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Adoption of new technologies by smallholder farmers: the contributions of extension, research institutes, cooperatives, and access to cash for improving tef production in Ethiopia

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Abstract

Agricultural intensification and extensification are standard responses to ecological and economic vulnerability among smallholder communities. Climate change has exacerbated this vulnerability and thrown the complexity of and critical need for managing a healthy natural resource base while increasing on-farm productivity into sharp light. Sustainable intensification is one of many mechanisms for accomplishing this balancing act. This study examines the adoption of sustainable intensification practices, namely input packages focused on tef row planting—designed to boost yield and promote more efficient use of inputs. This study utilized a mix methods approach to survey 115 smallholder farmers in the South Wollo zone of the Amhara region in Ethiopia. This study found that cash and capital, more so than contact with the AIS, influenced farmers' decisions to adopt row planting input packages. Khat production was an important source of cash for inputs and was more likely to be available to farmers with irrigation schemes. Long-term, farmers who cultivate khat may not successfully engage in SI, as khat replaces traditional food crop production in the region. Yet, for farmers who do not grow khat, long-term investment in SI practices is unlikely unless access to affordable credit options is improved.

Keywords Adoption · Innovation · Ethiopia · Sub Saharan Africa · Tef · Khat · Smallholder

Abbreviations

ADLI	Agricultural development-led industrialization
AIS	Agricultural innovation system
ATA	Ethiopian agricultural transformation agency
DOI	Diffusion of innovation theory
ETB	Ethiopian birr
FTCs	Farmer training centers
NAEIP	National Agricultural Extension Intervention Program
PADETES	Participatory Demonstration and Training Extension System
SI	Sustainable intensification
TLUs	Total livestock units

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Introduction

Agricultural intensification and extensification are standard responses to ecological and economic vulnerability among smallholder communities (Awulachew et al. 2007; FAO 2003). Climate change has exacerbated this vulnerability and thrown the complexity of and critical need for managing a healthy natural resource base while increasing on-farm productivity into sharp light. Sustainable intensification (SI) is one of many mechanisms for accomplishing this balancing act, and has gained critical leverage in the international agricultural development arena (Garnett et al. 2013; Foley et al. 2011; Tilman et al. 2011). This emphasis by the international development community and its potential for mitigating environmental and ecological uncertainties places SI squarely at the nexus of ecological sustainability and the social and economic viability of smallholder farms (Montpellier, USAID, etc).

Despite the prominence of SI innovations in international agricultural development programming, there is a marked gap in the number of studies documenting farmers' self-described motivations for adoption or non-adoption of SI practices and technologies. This gap is due, in part, to a lack of empirical household-level studies as well as an academic emphasis on information dissemination related to technologies. Additionally, most studies exploring adoption rely heavily on quantitative analysis, which provides important information, but fails to capture important nuances in context critical to understanding decision-making. Understanding context is essential to successfully changing behaviors around agricultural production.

The call for in-depth understanding of how smallholder producers' make decisions, initiated in 1985 by Feder et al. (1985) has gone largely unanswered. This study, in an effort to answer that call and address the deficiencies in contextual nuance, used a combination of qualitative and quantitative techniques to examine smallholder decision-making processes. Specifically, this research sought to answer two questions: (1) what are the major actors, institutions, or contextually specific factors influencing smallholder decisions to adopt (or not adopt) new technologies around tef row planting and (2) what is the relative impact of these factors on decision making compared to other actors, institutions, or contextually specific factors.

This investigation examined the assumption that increased exposure to agricultural innovation system (AIS) components—namely, extension, research institutes, farmer training centers, cooperative, and non-governmental organizations—promotes the adoption of tef row planting. This study also examined the impact other household factors have on the adoption of row planting including access to labor, cash, and assets (TLUs). This study took a grounded approach to qualitative analysis, allowing farmers to identify barriers then coding these responses into themes and combining them with quantitative analysis to explain the nuances in decision-making.

This study used primary data collected from smallholder households in the Ethiopian highlands. Acute exposure to increased climate variability, vulnerable ecologies, decreasing land size, and an AIS, all make Ethiopia a unique and important place to study the adoption of SI technologies. The study will look specifically at an input package, which includes row planting of *Erograstis tef* (tef), improved seed (when available), and fertilizer. This particular input package was selected because of its role in promoting food security and improved nutrition, as well as sustainably improving household production—key goals of SI innovations.

Smallholders manage 80% of farmland and provide up to 80% of the food supply in Sub-Saharan Africa and Asia. As such, barriers to adoption of SI practices smallholders in these nations have been at the forefront of the agricultural development discourse. Without systematic adoption of these innovations, widespread gains in agricultural productivity, environmental sustainability, and food security will remain unrealized. Ethiopia is no exception, 95% of agricultural GDP is produced by the poorest sector of the population—smallholders. As Ethiopia and other Sub-Saharan African countries continue to make investments in AISs to address these endemic problems, understanding how AISs potentially impact (or fail to impact) farm level decision making is critical for maximum effectiveness. Also understanding how particular components of the AIS work to promote technology adoption relative to other components allows for tailoring services in ways that are more effective, as well as social and culturally appropriate. This study provides a method for understanding this impact as well as pushes the conversation on the importance of context specificity when implementing more broadly conceptualized investments such as extension, training centers, and cooperative development.

