

# Factors that transformed maize productivity in Ethiopia

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**Abstract** Maize became increasingly important in the food security of Ethiopia following the major drought and famine that occurred in 1984. More than 9 million smallholder households, more than for any other crop in the country, grow maize in Ethiopia at present. Ethiopia has doubled its maize productivity and production in less than two decades. The yield, currently estimated at >3 metric tons/ha, is the second highest in Sub-Saharan Africa, after South Africa; yield gains for Ethiopia grew at an annual rate of 68 kg/ha between 1990 and 2013, only second to South Africa and greater than Mexico, China, or India. The maize area covered by improved varieties in Ethiopia grew from 14 % in 2004 to 40 % in 2013, and the application rate of mineral fertilizers from 16 to 34 kg/ha during the same period. Ethiopia's extension worker to farmer ratio is 1:476, compared to 1:1000 for Kenya, 1:1603 for Malawi and 1:2500 for Tanzania. Increased use of improved maize varieties and mineral fertilizers, coupled with increased extension services and the absence of devastating droughts are the key factors promoting the accelerated growth in maize productivity in Ethiopia. Ethiopia took a homegrown

solutions approach to the research and development of its maize and other commodities. The lesson from Ethiopia's experience with maize is that sustained investment in agricultural research and development and policy support by the national government are crucial for continued growth of agriculture.

**Keywords** Success story · Maize revolution · Productivity gains · Food security · Input use · African agriculture

## Introduction

Food security in Ethiopia, and elsewhere in Africa, is a major socio-political issue. Its economic wellbeing is also dependent on the success of its agriculture. Ethiopia has long suffered from food shortages and economic underdevelopment even though it is endowed with a wide range of crop and agro-ecological diversity. Maize, teff (*Eragrostis tef*), sorghum, wheat, and barley among cereals and enset (*Ensete ventricosum*) ("false banana") among "roots and tubers" provide the main calorie requirements in the Ethiopian diet. Crop productivity and production remained low and variable in the 90s for the most part but there have been clear signs of change over the past decade.

Maize has expanded rapidly and transformed production systems in Africa as a popular and widely cultivated food crop since its introduction to the continent around 1500 A.D. (McCann 2005). Maize arrived in Ethiopia slightly later, around the late 17th century (Huffnagel 1961), and was mainly grown as a subsistence crop in the mid-altitudes (1500–2000 m above sea level) in southern, south-central, and southwestern parts of the country. The production system in the 1960s and for the first quarter of 1970s was truly subsistence, the yields barely exceeding 1 metric ton (MT)/ha. The rate of

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growth for area declined following the great drought of 1974, and while there was expansion in the 1980s, the average annual yield was volatile and rarely exceeded 1.5 MT/ha. Maize production and its status in determining food security in the country received a major focus in the mid-1980s, particularly spurred by the 1984 devastating drought and the famine that followed. The wide adaptability of the crop and the potential to produce more calories and food per area of land cultivated than all major cereals grown in Ethiopia were important factors in considering maize as part of the national food security strategy, including its inclusion under the government-led intensive agricultural extension program.

With increased production driving market prices down, maize became more affordable (e.g., relative to other staples such as teff and wheat) to rural and urban consumers. It is now increasingly used both separately as well as in mixed flour with other more expensive cereals in traditional Ethiopian diets. Maize is the most important staple in terms of calorie intake in rural Ethiopia. The 2004/5 national survey of consumption expenditure indicated that maize accounted for 16.7 % of the national calorie intake followed by sorghum (14.1 %) and wheat (12.6 %) among the major cereals (Berhane *et al.* 2011). Compared to the 1960s the share of maize consumption among cereals more than doubled to nearly 30% in the 2000s, whereas the share of teff, a cereal that occupies the largest area of all crops in Ethiopia, declined from more than 30% to about 18% during the same period (Demeke 2012).<sup>1</sup>

The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the stover as animal fodder and source of fuel for rural families. Approximately 88 % of maize produced in Ethiopia is consumed as food, both as green and dry grain. Maize for industrial use has also supported growing demand. Very little maize is currently used as feed but this too is changing in order to support a rapidly growing urbanization and poultry industry. Unlike its neighbor, Kenya, which imports a significant share for its consumption needs, Ethiopia has increasingly attained self-sufficiency in maize production since early this decade and even exports some quantities to neighboring countries (e.g., Sudan and Djibouti) in years of surplus production. If production can be significantly expanded, the potential for maize export to all the neighboring countries including Kenya is very high although the national demand is expected to continue to grow in the coming years.

The emerging maize green revolution for Africa that Byerlee and Eicher (1997); Byerlee and Heisey (1997); Byerlee and Jewell (1997); and Eicher and Kupfuma

(1997) envisioned in the 1990s has remained elusive so far but is showing strong signs of becoming a reality now in Ethiopia and perhaps in other countries of sub-Saharan Africa (SSA). There is evidence that the increased productivity and production of maize is also having a significant positive impact on poverty reduction (Dercon *et al.* 2009; Zeng *et al.* 2013). In this article, we bring together our collective knowledge and experience to bear on Ethiopian agriculture and beyond. We analyze the drivers behind this rapid increase in production and productivity of maize and attempt to draw lessons. These lessons and insights are drawn from a review of recent literature, analysis of existing data and from our own long-standing field experience in observing the process of change and productivity growth in Ethiopian agriculture.

## Methods

The major source of production and agricultural input data was the time series publications of the Central Statistical Agency (CSA) ([www.csa.gov.et](http://www.csa.gov.et)); organized and comprehensive data on inputs are available starting 2004, even though records on production have been going on for a much longer period. We also used unpublished data from the Agricultural Inputs Marketing Directorate of the Ministry of Agriculture (MOA). References in this study have also been made to published sources (e.g., MOA 1984; Tolossa and Ransom 1993; Nigussie *et al.* 2002; Worku *et al.* 2012; FAOSTAT 2015) and secondary sources to describe the development of maize that could have significant implications for the future direction of agricultural research and development in Africa.

Furthermore, meteorological data for sites, including Gonder (1973 m asl<sup>2</sup>; 1099 mm rainfall), Finote Selam (1980 m asl; 1300 mm), Bako (1700 m asl; 1316 mm), Jimma (1750 m asl; 1564 mm), Wolaita-Sodo (1854 m asl; 1275 mm), Hawassa (1980 m asl; 941 mm), Chiro [formerly Asebe-Teferi] (1792 m asl; 767 mm), and Haramaya (1900 m asl; 748 mm), which represent the major maize production zones in Ethiopia were obtained from the National Meteorological Agency ([www.ethiomet.gov.et](http://www.ethiomet.gov.et)).

The various data sets mentioned above were used to calculate percent area covered by improved maize varieties as well as areas that received inorganic and organic fertilizers in the various administrative regions. As CSA provides mineral fertilizers as di-ammonium phosphate (DAP) and urea in kilograms, we converted these data sets into actual nitrogen (N) and phosphorus (P) nutrients for standardized comparisons. Information on agro-ecological zones was obtained from the Ministry of Agriculture (MOA 2005). Comprehensive long term yield data were sourced from FAOSTAT (<http://faostat>).

