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Adoption of Technologies and Crop Productivity in Ethiopia: The Role of Agricultural Information

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Abstract

Understanding how diffusion of new agricultural technology works and investigating the role of agricultural information in this process has an important contribution to inform policy and improve how diffusion policies function. Using a unique and two-round panel dataset, this study attempts to identify the type and channels of acquiring, agricultural information; and whether this information helps them in their decisions to adopt new technologies, and how using such inputs is translated into better and higher yield. The study suggests that community gatherings are an important source of agricultural information and encourage wheat and barley farmers to use more modern inputs such as chemical fertilizers and improved seeds. On-farm services of extension workers were also instrumental in encouraging wheat farmers to use more chemical fertilizers than wheat farmers who didn't benefit from such services. Moreover, the result also reveals that wheat yield responded to the use of chemical fertilizers, improved seeds and other chemicals (pesticides, fungicides etc.), while yield for barley farmers responded only to chemical fertilizers and other chemicals. Although a significant number of farmers reported that they use mass media as a source of information, the data doesn't support any link between the use of media and application of modern inputs. Moreover, a link between visiting demonstration plot and application of chemical fertilizers and improved seeds couldn't be established partly due to the fact that only few farmers used these plots as a resource in their decisions due to the limited number of demonstration plots. These findings suggest that community meetings and on-farm advisory services have the capacity to convince farmers to use new and improved technologies such as chemical fertilizers and improved seeds and need to be expanded. Furthermore, demonstration plots should be expanded to allow farmers access to a first-hand and experimental showcase of modern agriculture.

Introduction

Central to the transformation and commercialization of the Ethiopian agriculture is to increase smallholder productivity of the sector. Official sources from the Central Statistics Agency (CSA) indicate that productivity grew in Ethiopia for the last one and half decades. Across the main cereals, productivity has been growing in unison. Production increased from a level of 14 and 11 quintals per hectare in 1997 to 25 and 20 quintals per hectare in 2016 for wheat and barley, respectively. Growth has been steady, with a temporary decrease in some years.

Despite this productivity growth, performance still falls short of the target set in order to transform smallholder agriculture. The major factor for the short fall in achieving the planned level of agricultural productivity is related to the coverage and quality of implementation of agricultural extension system (National Planning Commission, 2016). As part of the general agricultural innovation system, the Ethiopian agricultural extension system disseminates available technologies and farming practices to end users (i.e. smallholder farmers) in the system. Well-functioning agricultural innovation system is crucial for smallholder farming in Ethiopia. Investments in research and development (R&D) of new agricultural technologies and their diffusion have been a steady component of the Ethiopian agricultural development strategy to improve and maintain productivity. Conducting R&D in high yielding varieties for selected crops, imports and distribution of chemical fertilizers and pesticides and an expansion of extension advisory services have been part of this effort to enhance crop productivity.

On average, 2.5 million quintals of chemical fertilizers were utilized annually during the period 2003-2015 for meher (i.e. main) season. In the same period, 0.2 million quintals of improved seeds were used; and 1.6 million ha of land was covered by pesticides and extension service each (Table 1).

Table 1:Actual utilization of modern inputs by small holder farmers (in millions): 2003-2016

Period	Modern inputs	Number of holders	Are covered (ha)	Quantity utilized (quintals)
2003/04-2009/10	Chemical fertilizer-DAP & Urea	2.5	1.5	2.4
	Improved Seeds	1.4	0.4	0.2
	Pesticides	2.6	1.5	-
	Extension package	2.5	1.5	
2010/11-2015/16	Chemical fertilizer (DAP & Urea)	3.9	2.4	3.4
	Improved Seeds	2.2	0.7	0.4
	Pesticides	3.5	2.2	-
	Extension package	3.6	2.2	

Source: Agricultural Sample Survey, Central Statistics Agency

However, adoption rate is still low. The share of area covered with improved seeds from total area cultivated is only 5 percent and that of pesticides 20 percent from total area cultivated using all cereal crops. Depending on sources, area covered with chemical fertilizer is also low ranging from 17 percent to 35 percent of total area of land cultivated with all cereal crops(Asrat, Getachew, and Taffesse 2012; CSA 2011, 2012).

Investigating the factors for the sluggish adoption rate and examining the dissemination apparatus and flow of agricultural information from extension agents to end users help policy makers identify important bottlenecks of diffusion and adoption mechanisms. There are some existing evidences on some of these factors. Given the supply of inputs, farmers willingness to adopt new technologies depends on household characteristics such as gender where male headed wheat farmers tend to adopt high yielding variety (Hailu, Abrha, and Woldegiorgis 2014; Tesfaye, Bedada, and Mesay 2016). Agricultural inputs such as land ownership security, use of irrigation, access to credit (Hailu et al., 2014); and ownership of livestock (Tesfaye et al., 2016) were found to be instrumental to an increasing adoption rates of modern inputs. Access to agricultural information plays a role in adoption behavior.

The flow of information through social networks contributes to adoption of improved seeds (Mekonnen et al., 2016). The use of mass media methods of information transfer has the potential to greatly help farming community (Ali, 2011). Furthermore, farmers who own radios tend to choose high yielding wheat varieties (Kelemu, Haregewoin, and Daniel 2016).

This study focuses on this last strand of the literature. The contribution of a new agricultural technology to enhance productivity can only be realized if the new technology is widely diffused, and if farmers have enough and applicable information about that technology. The type and content of agricultural information influences production decisions and farmers' willingness to use new technologies in a variety of ways. It is therefore imperative that the functions and use of a particular agricultural information system be understood in order to manage and improve its creation and dissemination.

Looking at the Ethiopian agricultural innovation process and the role of agricultural information in this process helps us understand the mechanisms of adoption and inform policy to improve the effectiveness of the agricultural extension system and in particular the diffusion of new technologies. This will allow us to answer a number of important questions. They include, among others: What are the sources and types of farmers' information set on new agricultural technologies and the channels for acquiring this information? Do farmers actually utilize existing stock of agricultural information in adopting new technologies? Do modern inputs and market information help farmers get productivity gains? The study is an attempt to identify the type and channels of acquiring agricultural information by farmers; and whether this information helps them in their decisions to adopt new and improved technologies, which can then be translated into higher yield.

We use a unique two-period panel data sets that come from surveys conducted in 2011 and 2013 by the Central Statistical Agency in collaboration with Ethiopian Strategic Support Program to evaluate Agricultural Growth Program (AGP). We do the analysis on wheat and barley farmers. These crops were chosen for a couple of reasons. First, production of wheat and barley account for 28 percent of total cereal crop output covering 26 percent of the area cultivated using these crops. Second, these crops are among a few cereal crops for which high yielding varieties have been developed. A particular emphasis is given to Oromia region, because 55 percent of total wheat output and 53 percent of total barley output produced in the country comes from this region (CSA 2011, 2012).

To exploit the longitudinal nature of the AGP dataset, we used fixed effects model as our analytical tool. As a synopsis of our findings, agricultural information from community gathering is an important source of agricultural information and encouraged wheat and barley farmers to use more modern inputs such as chemical fertilizers and improved seeds. Services of extension workers were also instrumental in encouraging wheat farmers to use more chemical fertilizers than wheat farmers who didn't benefit from such services. Moreover, the result also reveals that wheat yield responded to the use of chemical fertilizers, improved seeds and other chemicals (pesticides, fungicides etc.), while yield for barley farmers responded only to chemical fertilizers and other chemicals.

The rest of the document is organized as follows. Section 2 briefly discusses a brief overview of adoption of new technologies in Ethiopia and cereal productivity. Section 3 describes the source and nature of data and method of analysis of the study. Section 4 discusses the findings of the study. The final section concludes.

Cereal Productivity and Adoption of Technologies in Ethiopia

Cereal crops constitute 87 percent of total grain production which also includes pulses and oilseeds (CSA, 2016). Wheat and barley are two of the major cereal crops grown predominantly by Ethiopian smallholder farming system. Table 2 presents area covered, output produced of wheat and barley and their shares from total area and output of all major cereal crops. Wheat occupies 1.6 million ha of land, which constitutes 16.2 percent of the total area covered with cereal crops. It also constitutes 17.2 percent of cereal crop production. Average area covered with barely in the last six years is about 1 million, with 10 percent share of total cereal production. The final column of Table 2 shows that of the total wheat production, for the period 2011-2016, 55 percent of output is produced in Oromia region. Similarly, 53 percent of barley output comes from the same region. Because both wheat and barley crops grow in the same production belt with similar agro-ecology, both these crops are predominantly grown in the highlands of Arsi and Bale, West/East and North Shewa due mainly to favorable soil and moisture conditions, ideal for these two crops. Their importance in production and area covered by these crops is an indication that they are also basic staples in these areas.