Background

As a developing country where 85% of the population is engaged in agricultural production, Ethiopia relies heavily on its natural resources (Downing et al. 1997; Dejene 2003; Bekele 2006; Desalegn et al. 2006; Makombe et al. 2007; Feed the Future 2013). The sustainable utilization of these resources is crucial to the Ethiopian government's plans for national progress through agricultural development-led industrialization (ADLI) (World Bank Group 2007; MoWR 2001a, b). However, in many areas of Ethiopia, particularly in the highlands farming is dominated by rain-fed agriculture, and typically associated with low productivity (Devereaux 2000). This type of production is vulnerable to increased climate variability, and often results in localized food crisis and periodic, widespread famine as observed in the 1973–1974, 1984–1985, 2002–2003, and 2017–2018 (Devereaux and Guenthe 2009; Pankhurst 2009; Oxfam 2017). Thirty-two percent of Ethiopians are undernourished and 38% live on less than $1.25/day, which exacerbates the nature and impact of food insecurity (Central Statistical Agency 2012; World Bank Group 2013; WFP 2011). As the national population size continues to increase at an annual rate of 2.9%, the demands on food resources are likely to continue to overwhelm current domestic production capacity (Feed the Future 2013).

Consequently, smallholders continue to increase the amount of land put into production annually. In cereal production alone, farmers have increased the area under cultivation by more than 4% annually from 2004 to 2008

(Dercon and Hill 2009). This expansion process necessarily means marginalized lands—slopes vulnerable to erosion, degraded soil quality, moisture stress, and over-grazed plots—are farmed (Awulachew et al. 2007; Admassie and Abebaw 2014). By expanding production into these areas, farmers contribute to further degradation of Ethiopia's natural resource base and limit their options for future production intensification (Awulachew et al. 2007; FAO 2003). In an effort to simultaneously prevent further degradation and improve food security through agricultural intensification, the Ethiopian Government has invested heavily—more than 2% of the nation's GDP—in expanding their national agricultural extension system over the past 10 years. This investment, initiated in the mid-2000 s, supported the training of more than 60,000 diploma holding extension agents who work with communities through more than 10,000 farmer training centers (FTCs) (Gebremedhin et al. 2006; ATA 2013a, b). Each village is assigned three extension agents, with expertise in livestock, horticulture, and crop sciences, among others (Gebremedhin et al. 2009). This expansion was initiated to promote access to the agricultural knowledge information system, in the hopes that farmers would achieve food security through sustainable (cereal) intensification with the implementation of new technologies and improved management practices. The Government has also invested heavily in promoting fertilizer use, via the new extension system, and rural infrastructure, to help support extension activities and promote market access.

Why tef?

Because of its agricultural and nutritional significance, the cereal crop, *Eragrostis tef* (tef), is a priority for Ethiopia's Agricultural Transformation Agency, a government agency under the Prime Minister designed to shape national agricultural strategy and deliver associated programming. Subsequently, tef is also a priority for the newly expanded extension program. Its use in the major food staple, injera, makes tef an in-demand cereal both domestically and internationally, with the Ethiopian diaspora (ReliefWeb 2006; Refera 2001). This demand has resulted in continually increasing prices that incentivized vulnerable rural households to sell their tef at market rather than consuming it (ReliefWeb 2006; Refera 2001). This demand also resulted in a ban of raw tef in 2006, but processed tef was still exported, providing only partial relief for Ethiopian tef prices (ReliefWeb 2006; Nurse 2015). This demand is one of the reasons why, despite having significantly lower yields than most cereal crops, tef has more resources (energy, land, and inputs) dedicated to its production (Roseberg et al. 2005; CSA 2012). Tef is grown by more than six million smallholder farmers and accounts for 21% of total cereal production and 28% of total productive acreage in Ethiopia, with an average yield increase of 7.7% annually (Dercon and Hill 2009; CSA 2012; Viswanath 2012).

In terms of addressing malnutrition, tef contains the largest amount of protein (12–17%) and has the second largest energy content of any cereal (Stallknecht et al. 1993). Tef also contains significant amounts of the essential amino acid lysine, as well as high levels of iron, calcium, phosphorus, iron, copper, barium and thiamine, all crucial to a child's growth and development (Roseberg et al. 2005; Refera 2001; Stallknecht et al. 1993). This is not insignificant as tef makes up approximately two-thirds of the average Ethiopian's daily protein intake and accounts for 600 and 200 daily calories of the urban and rural diet respectively (Fufa et al. 2011; Refera 2001). As a note, the differences between rural and urban diets, is a product of overall reduced food intake in rural areas, as well as the inclination of rural households to substitute sorghum, wheat, or maize for tef in their injera.

A great deal of time and fiscal resources have been dedicated to increasing tef production in Ethiopia (Engeda and Benson 2013; IFPRI-EDRI 2013). Though there are several agronomic and post-harvest issues to address, row planting is one critical area where extension officers and local farmers, working together, could make inroads to finding solutions. Traditionally, tef, as with many other crops in Ethiopia, is sewn using a hand broadcast method which is highly inefficient in terms of seed use and typically results in plant crowding, resulting much lower yields than alternative methods, such as row planting (ATA 2013a; Abraham et al. 2014). Row planting allows for the correct and predictable seed rates and seedling space, which reduces crowding, and allows for easier weeding and more efficient fertilizer application, subsequently improving yields (ATA 2013a; Abraham et al. 2014).

Theoretical framework and literature review

Adoption diffusion theory: barriers and promoters of adoption

This study seeks to determine which AIS actors, programs, or contextual factors are strongly linked to adoption. Adoption diffusion theory (also diffusion of innovation, DOI) provides the theoretical tools for exploring these links. DOI helps determine what could be important (which factors) and the why (how are these factors influencing decision making). Rogers (2003) outlines four major influences in the adoption process—the innovation itself; how information about the innovation is spread; time; and the characteristics of the society in which the innovation is introduced. Each of these influences speak to the specific context of the time and place of introduction. This framework provides an initial tool for assessing potential barriers. However, Rogers' (2003) theory of perceived attributes outlines specific areas of potential resistance to the adoption of an innovation: (1) perceived *relative* advantage; (2) compatibility; (3) complexity; (4) triability; (5) and observability. Use of this theory provides specific options for targeted and proactive troubleshooting. Each of these areas is intimately tied to mechanisms for mitigating farmers' perceptions of risk associated with the innovation and are influenced by the types and delivery methods of information.