<sup>2</sup> asl=above sea level

<sup>1</sup> The contributions of all other cereals have either declined or showed little change; the only exception was wheat, with about 21 % in the 2000s compared to about 18 % in the 1960s (Demeke 2012).

**Table 1** Major agro-ecological zones for maize in Ethiopia (MOA 2005)

Agro-ecological zone	Elevation (m)	Rainfall (mm)	Estimated area (%)	Administrative regions
Moist and semi-moist mid-altitudes	1700–2000	1000–1200	30	Parts of SNNPR, SW and W Oromia; W and NW Amhara; Ben Shangul-Gumuz (BSG)
Moist upper mid-altitudes	2000–2400	>1200	25	Central highlands; highlands of SNNPR, Amhara and Oromia
Dry mid-altitudes	1000–1600	650–900	20	Parts of SNNPR, SW and W Oromia; W and NW Amhara; parts of BSG
Moist lower mid-altitudes	900–1500	900–1200	15	Pockets of Amhara, Oromia, SNNPR and BSG
Moist lowlands	<900	900–1200	5	Gambella and parts of BSG
Dry lowlands	<1000	<700	5	Afar and parts of Oromia and lowlands of Somali

Total maize area was 1.52 million ha

[fao.org/site/567/default.aspx#anchor](http://fao.org/site/567/default.aspx#anchor)), whereas yield data for 2004 to 2013 were obtained from CSA ([www.csa.gov.et](http://www.csa.gov.et)).

To calculate the rate of yield gains over the years, the FAO data were regressed on years. The resulting regression coefficient was taken as an annual rate of yield gain. Additionally, regression analyses were conducted to determine the relationship between maize grain yield and N and P applications for the major maize growing administrative regions and at the national level, using the CSA data for 2004 to 2013. We also calculated the annual rates of growth using log estimates. The GLM procedure in Statistical Analysis System (SAS 2007) was used to generate Least Square Means of the total annual rainfall recorded from 1990 to 2012.

## The maize story in Ethiopia

Maize is the second most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socio-economic conditions typically under rain-fed production. The maize agro-ecologies in Ethiopia can be broadly divided into six major categories (MOA 2005), including Moist and Semi-moist mid-altitudes (1700–2000 m above sea level; 1000–1200 mm rainfall), Moist upper mid-altitudes (2000–2400 m; >1200 mm), Dry mid-altitudes (1000–1600 m; 650–900 mm), Moist lower mid-altitudes (900–1500 m; 900–1200 mm), Moist lowlands (<900 m, 900–1200 mm), and Dry lowlands (<1000 m, <700 mm). As presented in Table 1, the moist and semi-moist mid-altitude zones comprise the bulk of the national maize area in Ethiopia. These are mostly located in the SW and W Oromia, W and NW Amhara, parts of the Southern Nations Nationalities and Peoples Region (SNNPR), and Ben Shangul-Gumuz (BSG). Taken together, the Semi-moist and Moist ecologies cover about 75 % of the national maize production area whereas the dry ecologies cover the remaining 25 %.

Smallholder farms account for more than 95 % of the total maize area and production in Ethiopia. The farmers use animal traction for land preparation and cultivation; almost all

production is rainfed, irrigated areas accounting for only about 1 % of the total.

Smallholders across all 70 administrative units of Ethiopia, which include 59 zones and 11 special *weredas*<sup>3</sup> grow maize (Fig. 1). The top five maize producing zones of Ethiopia, according to the 2011 CSA data, are West Gojjam, Jimma, East Welega, West Welega and East Gojjam. Most of these fall into the mid-altitude (1500–2000 m asl) range.

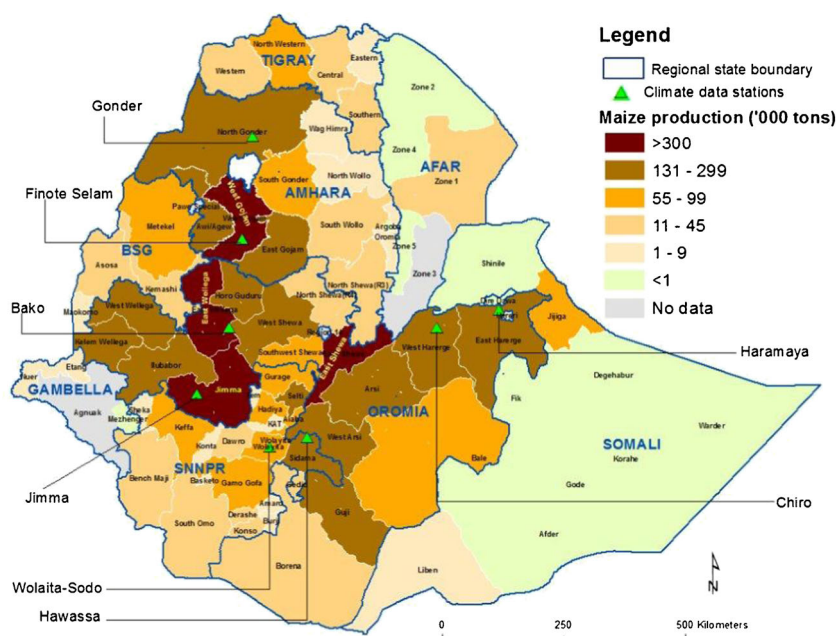
More than 9 million households, more than for any other crop, grow maize in Ethiopia (CSA, 2011–13 data). The annual rate of growth for the number of households cultivating maize grew at 3.5 % each year between 2004 and 2013, compared to 3.0 % for sorghum, 3.1 % for teff, 2.1 % for wheat, and 1.8 % for barley. At present, as a sub-Saharan country, Ethiopia has the fifth largest area devoted to maize but is second, only to South Africa, in yield and third, after South Africa and Nigeria, in production.

Maize currently occupies about 2 million ha with an average yield of upwards of 3 MT/ha (Fig. 2). National maize yields have doubled from about 1.50 MT/ha during the early 1990s to 3.23 MT/ha in 2013. Analysis of FAO data revealed that a highly significant ( $p < 0.0001$ ) annual yield gain of 68 kg/ha was recorded for maize in Ethiopia for the period 1990 to 2013. Only South Africa exceeded this figure (119 kg/ha/yr) in SSA whereas some countries such as Tanzania and Kenya registered negative growth. Ethiopia's figure is superior to Mexico (55 kg/ha/yr), China (55 kg/ha), and India (47 kg/ha/yr). Yield gains grew even faster (120 kg/ha/yr) between 2000 and 2013.

Despite the pockets of change across Africa, such change at the national level is a significant transformation in a region where a green revolution seemed largely unattainable (Howard and Mungoma 1997; De Groote et al. 2002; Smale et al. 2011; Smale and Olwande 2014). On average, maize area and productivity increased by 4.0 and 6.3 % pr annum, respectively, during the 10 years between 2004 and 2013.

