieties among maize farmers in the past 15 years.

Figure 2—Adoption rates of major inputs and agronomic practices by maize farmers during major season, 2012, in percentage of maize area



Source of raw data: CRI/SARI/IFPRI survey (November 2012–February 2013).

* Three inputs combined are fertilizer, herbicide, and certified seed (up to three seasons of replanting).

Varietal Adoption

In the major season of 2012, Obatanpa was by far the dominant variety of maize and was planted in 41 percent of maize area. It has become more popular over the years (from 16 percent adoption in 1997 to 40 percent in 2013). Whereas modern varieties older than Obatanpa accounted for 10 percent of maize area, varieties newer than Obatanpa released by CSIR accounted for only 1 percent of maize area (Annex 4). Private sector–promoted hybrids accounted for 3 percent of maize area. Forty percent of maize area was planted with local or traditional varieties (Aburowhoma and Ativi were the most common).

In general, the older varieties are still popular. The rate of varietal turnover[3] for maize in Ghana is 23 years, which is high compared with estimates for other countries (Table 4) and indicates weakness in the research and extension system. If varieties take too long to replace, the danger is that variety superiority and performance will collapse before replacement, given average longevity and environmental conditions (Alene and Mwalughali 2012), which translates into low productivity and economic loss to farmers.

Table 4—Area-weighted average age of improved maize varieties in selected countries

Country	Varietal age, yrs.
Western and Central Africa[†]	
Ghana	22.8* (12.7)
Benin	15.9
Burkina Faso	7.9
Cameroon	5.4
Cote d'Ivoire	13.9
D.R. Congo	13.0
Guinea	10.8
Mali	18.9
Nigeria	14.0
Senegal	6.3
Togo	8.7
Selected countries (open-pollinated variety)[‡]	
Average (for large maize-producing countries)	5.0–15.0
Selected countries with established hybrid maize production[‡]	
Average (for all selected countries)	11.0

Sources: [†] DIVA project report (Alene and Mwalughali 2012); [‡] Lopez-Pereira and Morris (1994); * CRI/SARI/IFPRI survey. Figure in parenthesis is derived from DIVA project report (Alene and Mwalughali 2012)

The average yield of modern varieties (1.33 tons/hectare) was significantly higher than that of local varieties (1.03 tons/hectare). The average yield of Obatanpa (1.28 ton/hectare) was significantly lower than that of the hybrids (2.17 tons/hectare) and similar to that of other modern OPVs (1.38 tons/hectare for before-Obatanpa varieties and 1.13 tons/hectare for post-Obatanpa varieties). The continuing popularity of Obatanpa can be explained by the lack of yield advantage of the newer OPVs over Obatanpa. Despite the higher yields from hybrids compared with Obatanpa, farmers seem to have little interest in replacing their Obatanpa and other OPVs with hybrids. Farmers reported that the inability to recycle seed for the next season is a disincentive to using hybrid seed. Farmers also reported that planting hybrids requires more fertilizer use, which adds to the disincentive to adopt. A regular supply of water is needed for hybrid production to realize its potential high yields, and therefore drought risk can also serve as a disincentive for farmers to adopt hybrid seeds.

A simple benefit-to-cost calculation was conducted to determine the profitability of hybrid maize versus the overwhelmingly popular variety Obatanpa. The cost of hybrid seed (8 cedi/kilogram) is four times higher than Obatanpa seed (1.5 to 2.0 cedi/kilogram). With an average seeding rate of 20 kilograms/hectare, the cost of hybrid seed is 160 cedi/hectare, which is 120 to 130 cedi/hectare higher than using Obatanpa. With a doubling of yield and the value of production, the additional profit will be 670 cedi/hectare, which is substantial and equivalent to 70 percent of the average profit of maize farmers under Obatanpa (Table 5). Given the higher expenses in terms of greater fertilizer use and more labor needed for harvesting, additional profits will be 545 cedi/hectare, or 56 percent of the average profit under Obatanpa. It is therefore not clear why

[3] The rate at which new varieties enter the system and replace older varieties depends on varietal traits, seed availability, and farmer preferences. The rate is computed as the average age of the modern varieties weighted by the area planted (see Brennan and Byerlee 1991).

farmers do not adopt hybrids. Key informant interviews conducted to complement the survey seem to suggest that hybrid varieties have not yet been promoted much in Ghana, and that can be the most likely reason for low uptake by farmers. Ghana has lagged far behind other African countries in hybrid adoption—one sees more than 90 percent adoption of hybrid maize in Zambia, Kenya, and Zimbabwe (Tripp and Mensah-Bonsu 2013) compared with only 3 percent in Ghana. The seeming lack of interest in hybrid seed among farmers in Ghana needs to be further investigated.

Table 5—Simple calculation of income differential of farmer using hybrid versus Obatanpa, cedi/hectare

Costs/values that potentially change	Hybrid	Obatanpa	Difference
Seed cost[a]	160	40	120
Fertilizer cost[b]	230	185	45
Additional labor cost for harvesting[c]	180	100	80
Total of above costs	570	325	245
Total value of production[d]	1,750	960	790
Total production value less above costs	1,180	635	545

Source of raw data: Assumptions are based on averages derived from the CRI/SARI/IFPRI survey.

[a] Assumes 8 cedi/kilogram of hybrid seed compared with 2 cedi/kilogram of Obatanpa.

[b] Assumes three bags of starter fertilizer and three bags of side-dress for hybrid maize production compared with two bags of started fertilizer and two bags of side-dress.

[c] Due to almost twice the quantity harvested, the cost of additional labor for harvesting is almost double.

[d] Plots with hybrid maize yielded almost double compared with plots with Obatanpa based on CRI/SARI/IFPRI survey.

Certified Seed Use

The low use of certified seed and high incidence of seed recycling are worrisome. Only 18 percent of maize area was planted with modern varieties and seed acquired or bought in 2012, and therefore 82 percent was planted with modern varieties recycled from last year's harvest. Moreover, not all newly bought seed was from certified sources (certified seed grower, registered input or seed dealer, MOFA, or researcher/breeder). Only 9 percent of maize area was planted with modern seed varieties purchased in 2012 from a certified source. Only 15 percent of maize area was planted with modern OPVs and seed from certified sources either newly bought or recycled for up to two seasons and newly acquired hybrids.

Many farmers recycle their seed for a long time (Table 6). Ten percent of Obatanpa growers, 11 percent of other modern variety growers, and 32 percent of local varieties growers have been recycling seed for more than 10 years. Only 4 percent of those growing local varieties, 15 percent of those growing non-Obatanpa improved varieties, and 20 percent of Obatanpa growers bought off-farm seed in 2012, instead of using recycled seed. The average number of years of seed recycling was four for Obatanpa, five for other modern varieties, and eight for local varieties, and even longer if those 36 farmers who could not specify the years are included. On average the survey results show that farmers in the Coastal Savanna zone have a higher number of years of seed recycling across all varieties than those in other zones—for example, nine years for Obatanpa and 14 for other modern varieties compared with four to six years in other zones.

Table 6—Distribution of maize farmers by years of seed recycling, percentage

Number of years of seed recycling	Obatanpa	Other modern varieties	Traditional varieties
	Proportion of farmers in each group		
0	20	16	4
1–2	14	11	12
3–4	21	20	16
5–6	16	25	15
7–8	8	9	6
9–10	10	8	16
> 10	10	11	32
Average	4	5[a]	8[b]

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).

[a] Excluding those four farmers reporting "many years."

[b] Does not include 36 farmers who cannot specify number of years and just said "many years."

The average yield from certified seed (1.4 tons/hectare) is greater than that from uncertified seed (1.2 tons/hectare) across all zones (Table 7). With or without fertilizer, there are significant differences in average yield between plots planted with certified and uncertified seed in the Transitional zone. With fertilizer, there are significant differences in average yield between plots planted with certified seed and uncertified seed in the Northern Savannah zone (no observations to compare plots without fertilizer). Without fertilizer, there are significant differences in average yield between plots planted with certified seed and uncertified seed in the Coastal Savannah zone (no observations to compare plots with fertilizer). There is no statistical difference in average yield in the Forest zone among plots with and without certified seed and with and without fertilizer.