Information access and other influencers

Not surprisingly, access to information on agricultural innovations is one of the most critically examined aspects of adoption and diffusion, especially in the developing world (see Rogers 2003; Napier and Cockerill 2010; Simpson 2015). Increased access to information and improved knowledge on the use and potential benefits of a technology allow farmers to properly assess, and to some extent mitigate, the (potential) risk associated with adoption of new innovations (Schultz 1964; Bandiera and Rasul 2006; Foster and Rosenweig 1995; Moser and Barrett 2006). Information, both theoretical (textbook, oral presentation, etc.) and applied (demonstration, on-farm trial, farmer field days), is critical to overcoming complexities associated with using the innovation, and accurately assessing its advantages and ability to meet famers' needs (Rogers 2003). Perhaps most important is the ability of farmers to see the new innovation in action—the ability to try the technology or process before committing scarce resources and observe tangible benefits are important to long-term and systematic adoption of the practice (Rogers 2003). Weir and Knight (2000) and Krishnan and Patnam (2012) noted the ability to observe neighbors using the practice, successfully, was particularly important for less educated farmers in Ethiopia.

The AIS, and specifically agricultural extension, has traditionally been the institutional response to information or knowledge barriers. As a "translator" of institutional knowledge, extension agents facilitate the flow of information, reducing barriers to access (Rogers 2003). The current Ethiopian Extension System is implementing the National Agricultural Extension Intervention Program (NAEIP), a scaled-up version of the post-civil war system of Participatory Demonstration and Training Extension Systems (PADETES), which focused almost exclusively on technology transfer and cereal production (Gebremedhin et al. 2006; Speilman et al. 2012; Egziabher et al. 2013). NAEIP, which has been in effect since the mid-1990s, relies on the Extension Management and Training Plots model and input packages. In this model farmers manage demonstration plots as educational tools for the community and extension agents and are supplied with agricultural packages that include information on agricultural technology or practices, the necessary inputs, and information on how to access credit to support their adoption (Alemu and Demese 2005).

In the Amhara region, the study region for this research, extension agents typically focus on a type of input package designed to increase household income above the national poverty line (1 USD) (Gebremedhin et al. 2009). This package tends to focus on adoption and implementation of improved technology or management practices and input use (Gebremedhin et al. 2009). As the purveyors of these input packages extension agents often see themselves as little more than fertilizer suppliers, rather than extension specialists (EEA/EEPRI 2006; Spielman et al. 2012).

The continued emphasis in extension on input-use rather than efficacy and profitability, though perhaps better suited to the agroecological context, has resulted in limited adoption of new methods and technologies generally (Spielman et al. 2010; Bonger et al. 2004). Additionally, research suggests extension still focuses little on resource poor farmers and as extension agents are responsible for selecting participants for on-farm demonstrations and participation in extension activities, the impact on the most vulnerable farmers is likely to be minimal (Assefa et al. 2008; Belay and Abebaw 2004).

Like the extension system itself, research on extension systems in Ethiopia has emphasized production outcomes and frequency of contact rather than quality of extension contact with farmers (Egziabher et al. 2013; Binam et al. 2004; Feder et al. 2004; Haji and Andersson 2006; Cunguara and Moder 2011; Benin and Pender 2001; Solis et al. 2009; Bekele and Drake 2003; Bewket 2007; de Graff et al. 2008; Abede et al. 2013). Yet, the research on extension's role in promoting adoption is unclear, while in some cases it has improved the uptake of new technologies and management practices, in others it has had no remarkable or significant impact (see Abede et al. 2013 and; Krishnan and Patnam 2012).

Critical capital

Though quality information and delivery are critical to the adoption process, there is evidence to suggest that an emphasis on information alone is short-sighted. Mendola (2007) and Gebissa (2004) note that among smallholders, the real barrier to adoption is in resource constraints experienced by farmers. This is particularly true for fiscally intensive inputs, such as fertilizer, or inputs in short supply, such as labor and seed (Dercon et al. 2009; Davis et al. 2010). Each of these resources requires a certain ability by households to free up or generate cash (i.e., accessing reasonable credit, selling cash crops or labor, renting land). However, in circumstances where these options are not available, farmers may experience a number of market inefficiencies which would render the household unable to adopt or risk adoption, or would make adoption unprofitable, and therefore undesirable (Jack 2013). Knowing the potential for market inefficiencies in a specific context to hinder adoption is essential in understanding farmers' decision-making processes, as well as, developing appropriate household mitigation strategies.

In addition to capital, researchers have explored, with mixed results, the role of a variety of farm and farmer characteristics which reduce the barriers to adoption by improving farmers' ability to absorb shocks—including farm size, income, land tenure, education, and family size (see Napier 2010; Weir and Knight 2000; Duflo et al. 2011). For the particular intervention explored here labor is of particular importance. Hand seeding rows, rather than using broadcast, requires a great deal more time and labor. Depending on family size, labor from the household may not be sufficient, requiring households to hire labor, necessitating on-hand cash.

Methods

Study site and data collection

Data were collected from December 2014 to March 2015. Research participants were selected from three peri-urban highland villages in the South Wollo zone of the Amhara region—Boru Seyu, Amemo, and Kuty. Villages were stratified in a way to provide information on a variety of production systems, agroecological conditions, and differing experiences with the AIS. Within each village accessibility sampling was used. A total of 115 farmers were surveyed. Only farmers currently growing tef were included. In addition to interviews with farmers, this research included interviews with five extension agents, two regional extension directors, one kebele chairmen, and one regional Productive Safety Net Programme administrator.

