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Adoption of Organic Farming Techniques

Evidence from a Semi-Arid Region of Ethiopia

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Menale Kassie, Precious Zikhali, Kebede Manjur, and Sue Edwards

Abstract

In the wake of the resource constraints for external farm inputs faced by farmers in developing countries, sustainable agriculture that relies on renewable local or farm resources presents desirable options for enhancing agricultural productivity. In this study, we used plot-level data from the semi-arid Tigray region of Ethiopia to investigate the factors influencing farmers' decisions to adopt sustainable agricultural production practices, with a particular focus on conservation tillage and compost. While there is heterogeneity with regard to the factors that influence the choice to use either tillage or compost, results from a multinomial logit analysis underscored the importance of both plot and household characteristics on adoption decisions. In particular, we found that poverty and access to information, among other factors, impact the choice of farming practices significantly. We also found evidence that the impact of gender on technology adoption is technology-specific, while the significance of plot characteristics indicated that the decision to adopt particular technologies is location-specific. Furthermore, the use of stochastic dominance analysis supported the contention that sustainable farming practices enhance productivity. They even proved to be superior to use of chemical fertilizers—justifying the need to investigate factors that influence adoption of these practices and to use this knowledge to formulate policies that encourage adoption.

Key Words: Sustainable agriculture, adoption, productivity, compost, conservation tillage, Ethiopia

JEL Classification: Q12, Q16, Q24

Contents

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Introduction

Sustainable agriculture can be broadly defined as an agricultural system involving a combination of sustainable production practices in conjunction with the discontinuation or the reduced use of production practices that are potentially harmful to the environment (D'Souza et al. 1993). More specifically, the Food and Agricultural Organization (FAO) argues that sustainable agriculture consists of five major attributes: it conserves resources (e.g. land, water, etc), and it is environmentally non-degrading, technically appropriate, and economically and socially acceptable (FAO 2008). In practice, sustainable agriculture uses fewer external off-farm inputs (e.g., purchased fertilizers) and employs locally available natural resources, as well as purchased inputs, more efficiently (Lee 2005).

Conservation agriculture and the use of organic fertilizers (e.g., compost) are two examples of sustainable agriculture practices. Conservation agriculture seeks to achieve sustainable agriculture through minimal soil disturbance (i.e., zero- or minimum-tillage farming—stubble tillage[1]), permanent soil cover, and crop rotations. The potential benefits from conservation agriculture lie not only in conserving but also in enhancing the natural resources (e.g., increasing soil organic matter) without sacrificing yield levels. This makes it possible for fields to act as a sink for carbon dioxide, increases the soil's water-retention capacities, and reduces soil erosion. It also cuts production costs by reducing time and labor requirements, as well as costs associated with mechanized farming, e.g., costs of fossil fuels (FAO 2008).

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[1] Hereafter in the paper, stubble tillage is referred to as conservation tillage. Stubble tillage is a type of conservation tillage, where farmers leave all of the stubble from the previous crop *in situ*.They mix it into the soil by rough tillage immediately after harvest to avoid grazing by livestock and to speed decomposition of the organic material before the next cropping season starts.

That conservation agriculture can address such a broad set of farming constraints makes it a widely adopted component of sustainable farming (Lee 2005). The use of organic fertilizers (such as compost), on the other hand, is part of an organic farming system which emphasizes maximum reliance on renewable local or farm resources. Compost is an organic fertilizer and mulch, which has the advantages of being cheap (if not free); improving soil structure, texture, and aeration; increasing the soil's water-retention abilities; and stimulating healthy root development (Twarog 2006). Thus, both conservation via tillage and compost are appealing options for enhancing productivity to resource-poor farmers especially in developing countries.