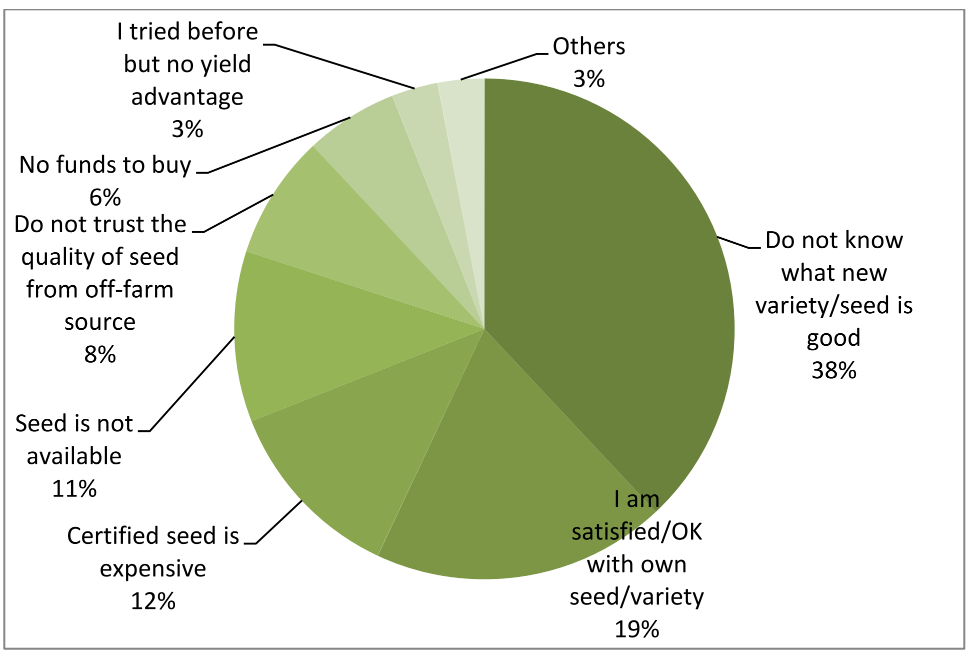
Table 7—Average yield of plots planted with certified or uncertified seed with or without fertilizer, in tons/hectare

Input use	All zones	Northern Savannah	Transitional	Forest	Coastal Savannah
With fertilizer					
Certified seed	1.68[a]	1.77[b]	1.95[c]	1.37	no obs.
No certified seed	1.35[a]	1.25[b]	1.52[c]	1.13	0.95
Without fertilizer					
Certified seed	1.10	no obs.	1.78[d]	1.04	1.52[e]
No certified seed	1.03	0.42	1.18[d]	1.06	1.01[e]

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).
Note: Figures with the same letter indicate that they are statistically significant at less than 5 percent level.

Reasons for nonuse of certified seed. The largest group of nonbuyers (38 percent) cited a lack of information about new varieties as the reason for not purchasing certified or commercial seed (Figure 3). Nineteen percent of respondents said that they are satisfied with their seed and variety and do not need fresh seed or new varieties. Another 8 percent reported reasons such as “do not trust input dealers or varieties from MOFA,” or “I prefer my own seed.” Such responses can imply a lack of information on the benefits of new varieties and fresh seed at the same time as it implies distrust in the seed system. A fifth of respondents reported the cost of seed or no funds to purchase certified seed as the main reason. A tenth of respondents cited unavailability of or lack of access to certified seed as the reason for not purchasing.

Figure 3—Distribution of maize farmers and their reported reason for non-purchase of certified seed



Source: CRI/SARI/IFPRI survey (November 2012–February 2013).

5. FERTILIZER USE

About 47 percent of the maize area received inorganic fertilizer (Table 8). That is more than twice the finding of Morris, Tripp, and Dankyi (1998) (21 percent) and much higher than the finding of Quiñones and Diao (2011) (25 percent) using the Ghana Living Standards Survey 5 (GLSS5) implemented in 2005 and 2006. This suggests that the fertilizer subsidy program may have encouraged more farmers to use fertilizer in their maize plots. This 2012 nationwide figure is much lower than the estimates of Mensah-Bonsu et al. (2011) (66 percent) and IFPRI (2011) (77 percent) pertaining to the middle parts of the country, indicating that districts in the middle parts of Ghana sampled in the earlier surveys apply more fertilizer than the rest of the country.

Table 8—Distribution of maize area by fertilizer use and application intensity

Variables	All zones	Forest	Transi-tional	Northern Savannah	Coastal Savannah
Inorganic fertilizer (% of maize area)	47	17	74	81	37
For all sample maize plots (kilograms [kg]/hectare[ha])					
Nitrogen (kg/ha)	22	5	35	50	8
Potassium (kg/ha)	9	3	11	24	4
Phosphorus (kg/ha)	9	3	11	24	4
For plots with fertilizer (kg/ha)					
Nitrogen (kg/ha)	47	27	48	57	29
Potassium (kg/ha)	20	16	15	27	17
Phosphorus (kg/ha)	20	16	16	27	17
For plots with fertilizer (% of farmers)					
NPK 15-15-15 (N 15%, P 15%, K 15%)	83	73	77	95	72
Sulfate of ammonia (N 21%, S 24%)	71	52	63	88	67
Urea (N 46%)	5	2	12	2	0
Actyva (N 23%, P 10%, K 5%, S 3%, Mg 2%, Zn 0.3%)	4	0	7	3	0
Foliar (N 5%, P 7.5%, K 5%, Mg 5%, S 5%, B 5%, Zn 5%, among others)	2	7	2	0	0
Sulfan (N 24%, NH4 12%, NO3 12%, S 6%)	1	0	1	2	0
NPK 20-20-0 (N 20%, P 20%)	1	4	0	1	0

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).
Note: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Mg = magnesium; Zn = zinc; B = boron; NH4 = ammonium; NO3 = nitrate.

Fertilizer Use Intensity

For those maize plots with fertilizer, the amount of nitrogen applied was 47 kilograms/hectare on average, and about 20 kilograms/hectare of phosphorus and potassium each was applied. That figure is half the recommended rate of 90 kilograms/hectare of nitrogen for maize plots that are continuously cropped (135 kilograms/hectare of nitrogen for hybrid). The subsidy may have encouraged more farmers to use and to apply higher rates, but the rates are still much lower than recommended. The highest rate of application was in the Northern Savannah zone (57 kilograms/hectare of nitrogen), followed by the Transitional zone (48 kilograms/hectare of nitrogen); the lowest was in the Forest (27 kilograms/hectare of nitrogen) and Coastal Savannah zones (29 kilograms/hectare of nitrogen) on average. Compound fertilizer (15-15-15) was the most widely applied (83 percent of farmers) for the first or basal application, and sulfate of ammonia was the most commonly used for the second application or top dressing (71 percent), whereas urea was applied to only 5 percent of plots. Most farmers applied fertilizer twice, but some applied only once and a few applied three or four times per season.

Fertilizer Use and Yields by Agroecological Zone

Fertilizer use varies widely across agroecological zones. The highest proportions were in the Northern Savannah and Transitional zones (at 81 percent and 74 percent of area, respectively), followed by the Coastal Savannah zone (37 percent). There was limited use of fertilizer in the Forest zone (only 17 percent of maize area), which is expected given the relatively more fertile land in that zone. Similarly, as noted in the preceding section, fertilizer use intensity in the Northern Savannah and Transitional zones was higher than in other zones. This disaggregation unpacks the national estimate of 49 percent of area and indicates that in the zones that are relatively more in need of fertilizer, namely, the Northern Savannah and Transitional zones, adoption is high.

The average yield of plots with fertilizer (1.41 tons/hectare) is significantly higher than of those without fertilizer (1.04 tons/hectare) (Table 7). Plots with combined fertilizer and certified seed use have a higher yield than those using only one or neither approach. If certified seed is used, fertilized plots have significantly higher yields (1.68 tons/hectare) than those lacking fertilizer (1.10 tons/hectare) (Table 7). If certified seed is not used, fertilized plots still have significantly higher yields (1.35 tons/hectare) than those without fertilizer (1.03 tons/hectare). This is mainly driven by the significant yield difference between fertilized and unfertilized plots without certified seed in the Transitional and Northern Savannah zones. The average yield is lowest in plots without fertilizer and planted with uncertified seed in the Northern Savannah zone (0.42 tons/hectare), compared with 1.25 tons/hectare in plots with fertilizer and without certified seed. In the Transitional zone, plots with uncertified seed and fertilizer have significantly higher yields (1.52 tons/hectare) than those without fertilizer (1.18 tons/hectare). The greater adoption rate and seemingly more responsive yields to fertilizer use in the Northern Savannah zone can be attributed to the much lower soil fertility (lower organic matter, nitrogen and phosphorus on average) in this zone compared to zones in the South (FAO 2005).