Table 2: Area, output and share (percent) of wheat and barley from cereal crops*

crop	Period	National				Oromia				share of Oromia	
		Area	Share	Output	share	area	share	Output	share	area	output
Wheat	1997-2001	0.9	14.1	12.0	15.1	0.5	18.3	7.6	19.1	57.9	63.3
	2002-2010	1.4	17.1	22.3	18.6	0.7	19.0	12.9	20.3	53.8	58.0
	2011-2016	1.6	16.2	35.3	17.2	0.8	18.1	19.4	19.4	51.9	54.8
Barley	1997-2001	0.8	11.6	8.0	10.0	0.4	12.5	4.3	10.9	48.1	54.4
	2002-2010	0.8	10.0	13.8	11.5	0.4	9.5	5.7	8.9	56.1	41.0
	2011-2016	1.0	10.1	17.3	8.4	0.5	10.2	9.1	9.2	52.7	52.8

Source: Central Statistical Agency, Annual Agricultural Sample Survey (1996-2016).

Note: The area column is in millions of hectares, and the output column is in millions of quintals

Official sources show that cereal yield grew in Ethiopia for the last one and a half decades. Across the main cereals, production increased from a level of 14 and 11 quintals per hectare in 1997 to 25 and 20 quintals per hectare in 2016 respectively for wheat and barley; growth has been steady, with a temporary decrease in some years (Source: Central Statistical Agency, Annual Agricultural Sample Survey (1996-2016)

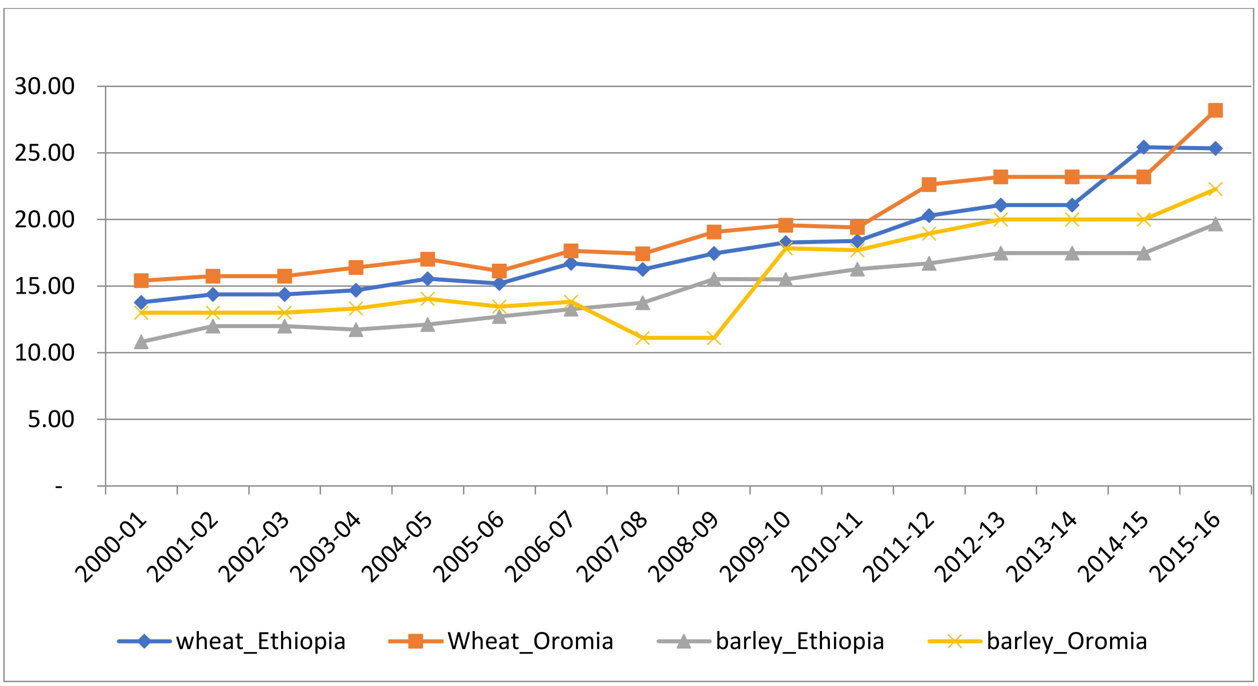
Figure 1). Production of major cereal crops seems to have been increasing in unison especially in recent years. There is no significant difference in yield growth of these crops unlike the experiences of other countries, which showed high yield growth during the green revolution, where crop specificity is an important feature.

Source: Central Statistical Agency, Annual Agricultural Sample Survey (1996-2016)

Figure 1 presents trends of wheat yield over the last 16 years at national level and for Oromia region separately. At national level, wheat yield, measured in quintals per ha of land, has been growing in the last one and a half decades from 14 quintals per ha in 2001 to 25 quintals per ha in 2016 with an average yield of 17 quintals. Overall, productivity of wheat is modestly higher in Oromia region with 15 quintals in 2001 and 28 quintals in 2016. Yield growth for is not peculiar just to wheat: other cereal crops have shown a tremendous yield growth (Taffesse, Dorosh, and Asrat 2012). Barley, for example, grew from 11 quintals in 2001 to 20 quintals in 2016.

Increases in productivity growth might have come with an increase in land cultivated for cereal crops provided (marginal) land joining these crops is more productive than existing land already cultivated. Data from CSA indicates that the average area covered with cereal crops increased from 6.7 million ha during the period 1996/97-2000/01 to 7.9 million ha during 2001/02-2009/10 period. For the period 2010/11-2015/16, this figure further increased to 9.8 million ha.

However, some research works in this area indicated that, despite the increase in area cultivated during the above periods, productivity gains appear to come mainly from intensification of modern inputs such as chemical fertilizers, improved seed varieties, and pesticides etc. A result of decomposition analysis of cereal production reveals that, although, during the 1990s, most of the increase in cereal production came from increases in area, in the 2000s, when area and yield increases each accounted for about half of production growth, and with initial start of increasing intensification (Taffesse et al. 2012).
Another study argues that production instability was caused more by increased yield instability than instability in an area; and that yield instability could be the result of changes in technology, changes in policy and changes in weather conditions (Alemu, 2005). Furthermore, modern inputs, though their adoption rate is low, helped households with sufficient land and fewer crops to gain efficiency benefits and increase productivity(Bachewe, Koru, and Taffesse 2015). Yield response of cereal crops were also found to be significant to chemical fertilizers and improved seeds, with some yield growth unrelated to modern inputs (Abegaz, 2011).



Source: Central Statistical Agency, Annual Agricultural Sample Survey (1996-2016)
Figure 1: Trends of yield in wheat and barley: National and Oromia Region-2000-2016

Table **3** presents utilization of the four major modern inputs (chemical fertilizers, improved seed varieties, pesticides and extension services) by wheat farmers for the last 14 years using data from agricultural sample survey of CSA. At national level, an average 0.6 million ha of land cultivated with wheat was applied with chemical fertilizer for the period 2011-2016, representing 36 percent. Application of pesticides and use extension advisory service are relatively on the high-end covering 50 percent and 38 percent respectively. Improved seeds were used for 0.1 million ha of land, constituting only 6 percent of total land covered with wheat. The table also shows that little change was registered by these shares over the period 2002-2016, especially for improved seeds. Similar stories can be told of barley farmers in the use of modern inputs.

Table 3: Use of modern inputs by wheat farmers: National and Oromia: 2001-2016*

		Chemical Fertilizer			Improved Seeds			Pesticides		Extension coverage	
Coverage	**Period**	Area (million ha)	Share (percent)	Quantity (million quintals)	Area (million ha)	Share (percent)	Quantity (million quintals)	Area (million ha)	Share (per cent)	Area (million ha)	Share (percent)
National	2002-2010	0.4	28.3	0.6	0.0	3.3	0.1	0.5	36.3	0.3	22.1
	2011-2016	0.6	36.1	1.0	0.1	6.4	0.2	0.8	50.2	0.6	38.4
Oromia	2002-2010	0.2	25.1	0.3	0.0	3.1	0.0	0.4	52.6	0.2	19.6
	2011-2016	0.2	27.0	0.4	0.0	5.0	0.1	0.6	75.1	0.3	33.6

Source: Central Statistical Agency, Annual Agricultural Sample Survey (1996-2016).

Note: share (in percent) of area applied with modern inputs is in comparison to total utilization of such inputs for cereal crops.

Some empirical evidence on the slow adoption rate include household and community characteristics, availability of other agricultural inputs, use of irrigation and access to credit, ownership of livestock, and land ownership security(Hailu et al. 2014; Tesfaye et al. 2016) Information on the presence and application of new technologies through radios and social networks have also an important role in influencing farmers adoption behavior (Kelemu et al., 2016; Mekonnen et al., 2016).

Data and Methods

Data

The data for this study comes from two-round surveys supervised by the Central Statistics Agency and Ethiopian Strategy Support Program. The first round of the surveys was conducted in 2011 and the second in 2013. A total of 7,927 households sampled from 93 woredas during the baseline and 7,503 during the midline surveys were interviewed. The sample covers Tigray, Amhara, Oromia and SNNP. The attrition rate (around 5%) was low compared to similar large surveys and appeared to be unrelated to the outcome variables of interest (Bachewe et al. 2013). Because the data was collected specifically to evaluate the performance of the AGP, we have enough information pertinent to this study. The modules in the questionnaire include basic household characteristics and demographics, land characteristics and utilization, crop production, input use, crop output and its utilization and marketing, agricultural extension, technology, and information networks, and household assets.