The agriculture sector in Ethiopia is the most important sector for sustaining growth and reducing poverty. However, lack of adequate nutrient supply, the depletion of soil organic matter, and soil erosion are major obstacles to sustained agricultural production (Grepperud 1996; Kassie et al. 2008). The key to a prolonged increase in agricultural production is to improve productivity, which can be achieved through better technology and efficiency. Inorganic fertilizer remains the main yield-augmenting technology being aggressively promoted by the government and institutions. Despite this, inorganic fertilizer adoption rates remain minimal. Until recently, only 37 percent of farmers used inorganic fertilizer, and application rates remained at or below 16 kg/hectare of nutrients (Byerlee et al. 2007, 37). In addition to low application rates, there is significant evidence suggesting a pull back from using fertilizer (EEA/EEPRI 2006). Escalating prices and production and consumption risks have been cited as one of the factors limiting the use of inorganic fertilizers in Ethiopia (Kassie, Yesuf, and Köhlin 2008; Dercon and Christiaensen 2007).

Thus, given the aforementioned challenges to inorganic fertilizer adoption, a key policy intervention for sustainable agriculture is to encourage adoption of agricultural technologies that rely, to a greater extent, on renewable local or farm resources. Organic farming practices, such as compost and conservation tillage, are among such technologies. The water retention characteristics of these technologies (Twarog 2006) make them especially appealing in water-deficient farming areas, such the Tigray region of Ethiopia analyzed here. In addition to reducing natural risks, they enable poor farmers to avoid the financial risk of buying chemical fertilizer on credit and—given that compost and conservation tillage are available when needed—overcome the prevailing problem of late delivery of chemical fertilizer.

Since 1998, Ethiopia has included conservation tillage and compost as part of its extension packages to reverse extensive land degradation (Edwards et al. 2007; Sasakawa Africa Association 2008). There exists ample evidence to show that compost and conservation tillage can result in higher and/or comparable yields, compared to chemical fertilizer (Edwards et al.

2007; Hemmat and Taki 2001; SG2000 2004; Mesfine et al. 2005; UNCTAD and UNEP 2008). This implies that these two organic farming techniques can create a win-win situation, where farmers are able to reduce production costs, provide environmental benefits, and at the same increase their yields.

While numerous studies have been conducted in Ethiopia to examine the determinants and the resulting economic impact of chemical fertilizer, improved seeds, and physical conservation structures (e.g. Croppenstedt et al. 2003; Dercon and Christiaensen 2007; Hagos 2003; Kassie et al. 2008; Kassie, Yesuf, and Köhlin 2008; Negatu and Parikh 1999; Shiferaw and Holden 1998), no study, to the best of our knowledge, has investigated the determinants of compost and conservation tillage adoption by farmers in Ethiopia. The objective of this study was to look at how socio-economic and biophysical characteristics determined adoption of compost and/or conservation tillage) in the semi-arid region of Tigray, Ethiopia. By identifying significant characteristics associated with adoption of sustainable agricultural production practices, such as compost and conservation tillage, we can provide better information to support policies that promote adoption of these practices. In addition, we used a dataset containing data on crop production and organic technology adoption (compost) to perform a stochastic dominance analysis with the aim of examining whether adoption of these technologies had any productivity impacts. By showing the importance of organic farming practices in enhancing productivity, we can validate the need to further investigate the factors that condition their adoption.

Our results revealed a clear superiority with the use of compost, compared to chemical fertilizers, when it comes to crop yields. Regarding the determinants of adoption decisions, we found that, while there is heterogeneity in the factors affecting the choice to use compost or conservation tillage, *both* plot and household characteristics influenced adoption decisions. Interestingly, we also found evidence that the impact of gender on technology adoption is technology-specific, while the significance of plot characteristics indicated the decision to adopt a given technology is location-specific.

The rest of the paper is structured as follows. Section 1 presents the analytical and econometric framework that forms the basis of the empirical approach used in the paper. The data used in the analysis is discussed in section 2, while a discussion of the empirical results is done in section 3. Section 4 concludes the paper with policy recommendations.