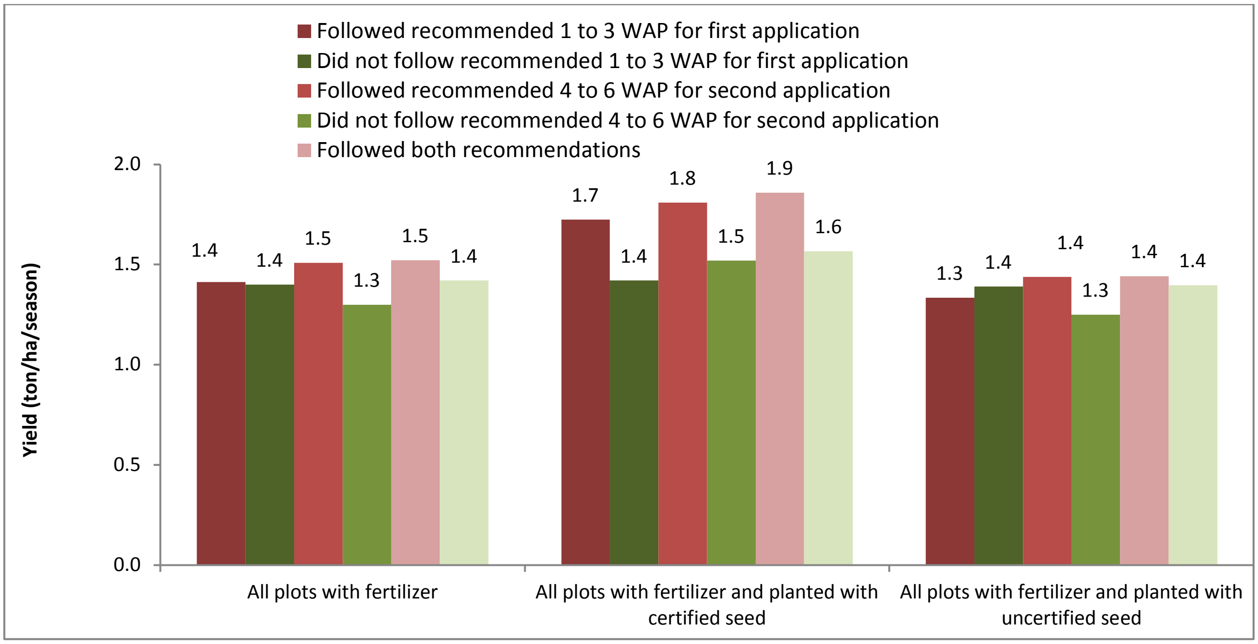
Reasons for nonuse. Half of the farmers who used no fertilizer were asked why. The majority reported that their plot was fertile and did not need fertilizer (48 percent of farmers), while 36 percent reported that they lacked funds or that the fertilizer was very costly. Whereas the proportion of farmers reporting fertile plots was greater in the South (50 percent in Forest, 45 percent in Transitional, and 57 percent in Coastal Savannah), the North had a greater proportion of farmers reporting lack of funds or expensive fertilizer as the main reason for not buying fertilizer (88 percent).

Timing of Application

Forty-six percent of maize plots received the first application of fertilizer during the first two weeks as recommended, another 34 percent received it one week later than recommended, and the remaining 20 percent received it much later. Only 19 percent of plots received the second application as recommended (four to five weeks after planting). The majority (53 percent) received it during the sixth week after planting, a week later than recommended, while the remaining 25 percent received it even much later. Whereas the majority of maize farmers applied twice (as recommended), some farmers applied three or four times. The survey offers no clear evidence why there seems to be a much later application of fertilizer for the majority of farmers and more split applications (up to three to four times) for some farmers than recommended.

There was no significant difference in average yield between plots following the recommended timing and those not following it, but the difference is greater for plots planted with certified seed (Figure 4). It will be important to understand better whether farmers lack information about proper timing or whether this is the preferred timing of farmers, which they think is optimal based on their years of experience. The timing of application may also be affected by untimely fertilizer supply or labor availability or a lack of funds to purchase fertilizer during the time it is needed. More focused interviews may help inform researchers and practitioners about these reasons, and using timing of application as one of the factors in the production models or productivity analyses will also provide information about whether particular application timings explain productivity.

Figure 4—Average yield of maize plots by timing of fertilizer application



Source: CRI/SARI/IFPRI survey (November 2012–February 2013).
Note: WAP = weeks after planting.

6. HERBICIDE USE

Herbicide is widely used among maize farmers in Ghana. Seventy-three percent of maize area was applied with herbicide either before or after planting. Fifty-four percent of maize area received herbicide after planting, whereas 35 percent received herbicide both before and after planting. Adoption was high in the Forest, Transitional, and Coastal zones (74 to 87 percent), but much lower in the Northern Savannah zone (39 percent). That may be due to less prevalence of weeds or greater availability of labor, or both, in the North than in the South. The average application rate was 9.2 liters/hectare, with highest rate in Transitional zone (10.3 liters/hectare) and lowest in Northern Savannah zone (5.3 liters/hectare). This rate is higher than the recommended rate of 6–9 liters/hectare.

Compared with the adoption rate of 73 percent of farmers in this 2012–13 survey, Quiñones and Diao's (2011) estimate is much lower at 19 percent of maize-producing households. For herbicide (during land preparation) specific to maize, Mensah-Bonsu et al. (2011) estimated a 38 percent adoption rate. Based on IFPRI's (2011) detailed farm budget dataset for maize, 83 percent of farmers used herbicide. Figures in Ghana are far higher than earlier estimates for Africa south of the Sahara: 3 percent adoption among maize smallholders in Africa south of the Sahara (Overfield et al. 2001); less than 5 percent adoption among smallholder farmers in Africa (Gianessi and Williams 2011); and 0.1 percent of acres treated with herbicide in Uganda (Magyembe 1997).

With the entry of inexpensive herbicide from mainly China, it is cheaper to purchase and use herbicide than spending much time weeding or hiring labor for weeding. A simple comparison of weeding costs of plots suggests that whereas farmers using herbicide spend 359 cedi/hectare total in buying herbicide (9 liters at 8 cedi/liter) and an additional 41 person-days for manual weeding, farmers not using herbicide spend 511 cedi/hectare for manual weeding for 73 person-days on average (Table 9). It is apparent from this calculation that buying herbicide is less expensive than hiring labor or using family labor for weeding.

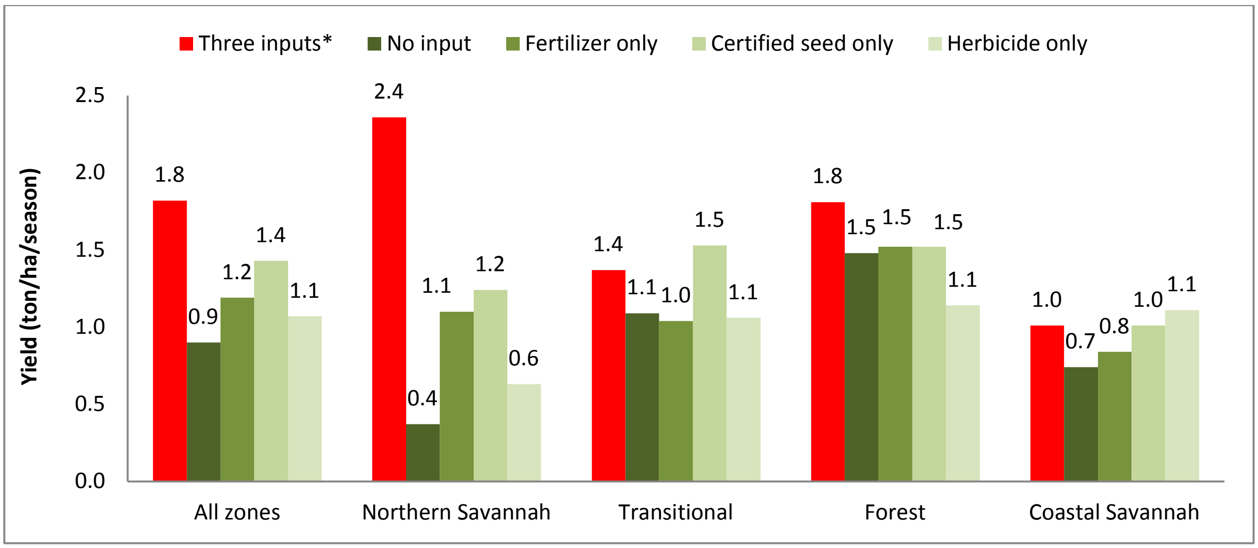
Table 9—Cost difference between herbicide use and manual weeding

Case	Without herbicide	With herbicide	Difference
Number of person-days for weeding	73	41	32
Average daily wage (cedi/person-day)	7	7	
Herbicide rate (liter/hectare)	0	9	-9
Price of herbicide (cedi/liter)	8	8	
Total costs for weeding (cedi/hectare)	**511**	**359**	**152**

Source: Assumptions are based on the averages computed from the CRI/SARI/IFPRI survey (November 2012–February 2013).