This zone is characterized by small diversified production, integrating cereals, pulses, livestock, and some cash crops. B. Seyu is located on the periphery of Dessie town, a major urban area in the region. Farmers in Boru Seyo are the most marginalized group within this sample. There is no cash crop production and cereal production is marginal at best. Farmers in B. Seyu tend to work in Dessie town or sell forestry products (firewood, charcoal, building materials) to supplement household income. In Amemo, farmers are more likely to have a highly diversified production system, growing mangoes, oranges, coffee, and guava in addition to cereal and pulse production. Here, farmers rely mostly on cash crop production and farmers here tend to be much wealthier than in surrounding communities as a result. Kuty farmers, like those in Boru Seyo, live at the edge of an urban area, Hyke. Many of the families in this village have members who work in the village as an income diversification strategy. Kuty farmers, like Amemo also have a more diversified production system, including khat, vegetables, cereals, and pulses.

Demographic characteristics for each village are available in Table 1. Of important note are the data on hectares cultivated. These refer strictly to hectares of land under food crop cultivation. Area under cash crop (i.e. *Catha edulis*—khat) cultivation is not included.

Quantitative analysis

Logistic regression was used to determine the association of a number of independent variables (IV) on the dependent variable (DV) "adoption." It is expected exposure to multiple facets of the AIS, FTCs in particular, are significant predictors of adoption among smallholders. Also, given the qualitative data, it is expected the number of individuals available to participate in the planting process is be critical in adoption. In terms of farmer assets, it is expected both khat income and TLU will be significant predictors of adoption. Logistic regression does not provide a definitive exhaustive explanation of all the factors which influence decision making, rather it provides a relative weight for the influence each of the independent variables associated with the AIS has on the decision making process. In keeping with DOI theory, this provides us with a specific method of intervention which might best promote adoption in this particular context.

To test the association of access to information and access to cash and capital, both indicated by the literature to be critical in adoption of SI practices, data on interactions with the AIS (extension, research centers, cooperatives) and a proxy for household cash availability—khat income—were

Table 1 Village level characteristics

Woreda	Dessie Ketema	Tehuledere	
Village	Boru Seyu/012 N = 40 (*SD*)	Amemo/008 N = 23 (*SD*)	Kuty/005 N = 53 (*SD*)
Cereal/pulse crops			
Belg (*Mar–April*)	Barley; wheat	Wheat	Wheat; vetch
Meher (*July–Oct*)	Tef; barley; maize; pea; fava	Tef; sorghum; vetch; maize	Tef; sorghum barley; chickpea
Production			
Cultivated area (Ha)	0.92 (*0.38*)	0.68 (*0.15*)	0.68 (*0.21*)
Belg (%)	0.56 (*0.28*)	0.25 (*0.12*)	0.22 (*0.08*)
Meher (%)	0.44 (*0.19*)	0.75 (*0.10*)	0.77 (*0.18*)
Tef (%)	0.10 (*0.09*)	0.60 (*0.04*)	0.48 (*0.07*)
Rain			
Belg	276	341	341
Meher	912	828	828
Altitude (MASL)	2500	1900	1800
Distance to market	< 1	8	< 1

collected. Because row planting in the study area is part of a capital intensive input package, including fertilizer, cash availability and capital came up as significant barriers during interviews and focus groups. This study uses khat income specifically because it represents a reliable, steady, and in irrigated production a non-time-constrained financial resource. There is some cash crop production in fruit, vegetables, coffee, and forest products in this region, but these forms of income are limited in several ways. Fruit and coffee production are time sensitive and the prices, even locally, are relatively volatile, making it an inconsistent source of income. The vegetable market is relatively saturated, as farmers in another nearby village have discussed their use of carrots and tomatoes as animal food because they cannot sell the produce in the market. Additionally, forestry products are often low return and time sensitive.

Adoption (DV)

The purpose of this study is to discern the factors which influence increase the likelihood of adoption of row planting. In this study area, because mechanized row planters are not commercially viable, farmers are being asked to row plant by hand. This means they are not only forming rows in their fields, which requires time and labor above and beyond traditional broadcasting, but they are being asked to distribute tiny tef seeds, less than one millimeter in diameter, evenly within those rows. Interviews and focus groups revealed that in the farmers' hands, these tiny seeds, have a tendency to clump up, resulting in uneven distribution, which negates the beneficial features of row planting (competitive advantage over weeds, easy access for fertilizer application and weeding). Additionally, this new practice is presented in conjunction with an input package including improved seed (in some cases), and fertilizer—a very capital intensive input. Improved seed, which is not always available, can cost farmers 1200ETB/quintal (55USD/100 kg), though because of reduced seed rate only 10 kg (120ETB) is recommended for planting a hectare. Fertilizer is nearly double this cost at 2000ETB/quintal (93USD/100 kg), though farmers typically spend between 300 and 800ETB for fertilizer purchases. Adoption was coded, (0) for no, (1) for yes.

Standardized khat income (IV)

Income from khat was collected as part of a land use survey. It was recorded as a continuous variable. Income from khat was standardized to better determine the odds ratio during logistic regression analysis. Standardization was calculated $[(\chi - \text{mean khat income})/\text{standard deviation for khat income})] \rightarrow (\chi - 5591)/(9599) = 1$ unit of standardized khat income.

The next set of variables are related to contact with the different agencies within the Ethiopian AIS. These variable were adapted from Abede et al. (2013) who conducted research near the study region on the adoption of a new variety of potato. These questions are designed to get at the quantity or number of contacts with AIS as well as the quality (variety of contacts, use of demonstration plots).