1. The Analytical and Econometric Framework

We began the analysis by using a non-parametric technique, the stochastic dominance analysis (SDA), to assess how the use of organic farming technology impacts crop productivity. Due to data limitations, we were only able to examine how the use of compost impacts crop production. Stochastic dominance analysis is used to compare and rank distributions of alternative risky outcomes according to their level and dispersion (riskiness) of returns (Mas-Colell et al. 1995). The comparison and ranking is based on cumulative density functions. Unlike other non-parametric (e.g., matching methods) and parametric (e.g., linear regression models) methods, the entire density of yields was examined in SDA instead of focusing only on mean yield. Our reason for this analysis was to encourage the use of organic farming technologies by establishing evidence that they enhance productivity. Thus, assuming that the main goal of farmers is to realize increased productivity of their plots, the next interesting research question is to investigate the factors that limit or encourage adoption of organic farming technologies and formulate policies accordingly.

We posited that both plot and household socio-economic characteristics influence the decision to adopt technologies. Plot characteristics condition the decision to adopt one specific technology over another by their impact on the increment of plot profit or the productivity impact derived from participation. Farmers' socio-economic characteristics and preferences, on the other hand, might result in different adoption decisions, even when plots have similar characteristics. Accordingly, the maximization of farmers' utility forms the basis of our econometric model and estimation strategy. This framework assumes that if adoption of several farming practices is possible, it is expected that, in deciding to adopt one or several practices, a farmer compares the indirect utility values associated with each practice or a combination of practices.

Consequently, to study the *i*th farmer's choice, we postulated random utility models, each one being associated with the *j*th choice of farming practice, such that:

$$V_{ij} = \mathbf{X}_i{}'\boldsymbol{\beta}_j + \varepsilon_{ij} \ , \qquad (1)$$

where V_{ij} is the indirect utility level which the *i*th farmer associates with the *j*th farming practice, and $\mathbf{X}_i$ is a vector describing the farmer's socio-economic characteristics, as well as plot characteristics. The vector of parameters to be estimated is denoted by $\boldsymbol{\beta}$, while ε is the stochastic error term. Given the two organic farming practices, we focused on conservation tillage and compost and had four feasible choices available to the farmer. These were classified such that j=0 if neither of the two practices is adopted, j=1 if compost is adopted, j=2 if conservation tillage is adopted, and j=3 if both compost and conservation tillage are adopted.

Given a dummy variable, d_{ij}, to capture the choice of the ith farmer regarding the jth farming practice, the farmer's decision rule then becomes:

$$\begin{cases} d_{ij} = 1 \\ d_{im} = 0 \ \forall m \neq j \end{cases} \Leftrightarrow \quad \left(V_{ij} > V_{im} \quad \forall m \neq j \right) . \tag{2}$$

To make the econometric model operational, we assumed that the disturbances of the different combinations are independent and identically distributed with the Gumbel cumulative distribution function, which implies that the probability of choosing the jth combination becomes (Greene 1997):

$$P_{ij} = \Pr(d_{ij} = 1) = \frac{\exp(\mathbf{X}_i' \boldsymbol{\beta}_j)}{\sum_{m=0}^{j} \exp(\mathbf{X}_i' \boldsymbol{\beta}_m)} . \tag{3}$$

This is the multinomial logit model, characterized by the independence of irrelevant alternatives, which implies that from equation (3) we can arrive at the following:

$$\frac{P_{ij}}{P_{im}} = \exp(\mathbf{X}_i' (\boldsymbol{\beta}_i - \boldsymbol{\beta}_m)) \quad \forall m \neq j , \tag{4}$$

a condition which holds for whatever subsets of eligible combinations include j and m. Given that the model is based on the difference of expected utility levels in each pair of combinations, we drew on the assumption that $\boldsymbol{\beta}_0 = 0$ to solve the problem of the indeterminacy, which could complicate the estimation of the model (Green 1997). The maximum likelihood procedure was used to solve the model.