Plots treated with herbicide have a significantly higher average yield than those without herbicide, with the greatest difference in the Northern Savannah zone. In plots with fertilizer and certified seed, those with herbicide have 1.4 tons/hectare more yield than those without herbicide in the Northern Savannah zone (Figure 5). In plots with fertilizer only, those with herbicide have 0.4 ton/hectare higher yield in the Northern Savannah zone. In plots with no fertilizer and certified seed, plots with herbicide have a higher yield than those without herbicide in the Coastal Savannah zone, but the opposite is the case in the Forest zone.

Figure 5—Average yield of maize plots by herbicide application



Source of raw data: CRI/SARI/IFPRI survey (November 2012–February 2013). Note: * Three inputs combined are fertilizer, herbicide, and certified seed (up to three seasons of replanting).

7. ZERO TILLAGE

Zero tillage, or no-till (defined here as slashing, no plowing, no burning, use of herbicide before planting, and planting with mulch, and which CRI, MOFA, and other development partners actively promoted in the 1980s and 1990s), was practiced in only 4 percent of maize area (Table 10). Ekboir, Boa, and Dankyi (2002) estimate about 300,000 small-scale farmers adopted no-tillage in 2001. Mensah-Bonsu et al. (2011) reported that almost half of farmers practiced no-burn during land preparation, and 38 percent practiced zero tillage, although it is not clear how they defined zero tillage in their study. Compared with the high adoption in the 1990s reported by some studies and cited by several experts as a success story, zero tillage may have been widely disadopted by many farmers, or earlier studies may not have captured the actual practices in a wider range of districts and regions decades ago.

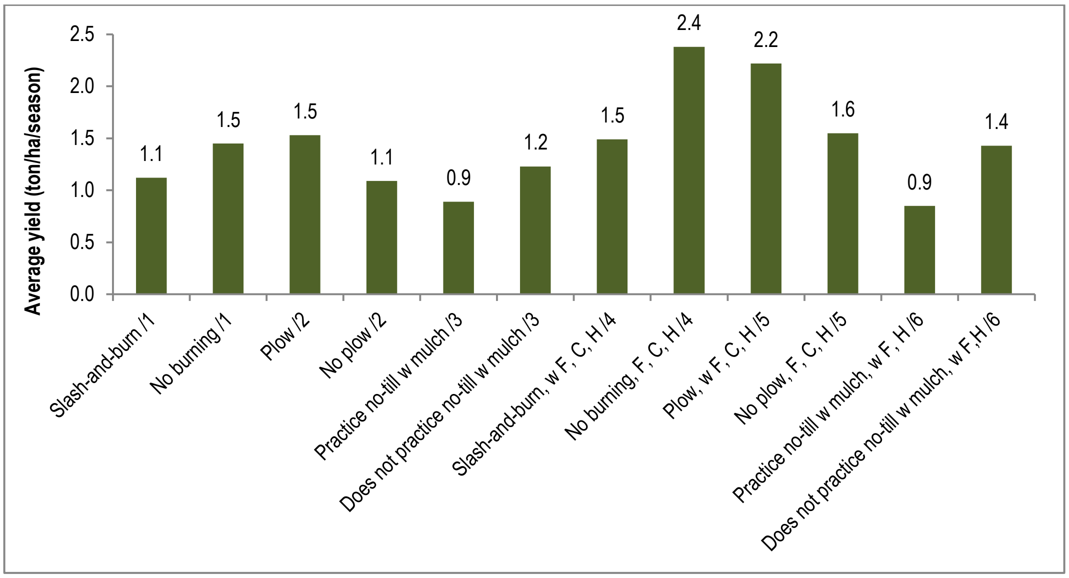
Many farmers only partially adopted the zero-tillage package (Table 10). Sixty-eight percent of maize area was not plowed (by either tractor or animal traction). About 28 percent of maize area was plowed using a tractor or power tiller, and 4 percent was plowed using animal traction (all in the North). Thirty percent of maize area was not under slash-and-burn. Fifty-three percent of maize area was applied with herbicide during land preparation. Only 9 percent of maize area was prepared by not plowing, not burning, and using herbicide. Only 4 percent was prepared by not plowing, not burning, using herbicide, and planting in mulch (the zero-tillage package as promoted by CSIR).

Table 10—Distribution of maize area by no-tillage adoption during major season, 2012, percentage

No-till system	Total	Forest	Transitional	Northern Savannah	Coastal Savannah
No plowing	68	98	61	25	61
No burning	30	15	42	42	48
No plowing, with burning	58	82	49	16	52
No tillage, with herbicide, without mulch	9	11	9	5	8
No tillage, with herbicide and with mulch	4	5	6	0	6

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).

Figure 6—Average yield of plots cultivated with or without no-tillage system during major season, 2012



Source of raw data: CRI/SARI/IFPRI survey (November 2012– February 2013).
Note: Technologies with the same number indicate that there is no significant difference in average yield between them at less than 5 percent level. w = with; F = fertilizer; C = certified seed; H = herbicide. Technologies enumerated with 1 through 3 are for all plots; those with 4 through 6 are restricted to plots with F and H, and C for some cases.

Plots under slash-and-burn have a lower average yield than those not cultivated under slash-and-burn (Figure 6). Plots that are plowed (mechanized or animal tractor) have a significantly higher average yield than those that are not plowed. Plots under no-till (no plowing, no burning, with herbicide, and with mulch) have a lower average yield than those not cultivated under no-till.

If we restrict the analysis to plots with fertilizer, certified seed, and herbicide, the differences are even more prominent. Plots with fertilizer, certified seed, and herbicide that are not under slash-and-burn have 0.9 ton/hectare more yield on average than those under slash-and-burn. Plots with fertilizer, certified seed, and herbicide that are plowed have 0.6 ton/hectare more yield on average than those not plowed. Plots with fertilizer and herbicide that are under no-till with mulch have 0.5 tons/hectare less yield than those that are not under no-till. The highest average yield was in plots with fertilizer, with certified seed, with herbicide, plowed, and not under slash-and-burn. The results seem to favor plowing and no burning, and they show evidence of lower productivity associated with the no-till practice, which may likely be the reason many farmers disadopted the practice. Several entomologists interviewed also highlighted that no burning and planting into mulch, which are key elements of no-till, would likely cause severe infestation of armyworms and other pests and therefore lower yields compared with clear-and-clean plots.

8. OTHER SOIL FERTILITY MANAGEMENT PRACTICES

The survey found limited adoption of other soil fertility management practices (Table 11). Only 3 percent of maize area was applied with animal manure. Manure is promoted by CISR and MOFA and farmers are willing to buy and use it, but a supply is just not available. Forty percent of maize area was intercropped, mainly with cassava, and only 3 percent of maize area was intercropped with nitrogen-fixing crops such as legumes, most of which was in the Northern Savannah zone. One percent of maize area had cover crops; mucuna, a heavily researched and promoted cover crop, was unpopular. Key informant interviews indicate that many farmers do not have much incentive to plant legumes as an intercrop or rotation crop since more profitable and more important food security crops exist that they prefer, such as cassava. Sixteen percent of maize area was plowed in with crop residue, and only 11 percent was planted in mulch.

Farmers were asked about other land management practices, such as ridging, mounding, earth bunding, stone bunding, contour plowing, live fence, and any other fence. However, almost no maize area was under any of those land management practices. The only exception is ridging, where 9 percent of maize area was ridged (4 percent in the Forest, 12 percent in the Transitional, and 27 percent in the Northern Savannah zones) (Table 11).