Extension services (IV)

"How many times in the last 12 months have you used your village extension services." Recorded as a continuous variable. Though a major critique of the literature on extension is the reliance on measures of "frequency of contact" it is still an important component of the smallholder ability to access the AIS. Additionally, in order to build relationships which might promote the use of a new management practices such as tef row planting, extension must be present in the village and accessible to farmers. Frequency of contact is used as an approximate value.

Local research institutes

"How many times have you used services provided by the local research institute in the last 12 months?" Recorded as a continuous variable. This refers to services provided by non-extension agricultural experts. In Ethiopia extension and research institutions (such as universities) operate independently of each other but often carry out research and interventions in the same communities. In this particular context this includes only two groups—agricultural faculty from Wollo University, who have active research agendas related to local production and sustainable agriculture, and agricultural experts from the Ministry of Agriculture, who are not associated with local extension. Though not specifically related to extension these institutions are part of the AIS, and are included in the model.

Cooperatives (IV)

"How many times have you used technical services from cooperatives in the last 12 months?" Recorded as a continuous variable. Cooperatives are one of many strategies used by the Government of Ethiopia to promote increased and sustainable intensification among smallholders (Abebaw and Haile 2013; Bernard and Spielman 2009). Association with cooperatives is important, particularly for more marginalized farmers (illiterate, poor), in technology adoption through their role in potentially providing access to high quality inputs, such as fertilizer and improved seeds and credit (Abebaw and Haile 2013). Credit is readily available from the government in this particular region, but accessing credit through cooperatives usually provides the borrower with more favorable interest rates. Again, though not directly associated with extension, cooperatives are an important part of accessing elements of the AIS.

Farmer training center (FTC) (IV)

"Days spent in farmer training centers in last 12 months." Recorded as continuous variable. Ability to see the technology or management practice in the case of tef row planting, and seeing it work well are major tenets of Rogers' Adoption of Innovation Theory (observability). Seeing is believing. Additionally, this variable begins to examine the quality aspects of extension. Farmer Training Centers are not new to agricultural extension and are a hallmark of the expanded extension system in Ethiopia. Their use and maintenance are a collective responsibility of the extension and the community—so their use by smallholders and inclusion in the model reflects, potentially, the quality of the relationship between extension and communities.

Total livestock units (TLU) (IV)

The number of each species of typical kinds of livestock was recorded for each household. These numbers were then consolidated into a single indicator, TLU. Livestock were weighted according to Sub-Saharan African specific weights (Otte and Chilond 2006): cattle/oxen/horses (0.5); camels (0.7); goats/sheep (0.1) chickens (0.01). In this region of Ethiopia TLU and specific types of livestock have been used as proxies for household wealth and savings (see Cafer et al. 2015; Little et al. 2004, 2006). Farmers often draw upon these stocks in times of emergency, and as qualitative analysis revealed as a means of repaying loans to pay for inputs.

Cultivated area (IV)

This is a measure of the number of hectares cultivated for food crops. This measure combined hectares cultivated in the Belg (early) growing season and the Meher (late) growing season, meaning double cropped hectares were counted twice. This departs from more traditional measures of land size, such as the FAO measure of arable land, which includes land under temporary crops (double cropped areas only counted once), pasture, gardens, and areas temporarily left fallow. This departure is important for two reasons: (1) it allows for the approximation of "activity" dedicated to tef among all food crop activities. Most households in this region of South Wollo, have a diversified system which includes a number of cereals, pulses, and market crops.

Available labor (IV)

This is a measure of members of the household between the ages of 15 and 65, and estimates available household labor for both on-farm and off-farm activities. Farmers revealed during focus groups that row planting tef was a tedious practice and required additional labor, at least three people. This was an important barrier discussed across all villages, suggesting additional labor would entice farmers to adopt row planting, if the labor shortage could be overcome.

A Box-Tidwell test was conducted to ensure predictor variables did not violate statistical assumptions.

Qualitative analysis

A mix of both in-depth interviews and focus group interviews were used to delineate reasons for adoption or non-adoption of tef row planting. Farmers not using row planting were asked, simply, "[w]hat are the reasons you do not use row planting when growing tef?" Farmers who did use row planting were asked, '[w]hat are the reasons you use row planting when growing tef?' These responses were recorded and transcribed. The transcriptions from these interviews were analyzed using open and axial coding (Table 2). Axial codes were then grouped into themes.

Results

Quantitative

In this sample 13% of farmers used row planting (Table 3). The highest concentration of adopters was in Amemo, this is also the village where farmers have the highest incomes from khat and were more likely to report having seen row planting in practice through an extension supported demonstration plot. Average yearly khat income for the sample was roughly ETB 5065 ($232).

Model 1-AIS only [extension services, research institutes, cooperatives, and FTCs]

This model looked only at the effects of farmer engagement with AIS actors (extension, local research centers, cooperatives, and farmer training centers) on the likelihood of adoption (Table 4). This model correctly classifies 87.4% of cases for the sample (99.0% of non-adopters and 13.3% of adopters). Though this correctly classified a significant number of research participants, it does not do a good job of classifying adopters. A test of the AIS model against a constant-only model was statistically significant, and indicated that the predictors as a group, reliably distinguish between the adoption and non-adoption of tef row planting