<sup>3</sup> A *wereda* (also *spelt woreda*) is an equivalent of a county or a district

**Fig. 1** Distribution of maize production in Ethiopia. Source: based on CSA data for 2011 ([www.csa.gov.et](http://www.csa.gov.et))



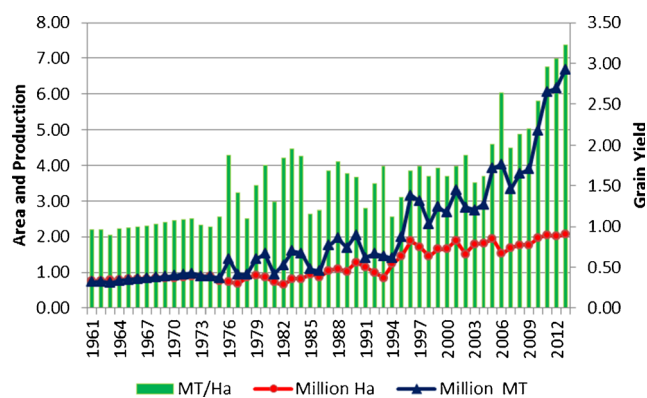
Similarly, the annual rate of growth for production during the same period was 10.5 %.

It is interesting to see that the increases in maize production in Ethiopia resulted more from increases in productivity rather than area expansion - i.e., the yield grew faster than the area (Fig. 2). The current performance of maize in Ethiopia compares favorably with the main maize producing countries in SSA (Fig. 3). Ethiopia is the only country in SSA outside South Africa that has attained >3 MT/ha yield; only Zambia and Uganda have achieved >2.5 MT/ha, followed by Malawi, with >2 MT/ha. The SSA average is about 1.8 MT/ha.

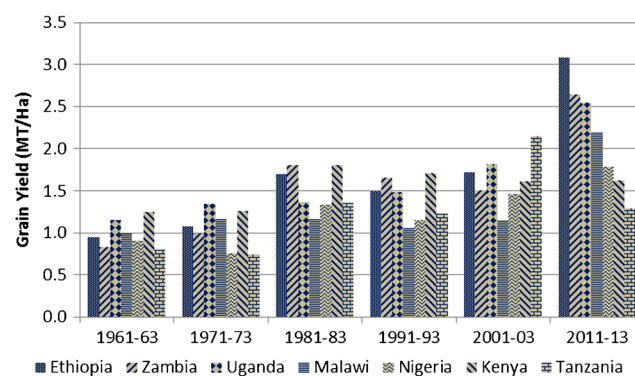
Largely because of the increasing demand (Rosegrant et al. 2001) driven by population growth and competitiveness of the crop, maize area in Ethiopia also doubled during the past two decades from 1 to 2 million ha. This increase in area came mainly from two sources. First, the traditionally sorghum-

growing smallholder farmers in the rift valley shifted to maize because of the weaver bird (*Quelea quelea*) invasion that resulted in the total destruction of sorghum in the early 1980s. The second driver of maize area increase was the adoption of maize by the traditional teff-growing farmers in north-central Ethiopia – particularly in West Gojjam, North Gondar, and other surrounding agro-ecologies – because of its high productivity achieved through new hybrids (starting with the hybrid BH140) and diversity in end-uses of maize. Unlike in the central rift valley, farmers here did not necessarily shift from teff to maize but rather expanded the area of the latter.

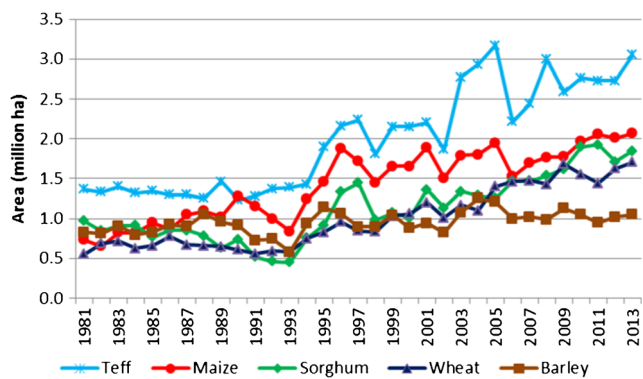
In general, the growth in the proportion of maize area was higher than all other major cereals over the last three decades (Fig. 4). For example, maize occupied roughly 16 % of the total cereals area in 1981–83 compared to 30 % for teff, 20 % for sorghum, 14 % for wheat, and 19 % for barley; the area occupied by maize, teff, sorghum, wheat and barley in 2001–03 was 24, 31, 17, 15, and 13 %, respectively. Currently teff, maize, sorghum, wheat and barley occupy 30, 22, 20, 17, and



**Fig. 2** Performance of maize in Ethiopia, 1961–2013. Source: constructed by the authors from FAOSTAT, accessed on 21/11/2014; the lines (Y1-axis) represent area and production whereas the yield (Y2-axis) is represented by the bars



**Fig. 3** Maize yield in selected countries of SSA. Source: constructed by the authors from FAOSTAT, accessed on 02/01/2015



**Fig. 4** Area occupied by major cereals in Ethiopia, 1981–2013. Source: constructed by the authors from FAOSTAT, accessed 29/11/2014). Please note that FAOSTAT lumps teff with other cereal data for Ethiopia

11 %, respectively, of the total cereal acreage of Ethiopia. It should be noted here that production of major cereals in Ethiopia remained stagnant in the 1960s and showed dramatic declines in the 1970s and 1980s due to major droughts and political conflicts.

## Maize transformation in Ethiopia

The expansion and productivity change in maize production in Ethiopia is attributable to multiple factors. These include a) increased availability of modern varieties, b) increased commitment to enhance farmer access to and use of modern inputs through better research-extension linkages, c) wider adaptability of the crop and modern varieties, d) better production conditions and low production risks and e) growing consumption demand and market access for producers to support market-based production to absorb surplus supply. We discuss some of these factors and draw lessons on the key drivers of change in the following section to show the relevance of similar processes of transformation in African agriculture.

### Maize research and development

Maize research and development in Ethiopia has gone through a number of changes over the last several decades, which marked critical periods in terms of driving the current change in production and productivity. We summarize the major ones in Table 2 below. Some of the key events that warrant specific mention include the 1984 major drought and famine that helped to increase the profile of maize in attaining national food security; the introduction of nationally developed hybrids adapted to the local production conditions in the late 1980s and early 1990s; the launching in 1993 of the government campaign, NEIP (National Extension Intervention Program) in partnership with Sasakawa Global 2000 (or SG2000) to increase food security; the introduction of a maize grain floor price in the early 2000s; the introduction of an

integrated systems approach for research and development by the Ethiopian Institute of Agricultural Research (EIAR) in the early 2000s (Abate 2006, 2007); and inclusion of maize in the commodity exchange in recent years. Earlier attempts made to introduce hybrids from Kenya were unsuccessful due to poor adaptation to the prevalent production systems and high seed price. Further details can be found in Table 2.

### Modern varieties (MVs)

Undoubtedly, the maize story in Ethiopia is largely homegrown and improved maize germplasm has played a key part in catalyzing change in production practices by replacing traditional varieties with input-responsive, stable and high yielding MVs. The Ethiopian NARS has released a total of 61 maize varieties between 1973 and 2013. The first locally developed hybrid (BH140, in the early- to intermediate-maturity group) was released in 1988, followed by a late- maturing hybrid (BH660) in 1993, and BH540 and the Pioneer Hi-bred Seed Ethiopia hybrid PHB3253 (marketed as Jabi) in 1995.