Table 4: Distribution of the Sample across Regions and Year

	Baseline (2011)			Midline (2013)		
Region	**AGP**	**Non-AGP**	**Total**	**AGP**	**Non-AGP**	**Total**
Tigray	1222	390	1,612	1126	383	1,509
Amhara	1404	702	2,106	1301	671	1,972
Oromiya	1402	701	2,103	1326	675	2,001
SNNP	1404	702	2106	1341	680	2021
Total	**5302**	**2625**	**7927**	**5094**	**2409**	**7503**

Source: Bachewe et al. 2013

Sampling design

The sampling design is based on purposive woreda selection due to the objectives and nature of the program (i.e. AGP) itself. Woredas eligible for the AGP are those where existing location factors are conducive for agricultural growth. The criteria for the selection of AGP woredas include access to markets; natural resource endowments; suitable rainfall and soil for crop and fodder production; potential for development of small-scale irrigation facilities; institutional plurality of service providers, including good basis and growth of viable cooperatives and farmer groups; and existing partnership engagements with private sector.

The sample households for this study were taken as follows: first, 61 woredas were randomly selected from among the 83 AGP woredas. Similarly, 32 woredas were randomly selected from among non-PSNP and non-AGP woredas in the four regions, namely Tigray, Amhara, Oromiya, SNNP, and Tigray, within which AGP operates. At the second stage, 3 EAs where randomly chosen from among EAs in each woreda. Tigray is the exception to this rule because, though the same number of households is demanded by the desired level of precision and power, there are fewer woredas to include. Thus, 5 EAs each from ten woredas and 6 EAs each from two woredas were selected in Tigray.

The final step is the selection of 26 households from within each EA. This is done based on a fresh listing of households residing within each EA and selecting households randomly until the desired number and composition of households is obtained. Each household included in the AGP baseline sample represents a certain number of households reflecting the selection probability associated with it, which is its sample weight (Berhane et al. 2011).

Methods

Linking farmers access to agricultural information with the use of new technology, and adoption of new technology with productivity, we need a more structured and controlled analysis. An ideal strategy to make this inference would be a random assignment of the treated and control groups

(Angrist and Pischke 2010). However, the AGP sample has the following important characteristics due to the very nature of the program itself (Berhane et al. 2011).

1. woreda selection of AGP is purposive,
2. the services (interventions) of AGP is demand driven (i.e. participation in the program comes from the farmers themselves, entailing potential for self-selection),
3. presence of multiple interventions and possible spillover effects.

Consequently, there exist problems that make the use of randomized experiments and even regression discontinuity designs infeasible; because these methods produce estimates of the counterfactual through an explicit program assignment rules that the researcher knows and understands. The fact that participation in the AGP interventions such as use of modern inputs comes from the farmers themselves has a potential of self-selection in using these inputs due to unobservable characteristics such as motivation-to-use-inputs of farmers. This is an important challenge in using propensity score matching, which matches farmers based on an observable characteristic only.

Furthermore, at least for the purpose of this study, the control woredas are not strictly controlled because the type of AGP interventions that constitute the major components of the program (e.g. enhancing productivity through modern inputs, expanding extension package etc.) also exist in other non-AGP woredas. Consequently, in this study we use fixed effects model to exploit the longitudinal nature of the data. This method helps us control time-invariant confounding factors.

Methods of data analysis

Fixed effects model

Following Cameroon and Trivedi (2005), given a very general linear model for panel data with the intercept and slope coefficients allowed to vary over both farmers and time,

$$y_{it} = \alpha_{it} + x'_{it}\beta + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(i)$$

where y_{it} is a scalar dependent variable (quantity of inputs, or crop productivity measures such as yield), x_{it}'s are repressors (household socio-economic and community characteristics), α_{it}'s are random individual-specific effects and ε_{it} is an idiosyncratic error.

The individual-specific-effects model for the dependent variable y_{it} specifies that

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(ii)$$

where all the variables in equation (i) also hold for equation (ii) except that, α_i are random individual-specific effects that vary only across farmers, and that capture any time-invariant unobserved heterogeneity. The α_i's represent motivation to use modern inputs, cultural attitude towards modern agriculture etc, that would potentially be correlated with one of the explanatory variables. In the fixed effects model, these individual -specific effects are permitted to be correlated with the repressors x_{it}.

Two variants of equation (ii) will be specified. The following model is specified to estimate the impact of using one or more sources of agricultural information on technology adoption.

$$\mathbf{quant\_input_{it}} = \boldsymbol{\alpha}_\mathbf{i} + \mathbf{AgInf_{it}}\boldsymbol{\beta}_\mathbf{i} + \mathbf{E_{it}}\boldsymbol{\beta}_\mathbf{i} + \mathbf{H_{it}}\boldsymbol{\beta}_\mathbf{i} + \boldsymbol{\varepsilon}_\mathbf{it} \dots\dots\dots\dots\dots\dots\dots..(\mathbf{iii})$$

where $\mathrm{quant\_input_{it}}$ quantity of chemical fertilizers and improved seeds used by farmer i at time t, and $\mathrm{AgInf_{it}}$ are dummy for participation in community meetings, receipt of advisory services from an extension worker, visiting demonstration plots and use of media by farmer i at time t. $\mathrm{E_{it}}'$s are economic factor that have potential impact on use of inputs such as access to credit, area of land cultivated for a given crop, price, number of livestock, labor used. The $\mathrm{H_{it}}'$s represent household demographics/characteristics and community characteristics.

A second model is specified to estimate the impact of using modern inputs such as fertilizer and improved seeds on yield.

$$\mathbf{yield_{it}} = \boldsymbol{\alpha}_\mathbf{i} + \mathbf{quant\_inputs_{it}}\boldsymbol{\beta}_\mathbf{i} + \mathbf{E_{it}}\boldsymbol{\beta}_\mathbf{i} + \mathbf{H_{it}}\boldsymbol{\beta}_\mathbf{i} + \boldsymbol{\varepsilon}_\mathbf{it} \dots\dots\dots\dots\dots\dots\dots..(\mathbf{iv})$$

where $\mathbf{yield_{it}}$ is quantity of output per ha, $\mathrm{quant\_input_{it}}$ quantity of chemical fertilizers and improved seeds used by farmer i at time t, $\mathrm{E_{it}}'$s are economic factor that have potential impact on productivity such as access to credit, area of land cultivated for a given crop, price, number of livestock, labor used. The $\mathrm{H_{it}}'$s represent household demographics/characteristics and community characteristics. The list of major variables used for the analysis and their description is given in Table 5.

Table 5: List of major variables considered for the analysis and their description

Variables	Description/questions
Yield	Output (in quintals) produced per hectare
Improved seeds	Quantity (in Kg) of improved seeds (bought and saved from previous year) used for each crop
Chemical fertilizer	Quantity (in Kg) of fertilizer (both DAP and urea) applied for each crop
Chemicals (pesticides, fungicides etc.)	Volume (in litters) of chemicals such as fungicides, pesticides used for each crop
Credit	Dummy for credit (whether a farmer has borrowed from some source): (1 borrowed; 0 otherwise)
Irrigation	Dummy for irrigation (whether a plot is irrigated or not): (1 irrigated; 0 otherwise)
Number of livestock	Number of livestock (in tropical livestock unit)
Total labor available	Total labor (in man-days) used for production for each crop-(family labor plus hired)

Total land area cultivated	Total land area cultivated (in hectare)
Participation in meetings	Dummy for participation in community meetings/ discussions (1 participated; 0 otherwise)
Advised by an ext. worker	Dummy for extension worker advice (1 advised by an extension agent; 0 otherwise)
Use of media	Dummy for use of mass media to get agricultural information (1 used mass media; 0 otherwise)
Visited demonstration	Dummy for visiting demonstration plots (1 visited; 0 otherwise)
Age	Age (in years) of household head
Marital status	Dummy for marital status of household head (1 married; 0 otherwise)
Major occupation of head	Dummy for occupation of household head (1 agriculture; 0 otherwise)
Family size	Number of household members
Education	Level of education of household head

Discussion of Results

Sources and types of agricultural information

The common channels through which farmers get access to agricultural information include on-farm advice by extension advisory services, broadcasts through the media, discussions in community meetings and through visiting demonstration plots. Apart from local and national mass media where general topics of adoption techniques are discussed, agricultural extension workers are the core players in all other three means of transferring agricultural information (i.e. providing on-farm advice, encouraging farmers to visit demonstration plots, organizing community meetings).

Figure 2 presents channels of acquiring information based on the total AGP sample and on the sample for Oromia region separately. The graph shows the proportion of wheat and barley farmers who use a given means of obtaining agricultural information. Extension worker visiting farmers' plots, participation in discussions on modern inputs application, and the media are the major sources of agricultural information available to farmers. A relatively fewer farmers used demonstration visits as a source of information for their decisions to adopt new technologies.