Table 11—Distribution of maize area by land preparation and planting methods during major season, 2012, percentage

Management practice	All	Forest	Transitional	Northern Savannah	Coastal Savannah
Applied animal manure	3	1	1	11	4
Plowed in crop residue	16	11	19	21	49
Practiced ridging	9	4	12	27	0
Intercropped with nitrogen-fixing crops	3	0	0	16	2
Intercropped with any crops	40	45	38	30	37
Planted in mulch	11	8	21	7	44
Practiced relay cropping or crop rotation	1	1	1	1	0

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).

These figures are much lower than the estimates of Mensah-Bonsu et al. (2011) in the middle part of Ghana. For example, about 18 percent practiced mulching and 40 percent plowed in vegetative cover. Water management practices (such as ridging, bunding, and mounding) were practiced by 3 to 12 percent of respondents. Animal manure was applied by 17 percent of farmers, and cover cropping was practiced by 20 percent of maize farmers. CIRAD (Agricultural Research for Developing Countries) (2006) paints a more pessimistic picture of limited or artificial adoption of conservation agriculture or soil fertility management practices in Ghana. Most such practices have remained at the experimental or local implementation stage by ad hoc projects. CIRAD found that disadoption is quite common in the Ashanti and Brong Ahafo regions.

Almost all plots in the Northern Savannah and Transitional zones have been continuously cultivated in the past 11 years (Table 12). Some fallowing is still practiced in the Forest and Coastal Savannah zones, but that is rapidly disappearing due to population growth pressures and greater demand on land. Continuous cropping and the limited adoption of soil fertility management practices put much stress on the land.

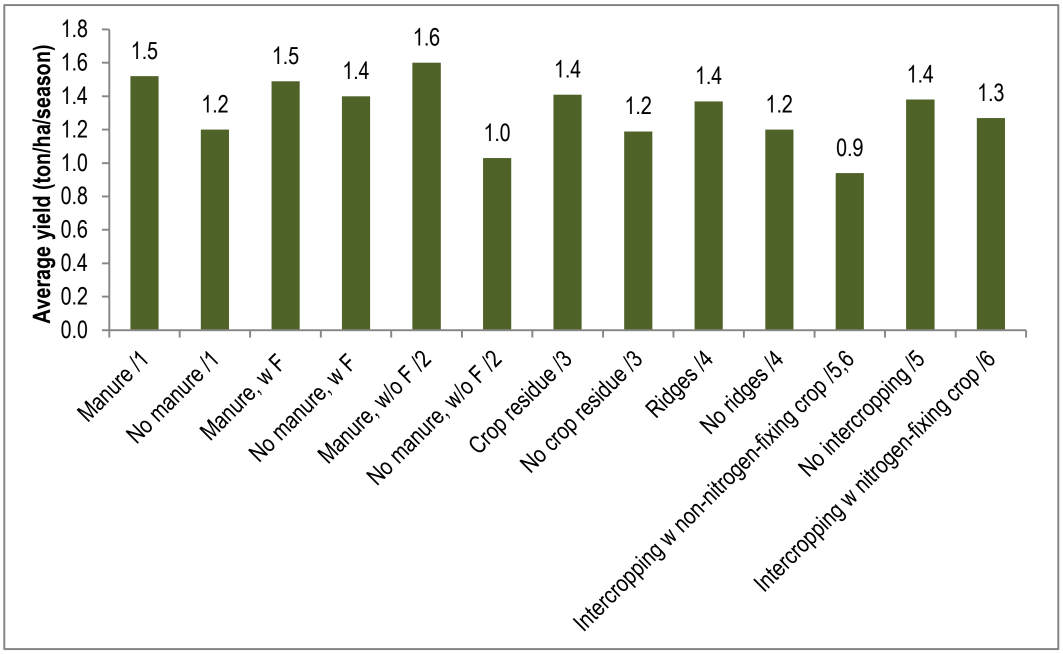
Table 12—Distribution of maize area by fallow system, percentage

Zone	Continuously cropped in the last 11 years	Fallowed for 1 to 3 years in the last 11 years	Fallowed for 4 to 6 years in the last 11 years	Fallowed for 7 to 9 years in the last 11 years	Fallowed for 10 to 11 years in the last 11 years
Forest	39	33	15	3	10
Transitional	71	22	5	1	2
Northern Savannah	82	13	3	2	0
Coastal Savannah	40	30	18	3	9
Total	59	27	12	2	0

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).

Plots with animal manure have higher average yields than those without animal manure (Figure 7). The difference is much more prominent for plots with no inorganic fertilizer. Plots without inorganic fertilizer but with animal manure demonstrate a 0.6 ton/hectare additional yield than those without both inorganic fertilizer and animal manure. This means that in areas with more abundant animal manure, such as in the Northern Savannah zone, animal manure can be a good substitute for inorganic fertilizer in increasing yield. Plots with crop residue have a higher average yield than those without crop residue. Plots in ridges, as a sustainable land management practice, have a higher average yield than those without ridges. Plots intercropped with nitrogen-fixing crops, such as legumes, have a higher average yield than those intercropped with non-nitrogen-fixing crops, such as cassava. There was no difference in maize yield between monocropped plots and those with nitrogen-fixing crops.

Figure 7—Average yield of plots cultivated with different land management systems during major season, 2012



Source of raw data: CRI/SARI/IFPRI survey (November 2012–February 2013).
Note: Technologies with the same number indicate that there is significant difference in average yield between them at less than 5 percent level. w = with; F = fertilizer.

9. PLANT CONFIGURATION

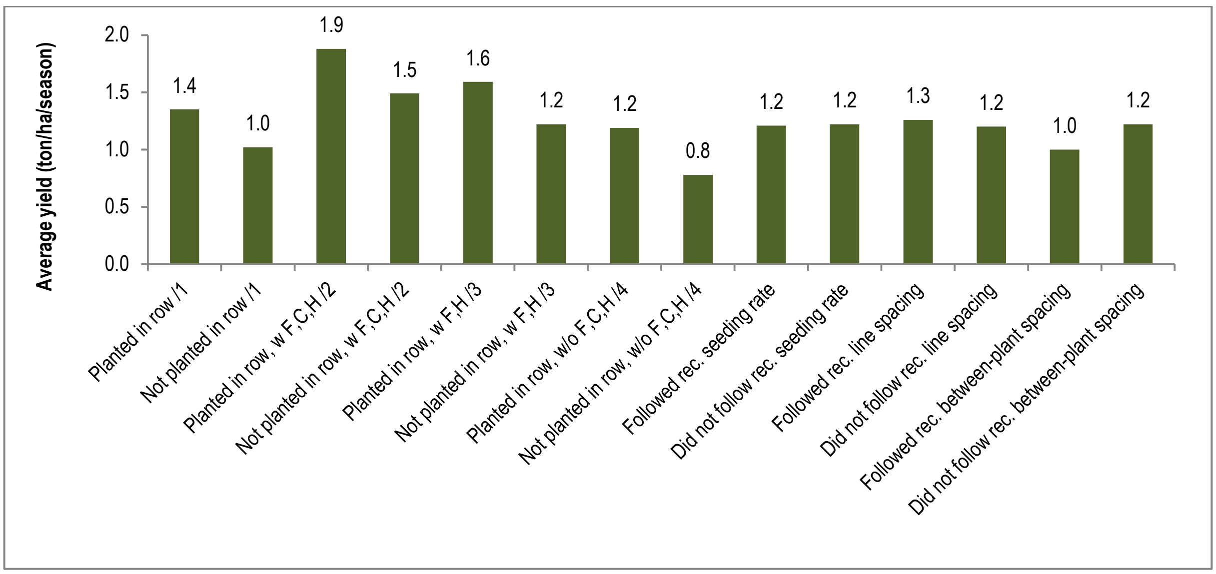
The majority of maize area (58 percent) was planted in rows or lines, with the highest proportions in the Transitional (71 percent) and Northern Savannah zones (69 percent) and the lowest proportions in the Coastal Savannah (50 percent) and Forest zones (48 percent) (Annex 5). If plots under ridges are not included, the proportion of maize area under row planting was 53 percent on average, the highest being in the Transitional zone (63 percent). This is the same as the adoption rate of row planting in 1997 (Morris, Tripp, and Dankyi 1998), suggesting that there was not much of a dissemination effort after GGDP. The majority of farmers in the Northern Savannah zone (86 percent) and the Coastal Savannah zone (73 percent) said that they did not plant in rows because of a lack of information about row planting or the benefits of row planting. Across all zones, 8 percent of farmers said that they did not notice any difference between planting in rows and planting at random, and that was why row planting was discontinued. Key informant interviews reveal that row planting takes relatively more time, and therefore hired laborers usually ask for higher compensation if row planting is practiced instead of random planting. Overall, the two main reasons for the stagnant adoption of row planting seem to be lack of information and labor constraints.