There was a total of 16 hybrids and 4 Open Pollinated Varieties (OPVs) under production in 2013 (Table 3). Hybrids accounted for 97 % while OPVs represented only 3 % of the total seed market. Furthermore, the Ethiopian seed market has been dominated by BH660 and BH540; the average age of 80 % of the currently grown varieties is more than 20 years. There are also hybrids that came into production between 2005 and 2008, but their amounts remain limited, with the exception of the Pioneer hybrids Shone and Agar (Table 3).

BH661, promoted under the auspices of the Drought Tolerant Maize for Africa (DTMA) project, is of particular significance because of its drought tolerance, resistance to major diseases, higher yield potential and wide adaptability. This variety is expected to replace both BH660 and BH540. The demand for foundation seed by seed companies of this new hybrid is rapidly growing. In 2012 Ethiopian Seed Enterprise (ESE) produced 6 MT of certified seed; by 2014 five companies, including Amhara Seed Enterprise (ASE), Avallo, ESE, Oromia Seed Enterprise (OSE), and Southern Seed Enterprise (SSE) produced nearly 2,900 MT.

Only four OPVs are at all common but their use is limited to the more drought-prone areas such as the central rift valley. The OPVs Melkassa2 and Melkassa4 have been used extensively in the last several years; two new ones (Melkassa6 and Gibe2) were recently introduced into the market and their use is expected to expand before getting replaced by higher yielding hybrids that are in the process of development.

### Uptake and diffusion of modern inputs

Maize inputs in Ethiopia include mainly improved seed and fertilizers. The use of pesticides (including fungicides,

**Table 2** Milestones in maize research and development in Ethiopia

Year	Event	Outcome/Consequences
1966	Establishment of EIAR (Apex body for National Agricultural Research)	Nationally coordinated, agro-ecological zone-based research launched; accelerated training of researchers; regional and international collaboration in AR&D initiated
1973	First releases of two improved varieties (A-511 and Alemaya Composite)	Farmers exposed to new, improved maize varieties (this was followed by an early maturing variety – Katumani - that remained popular until recent years)
1974	Major drought and famine (mainly northern Ethiopia)	Increased demand for food; massive food-aid inflow from abroad; the famine was the major rallying point by the military to overthrow Emperor Haileselassie
1976	Introduction of maize research for moisture stress (at Awassa College, southern Ethiopia)	Expansion of maize in lower rainfall areas (e.g., central rift valley)
1979	Establishment of ESE (Ethiopian Seed Enterprise)	Enhanced availability of improved/clean seed; savings on imported seed
1980	Establishment of multidisciplinary maize research team	Centers of excellence identified; more research centers built; international experts recruited through IDA loan; enhanced understanding of constraints
1982	Introduction of joint research and extension sites	Trials conducted under farmers' conditions; enhanced adoption of improved technologies
1984	Another major drought strikes	Tarnished image and wounded national pride; search for solutions and strategies; maize receives high priority
1985	Official start of National Variety Release Committee	Criteria for desirable traits and quality standards established; national commercial variety registry issued
1988	First release of a locally developed hybrid (BH140)	Increased potential to improve productivity (in mid- and lower altitudes)
1993	Release of BH660 (most productive and popular hybrid even at present)	Increased interest in maize adoption and production in the traditional growing areas with adequate rainfall; increased appreciation of for research by policy makers
1993	Government campaign for increased food production (in collaboration with Sasakawa Global 2000)	Increased demand for mineral fertilizer and improved seed; increased demand for extension
1995	Release of the hybrid BH540	Suitable variety for intermediate altitudes made available; expansion of maize production in non-traditional areas
1995	First private release by Pioneer of a hybrid, Jabi (PHB3253)	Increased availability of improved variety seed; more options for farmers
1995	Launching of NEIP (National Extension Intervention Program) using what is known as PADETS (Participatory Demonstration and Extension Training System) approach	Improved coverage of extension services; increased demand for extension personnel
1996	ARTP (Agricultural Research and Training Program) launched	Increased research capacity; increased training and deployment of extension staff
2001	Maize prices plummet	Doubts whether farmers would be still interested in maize production in light of market failure
2002	Government fixes floor price for maize	Improved confidence in maize production
2004	EIAR leads the so-called "Ejj-Le-Ejj (hand-in-hand) campaign	Partnership among AR&D stakeholders strengthened; promotion and scaling up/out available technologies intensified; adoption of improved technologies enhanced
2007	Partnerships with Drought Tolerant Maize for Africa (DTMA) and the Program for Africa's Seed Systems (PASS) projects launched	Drought and other stress tolerant varieties made available to smallholder farmers; frequency of variety releases and commercialization enhanced; increased involvement of private sector in seed production; increased availability of improved maize seed
2012	Maize traded on ECX (Ethiopian Commodity Exchange)	Farmers benefit from improved market

**Table 3** Maize hybrids and Open Pollinated Varieties (OPVs) on the seed market and their relative importance in Ethiopia (as at December 2013)

Release name	Variety name	Release year	Age (years)	Owner	Percent of total seed production
Hybrids					
Limu	P3812W	2012	1	Pioneer	0.67
Shala	P2859W	2011	2	Pioneer	0.24
BH661	BH661	2011	2	EIAR	0.04
Wabi	AMH760	2011	2	EIAR	0.08
Agar	P30G79	2008	5	Pioneer	1.96
Morka	UCBS1C2	2008	5	EIAR	0.10
BHQPY545	BHQPY545	2008	5	EIAR	0.05
Wenchi	AMH850	2008	5	EIAR	0.02
Shone	P30G19	2006	7	Pioneer	7.67
BH543	BH543	2005	8	EIAR	5.78
Argane	AMH800	2005	8	EIAR	0.03
BH542	BH542	2002	11	EIAR	0.16
BH540	BH540	1995	18	EIAR	21.31
Jabi	PHB3253	1995	18	Pioneer	2.38
BH660	BH660	1993	20	EIAR	51.40
BH140	BH140	1988	25	EIAR	5.02
Sub-total					96.92
OPVs					
Gibe2	ZM721	2011	2	EIAR	0.01
Melkassa6	Pool 15C7 QPM	2008	5	EIAR	0.25
Melkassa4	ECA-EE-36	2006	7	EIAR	1.73
Melkassa2	ZM521	2004	9	EIAR	1.10
Sub-total					3.08

Varieties are from the National Variety Registry of MOA; percentages are calculated by the authors from MOA (unpublished data)

herbicides and insecticides) is insignificant and available data are sparse. Therefore, below we only analyze available data on the use of improved seed and fertilizers.