On average, 50 percent of wheat farmers participated in community meetings discussing on one or more of topics on agricultural technologies during the years 2011 and 2013. This figure was 52 percent in Oromia region.

Another important means of providing agricultural information to farmers is through on-farm extension advisory services visiting farmers plots. Fifty two percent of wheat farmers were visited by extension workers during the two years. Extension service in Oromia region is much lower (i.e. 37 percent) than the total sample for these farmers. Media as a source of agricultural information is also considerably used by farmers to get market/price information and/or information on different production methods. According to the AGP sample survey, on-farm demonstration visits by farmers is the least utilized means of diffusion of new agricultural technologies. Although there is minor differences across the two years, the importance of the above channels of diffusion have a similar pattern in 2013.

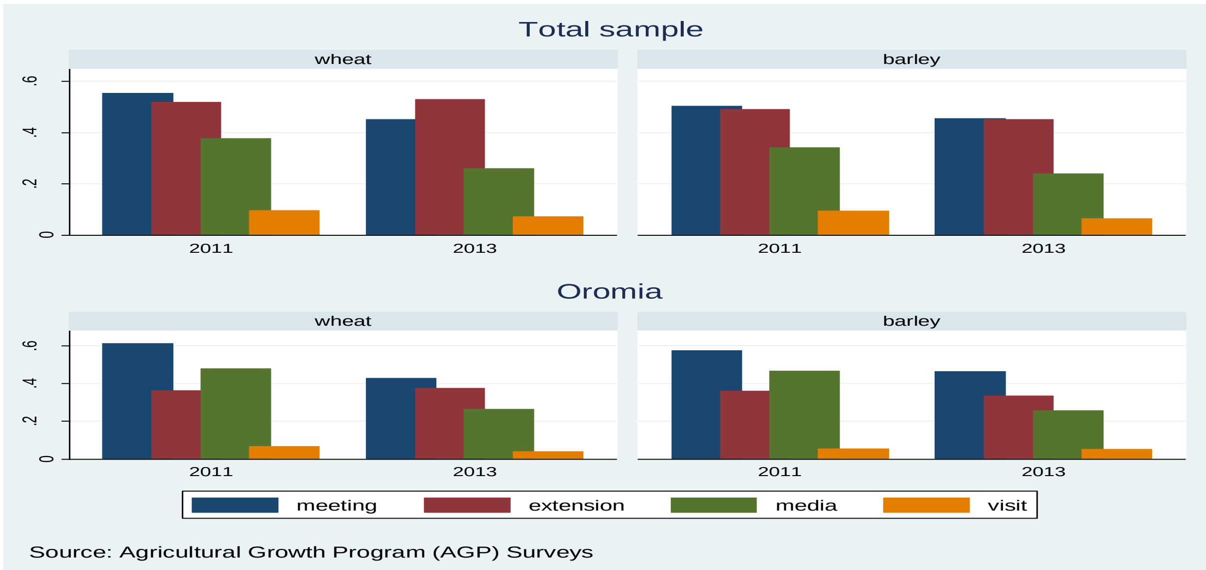


Figure 2: Sources of agricultural information: total sample and Oromia region

Moreover, this pattern extends to barley farmers both in the total sample and in the sample for Oromia region. Over the two periods, barley farmers reported that they used community discussions (48 percent), extension workers (47 percent), and the media (30 percent) to get different types of agricultural information such as importance and application of fertilizers, use of improved seed, pesticides, land preparation techniques etc. Although small in terms of percentages, there are still a significant number of barley farmers who acquired information from visiting demonstration plots especially in 2013.

Looking further into Oromia, where the bulk of wheat and barley production comes from, we presented the same graph as above for Arsi zone and Tiyo woreda, which is one of the woredas in Arsi zone. As in the total sample and Oromia region, we find that extension services, community meetings and the media are the major sources of agricultural information in Arsi zone and Tiyo woreda with some varying degree across the two periods, and crops (Figure 3).

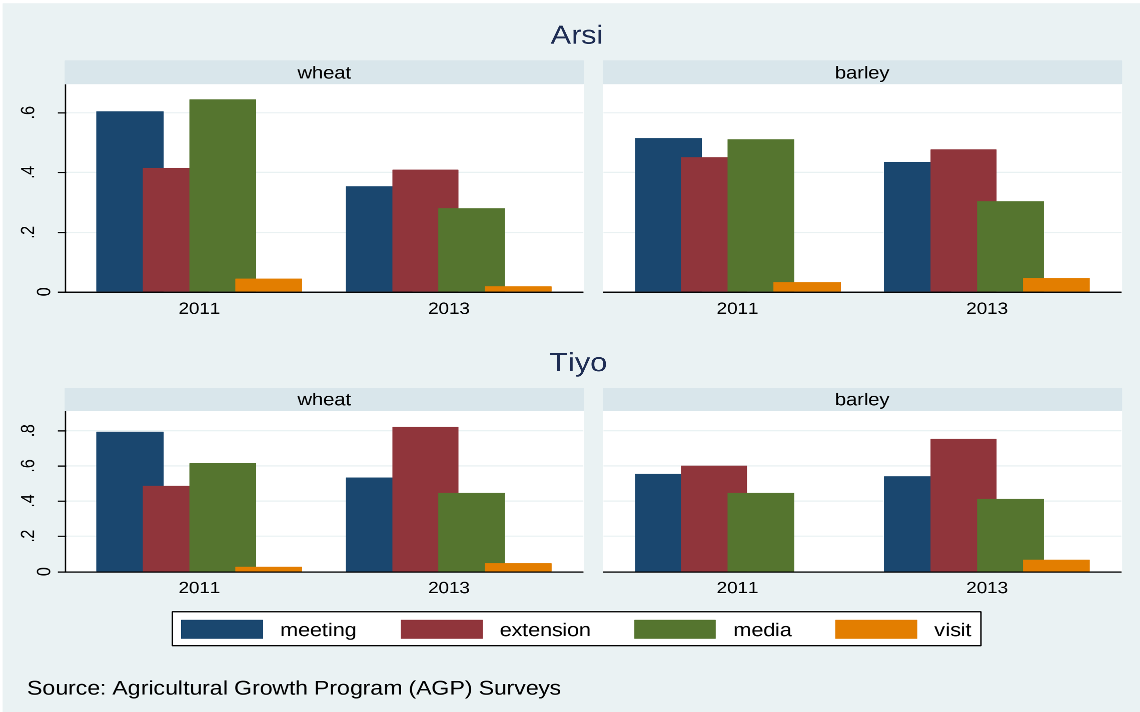


Figure 3: Sources of agricultural information: Arsi Zone and Tiyo Woreda

Extension advisory service is the major sources of agricultural information in other developing countries. For example, 62 percent of small holder farmers in Nigeria use the agricultural extension system as a source of information (Daudu S., Chado S. 2009). Using mass media, still important in Ethiopia (e.g. Kelemu, Haregewoin, and Daniel 2016) and in other developing countries, is a leading means of acquiring information in the context of commercial agriculture in more developed countries (e.g. Breathnach (1970).

On-farm extension advisory services

Agricultural extension service is one of the institutional supports provided by the Ethiopian government to smallholder farmers. Different approaches have been designed and implemented over the history of the Ethiopian agricultural extension program since the 1930's, which differ with each successive political regimes in the country. Since the 1980s, Ethiopia’s extension system has followed a “training and visit system” that was introduced under the PADETES (Belay 2003; Spielman, Kelemwork, and Alemu 2011).

The objective of the current Ethiopian extension system is "to transform Ethiopia’s agriculture through implementation of pluralistic extension system by providing demand-driven and market-led extension services..." (MoARD 2014). This pluralistic extension system recognizes the inherent diversity of farmers and farming systems and the need to address challenges in rural development with different services and approaches (World Bank 2012).

In this subsection, we identified a number of skills farmers acquire from on-farm visits of extension workers. These include importance and application of fertilizers, use of improved seeds, pesticides, land preparation techniques, timing of seed planting, and harvesting and threshing techniques. By far the most important ones are, however, on improved seeds, chemical fertilizers and farming methods. The proportion of farmers who were visited and advised on these three major components of advisory services is presented in **Error! Reference source not found.**.