Table 2 Reasons for non-adoption of tef row planting among farmers

Themes	Axial codes	Open codes	Count
Time constraints	Labor constraints	Too old; not enough help; need to work cooperatively	9
	Tedious	Tedious, heard it was tedious; time consuming; energy consuming	26
Land	Land size	Smallness of the land; land too small; need at least 2 timod; small farm size	5
	Shared land	Shared Land	1
	Land fragmentation	Land fragmentation	5
Market	Debt	Loan for inputs has unbearable interest; tef production only for household consumption—not willing to borrow to purchase input; avoid debt; because not sell at market, unable to repay loan	15
	Resource allocation	Only use irrigation for vegetable (market) production; Need irrigation for khat production; prefer to spend labor on income generating activities; uneconomic use of land	21
	Khat	Want to focus on khat production	8
Learning	Personal experience	Tried with lower productivity; tried but bad results	8
	Neighbor experience	Heard from neighbor less productive; Heard from neighbor it's disadvantageous; saw neighbor try with poor results; negative experiences of neighbors	9
	Training and knowledge	Demonstration plot failed; Need to watch before I try it; Need to see it; No information; No training	21
Agroecology	Rainfall	Rain inconsistent; Race against the rain; lack of rain	8
	Soil	Black soil not suitable (too muddy to plant)	1
	Frost	Heard from neighbor RP makes tef vulnerable to frost; Frost	2
Perceptions	Negative perceptions	Negative attitude toward RP; Believe conspiracy to make farmers more dependent on safety nets	8
Inputs	Inputs-general	No free seed or fertilizer; Input ineffective—wag; selected seed and fertilizer very bad results	1
	Seed	Not using selected seed; seed clumping	3
	Fertilizer	Not use fertilizer because it damages the crop; Fertilizer aggravate/cause wag—refuse to purchase; fertilizer unaffordable; fertilizer bad for soil; use compost instead	21
	Irrigation	(No) Irrigation; only just started using irrigation	11

Table 3 Descriptive statistics for quantitative variables

	Sample N = 115 (*SD*)	B. Seyu N = 40 (*SD*)	Amemo N = 22 (*SD*)	Kuty N = 53 (*SD*)
Adoption (# of farmers)	15 (13%)	2 (5%)	10 (45%)	3 (6%)
Peasant association extension services (# of visits)	0.77 (*1.00*)	1.35 (*1.23*)	1.14 (*0.56*)	0.14 (*0.40*)
Local research institutes (# of visits)	0.76 (*1.53*)	0.70 (*1.32*)	1.64 (*2.59*)	0.41 (*0.73*)
Cooperatives (# of visits)	2.45 (*2.58*)	3.20 (*2.34*)	4.77 (*2.69*)	0.82 (*1.44*)
Farmer training centers (# of visits)	0.29 (*1.13*)	0.10 (*0.38*)	1.32 (*2.25*)	0.00 (*0.00*)
Khat income (USD, $)	232 (*437*)	0.00 (*0.00*)	887 (*618*)	138 (*186*)
Total livestock units	1.97 (*1.10*)	2.30 (*1.35*)	2.20 (*1.04*)	1.66 (*0.82*)
Head of household age (years)	44.01 (*15.34*)	44.28 (*12.33*)	39.00 (*15.99*)	45.9 (*16.99*)
Available labor	2.66 (*10.4*)	2.92 (*1.17*)	2.67 (*0.91*)	2.45 (*0.94*)

Exchange rate as of January 2015 0.0459USD = 1ETB

($\chi^2 = 10.020$, $p < 0.040$ with df = 4). The Wald criterion demonstrated that only the number of times farmers engaged cooperatives (0.007) made significant contributions to prediction of adoption. Number of interactions with extension (0.824) and research institutes (0.218) as well as the number of days spent at a farmer training center (0.889) were not significant. The EXP(B) value suggests that for every additional interaction with cooperatives a farmer increases the likelihood of adoption by 37.5%.

Model 2-AIS and capital [khat income and TLUs]

The second logistic model combined AIS and the two most common forms of capital available to farmers in this

Table 4 Logistic model for predictors of adoption of row planting

	Model 1 (N = 111)		Model 2 (N = 103)		Model 3 (N = 92)	
	B	SE	B	SE	B	SE
Extension services	− 0.071	0.320	− 0.097	0.411	− 0.008	0.429
Local research institutes	0.251	0.204	0.230	0.280	0.629	0.452
Cooperatives	0.318**	0.119	0.199	0.130	0.209	0.169
Farmer training centers	− 0.036	0.262	− 0.704	0.414	− 0.423	0.470
Khat income			1.456**	0.449	0.000*	0.000
Total livestock units			0.338	0.338	0.556	0.405
Available labor					− 0.351	0.401
Cultivated area					− 3.400	2.505
Constant	− 3.032***	0.594	− 2.670**	0.901	− 1.159	1.863
Sig	0.040		0.000		0.002	
X^2	10.020		25.699		24.457	
− 2 Log Likelihood	77.900		59.802		52.310	
df	4		6		8	
% of adopters predicted	13.3		46.7		50.0	
% of non-adopters predicted	99.0		98.9		98.6	
Total sample predicted	87.4		91.3		90.8	
Nagelkerke R square	0.158		0.392		0.418	

*p < 0.05; **p < 0.01; ***p < 0.001

region—cash income from khat and livestock. This model correctly classifies 46.7% of cases for the sample (98.9% of non-adopters and 46.7% of adopters). A test of the AIS and capital model against a constant-only model was statistically significant, and indicated that the predictors as a group, reliably distinguish between the adoption and non-adoption of tef row planting ($\chi^2 = 25.699$, $p < 0.000$ with df = 6). The Wald criterion demonstrated that only standardized khat income (0.001) made significant contributions to prediction of adoption. Again, number of interactions with extension (0.814), research institutes (0.411), and days spent at FTCs (0.089) were not significant. Additionally, after adding capital to the model, cooperatives also lost significance (0.126). TLUs were not significant in the model (0.272). The EXP(B) value suggests that for every unit increase in standardized khat income (~ $697.22) a farmer increases the likelihood of adoption by 429%.