### Improved seed

In order to see the patterns of diffusion across the country, we conducted an analysis of CSA data<sup>4</sup> on use patterns of improved seed across major maize growing administrative regions of Ethiopia – viz. Amhara, BSG, Oromia, SNNP, and Tigray. Owing to the size of maize area, Oromia, followed by Amhara and SNNP, have the largest amount of improved seed usage.<sup>5</sup> The share of total MVs used in Oromia region during 2010–12 was 49 % of the total; Amhara and SNNP accounted

for 33 and 18 %, respectively, with BSG and Tigray both receiving <1 % each.<sup>6</sup>

Table 4 depicts the percent area coverage by MVs in Ethiopia between 2004 and 2013. The area covered by MVs varied according to regions and years. The Amhara Region has shown consistently higher percentages of coverage through the 10 year period. For example, the area under MVs was 24 % in 2004, compared to 55 % 10 years later. This was followed by SNNP and Oromia, in that order. The national average also followed consistent upward trends, especially over the last 5 years. The national average maize area under MVs in 2013 was 40 %, compared to 16 % in 2004. This is a far cry from reports in the distant and recent past (MOA 1984; Langyintuo et al. 2011; Spielman et al. 2013). Most recent studies and adoption monitoring surveys of DTMA suggest that the total maize area covered by MVs is more than 65 % (CIMMYT 2014) but these have mostly

<sup>4</sup> The CSA data do not include recycled seed.

<sup>5</sup> Oromia, Amhara, and SNNP account for 54, 25, and 14 %, respectively, of the total maize production of Ethiopia whereas Tigray and BSG cover about 2 % each.

<sup>6</sup> Unpublished data from MOA.

**Table 4** Percent maize area covered by modern varieties in selected administrative regions of Ethiopia (2004–13)

Region	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Amhara	24	26	29	37	35	35	45	50	47	55
SNNP	17	23	10	17	20	18	25	33	32	43
Oromia	15	19	14	15	16	–	25	25	33	38
BSG	3	8	0	6	8	–	8	14	10	17
Tigray	1	2	0	0	1	–	1	1	2	3
Ethiopia	14	20	15	20	20	23	29	33	34	40
Million ha	1.39	1.52	1.69	1.77	1.77	1.77	1.96	2.05	2.01	2.00

Constructed by the authors from CSA ([www.csa.gov.et](http://www.csa.gov.et))

Data for Oromia, BSG and Tigray were inconsistent and left out of the calculation; the national figure is a weighted average of Amhara and SNNP

Total area of maize for the year

sampled only limited households in the central rift valley and cannot reflect the national picture.

The federal government-owned company ESE has been the largest supplier of foundation and certified seed in the country until recently. Regional government-owned companies, including the ASE, OSE, and SSE have also entered the seed market in recent years.

The role of the private sector has been limited in the past and private seed companies have been affected by limited technical capacity, lack of land and capital, inadequate access to breeder seed of publicly-bred varieties, less competitive seed pricing, and lack of clarity on freely marketing their materials (Alemu 2010; Alemu et al. 2010; Spielman et al. 2013).

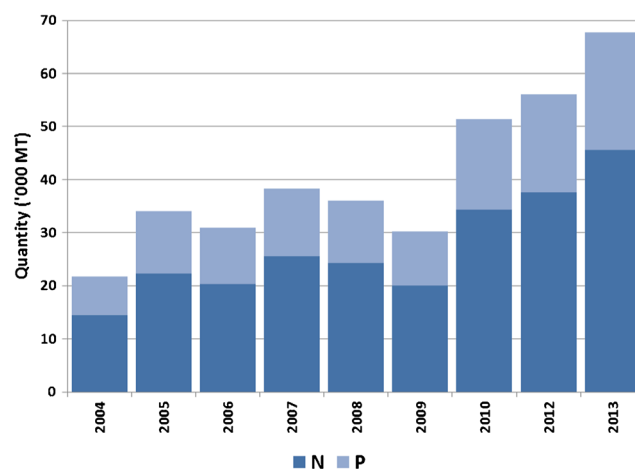
Pioneer Hi-Bred Seed (Ethiopia)<sup>7</sup> has been an important supplier of hybrid seed since the mid-1990s; its annual average market share between 2004 and 2013 was 21.1 %. National small seed companies and community-based organizations (CBOs) such as Meki-Batu Union (MBU) have also entered the maize seed market in recent years. The combined seed market share of parastatals (ESE, ASE, OSE, and SSE) in 2014 was 63 %, compared to 31 % for Pioneer Hi-Bred Seed (Ethiopia), 4 % for CBOs, and 2 % for all national small seed companies combined. MBU is the only CBO marketing maize seed in Ethiopia. Small national seed companies marketing improved maize are represented by Avallo, Ano Agro-Industry, Gadisa Gobena Farm, Hadia, and Ethio VegFru. The southern Africa-based regional seed company, SeedCo, has recently started marketing the maize variety Duma (SC 403) through its local representation by Alemayehu Makonnen Farm. Two new seed companies from India – Advanta Seeds and CP Seeds registered new maize varieties in 2013 but have not started marketing them.

<sup>7</sup> It should be noted that this company does not have a breeding program in Ethiopia; they test existing hybrids bred in southern Africa and release the best.

## Fertilizer use

Historically, Ethiopian farmers have used organic fertilizers (such as farmyard manure, compost, crop residue, and household refuse) for agricultural production. Today, commercial fertilizer use is the dominant input that goes with modern varieties. All of Ethiopia's mineral fertilizer is imported. Based on CSA data for 2004 to 2013, we estimated that about 23 % of the total mineral fertilizer in Ethiopia is applied to maize. Mineral fertilizers in Ethiopia are marketed as DAP (di-ammonium-phosphate) and urea. Potassium fertilizers are not considered to be important in Ethiopian agriculture, as there is a perception that Ethiopian soils are not deficient in this element. Historical data show that, on average, DAP accounts for about 64 % of the total volume of fertilizer used, with urea accounting for the remaining 36 %. We converted the two products into N and P equivalents and report here the total N and P consumption, the area fertilized and application rates.

Figure 5 shows the overall N and P consumption by maize in Ethiopia between 2004 and 2013. The total nutrient



**Fig. 5** N and P consumption by maize in Ethiopia. Source: Constructed by the authors from CSA data ([www.csa.gov.et](http://www.csa.gov.et)). Data for 2011 were incomplete and discarded



**Table 5** Percent maize area covered by N and P fertilizers in selected administrative regions of Ethiopia

Region	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Tigray	88	80	78	78	82	83	88	89	89	92
Amhara	84	81	83	82	82	83	86	87	90	85
Oromia	49	53	51	50	50	–	59	59	66	67
SNNP	48	53	45	49	49	49	54	64	54	61
BSG	36	44	42	41	39	33	41	38	42	41
Ethiopia	56	59	57	56	57	62	65	66	68	69

Constructed by the authors from CSA ([www.csa.gov.et](http://www.csa.gov.et))

Data for Oromia were inconsistent and left out

consumption on maize in 2013 was 68,000 MT compared to 20,000 MT in 2004 – a more than 3-fold increase. In other words, fertilizer consumption increased at an annual rate of about 12 % over the 10 years. Overall, N and P accounted for approximately 67 and 33 % of this, respectively.

Oromia and Amhara accounted for 43 % each of the total nutrient consumption, with SNNP, Tigray and BSG receiving about 11, 2 and 1 %, respectively, of the total fertilizer in 2013.