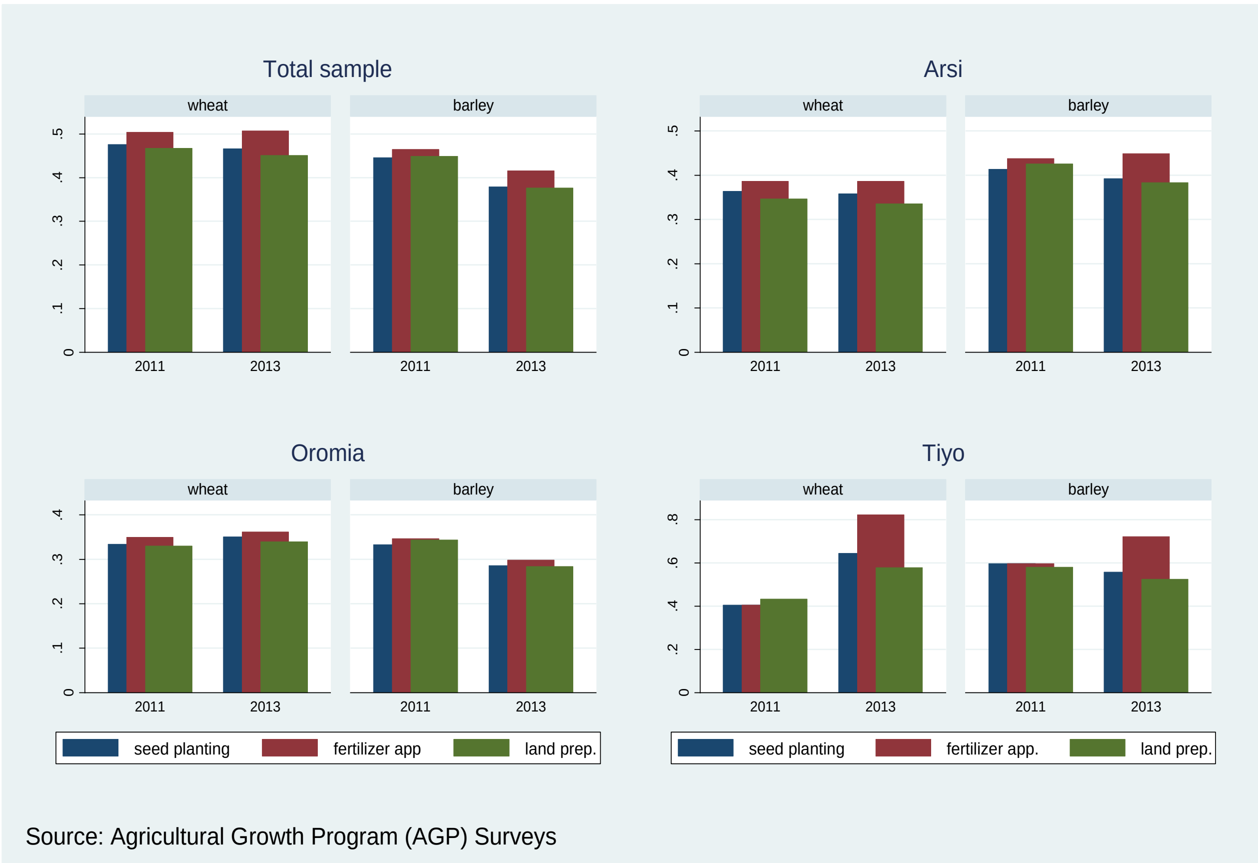


Figure 4: Advice by an Extension Worker by Type of Advice

In both 2011 and 2013, close to half of wheat farmers reported that they discussed with an extension worker on the importance and application of chemical fertilizers. Advices on seed planting and land preparation is also the leading points of discussions between these farmers and an extension worker during these periods. We can see the same pattern, but with less importance than the total sample, on these services for Oromia region and Arsi zone. In Tiyo woreda, we see a soaring proportion of wheat farmers in 2013 compared to 2011, especially in chemical fertilizers application. On the other hand, the share of barley farmers who received agricultural extension services turned down in 2013 all in the four regions.

Community meetings

Community meetings and discussions are other major sources of agricultural information. By far the most important organizers of these discussions are the local government (for 80 percent of farmers in 2011 and 87 percent in 2013) and agricultural cooperatives (for 17 percent in 2011 and 13 percent in 2013).

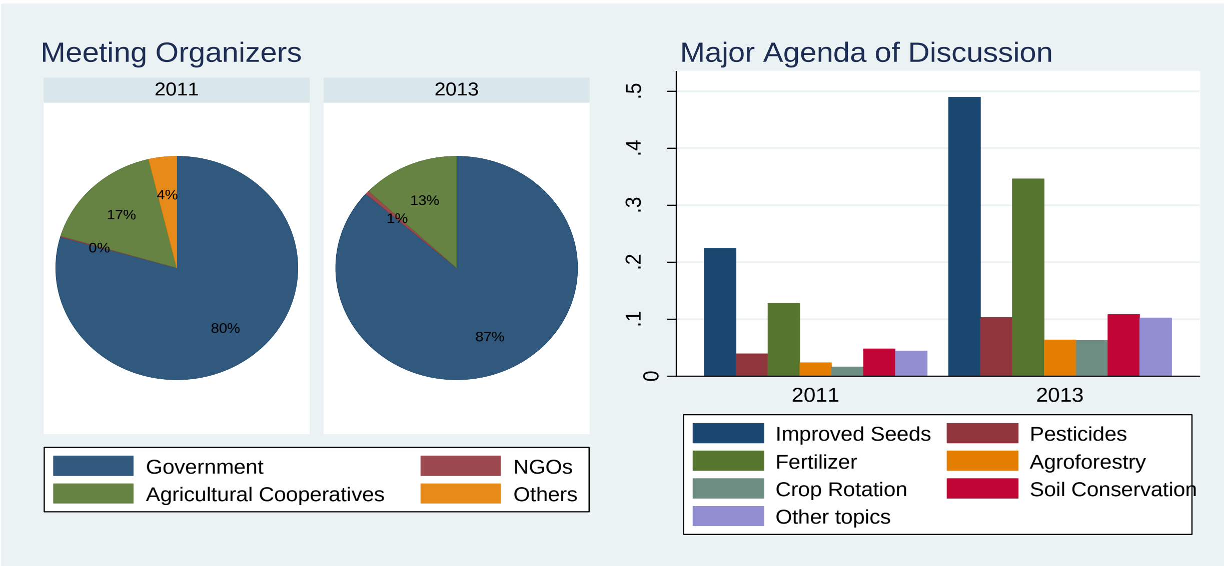


Figure 5: Meeting organizers and major agenda of discussion: Oromia region

The major agendas of the discussions were on improved seeds, application of fertilizers, application of pesticides, protection of crops from pesticides, crop rotation, agro-forestry and soil conservation (Figure 5).

The share of farmers who benefited from these discussions on the topics just mentioned has increased during the two periods. The two main agendas of discussions in these community gatherings, improved seeds and fertilizer application, were discussed respectively by 23 percent and 13 percent of the farmers in 2011. In 2013, close to 50 and 34 percent of farmers discussed about these agendas (Figure 5).

Demonstration visits and using mass media

Plot demonstration visits serve as one of the means of channeling agricultural information to farmers. Although only few farmers (less than 1 percent) participated in visiting demonstration plots in 2011, there was an improvement in 2013, when, among those who visited, 45 percent and 20 percent of wheat and barley farmers had discussion on improved seeds and fertilizer applications during their visits (Figure 6). The fact that there are few demonstration plots, hence poor access to these plots, might be a major factor for the smallest share of farmers visiting these plots.

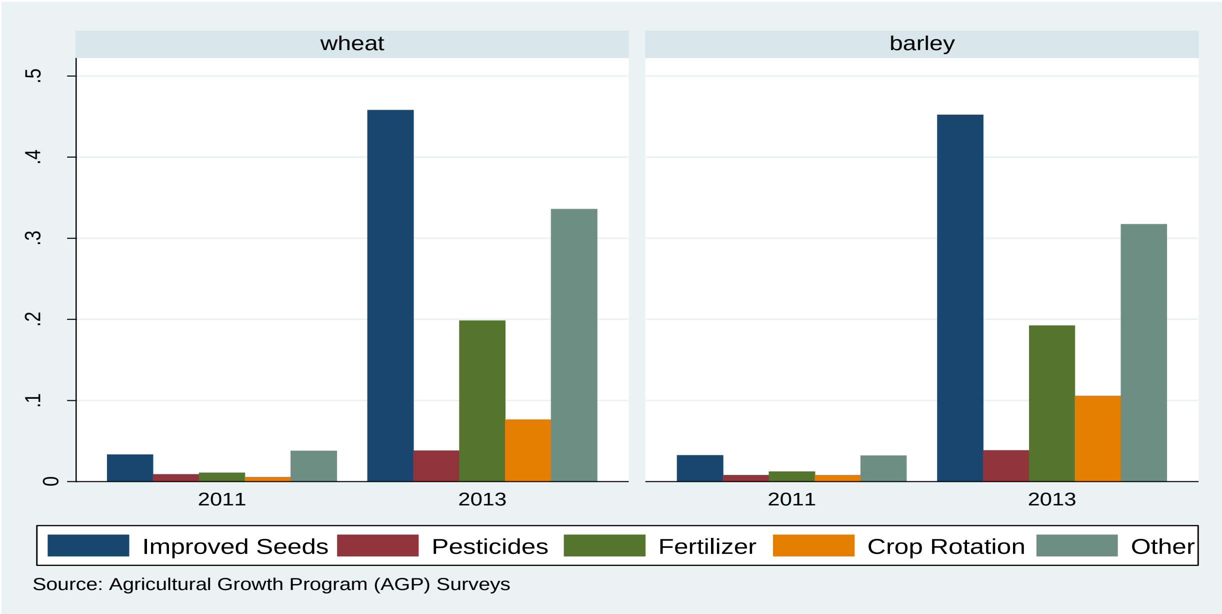


Figure 6: Proportion of farmers who visited demonstration plots

Local and national mass media play an important role in providing agricultural information to farmers. Two such information types are on methods of production and market price information. Classifying wheat farmers by the level of education, we find that farmers whose level of education is either primary, secondary or higher education tend to use the media more often than those with no schooling or having other forms of education (Figure 7). This pattern exists in the total sample and for Arsi zone.