Model 3-optimized model [AIS, capital, farm(er) level characteristics]

The third and final logistic model, used AIS, capital, and variables (land size, extra labor) indicated in the qualitative analysis to be important in farmers' decision to adopt. This model, correctly classifies 90.8% of cases for the sample (98.6% of non-adopters and 50.0% of adopters). A test of the optimized model against a constant-only model was statistically significant, and indicated that the predictors as a group, reliably distinguish between the adoption and non-adoption of tef row planting ($\chi^2 = 24.457$, $p < 0.002$ with df = 8). The Wald criterion demonstrated that standardized khat income (0.033), made a significant contribution to prediction of adoption. Extension (0.985), research institutes (0.164), cooperatives (0.216), FTCs (0.368), TLUs (0.170), available labor (0.382), and cultivated area (0.175) were not significant predictors of adoption in this model, but all increased the predictive power of the overall model. The EXP(B) value suggests that for every unit increase in standardized khat income (~ $697.22), unit increase in TLU, and additional hectare cultivated a farmer the likelihood of adoption increases by 310, 225, 9.5% respectively.

Qualitative

Several themes emerged as significant barriers to row planting (Table 2); tediousness, need for additional labor, land, or rather land size was a major issue for farmers, particularly in Boru Seyu, where multiple farmers commented on how small their land was due to land fragmentation. These farmers were also much more sensitive to agroecological constraints, particularly rainfall and the ability to plant in a timely manner using row planting. In this particular region of Ethiopia there has been a documented increase in rain variability over the last two decades (Rosell and Homer 2007). This increased rain variability requires farmers to be able to plant quickly, and farmers noted during focus groups and in-depth interviews that row planting require an additional 2–3 days. Issues of debt and resource allocation as well as the cost and effectiveness of inputs were major concerns for farmers in Kuty. Perhaps of most interest are the Market, Learning, and Input themes as they help illuminate and the nature and context of farmers' engagement with the AIS as well as khat production in the study area and their relation to adoption of SI practices.

For example, open codes within the market and input themes clearly demonstrate farmers are keenly aware of their economic situation and are more likely to invest scarce resources such as irrigation, labor, and financial capital in an agricultural product, such as khat, likely to return the most cash for their investment, rather than invest resources, particularly financial, in the purchase of improved seed and fertilizer associated with row planting of tef. Tef in these communities is almost exclusively for household consumption and would not provide any return on investment, other than reducing the amount of food purchased in the market. In this region even farmers who grow their own cereals are still forced to purchase food in the market because of small plot sizes. Khat allows them to make those purchases *and* maintain a cash flow.

For farmers who did employ row planting (Table 5), formal training, access to demonstration plots, the use of inputs, particularly improved seed, and the use of labor saving technologies were important facilitators in adoption. These were also isolated primarily to one community. In this community (Amemo) farmers and extension had an amicable relationship and extension were active in engaging farmers in education and modeling behavior. Additionally, this village had adopted the use a "bottle planter." The tool was designed from a common resource—a water bottle—with a small hole in the cap to allow the seeds to fall in the rows evenly, overcoming the common problem of seed clumping in the farmer's hand. This is important in helping farmers insure even seed spacing which is critical to higher yields. This may also explain why so many farmers reported success with this technique, as compared to other villages.

Discussion

Training matters…less than we thought…

There were several questions in the structured questionnaire designed to capture the extent and nature of farmers' relationship with AIS personnel as well as the level of training and exposure farmers received on row planting. Results from the first model suggest that the combined positive effect of these interactions on row planting adoption is relatively minimal. In fact, the two components of AIS which might have the greatest impact, extension and the farmer training center—where the Government has invested the most resources, did not significantly increase the likelihood of adoption. Additionally, as other explanatory variables are added to the model the importance of AIS related variables becomes significantly smaller. In the case of all but accessing cooperatives, the inclusion of AIS variables actually decreases the predictive power of the model.

However, in-depth interviews revealed a lack of training and practical information on row-planting was a significant barrier to implementation for 18% of farmers. Qualitative analysis also revealed that the most vulnerable households (those with less productive land, smaller plots, and contentious relationships with extension) were not targeted for practical training (demonstration plot). Instead these households, concentrated in Boru Seyu and Kuty were more likely to receive only oral training from extension, or no training at all but still expected to implement row planting and purchase inputs (see Table 2, Learning theme). Interviews with farmers from B. Seyu revealed local extension agents are rarely in the village and the demonstration plot routinely goes unused. Farmers in Kuty made repeated remarks, captured in the "perceptions" theme, they believe extension has malicious ulterior motives for promoting row planting, which is perhaps inflated by the lack of practical training from extension and observed negative outcomes on neighbors' plots who did use row planting.

Table 5 Reasons for adoption of tef row-planting among farmers

Themes	Axial codes	Open codes	Count
Experience	Formal training	Was formally trained on the technology; extension visited	12
	Demonstration	Witness/accessed a demonstration plot	7
	Model farmer	As an expert I should serve as a model; I am extension worker	
	Success	Convinced by first year production; convinced/persuaded by its benefits	2
Production system	Planting frequency	Plants tef more frequently	2
	Inputs	Have access to irrigation; access to loan for seed; have extra labor; uses improved seed	7
Barrier mitigation	Helper technology	Uses planter bottle	6
	Labor	Have extra labor in household	1