Table 5 depicts the average maize area covered by mineral fertilizers in different regions of the country between 2004 and 2013. An average of 69 % of all maize grown in 2013 in Ethiopia received some amount of mineral fertilizer application, compared to 56 % in 2004. There were appreciable differences in the maize area receiving fertilizer application among the regions. For example, about 92 % of the area planted to maize in Tigray and 85 % in Amhara received fertilizer in 2013 whereas Oromia, SNNP, and BSG showed lesser area coverage of 67, 61, and 41 %, respectively. In other words, the fastest growth in the area covered by mineral fertilizers was in Oromia (with an annual growth rate of 3.0 %), followed by SNNP (2.6 %) and Tigray (1.3 %); annual growth

rates in the maize area covered by fertilizer for Amhara (0.7 %), and BSG (0.1 %) were less appreciable. The overall annual growth rate for Ethiopia was 2.3 %. The relatively lesser growth rate in area coverage for Amhara is because it was already high even in 2004 (Table 5).

Application rates showed appreciable differences across regions and years both for the overall national average as well as for those who do apply fertilizers (Table 6). The overall application rates more than doubled for all administrative regions and the country as a whole between 2004 and 2013; application rates for those who do apply fertilizers changed little over the course of the 10 years, perhaps with the exceptions of Amhara and SNNP. These two regions showed the fastest annual rates of growth of application rates both for the national average (and those who do use fertilizers) of 8.7 % (4.5 %) and 9.7 % (4.2 %), respectively.

The national average for all growers is 34 kg/ha of N and P nutrients. This falls short of the NEPAD recommendation of 2006 (also known as Abuja Declaration) that suggested 50 kg/ha (Wanzala 2011). Obviously, the national application rate of 68 kg/ha in 2013 by those who use fertilizers (and throughout

**Table 6** Application rates (kg/ha) of N and P nutrients on maize in selected administrative regions of Ethiopia

Region	2004	2005	2006	2007	2008	2009	2010	2012	2013
A: Overall maize growers									
Amhara	26	35	31	43	41	50	48	47	57
Oromia	14	21	17	16	15	–	20	25	29
SNNP	11	17	13	21	18	19	24	21	28
Tigray	5	0	5	6	4	7	9	19	19
BSG	5	12	9	10	7	8	10	14	13
Ethiopia	16	22	18	22	20	–	26	28	34
B: Exclusively those applying fertilizers									
Amhara	57	70	62	82	83	92	79	74	91
Oromia	58	62	57	61	61	51	52	54	60
BSG	49	70	65	69	56	88	62	65	58
SNNP	37	42	40	58	54	56	54	49	53
Tigray	36	0	36	34	28	32	31	45	44
Ethiopia	54	62	56	68	68	71	61	59	68

Calculated by the authors from CSA ([www.csa.gov.et](http://www.csa.gov.et))

Data for 2011 were incomplete and left out

the 10 years' period) is higher than the NEPAD recommendation. However, both of these still fall short of the national recommendation of about 110–130 kg/ha of N and P nutrients (or the equivalent of 150–200 kg/ha of urea and 100–150 kg/ha of DAP), depending on the variety (higher rates are recommended for hybrids). This suggests that, most often, farmers do not always implement the whole package of technologies. The implication of this is that priority for policy makers must be expanding fertilizer use to areas that have not been covered previously, which at present account for more than 30 % of the total maize area in Ethiopia.

We also observed appreciable variation among the regions in the use of organic fertilizers on maize. Application rates were extremely low – averaging about 45 kg/ha - and showing little change over the 10 years (not shown in the table). However, there was a persistent decline in the percent area covered by organic fertilizers across the regions and years (Table 7). The national average declined from 27 % in 2004 to 18 % in 2013, an average annual negative growth rate of 2.9 %. This has been the case for all regions but some were more seriously affected than others. For example, the annual growth rates for SNNP, Amhara, BSG, and Oromia declined by 6.2, 4.9, 3.8, and 1.3 %, respectively. Tigray maintained its highest percentage of area under organic fertilizers over the years but the 2013 level was much lower than that in 2004 (Table 7).

The declines in the area covered by organic fertilizers may be attributed to one or both of two things. First, there has been a general decline in the unit area of land available for animal grazing, particularly in the highlands, over the last several decades and therefore associated declines in the number of animals (cattle in particular) kept per family. Second, cow dung is widely used as fuel by farmers or sold as an important source of immediate income. It is also possible that the availability of mineral fertilizers at affordable prices might have also contributed to the decline in the use of organic fertilizer.

To quantify the contribution of the various factors to increases in maize productivity in Ethiopia, we ran regression analyses using grain yield as a dependent variable and each factor as an independent variable (Table 8). We observed significant correlations between maize yield with percent area

under MVs, percent area under N and P fertilizers, N and P application rates for all maize growers, and percent area under organic fertilizer. Correlations between yield and application rate by those using fertilizers were non-significant for Ethiopia and all regions.

There were obvious regional differences for many of the variables tested. For example, area under MVs was significant at  $P < 0.001$  probability level for Ethiopia, Amhara and SNNP whereas it was significant at  $P < 0.01$  for Oromia and BSG and non-significant for Tigray. Area under N and P fertilizer was highly significant ( $P < 0.01$ ) for Ethiopia and SNNP, significant ( $P < 0.05$ ) for Oromia and Amhara and non-significant both for Tigray and BSG. The overall N and P application rate was highly significant for Ethiopia ( $P < 0.001$ ) and Amhara ( $P < 0.01$ ); significant for Oromia, SNNP and BSG ( $P < 0.05$ ), and non-significant for Tigray (Table 8).

There was a highly significant negative correlation between yield and area under organic fertilizer for Amhara ( $P < 0.001$ ), and SNNP and BSG ( $P < 0.01$ ), and significant correlation at the national level ( $P < 0.05$ ). Correlations for Tigray were non-significant (Table 8). Declines in the area covered by organic fertilizers may be a consequence of increases in the availability and use of inorganic fertilizer.

## Drivers of change: lessons and insights

It is perhaps safe to conclude that the major driver of the rapid growth in the production and productivity of maize in Ethiopia is the increased use of MVs, coupled with area covered by N and P fertilizer and increased application rate. However, as discussed above, it is also fair to say that there were several other contributing factors to this success. Several of these came together for maize research and development in Ethiopia. In terms of scalability of the process to reach new areas, it is important to identify and draw on those lessons and insights that made this dramatic change in Ethiopia possible. Here we provide highlights of those important enabling conditions.