On average, the seeding rate is close to the recommendation of about 20 kilograms/hectare, but there is some variation across agroecological zones. The rate is higher in the Transitional zone (22 kilograms/hectare for intercropped plots and 26 kilograms/hectare for maize monocropped plots) and lower in the Coastal Savannah zone (15 kilograms/hectare for inter-cropped plots and 12 kilograms/hectare for maize monocropped plots). About 42 percent of plots were planted with close to the recommended spacing between rows (71 to 90 centimeters), whereas more than half of plots were planted with much less than the recommended spacing between rows. Only 35 percent of plots came close to the recommended spacing between plants in a row (31 to 50 centimeters in Annex 5; the recommendation is 40 centimeters), and the rest of plots were planted either much closer or farther than the recommendation. For those plots not planted in rows, only about 35 percent were planted with an estimated spacing of 51 to 70 centimeters, which would be the average of the recommended spacing between lines and between plants; the large majority of plots were planted either too close or too far from each plant compared with the recommended spacing.

The number of seeds per hill averages three. Only 35 percent of plots were planted with two seeds per hill, the recommendation for seeds that have good germination. Half of the plots were planted with three seeds per hill, the recommended rate for seeds with poorer germination. About 11 percent of plots were planted with four seeds per hill. Only 1 percent of farmers performed the recommended germination test (planting 100 seeds in lines and checking germination, or a similar approach). About 2 percent of farmers placed seeds in water to remove those that float. The large majority of farmers (72 percent) just inspected the seeds visually, and the remaining 25 percent of farmers did nothing. Many farmers plant more seeds in a hill rather than testing the seeds first for germination to determine whether they need to plant more than two seeds per hill or whether they need to replace their seed stock because of poor germination. The 2012–13 survey shows that although the seeding rate seems close to recommendations in general, the actual spacing being followed by farmers and number of seeds per hill appear different from recommendations. The survey shows that farmers are planting more seeds per hill than recommended; they are planting closer rows than recommended; the spacing of planting within rows is different from the recommended spacing; and germination tests are unpopular.

A simple means comparison of yield suggests that plots planted in rows have significantly higher yields than those not planted in rows, but yields were not different between those following or not following the recommended spacing, seeding rate, and number of seeds per hill (Figure 8).

Figure 8—Average yield of plots cultivated with different planting practices during major season, 2012



Source of raw data: CRI/SARI/IFPRI survey (November 2012–February 2013).

Note: Technologies with the same number indicate that there is a significant difference in average yield between them at less than 5 percent level. w = with; F = fertilizer; C = certified seed; H = herbicide; rec. = recommendation

10. CONCLUSIONS AND FURTHER RESEARCH

Using nationally representative survey data from maize production areas, we find interesting and at times surprising results.

First, fertilizer use was quite high compared with earlier estimates, currently 47 percent versus 21 percent of maize farmers according to Morris, Tripp, and Dankyi (1998) and 25 percent of maize farmers based on the GLSS5 conducted in 2005–06. Compared with estimates of 5 kilograms/hectare of nutrient average for all crops (FAO 2005, Banful 2009), the current 47 kilograms of nitrogen application for maize is much higher, although it is only half of the recommended 90 kilograms/hectare of nitrogen for continuously cropped plots. This finding suggests that the national fertilizer subsidy program may have helped lower fertilizer costs and thereby encouraged more adoption of fertilizer. However, still more than half of maize farmers did not apply fertilizer, and the average rate of application is lower than recommendations. It seems that other factors are more binding constraints in maize than the cost of fertilizer. A simple means comparison suggests that fertilized plots show a small or no difference in yield compared with unfertilized plots, except in the Northern Savannah zone. Further research is needed to look more closely at the profitability of maize production with and without fertilizer and low-input soil fertility management practices.

Second, herbicide use is high compared with earlier estimates, currently 73 percent versus 19 percent based on the GLSS5. Given serious labor constraints and the relatively cheaper herbicide formulations available, herbicide use has been popular across all regions. Comparison of weeding costs suggests that whereas farmers using herbicide spend 359 cedi/hectare total in purchasing herbicide (9 liters at 8 cedi/liter) and an additional 41 person-days for manual weeding, farmers not using herbicide spend 511 cedi/hectare for manual weeding for 73 person-days on average. It is apparent from this calculation that it is cheaper to purchase herbicide than to hire labor or use family labor for weeding. Moreover, a simple means comparison shows that plots with herbicide have a higher yield than those without herbicide in the Northern and Coastal Savannah zones, although no difference is seen in the other zones. Therefore, economic incentives dictate the use of herbicides among maize farmers in Ghana. However, along with high pesticide use (50 percent of areas with pest problem) and greater use of fertilizer (47 percent of maize area), excessive use and improper handling of chemicals may pose serious health, food safety, and environmental issues for farmers. More research on these effects, the proper handling of chemicals, and low-chemical alternatives for crop protection is needed.

Third, the adoption of modern varieties and certified seed was less encouraging. The current rate of 61 percent of maize area is slightly higher than the DIVA project's estimated 57 percent and just a slight increase over Morris, Tripp, and Dankyi's (1998) estimate of 54 percent in 1997. This shows a little improvement in the efforts to disseminate modern varieties, especially the newer varieties, among maize farmers in the past 15 years.

The older varieties are still popular. The rate of varietal turnover for maize in Ghana is 23 years, which is far higher than estimates for other countries and indicates a serious weakness in the research and extension system. Ghana's research system develops and releases seven varieties every 10 years on average, which is very active and high according to African and international standards. However, a very high varietal turnover rate signals a research system that is breeding and producing varieties that do not necessarily address the needs and binding constraints faced by farmers or an ineffective extension system, or a combination of both.

Maize production is dominated by a single variety, Obatanpa (accounting for 96 percent of certified seed production from 2001 to 2011). Obatanpa was released in 1992 and is still the predominant variety and is even increasing in popularity over the years, whereas the newer varieties did not seem to take off. Obatanpa has a slightly higher yield than the newer OPVs but seems to be yielding only half that of the hybrids. Moreover, calculation of the additional costs and benefits of hybrid maize suggests that the additional value of production outweighs the additional seed and other costs, and the profit is 60 to 70 percent of the value of production under Obatanpa. However, promotion of hybrids has lagged behind, and hybrids occupied only 3 percent of maize area.

Although 61 percent of maize area was planted with modern varieties, only 15 percent was planted with certified seed. Purchase of certified seed was unpopular; however, seed recycling and sourcing of seeds from other farmers were common among the overwhelming majority of maize farmers. Given the high incidence of outcrossing and poor storage practices among farmers, seed recycling and the sourcing of seeds from other farmers and other uncertified sources does not provide quality seeds with the vigor and performance expected of the improved varieties. Plots planted with certified seed have a higher yield than those without, and the difference is even greater between fresh certified seed and recycled seed.

Fourth, in the Northern Savannah zone, using all three inputs (fertilizer, herbicide, and certified seed) makes a huge difference compared with using only one or none of them. Plots that used all three had a 2-ton higher yield than those that did not use any, and they had a 1.2- to 1.8-ton higher yield than those plots that used only one of these inputs. Plots in the Northern Savannah seem to respond well to the three inputs, indicating huge improvements in productivity with the promotion of fertilizer, herbicide, and certified seed in this zone. However, in the other zones, plots using only one or two of these inputs produced either a similar or lower yield than those plots that used all three inputs, indicating a much lower responsiveness of yield to the three inputs.

Fifth, whereas the adoption of herbicide especially before planting is impressively high, the full adoption of a no-tillage system is very low, a surprising result after the much-hailed success of no-till technology in Ghana in the 1990s. Burning and plowing were common practices. Plots that are plowed have a significantly higher yield, and plots under slash-and-burn have a significantly lower yield. Plots under no-till with or without mulch have a significantly lower yield than those not under no-till, and that may likely be the main reason for its declining popularity.