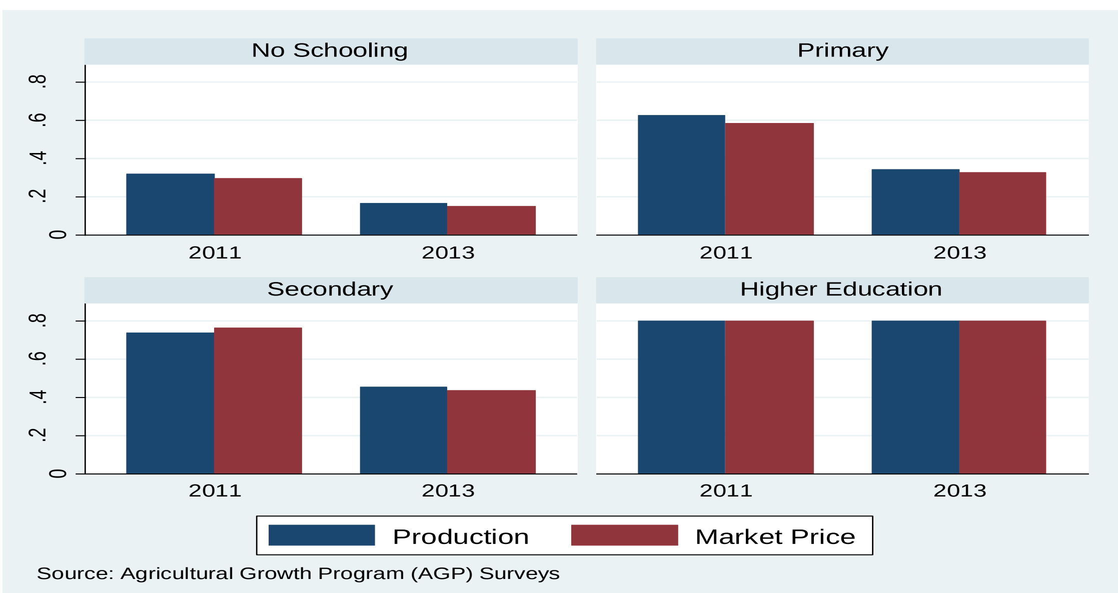


Figure 7: Sources of agricultural information: Oromia

Information and adoption of new technologies

Providing farmers with agricultural information on new technologies is only a first step in diffusing modern inputs and making them accessible to farmers. The utilization of this information in actually applying new technologies is a necessary undertaking, if not an ultimate objective, in the innovation process; because, in addition to farmers' awareness on the importance and application of new technologies, there might be a problem in accessing these technologies.

The objective of this section is to see whether farmers who have participated in community meetings, consulted an extension worker, visited demonstration plots or used the media also applied more modern inputs. In Figure 8, a graph is drawn based on the fact that farmers acquire agricultural information in at least one of the channels: community meetings, extension advice, demonstration visit or using the media.

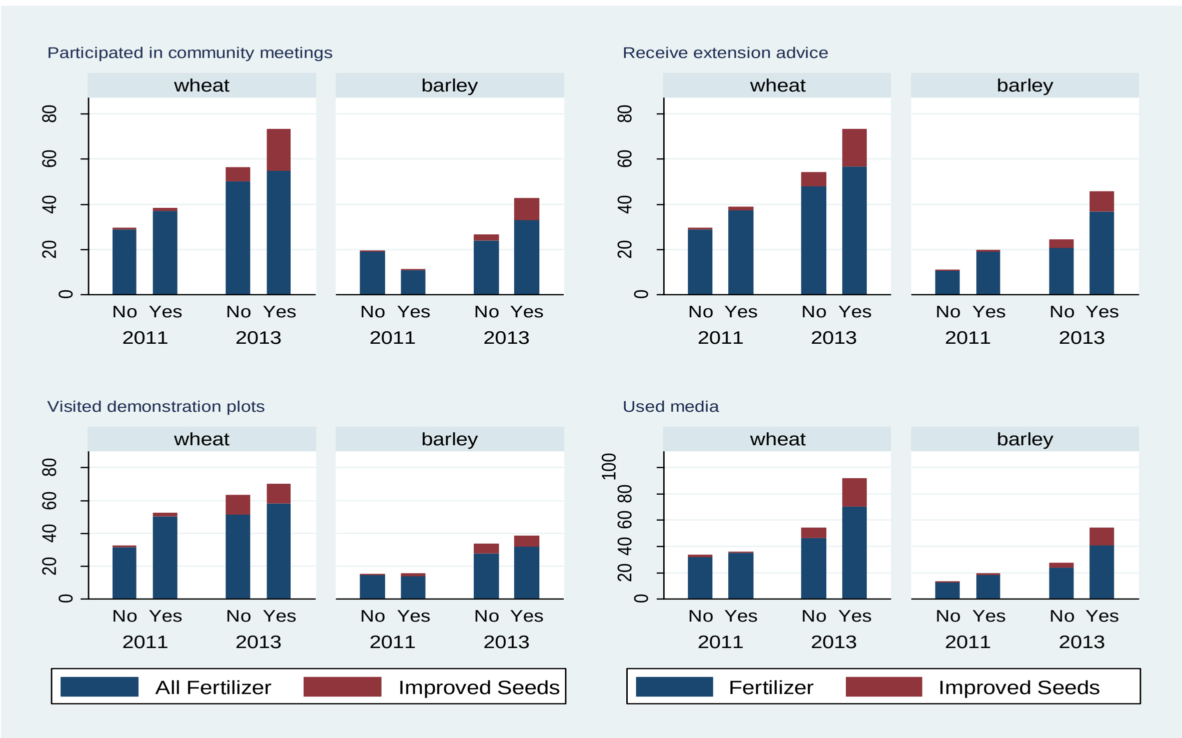


Figure 8: Quantity of modern inputs and source of on information: total sample

Overall, wheat farmers used more of chemical fertilizers and improved seeds in 2013 compared to 2011. Among these farmers, those who were exposed to one of the channels of agricultural information applied more chemical fertilizers and used more improved seeds than farmers who were not exposed to such sources of information.

Barely farmers also intensified their plots with both chemical fertilizers and improved seeds over the two years. Moreover, farmers who benefited from the services of extension advisory services or visited demonstration plots or used the media for information used both these inputs than those who didn't. Use of inputs follows similar patterns and trends over the different source of formation and over the two years (**Error! Reference source not found.** and **Error! Reference so urce not found.**).

A pair-wise correlation coefficient between modern inputs use and sources of agricultural information were estimated (Table 6). The correlation between wheat farmers who participated in community discussions, received on-plot advisory services, visited demonstration visits also used improved seeds and applied chemical fertilizer for their farms. There appears to be a correlation between barley farmers using the different source of information and input application, with less significance though. We can also note a high complimentarily of using modern inputs and between means acquiring information for both wheat and barley farmers.

Table 6: Pair-wise correlation coefficients between input use and sources of information

Variables	Improved Seeds	Chemical Fertilizer	Other chemicals	Participation	Receiving advice	Use of media	Demonstration visit
			Wheat				
Improved Seeds	1						
Chemical Fertilizer	0.192**	1					
Other chemicals		0.042**	1				
Participation	0.064**	0.033*		1			
Receiving advice	0.071**	0.062**		0.232**	1		
Use of media	0.050**	0.058**		0.248**	0.116**	1	
Demo. visit		0.052**		0.229**	0.161**	0.140**	1
			Barley				
Improved Seeds	1						
Chemical Fertilizer		1					
Other chemicals		0.034*	1				
Participation	0.059**			1			
Receiving advice	0.056**	0.036*		0.234**	1		
Use of media	0.061**		0.0379*	0.240**	0.139**	1	
Demo. visit				0.229**	0.143**	0.146**	1

** $p<0.01$, * $p<0.05$, empty spaces $p>0.1$

To see whether the above differences in the use of information significantly explain the divergence in the utilization of chemical fertilizers and improved seeds, a fixed effects estimations were made following the model specified in Data and Methods section. Panel data descriptive statistics of the outcome variable and a partial list of major explanatory variables of interest are provided in Table 7.

Fixed effects estimations were made to control for individual heterogeneity of farmers. However, a formal test was made to choose between fixed effects and random effects estimations using

Hausman test. The results of the test was provided in **Error! Reference source not found.Error! Reference source not found.**. Observable household and community characteristics such as age, education level, gender, marital status, major occupation of household head and family size were taken as covariates. Other variables such as number of livestock, labor devoted to the production of wheat and barley were also used.