First, Ethiopia has a well-organized, nationally coordinated agricultural research and development (AR&D) system with

**Table 7** Percent maize area covered by organic fertilizers in selected regions of Ethiopia (2004–13)

Region	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Tigray	74	–	65	59	66	60	56	55	46	48
Amhara	37	31	32	29	32	27	24	28	25	20
Oromia	24	19	22	23	25	17	21	23	19	19
BSG	26	24	28	26	27	25	24	20	20	18
SNNP	18	13	13	13	16	14	9	11	11	8
Ethiopia	27	22	24	24	26	20	21	23	20	18

Constructed by the authors from CSA ([www.csa.gov.et](http://www.csa.gov.et))

**Table 8** Regression of maize grain yield on various factors across selected administrative regions of Ethiopia (2004–13)

Factors	Parameters	Administrative Regions					
		Ethiopia	Oromia	Amhara	SNNP	Tigray	BSG
Area under MVs (%)	<i>b</i> -value	0.50***	0.40**	0.40***	0.49***	1.58	0.84**
	R <sup>2</sup>	0.84	0.67	0.86	0.78	0.11	0.73
Area under NP fertilizer (%)	<i>b</i> -value	0.51**	0.32*	1.04*	0.74**	0.51	0.20
	R <sup>2</sup>	0.60	0.47	0.34	0.65	0.30	0.02
NP application rate (kg/ha) – overall maize growers	<i>b</i> -value	0.77***	0.56*	0.39**	0.79*	0.47	1.05*
	R <sup>2</sup>	0.09	0.06	0.13	0.27	0.22	0.01
NP application rate (kg/ha) – exclusively those applying applying fertilizers	<i>b</i> -value	0.18	−0.13	0.22	0.21	0.08	−0.05
	R <sup>2</sup>	−0.09	−0.12	0.23	−0.04	−0.08	−0.13
Area under organic fertilizer (%)	<i>b</i> -value	−1.31*	−0.62	−0.86***	−1.56**	−0.05	−1.31**
	R <sup>2</sup>	0.52	0.10	0.81	0.73	0.06	0.73

\*, \*\*, and \*\*\* denote significant difference from zero at  $p < 0.05$ ,  $p < 0.01$  and  $p < 0.001$  levels, respectively (source: calculated by the authors from CSA [www.csa.gov.et](http://www.csa.gov.et))

clearly defined vision and responsibilities. Moreover, Ethiopia's AR&D system is not dependent on external funding. Government support for research has been consistent throughout the years. Ethiopia's spending on AR&D grew by 10.9 and 16.5 % per year between 1991 and 96 and 1996 and 2001, respectively; similarly, the number of researchers also grew at 8.7 and 10.3 % during the same period (Beintema 2011). Ethiopia spent 16.5 % of its total expenditure in agriculture in 2005 (Fan and Saurkar, undated). The research system introduced hybrid maize for the first time in the early 1990s. The introduction of hybrid maize came at a very opportune moment when the government was about to launch its program on improved food security and ending extreme poverty. These efforts demonstrated the importance of locally-led innovations and appropriate technologies in igniting the process of a green revolution in Ethiopia.

Second, the Government support and commitment for agricultural extension in Ethiopia. These created farmer awareness<sup>8</sup> of available technologies and enhanced knowhow in many major growing regions, especially on major and priority staple crops such as maize, wheat, teff, and legumes, which has led to improvement of food security across the country. Whereas public extension systems across SSA have declined significantly over the years, Ethiopia has trained nearly 63,000 young men and women as agricultural extension agents throughout the country starting in the first half of 2000 (Davis et al. 2009). Ethiopia's extension agent to farmer ratio is estimated at 1:476, compared to 1:1000 for Kenya, 1:1603 for Malawi, and 1:2500 for Tanzania (Kassie et al. 2015). This has had a significant effect in creating awareness of the new

<sup>8</sup> The international NGO SG2000 played a significant role in creating awareness by smallholder farmers about improved maize and other major cereals technologies.

technologies by smallholder farmers and enhanced adoption, thereby contributing to poverty reduction (Dercon et al. 2009; Dorosh and Thurlow 2013; Spielman et al. 2013; Zeng et al. 2013). Working with 15 villages in Ethiopia, Dercon et al. (2009) reported that receiving at least one extension visit reduces poverty by nearly 10 % and increases consumption by more than 7 %.

Third, whereas farmers historically received seasonal input credit for seed and fertilizer through cooperatives and development banks, this has changed significantly over time. Following the structural adjustment and liberalization policies implemented since the early 1990s, there has been no direct input or credit subsidy provided by the government. Given the high input costs for smallholder farmers to benefit from integrated input packages, seasonal credit is important for the relaxation of liquidity constraints. Most of the credit for fertilizer, improved seed and agrochemicals comes from farmer cooperatives, the offices of agriculture and rural development, and the private sector. In 2009, the cooperatives provided about 60, 38 and 12.5 % of the credit for fertilizer, improved seed and agrochemicals, respectively (Gebremedhin et al. 2009). The role of development banks as sources of direct credit to farmers has declined significantly.

Fourth, EIAR introduced a paradigm shift in AR&D in the early 2000s towards an innovation systems approach that is based on active participation of farmers in technology development and diffusion and involvement of partnerships with several actors along the value chain (Abate et al. 2011); agricultural technology scaling was championed by the top leadership and started to show results in terms of enhancing the relevance of research itself and approaches for linking research with smallholders.

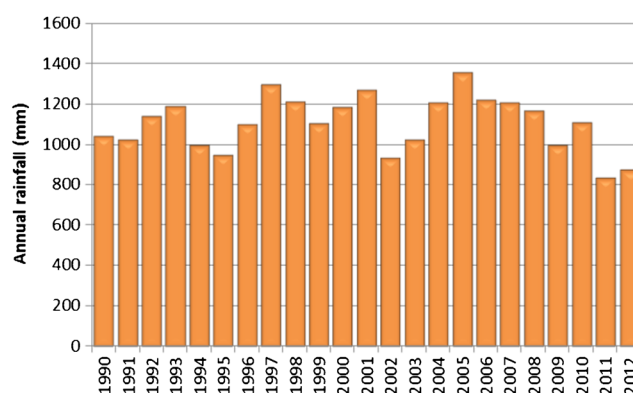
Fifth, through proper targeting of the technology, maize varieties were adopted by farmers in north-central and

northwest Ethiopia where the crop had not been grown traditionally on such a large scale; today these areas are among the most highly productive and largest producers of maize in the country. As new adopters, the farmers in these areas have the advantage of adopting the most modern methods of production – planting in rows, increased use of MVs and fertilizer, and good crop management.

Sixth, increased liberalization and investment in marketing systems, including farmer cooperatives and infrastructure development in rural areas has created opportunities to remedy traditional market failures as farmer coops, agro-dealers, traders and other service providers increasingly connected the remote producing regions into the national economy. A hard lesson was learned at early stages about the importance of market development and commercialization when maize prices collapsed in 2001/02 following a bumper harvest the previous year. In the absence of storage and processing facilities, farmers were forced to sell maize at throwaway prices. This made it abundantly clear that productivity change cannot be sustained without commensurate interventions to improve the marketing systems. The increased liberalization and participation of both the private sector and farmers' cooperatives in grain marketing has reduced the market risks for farmers and fueled the uptake of modern technologies (Bernard and Spielman 2009; Gebremedhin et al. 2009). More recently, maize has also been included along with other crops under the commodity exchange (ECX) system, further reducing the problem of asymmetric information and transaction costs through adoption of harmonized standards and warehouse receipt systems. The overall impact of this on cereal marketing in Ethiopia is yet to be evaluated.

Finally, the human effort has benefited from adequate rainfall and absence of extended drought over the last two decades (Fig. 6)<sup>9</sup> affecting large production regions similar to those of the mid-1970s and early 1980s. As shown in Fig. 6, the national average annual precipitation varied from 829 to 1352 mm for 23 years, with differences among years being not statically significant. This has helped the continued growth of maize production and productivity. How this will play out in the future under climate variability and change is uncertain. Farmers will need to adopt sustainable intensification options along with modern inputs to cushion themselves from such shocks (Shiferaw et al. 2014b).