Khat, livestock, and the importance of capital

Information on row planting practices is offered in conjunction with other agricultural inputs, namely fertilizer and improved seed, as a comprehensive input package to be purchased and used by farmers. These inputs are incredibly expensive, particularly for farmers who are producing tef exclusively for household consumption, rather than market. The average cost, as revealed through one particular focus group, is roughly 900–1000 birr ($41–46). For Amemo farmers, this represents less than 5% of documented income (from khat), but for farmers in Kuty this represents nearly 30% of income (from khat). For farmers in B. Seyu who are engaged less in cash cropping, this would represent a significantly larger portion of household income. As such, lack of capital is an important gap to bridge for smallholders and cash income is essential in bridging that gap (Chirwa 2005). Income from khat played a critical role in the facilitation of row planting input package adoption in both the second and third models, and had the largest significant predicative impact on a farmer's likelihood of adoption. In this particular study area khat is one of the most culturally and economically important crops, outside of tef. Income from khat is used to improve household building materials, pay school fees, and provide a financial buffer between a family and chronically severe food insecurity. Yet this study, through mixed methods revealed that the nature of khat income is more complicated. The benefits of khat income in mitigating the risk associated with adoption of new technologies and helping farmers overcome the capital gap were only realized at an income level equivalent to USD $697.22 ($X=(9599\times 1)+5591=15190\times 0.0459$ (exchange rate) $=697.221$. Fewer than 26% of farmers earned this much in khat income. Additionally, farmers who were likely to produce khat at this level were concentrated in one village, Amemo, and were more likely to have access to well-equipped extension services and irrigation—a critical component of intensive khat production.

Livestock are another important source of capital for Ethiopians. The land tenure system has prevented the building of wealth through land accumulation, and consequently livestock have become an important economic tool (Desalegn et al. 2006). Though TLUs were not significant predictors in the logistic models they did improve its predictive power. Additionally, a number of farmers indicated, during focus groups, their need to liquidate smaller assets, such as sheep, to pay for agricultural inputs. This economic role of livestock, outside of their use for agricultural means (plowing, planting, etc.), is even more prominent among smallholders who do not produce khat, and indicates how important access to capital is in facilitating adoption of new practices tied to input purchases. It is important to note that livestock represent as sort of emergency fund in comparison to khat income. Livestock are the one of the last resources to be liquidated in order to repay input loans. This, in part, explains their lack of significant influence on adoption.

Short sighted adaptation…

Khat's role in technology adoption though significant, is perhaps short-lived. A number of farmers indicated their reservation in adopting row planting was tied, in part, to a lack of irrigation (mostly Kuty), but simultaneously revealed they would reserve such resources solely for khat production. This is reinforced by observations in Amemo, where irrigation is used only for khat production and was given as a reason for non-adoption of row planting. Furthermore, a number of farmers in Kuty revealed they hoped to rely exclusively on khat production in the future and would gradually replace cultivated area in tef and vegetables with khat. As a water intensive activity, increased khat production has serious implication for natural resource management in the region (Heffez 2013). However, khat's role in poverty reduction and subsequent potential for increased food security through improved household purchasing power, will likely make it a go-to strategy for households.

Conclusion

The adoption of a new technology or practice is risky business, particularly among extremely vulnerable populations dealing with chronic hunger and extreme poverty. A degraded resource base combined with weak market access and episodes of climate-induced drought and flooding crescendo into devastating cycles of poverty. These cycles of poverty and uncertainty can increase farmers' perceptions of vulnerability which impact their willingness to adopt modern agricultural inputs, and can translate to an unwillingness to adopt new technologies or crop management practices associated with inputs (Shiferaw and Bantilan 2004; Shiferaw et al. 2009).

This study found that only cooperative involvement was a significant predictor of adoption. Using DOI theory, this is likely a result of cooperatives' general capacities for improving access to credit and overcoming the financial barriers to adoption, lowering the risk of investment. This study did not support mainstream assumptions that interactions with the AIS alone necessarily improve the likelihood of adoption. Instead, this study supports the idea presented by Jack (2013) that access to resources that mitigate market inefficiencies were the most significant predictors of adoptions. Specifically access to cash, for the purchase of expensive inputs. This study has provided a nuanced look decision-making among smallholders. Additionally, the study has provided a model for mix-methods research in examining on-farm decision-making around the adoption of technologies and explored the importance of a relatively understudies crop, khat, in promoting (short-term) and potentially hindering (long-term) the adoption of new SI practices.

In Ethiopia less than 14% of the rural population has access to credit (Agrifin 2012). Additionally, most of the traditional lending institutions require collateral, typically in the form of larger farm equipment as land is owned by the government. Most smallholders simply do not have access to this type asset. In an effort to increase access to credit at reasonable rates the ATA is piloting eVoucher system as part of a more comprehensive Rural Financial Services Strategy that will help transition savings and credit cooperatives into mature professional financial service providers. This study indicates that these programs could play a vital role in the adoption of SI technologies promoted by the ATA and the international development community.

In the interim, cooperatives have been used by the Government as a strategy of agricultural led industrialization and have documented positive spillover effects for communities, often with poor more marginalized farmers, who are not members of the cooperative, benefiting (Bernard and Spielman 2009). Cooperatives have also been linked to other sustainable intensification practices (see Abebaw and Haile 2013) and increased likelihoods of technology adoption in Ethiopia, namely through improving access to reasonable loan rates and cheaper inputs. Findings from this study suggests that while the ATA continues to strengthen rural financial services, continued and increased investment in these types of organizations and policy to facilitate their operation may provide a larger return on investment for the Ethiopian Government.

Further research is needed to explore the specific mechanisms by which khat income is translated to increased technology adoption and to what degree khat production will negate the need for technology adoption as it becomes the dominant agricultural product in these areas. Furthermore, additional research is needed to understand the larger role of the AIS in building community capacities in other areas and its contribution to community resilience by mitigating market inefficiencies.

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