Table 7: Descriptive statistics of yield and major variables

	Variable	Variation	Mean	Std. Dev.	Min	Max	Observations
Wheat	Yield (quintal per ha)	overall	14.5	15.6	0.0	400.0	N = 4159
		between		13.2	0.0	256.0	n = 2710
		within		8.8	-179.5	208.5	T-bar = 1.53
	Improved seeds (log)	overall	6.0	38.0	0.0	1510.0	N = 4106
		between		24.8	0.0	755.0	n = 2683
		within		26.6	-749.0	761.0	T-bar = 1.53
	Chemical fertilizer (log)	overall	42.4	70.4	0.0	1400.0	N = 4106
		between		54.5	0.0	700.0	n = 2683
		within		41.3	-657.6	742.4	T-bar = 1.53
Barley	Yield (quintal per ha)	overall	15.9	45.75	0.00	2020.00	N = 3901
		between		45.13	0.00	2020.00	n = 2611
		within		21.97	-726.14	757.86	T-bar = 1.49
	Improved seeds (log)	overall	2.76	21.64	0.00	500.00	N = 3905
		between		15.87	0.00	300.00	n = 2614
		within		14.20	-247.24	252.76	T-bar = 1.49
	Chemical fertilizer (log)	overall	20.42	154.95	0.00	8000.00	N = 3905
		between		166.99	0.00	8000.00	n = 2614
		within		59.66	-2467.08	2507.92	T-bar = 1.49

Estimates of the coefficients Table 8 point out that application of chemical fertilizers responds to participation in community meetings by both wheat and barley farmers, given other factors that can potentially affect use of this input. Participation in community meetings resulted in a difference of 63 percent more chemical fertilizers and 67 percent more improved seeds for wheat farmers.

In the same vein, these meetings made a difference in the use of inputs for barley farmers. That is, 86 percent more chemical fertilizers and 44 percent more improved seeds were used by barley farmers who participated in community discussions. Most of the farmers participate in meetings mainly organized through the local government, and more adoption might be expected given that access to credit is facilitated and provided by the government and by institutions close to the local government. Membership to farmers cooperatives might have helped farmers use more chemical fertilizers (Abebaw and Haile 2013).

Table 8: Fixed effects estimates of coefficients of factors of technology adoption

Explanatory variables	Chemical Fertilizer (log)		Improved Seeds (log)	
	Wheat	**Barley**	**Wheat**	**Barley**
Participation in meetings (1 participated)	0.63**	0.86*	0.67**	0.44*
	(0.32)	(0.48)	(0.30)	(0.23)
Advised by an ext. worker (1 advised)	0.68***	0.72*	-0.21	-0.17
	(0.26)	(0.43)	(0.29)	(0.20)
Visited demonstration (1 visited)	0.62	0.27	0.07	-0.19
	(0.63)	(0.65)	(0.35)	(0.24)
Use of media (1 used)	-0.01	0.49	0.78**	-0.05
	(0.33)	(0.44)	(0.32)	(0.12)
Credit (1 borrowed)	0.11	0.57	-0.20	0.02
	(0.34)	(0.50)	(0.30)	(0.20)
Area of land cultivated (ha)	-0.37	0.35	-0.20	0.83**
	(0.32)	(0.57)	(0.44)	(0.36)
Value of production of crop	0.00***	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Number of livestock (in TLU)	0.02	0.04	-0.04	0.02
	(0.05)	(0.03)	(0.04)	(0.01)
Total labor utilized	0.01	0.01	-0.00	-0.00
	(0.01)	(0.01)	(0.00)	(0.00)
Age of household head	0.06*	0.02	0.01	0.03*
	(0.03)	(0.04)	(0.02)	(0.02)
Marital status (1 married)	0.21	-0.21	-1.60**	0.04
	(1.54)	(1.93)	(0.75)	(0.93)
Major occupation (1 agriculture)	0.68	0.18	-0.45	0.16
	(0.58)	(1.15)	(0.73)	(0.30)
Family size (number of household members)	0.15	0.24	0.07	0.17
	(0.15)	(0.16)	(0.10)	(0.12)
Education (comparison: no education)				
Primary	0.15	2.14***	0.90	-0.37
	(0.67)	(0.56)	(0.67)	(0.26)
Secondary	-0.55	2.65***	-0.00	1.11**
	(1.00)	(0.99)	(0.98)	(0.45)
Higher education	-0.22	0.73*	0.42	0.60**
	(0.37)	(0.42)	(0.52)	(0.28)
Constant	-3.85**	-3.91**	-0.76	-2.53**
	(1.72)	(1.85)	(0.82)	(1.13)
Observations	2,265	2,173	2,248	2,160
R-squared	0.43	0.33	0.21	0.34
Household FE	YES	YES	YES	YES
Region FE	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Use of on-farm visits by agricultural extension services were found to have an effect on the use of chemical fertilizers for wheat and barley farmers. Farmers' learning through an extension worker led to use of 68 percent and 72 percent more chemical fertilizers. The data doesn't support any relationship between the application of improved seeds and advisory services of extension workers.

The level of education of household heads influences whether farmers used more inputs for barley. Farmers whose level of education is either primary, secondary or higher education, would use more modern inputs compared with farmers who cannot read and write.

Technology adoption and productivity

Yield, measured in output in quintal per hectare, is presented in Table 9 for the total sample and sample for Oromia region (total and by administrative zones). Overall, wheat and barley producers had a productivity gain of 29.6 percent during the two intervening periods (i.e. between 2011 and 2013). Overall, wheat yield increased from 14.2 quintal per ha in 2011 to 18 quintal per ha in 2013. Yield for barely was also spurred from 14 quintals to 18 quintals during the same period resulting in a 26 percent of growth.

Table 9: Estimates of Yield

			Wheat			Barley	
Zone, Woreda		2011	2013	growth rate	2011	2013	growth rate
Overall		14.2	18.3	29.6	14.2	18.0	26.4
	Oromia	15.9	20.9	31.8	17.3	22.2	28.3
Zones in Oromia	West-Shewa	9.6	9.2	-4.2	16.3	19.2	17.8
Zones in Oromia	North-Shewa	18.6	21.7	17.1	11.3	5.9	-48.1
Zones in Oromia	East-Shewa	17.0	15.1	-11.6	15.5	10.4	-32.5
Zones in Oromia	Arsi	25.4	35.3	38.9	26.4	30.7	16.4
Zones in Oromia	Tiyo woreda	26.2	25.5	-2.8	30.1	29.7	-1.6
Zones in Oromia	Bale	13.3	24.2	82.1	10.1	23.5	132.6
Zones in Oromia	Horo-Gudru-Wellega	12.1	11.8	-2.5	12.9	11.8	-8.2
Zones in Oromia	Other zones (avg.)	9.5	11.9	26.2	8.4	11.9	41.5

Source: Agricultural Growth Program (AGP) Surveys

We also note that yield growth in Oromia zone is higher than overall growth for both crops. The mean wheat yield for the region was 16 quintals per ha in 2011 and 21 quintals per ha in 2013, leading a growth rate of 32 percent over this period; while the productivity of barley was 17 quintals and 22 quintals for 2011 and 2013 respectively. The highest yield was registered in Arsi where 25 and 35 quintals per ha were produced in 2011 and 2013 respectively. Wheat production in Bale zone exhibited the highest growth (82 percent) from a low base of 13 quintals in 2011 to 24 quintals in 2013.

Figure 9 shows differences in the levels of yield between farmers who applied chemical fertilizers and/or used improved seeds and those who didn't. Wheat productivity for fertilizer adopters is higher both in the overall sample and Oromia region. We also note that, except for farmers who didn't apply fertilizer where yield declined, there was yield growth during the period 2011-2013. The result on use of improved seeds and yield is rather mixed, however. While both adopters and non-adaptors of improved varieties gained higher yield in 2013 compared to 2011, yield for non-adopters is a little higher than adopters.