The lessons for policy makers in Ethiopia are obvious – maize has demonstrated that productivity change is achievable: indigenous innovation and investment in agriculture are paying dividends and they need to be expanded to large areas which have not yet benefited from these game-changing research products. This requires further strengthening of the



**Fig. 6** Average annual rainfall for maize growing areas of Ethiopia (source: constructed by the authors from National Meteorological Agency data; sample station names are shown in Fig. 1)

research, extension and input supply systems through increased investment in generating new products, enhancing the use of home-grown research results, giving recognition to outstanding researchers, retaining experienced researchers and increasing competitiveness in the delivery of quality seed, complementary inputs and services to farmers. The maize story has clearly shown that technology alone will not lead to transformation; farmers will need access to credit, extension and market services to drive and benefit from sustained productivity growth. The lesson for other African countries is the fact that there are no shortcuts to increasing agricultural production and productivity; long-term and sustained investment is the key to achieving that goal, as seen here for maize, and for other crops such as legumes (Abate et al. 2011) and wheat (Shiferaw et al. 2014a; Zeng et al. 2013).

## Conclusions and policy implications

This study has shown that maize area and yields in Ethiopia have doubled since the early 1990s, making it feasible for national yields to reach more than 3 MT/ha which is significantly higher than the average for SSA. This change and transformation were fueled through indigenous innovation processes ranging from development of widely adapted and profitable varieties and hybrids, increased investment in public extension systems, seed and fertilizer supply and improved access to markets for smallholder producers in the outlying areas. This has clearly shown that maize can be a model for scaling agricultural innovations to achieve locally driven transformation to greatly improved productivity.

Despite the significant changes, there are unexploited opportunities for further increasing maize productivity and production in Ethiopia. Most importantly, a significant portion of the maize area is yet to be reached with modern innovations and several new hybrids are yet to be integrated into the seed production and extension systems. Exploiting these potentials will require replacing the old varieties such as BH140, BH660

<sup>9</sup> Please note that the seasonal average rainfall between 2003 and 2012 was always greater than 800 mm – adequate for maize production – provided that it is well distributed.

and BH540, which are still dominating the seed system; increased participation of private seed companies in the production and marketing of both foundation and certified seed; expanding the use of improved varieties; and increasing both the application rate and the share of area under mineral fertilizers. These will require addressing some of the remaining handicaps that reduce farmer access to modern varieties, inputs and services. Some of the institutional and policy issues raised by several authors, especially around the seed system (e.g., Alemu 2010; Alemu et al. 2010; Dorosh and Rashid 2013; Rashid et al. 2013; Spielman et al. 2013), have been changing, albeit slowly, through partnerships with the national program and regional initiatives such as DTMA, Program for Africa's Seed Systems (PASS), and other bilateral programs. We highlight below some of the key issues, including the need for variety replacement, addressing issues related to seed systems, raising the level of input use, and maintaining a critical mass of researchers.

The first issue is increased transformation and modernization of the extension system. The public sector extension programs currently coordinate the provision of credit and the supply of inputs, including seed, fertilizer and credit. Part of this service needs to be privatized (including farmers' co-ops) so that extension workers can focus on farmer education and innovation. The conventional top-down and supply-driven approaches for extension still remain across the country and this needs to quickly give way to provision of efficient services in terms of information, knowledge, and skills, and facilitation of linkages with other institutional support services of input supply, credit service, and output marketing (Gebremedhin et al. 2009). In a competitive environment, farmers' cooperatives can play a greater role in enhancing farmer access to local public goods (extension, market information) and services (credit and rural finance), especially when there are no alternative providers (e.g., remote villages).

The Ethiopian farmer cannot rely on varieties that are, or close to, 20 years old, mainly BH660 and BH540, which accounted for nearly 73 % of seed produced of all varieties in the country in 2013. There are reports that these hybrids are deteriorating in their reaction to diseases and their yield performance. BH140 was released more than 25 years ago and was still in use in 2013. Proven technologies with high adaptability and productivity potential need to reach farmers both to enhance competitiveness and build resilience in the face of climatic and market-induced shocks.

There are a good number of new hybrids and a couple of OPVs released within the last 5 years (Table 2) and entering the seed system, but their seed production and use needs to be accelerated. Emphasis should be put on the promotion and inclusion of high-yielding and low-risk varieties that have been released more recently (e.g., BH661, MH130, MH138Q, MH140, BH546, BH547, and Gibe-2).

Initiatives are being undertaken by MOA to implement the "direct seed marketing"<sup>10</sup> – i.e., private seed companies can sell their seed to farmers directly even beyond their immediate vicinities but there is a strong need for a more inclusive approach; the role of the private sector is crucial to making this approach more effective. Increased access to modern inputs through improved seed systems and better access to credit and markets will reduce seed recycling and encourage farmers to invest in fresh and high quality seed. Recycling of seed (including maize hybrids) is a common problem, partly because of credit and capital constraints, and partly due to inadequate supply of modern varieties.

One major factor limiting increased production and use of improved seed in Ethiopia is the inadequate quantity and quality of foundation seed (FS). Currently, the public sector, more specifically, the research centers at Bako and Melkassa and ESE are responsible for FS production. Mechanisms need to be established to help expand FS production by the private sector. The private sector should be encouraged and supported to include FS production into their seed business portfolio.

As stated earlier, the overall fertilizer application on maize in Ethiopia has shown significant growth over the last decade. The consumption rate grew at more than 12 % per annum between 2004 and 2013, in comparison to the SSA average of 3.8 % (between 2004 and 2012). Ethiopia has one of the fastest growth rates of fertilizer usage in SSA. However, the country needs to make every effort towards achieving the Abuja Declaration of 50 kg/ha fertilizer use – from its current figure of about 34 kg/ha. The declining trend of organic fertilizer application on maize should be of concern to researchers and policy makers alike; there is urgent need to find mechanisms to reverse the current condition (e.g., through rotations and intercropping with legumes and manure application).

Finally, although it has taken substantial time and more needs to be done yet, the recent trends in maize productivity and diffusion of modern inputs clearly indicate that Ethiopia is now on track to consummate the full potential for productivity change and green revolution. As popular as it is, maize certainly offers these possibilities for dramatic improvement in food security and can become an example for other crops to emulate. The homegrown research, institutional support and sustained commitment to agricultural research and development are the key drivers of this change. Hence, it is essential to progressively improve access to and effectiveness of extension and marketing services and continue to increase the critical mass of researchers and retain highly skilled and qualified scientists by providing appropriate incentives if further advances are going to be made in improving the productivity of maize and other crops in a sustainable manner.

<sup>10</sup> Past regulations restricted seed sales by private companies to government designated areas or parastatals.

The rapid growth in population and urbanization will increase the demand for more food as well as for industrial and other uses of maize in Ethiopia. Consequently, maize will remain a strategic crop to meet this demand in the foreseeable future. The rapid emergence of new indigenous seed companies, coupled with the continued generation of a large number of productive hybrids adapted to the diverse production systems and socio-economic circumstances will enhance competitiveness of the seed system, which in turn will further contribute to sustained maize productivity gains in Ethiopia.

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