The fallow system has almost disappeared as towns become more densely populated and demand for land becomes greater. At the same time, the use of soil fertility management practices is limited. The use of nitrogen-fixing crops, such as legumes, for intercropping, crop rotation, or crop relay, was unpopular. Intercropping with cassava is common as farmers find this more profitable and better for household food security than intercropping or rotation with legumes. Crop relay with mucuna, a nonfood legume, which was much researched and promoted for two decades, remains unpopular as it means lost opportunities to plant food crops, for more profit or food, during the minor season. Continuous cropping and limited soil fertility management practices put much stress on the land.

Sixth, other management practices differed from the recommended practices. Only a very few farmers performed a germination test. The large majority (72 percent) just inspected the seed visually, and the remaining 25 percent did nothing. The 2012–13 survey shows that although the seeding rate approaches the recommendation in general (20 kilograms/hectare), the actual spacing being followed by farmers and number of seeds per hill seem to be different from recommendations. A simple means comparison suggests that plots planted in rows have a higher yield than those planted at random. There was no statistical difference between plots following recommended spacing and density and those not following the recommendations.

The timing of fertilizer application differs substantially from the recommendations. In general, there was a much later application of fertilizer than recommended. Based on the survey, we cannot say why the majority of farmers apply fertilizer later than what is recommended or why some farmers split their applications (up to three to four times). A simple means comparison shows no difference between plots following the recommended timing and those not following it. There is need to understand better whether farmers lack information about proper timing or whether farmers simply prefer their own timing, which they think is optimal based on their years of experience. Departures from recommended timing may also be because of untimely fertilizer supply or labor availability or a lack of funds with which to purchase fertilizer when it is needed. More focused interviews may be of help, and using timing of application as one of the factors in the production models or productivity analyses will also provide information about whether particular application timings explain productivity.

Despite being in the form of a descriptive report, our findings provide an up-to-date picture of the pervasiveness of adoption of technologies, as well as providing some indication of why certain technological packages were adopted or not. The report provides initial analysis on yield comparisons. The paper provides some empirical evidence that needs to be further investigated by looking more closely at the dataset and complementing it with more focused interviews. The following themes emerge and can be further investigated and tested:

- Hybrid maize production is more profitable than using Obatanpa. Low dissemination and promotion of hybrid maize seems to be the main reason for minuscule adoption of hybrids in Ghana.
- Lack of information and dissemination seems to be the main reason for low use of certified seed and new varieties. CSIR has a major role to play in the dissemination effort. A possible approach is participatory varietal selection (PVS), an approach being adopted for rice. PVS in rice seems to be successful in getting the varieties into the hands of farmers faster—even before their official release.
- Plots in the Northern Savannah zone are very responsive to fertilizer, herbicide, and certified seed use, but not those in the other zones. The highest productivity gains can be achieved by promoting these three inputs in the Northern Savannah zone.
- Many of the recommended practices (no-till, plant density, spacing, and fertilizer timing) did not provide a significant yield advantage compared with nonadoption.
- Practices such as row planting, plowing, and no-burn seem to have significant yield advantages compared with nonadoption.
- Soil fertility management practices other than fertilizer use, such as the use of nitrogen-fixing crops for intercropping, crop rotation, and crop relay, are less economically advantageous to farmers, which seems to be the main reason why they are unpopular among maize farmers.
- There seems to be a lack of trust in the seed system among some farmers. Farmers seem to be satisfied recycling the variety and seed that they have, and many explicitly reported that they do not trust varieties and seed from agrodealers or MOFA. Stricter regulation and inspection systems in the seed system are needed to persuade farmers and seed users to again trust the seed system. At the same time, more rigorous field trials and socioeconomic analysis on the feasibility of the newer and promising varieties are necessary before an extensive promotion can be conducted.

ANNEX 1. LIST OF PROJECTS ON MAIZE IMPLEMENTED IN GHANA SINCE THE 1970S

Project	Period	Estimated funding	Funding source/ partners	Geo-graphical focus	Key components
Projects focusing on maize					
Ghana Grains Development Project	1979–97		Canadian	Country-wide	Research and technology transfer for maize and cowpeas; institutional development in research and extension
Food Crops Development Programme	2000–08		AfDB	8 districts; different regions	Research; extension; credit; subsidized inputs provision; storage and processing
Drought Tolerant Maize for Africa (DTMA)— various countries including Ghana	2007–ongoing		BMGF	Northern, Upper East, Upper West, Brong Afaho, Ashanti	Research
AGRA-Maize (Phase 1 and 2)	2008–12 (first phase); 2013–17 (second phase)		AGRA		Varietal development (released six new varieties)
AGRA-PASS			AGRA		Seed multiplication, seed system, seed growers
WAAPP Phase 2 (includes maize)			World Bank		Varietal promotion
Sustainable Seed Production and Promotion of Maize and Other Selected Crops in the Forest and Forest Transition Zones of Ghana	2008–10	USD 150,000			Seed production
Projects that include maize as one of the focus commodities					
Sasakawa Global 2000	1990s			Whole country	Supported farm demonstrations; seed production; subsidized input provision through credit; institutional strengthening in extension
Farmers-to-Markets Project	2010–13				M-Farms Electronic Platform Roadmap implementation
AGRA Soil Health Programme	2007–14	USD 164.5 million		116 farmer-based organization	Research, technology transfer on advanced soil management methods; build the fertilizer supply chain to increase farmers' access to fertilizer and other input
A Project to Supply Quality Seed of Cereals, Legumes, and Oil Crops to Resource-Poor Farmers in Northern Ghana	2008–10	USD 149,973			Seed production
Enhancing Access to Quality Seeds for Higher Productivity of Small-Scale Farmers in the Upper West Region of Ghana	2010–12	USD 146,603		Northern Ghana	Seed production
Poverty Reduction among Farmers through the Use of Improved Seeds	2011–14	USD 153,543			Seed production
Improvement of Small-Scale Farmers' Access to High-Quality Improved Seeds for Higher Productivity in the Northern Region of Ghana	2011–14	USD 197,770			Seed production
Production and Distribution of Certified Improved Maize, Sorghum, Soybean, Cowpea, and Tomato Seeds for Poverty Reduction and Food Security in the Transitional Agroecological Zone of Ghana	2011–13	USD 129,948			Seed production

Source: Compiled by authors from several documents.

ANNEX 2. CERTIFIED SEED PRODUCTION OF MAIZE, 2001–2011

Name of variety	Seed production (tons) (based on PPRSD, MOFA data)												
	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Total	%
Obatanpa	2,584	4,185	3,630	2,372	1,585	1,587	2,012	1,303	1,283	1,424	921	**22,886**	***96.27***
Mamaba	3	54	35	30	40	70	24	11	0	0	0	**267**	***1.12***
Golden Jubilee	0	32	53	59	51	0	0	0	0	0	0	**195**	***0.82***
Okomasa	0	0	18	0	0	0	0	25	29	18	16	**106**	***0.45***
Dorke SR	1	3	12	4	0	14	0	16	17	14	15	**96**	***0.40***
Etubi	11	45	40	0	0	0	0	0	0	0	0	**96**	***0.40***
Abeleehi	0	0	0	9	0	0	0	0	0	0	30	**39**	***0.16***
Dodzi	0	0	2	0	1	1	0	1	1	15	14	**35**	***0.15***
Omankwa	14	0	0	0	0	0	0	0	0	0	0	**14**	***0.06***
Akposoe	0	8	0	0	0	0	0	0	0	0	0	**8**	***0.03***
Abontem	7	0	0	0	0	0	0	0	0	0	0	**7**	***0.03***
Others	0	0	0	0	0	0	0	0	0	29	0	**29**	***0.12***
Total	**2,620**	**4,327**	**3,789**	**2,474**	**1,677**	**1,672**	**2,035**	**1,356**	**1,330**	**1,498**	**996**	**23,774**	***100.00***

Source: Compiled by authors based on raw data from Plant Protection and Regulatory Services Directorate (PPRSD), MOFA.