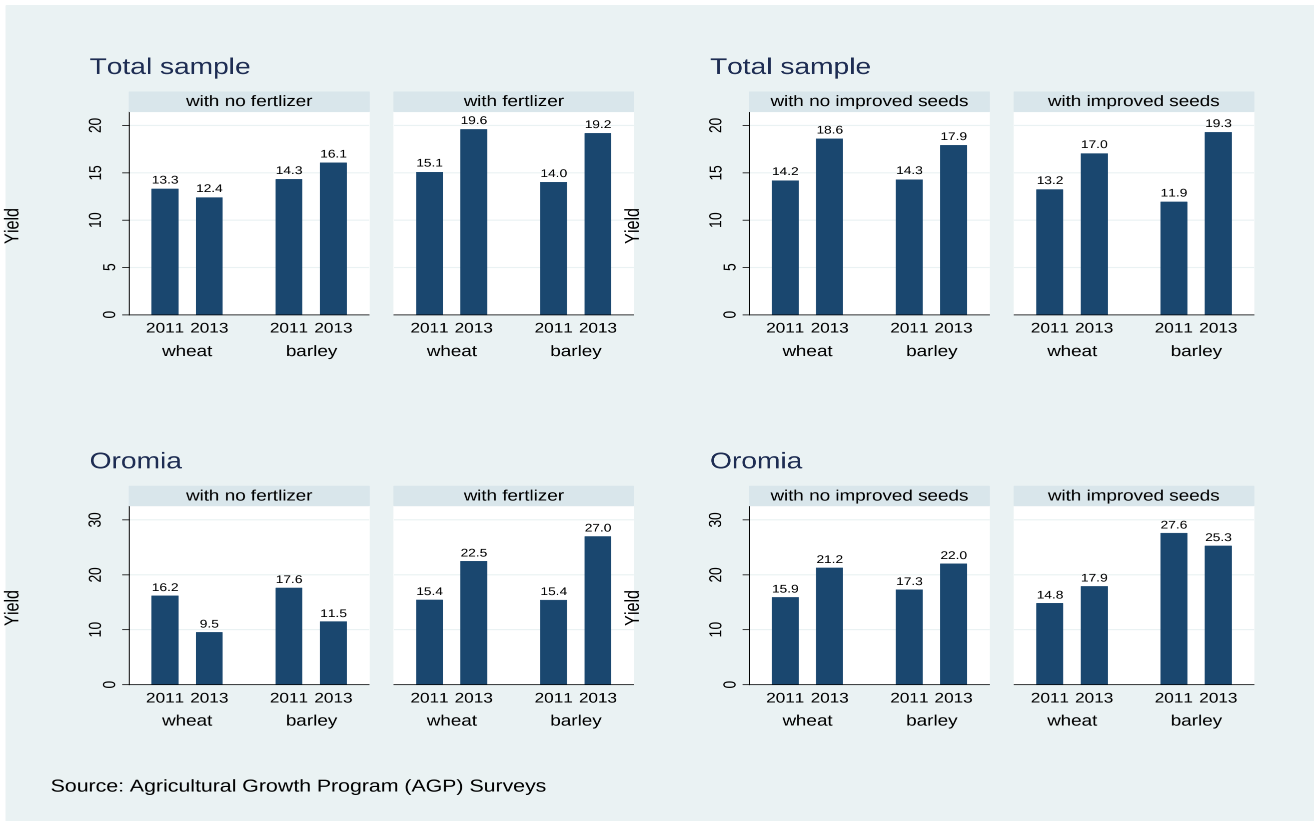


Figure 9: Wheat yield and application of modern inputs: total sample

Evidently, grouping farmers based on use of improved seeds is blemishes the exact relationships between those groups, mainly due to other variables that have potentially an impact on yield. Quantifying the difference and giving them a little statistical context, Table 10 presents a group mean t-test. Chemical fertilizer application matters for both wheat and barley farmers. However, we cannot see any correlation between use of improved seeds and productivity gains for both crops.

Table 10: Group mean t test based on total sample

Crop	Modern input	Not used	Used	Difference	p value (Diff<0)
Wheat	Chemical fertilizer	13.1	15.2	-2.1	0.00
	Improved seeds	14.5	14.2	0.3	0.70
Barley	Chemical fertilizer	14.8	17.5	-2.7	0.05
	Improved seeds	15.8	17.6	-1.8	0.23

In a more structured setting, estimations from fixed effects specification reveals that wheat yield responds to the use of chemical fertilizers, improved seeds and use of other chemicals (such as pesticides, fungicides etc.) based on the total sample. As argued by Bachewe, Koru, and Taffesse (2015), Alemu (2005) and Abegaz (2011) these inputs, though their adoption rate is low, helped households gain efficiency benefits and increase productivity. However, using the Oromia sample, while farmers who applied chemical fertilizers had higher yield than those who didn't use these inputs, we could not find any evidence on the impact of improved seed variety on yield. Yield for barley farmers also increased with more application of fertilizers. The magnitude of coefficients is low, however. As argued by Endale (2011) specifically, for chemical fertilizers, this might be because of problems arising from applying below recommended rates and failure to use the two nutrients (i.e. DAP and urea) in proper combination.

Table 11: Estimates of coefficients of fixed effects on yield

	wheat		**Barley**	
VARIABLES	total sample	Oromia	total sample	Oromia
Improved seeds (log)	0.001**	0.003	0.000	0.002
	(0.00)	(0.00)	(0.00)	(0.00)
Chemical fertilizer (log)	0.002***	0.004***	0.000	0.004***
	(0.00)	(0.00)	(0.00)	(0.00)
Chemicals (pesticides, fungicides etc.)	0.001***	-0.000	0.010*	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Credit (borrowed=1; 0 other wise)	0.012	0.010	0.084	0.461***
	(0.07)	(0.08)	(0.08)	(0.13)
Irrigation (1 irrigated; 0 otherwise)	0.020	0.353**	-0.081	0.060
	(0.12)	(0.16)	(0.16)	(0.27)
Number of livestock (in TLU)	0.010**	0.000	0.001**	0.000
	(0.01)	(0.01)	(0.01)	(0.01)
Total labor available	0.000	0.001	0.001	0.000
	(0.00)	(0.00)	(0.00)	(0.00)

Total land area cultivated (ha)	-0.953***	- 0.701***	-1.420***	-1.531***
	(0.12)	(0.14)	(0.16)	(0.20)
Square of land area cultivated (ha)	0.061***	0.030**	0.251***	0.341***
	(0.02)	(0.01)	(0.05)	(0.06)
Age (years)	0.013	0.001	0.012***	0.012
	(0.01)	(0.01)	(0.00)	(0.01)
Marital status (1 married; 0 otherwise)	-0.031	0.484	0.390	1.190***
	(0.24)	(0.40)	(0.33)	(0.40)
Major occupation of head (1 ag.; 0 otherwise)	-0.103	-0.081	-0.080	-0.202
	(0.09)	(0.10)	(0.10)	(0.16)
Family size	0.020	0.090**	-0.010	-0.031
	(0.02)	(0.04)	(0.02)	(0.03)
Education (comparison: no education)				
Primary	0.121	0.130	0.222**	0.091
	(0.09)	(0.13)	(0.09)	(0.13)
Secondary	0.151	-0.143	0.571**	0.250
	(0.31)	(0.31)	(0.28)	(0.29)
Higher education	0.671	0.610	1.660***	
	(0.49)	(0.47)	(0.12)	
Other forms of educ.	-0.040	-0.322*	0.151	0.151
	(0.09)	(0.18)	(0.10)	(0.17)
Constant	2.151***	2.11***	2.18***	3.00***
	(0.30)	(0.37)	(0.23)	(0.29)
Observations	3,850	1,447	3,568	1,143
R-squared	0.13	0.20	0.14	0.17
Number of hhId	2,518	924	2,409	726
Household FE	YES	YES	YES	YES
Region FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Other factors effecting yield include area cultivated where smaller size farms are used more intensively than larger ones, credit where barley farmers with more access to credit have also gained higher yield.

Conclusion

Cereal productivity has been boosted for the last couple of decades. Adopting new and improved technologies has been key to this yield growth. An issue of concern in the Ethiopian agriculture is both sustainability of existing performance and further productivity growth. The performance of agricultural extension system in the country has improved over the years. However, the diffusion mechanisms of new and improved technologies need further scrutiny.

In agricultural innovation systems, R&D is only a first stage in actually using a new technology. New and improved technologies need to reach the farmer; and information in the proper application of these agricultural inputs is key to attain the expected outcomes from these inputs. How farmers are informed of the availability of new technologies and their proper application is therefore central to this process. This study focused on this last component of the innovation system. The Ethiopian government uses different means of diffusing new technologies: through on-farm extension advisory services, discussions with farmers during community gatherings, creating awareness through mass media and through encouraging farmers to visit on-farm demonstration plots.

This study indicates that the majority of farmers used on-farm advisory services of the extension worker, community meetings and mass media as a major source of agricultural information which includes, among other things, how chemical fertilizers, improved seeds and other chemicals are applied, and how land is prepared. However, only few farmers used demonstration plots to acquire such information.

Furthermore, application of chemical fertilizers responds to participation in community meetings by both wheat and barley farmers, given other factors that can potentially affect use of this input. It resulted in a difference of 63 percent more chemical fertilizers and 67 percent more improved seeds for wheat farmers. For barley farmers who participated, 86 percent more chemical fertilizers and 44 percent more improved seeds were used. Yield responds to the use of chemical fertilizers, improved seeds and use of other chemicals (such as pesticides, fungicides etc.) for wheat farmers. Yield for barley farmers also increased with more application fertilizers. We could not find any evidence on the impact of improved seed variety on barley yield.

These findings suggest that making modern inputs available to farmers is only a necessary condition for effective utilization of new and or improved technologies. Farmers should be informed of the availability of such inputs and be convinced to use them. Community meetings and on-farm advisory services have the capacity to influence farmers to use new and improved technologies such as chemical fertilizers and improved seeds and need to be expanded. Furthermore, demonstration plots should be expanded to allow farmers access to a first-hand and experimental showcase of modern agriculture.

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