ANNEX 3. SAMPLE MAIZE-PRODUCING DISTRICTS INCLUDED IN THE SURVEY

Sample maize-producing districts	Number of sample farmers	Production (tons) (average 2009–11)	Area cultivated (ha) (average 2009–11)	Yield (tons/ha) (average 2009–11)	Main agroecological zone**
ASHANTI	**105**	4,484	3,656	1.23	
Adansi South (East)	21	11,454	8,410	1.36	Forest
Amansie Central	21	5,758	4,509	1.28	Forest
Ejura Sekyedumase	21	27,294	19,314	1.41	Transitional
Sekyere East*	21	24,624	17,419	1.41	Forest
Sekyere South*	21				Forest
BRONG AHAFO	**147**				
Berekum	21	20,749	10,706	1.94	Forest
Dormaa	21	71,717	36,210	1.98	Forest
Nkoranza	21	71,648	37,645	1.9	Transitional
Kintampo North	21	54,847	26,348	2.08	Transitional
Kintampo South	21	26,369	13,238	1.99	Transitional
Sunyani	21	62,474	38,095	1.64	Forest
Wenchi	21	24,106	3,141	1.81	Transitional
CENTRAL	**63**				
Agona	21	14,214	5,935	2.39	Forest
Gomoa	21	14,912	6,719	2.22	Coastal Savannah
Awutu-Efutu-Senya	21	2,324	8,987	1.7	Coastal Savannah
EASTERN	**105**				
Fanteakwa	21	28,346	15,173	1.87	Forest
Suhum K Coaltar	21	18,225	8,417	2.17	Forest
West Akim	21	30,458	12,917	2.36	Forest
Yilo Krobo	21	20,557	9,803	2.1	Transitional
Kwahu South	21	10,817	5,873	1.84	Forest
NORTHERN	**63**				
East Gonja	21	6,626	3,833	1.73	Northern Savannah
West Gonja	21	12,303	7,970	1.54	Northern Savannah
West Mamprusi	21	11,380	6,873	1.66	Northern Savannah
UPPER EAST	**21**				
Bawku Municipal	21	25,226	11,397	2.21	Northern Savannah
UPPER WEST	**42**				
Wa East	21	10,705	7,510	1.43	Northern Savannah
Wa West	21	6,403	4,740	1.35	Northern Savannah
VOLTA	**42**				
Jasikan	21	19,355	11,534	1.68	Transitional
Ketu	21	19,355	11,534	1.67	Coastal Savannah
WESTERN	**42**				
Aowin-Suaman	21	12,721	8,407	1.51	Forest
Sefwi-Wiaso	21	10,575	7,130	1.48	Forest
Total (sample districts)	**630**	**668,202**	**365,294**	**1.77**	
Total (Ghana)		**1,730,988**	**989,759**	**1.75**	
Percentage of sample to Ghana total (%)		**39**	**37**		

Source: CRI/SARI/IFPRI survey for sample farmers; MOFA (2009–2011) for production data.
* MOFA has data only on Sekyere West, which most likely is a split between Sekyere East and Sekyere South. ** Classifications are all based on MOFA classifications and definitions, except for Gomoa and Ketu, both of which are classified as Coastal Savannah instead of Transitional based on the description of the farming system in those districts and adopting the farming systems used in Morris, Tripp, and Dankyi (1998).

ANNEX 4. DISTRIBUTION OF MAIZE AREA BY VARIETIES PLANTED, MAJOR SEASON, 2012

Varieties	All zones	Forest	Transitional	Northern Savannah	Coastal Savannah
CSIR-released varieties	**56.7**	**63.3**	**54.2**	**55.7**	**33.5**
Obatanpa (1992)	40.6	54.2	32.3	31.2	27.3
Aburohemaa (2010)	0.1	0.0	0.0	0.0	1.0
Abeleehi (1990)	0.3	0.0	1.1	0.0	0.0
Aburotia (1983)	2.7	0.0	5.7	4.6	0.7
Akposoe (2007)	0.2	0.0	0.7	0.0	0.0
Aziga (yellow) (2007)	0.4	0.9	0.0	0.0	0.0
Comp 4 (1972)	0.2	0.0	0.0	0.0	2.5
Comp W (1972)	0.3	0.0	0.6	0.0	2.0
Dobidi (1984)	2.1	0.2	7.4	0.0	0.0
Etubi (hybrid) (2007)	0.0	0.0	0.0	0.2	0.0
Golden Crystal (1972)	0.7	0.7	0.0	1.5	0.0
Golden Jubilee (yellow) (2007)	0.5	0.9	0.0	0.8	0.0
Laposta (1972)	2.1	2.4	2.3	2.2	0.0
Okomasa (1988)	0.1	0.0	0.4	0.0	0.0
Agric (cannot be named)	6.3	3.9	3.7	15.2	0.0
Private-sector varieties	**3.3**	**0.0**	**4.2**	**8.8**	**0.0**
Pan 53 (hybrid)	0.3	0.0	0.0	1.2	0.0
Pan 23 (hybrid)	0.5	0.0	0.0	2.2	0.0
Pannar (cannot be specified)	2.1	0.0	4.2	4.0	0.0
Pioneer	0.2	0.0	0.0	0.8	0.0
Proseed	0.2	0.0	0.0	0.6	0.0
Local/traditional varieties	**38.0**	**35.9**	**40.8**	**29.8**	**65.3**
Abrohoma/Aburowhoma	11.8	16.8	18.2	0.0	0.0
Aditsi/Adikyeble	1.6	0.0	0.0	0.0	21.5
Asante aburoo	0.4	1.1	0.0	0.0	0.0
Owufumpe	0.8	2.0	0.1	0.0	0.0
Ahomatea	1.2	0.6	3.6	0.0	0.0
Appiah	2.8	0.6	9.6	0.0	0.0
Ativi	0.9	0.0	3.5	0.0	0.0
Pagtaaba	0.3	0.0	0.0	1.1	0.0
Kawan pieli/Kawan pielgu	0.7	0.0	0.0	2.8	0.0
Toxpino	0.1	0.2	0.0	0.0	0.0
Yasen	0.3	0.0	0.0	0.0	4.6
Deb balli	0.3	0.0	0.0	1.1	0.0
Deb balgo	0.3	0.0	0.0	1.1	0.0
Abibifoabroo	0.0	0.1	0.0	0.0	0.0
Yegboni	3.1	0.0	0.0	12.7	0.0
Yaro	0.2	0.0	0.0	0.6	0.0
Abropa/Aburopaa	0.2	0.4	0.0	0.0	0.0
Kwahu aburo	0.2	0.6	0.0	0.0	0.0
Other local/traditional varieties	12.7	13.7	5.8	10.4	39.3
Do not know (cannot be named)	**2.1**	**0.8**	**0.8**	**5.7**	**1.2**
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).
CSIR = Council of Scientific and Industrial Research.

ANNEX 5. DISTRIBUTION OF MAIZE AREA BY PLANTING METHOD

Categories	All zones	Forest	Transitional	Northern Savannah	Coastal Savannah
Seeding rate (kilograms/hectare)					
Monocrop	21	22	26	16	15
Intercrop (mainly with cassava)	19	19	22	23	12
Row planting					
% of total maize area	58	48	71	69	50
% of total maize area (excluding ridges)	53	46	63	51	56
Average seeds planted in a hill (% of area)					
1	3	0	3	11	2
2	35	22	25	84	16
3	51	62	65	5	63
4	11	16	7	0	20
5	0.2	0.3	0	0	0
6	0.3	0.7	0	0	0
Distance between rows (% of area)					
30 centimeters (cm) or less	3	4	0	5	0
31–40 cm	4	4	0	10	0
41–50 cm	8	4	5	16	0
51–60 cm	30	29	25	30	42
61–70 cm	10	7	17	13	0
71–80 cm	26	22	36	23	23
81–90 cm	16	25	13	0	32
91–100 cm	3	3	4	2	3
More than 100 cm	1	2	0	0	0
Distance between plants (% of area)					
20 cm or less	13	14	4	23	3
21–30 cm	18	23	22	13	0
31–40 cm	22	20	21	22	35
41–50 cm	13	4	19	18	16
51–60 cm	22	26	26	15	13
61–70 cm	5	3	6	8	3
More than 70 cm	7	9	1	1	29
Estimated distance between plants if not planted in rows (% of area)					
30 cm or less	14	16	0	16	0
31–40 cm	13	10	0	26	0
41–50 cm	5	3	0	10	0
51–60 cm	23	22	10	23	100
61–70 cm	12	5	20	26	0
71–80 cm	3	5	0	0	0
81–90 cm	15	25	0	0	0
91–100 cm	8	5	60	0	0
More than 100 cm	7	10	10	0	0

Source: CRI/SARI/IFPRI survey (November 2012–February 2013).

Note: Those highlighted in darker shade are those closest to the recommendations. Those highlighted in lighter shade are recommendations if germination rate is 70 to 84 percent.

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