2. The Data and Descriptive Statistics

This study benefited from two datasets. The first data was a cross-sectional dataset collected in 2006 in the Ofla *wereda* (district) of the Tigray region to analyze the determinants of adoption of compost and conservation tillage. It included a random sample of 130 households, 5 villages, and 348 plots. In addition to information on adoption of compost and/or conservation tillage, the dataset contained household and plot characteristics, plus indicators of access to infrastructure, which—based on economic theory and previous empirical research—were included in the analysis. The descriptive statistics of variables used in the regression analysis are presented in table 1.

Table 1. Descriptive Statistics (Means) of Variables Used in the Analysis

Variable	Description	Non-adopters	Compost	Conservation tillage	Both
Socio-economic characteristics					
Male	Sex of household head (1=male; 0=female)	0.83	0.67	1.00	0.98
Age	Age of household head	44.17	41.00	38.36	38.98
Dependents	Number of economically inactive household members	2.71	2.50	2.61	2.54
Household labor	Number of economically active household members	2.23	2.28	2.51	2.46
Illiterate	Household head has no education (1=yes; 0=otherwise)	0.60	0.28	0.38	0.42
Religious education	Household head has religious education (1=yes; 0=otherwise)	0.11	0.11	0.05	0.07
Formal education	Household head has formal education (1=yes; 0=otherwise)	0.29	0.61	0.58	0.51
Farmer organizations	Membership in farmers' organization (1=yes; 0=otherwise)	0.08	0.22	0.25	0.22
Extension	Household extension contact (1=yes; 0=otherwise)	0.56	0.83	0.82	0.83
Livestock	Household livestock holding, in tropical livestock units	2.92	4.09	3.69	3.42
Farm size	Total farm size, in hectares	0.83	0.92	1.39	1.09
Market distance	Distance from residence to the district market, in hours	2.01	2.30	2.48	2.07
Plot characteristics					
Ownership	Whether the household owns the plot (1=yes; 0=otherwise)	0.71	0.83	0.67	0.83
Distance	Distance from residence to the plot, in minutes	0.62	0.69	0.64	0.61
Flat or moderate slope	Plot has flat-to-medium slope (1=yes; 0=steep slope)	0.35	0.17	0.30	0.17
Fertile soil	Plot has fertile soil (1=yes; 0=infertile)	0.33	0.50	0.36	0.32
Black soil	Plot has predominantly black soil (1=yes; 0=otherwise)	0.57	0.50	0.72	0.61
Deep soil	Plot has deep soil depth (1= yes; 0=otherwise)	0.39	0.50	0.30	0.44

Moderately deep soil	Plot has moderately deep soil depth (1=yes; 0=otherwise)	0.24	0.11	0.31	0.15
Shallow soil	Plot has shallow soil depth (1=yes; 0=otherwise)	0.37	0.39	0.39	0.42
Degradation	Plot is perceived as degraded (1=yes; 0=otherwise)	0.36	0.28	0.38	0.37
Number of observations		202	18	87	41

Source: Authors' own calculations

Around 5, 24, and 12 percent of the plots used compost, conservation tillage, and a combination of both, respectively. Regarding the households' perceptions of compost and reduced tillage, about 40 and 74 percent of compost and reduced tillage adopters, respectively, perceived positive impacts of these technologies on soil fertility; about 20 and 42 percent of compost and tillage adopters, respectively, believed that these technologies reduced soil erosion; and 32 and 69 percent of compost and reduced tillage adopters, respectively, believed that these technologies were labor intensive. The data also revealed that adopters of compost had more livestock compared to tillage adopters. On the other hand, tillage adopters had larger farms compared to compost adopters, from which it was expected that they would produce more straw for livestock feed and would till their stubble mulch to increase soil fertility.

The fact that the first dataset did not include production data limited our use of it to analyze how adoption of these technologies impacted crop production. To achieve this objective, we employed a second dataset to conduct a stochastic dominance analysis. It was a cross-section time series of on-farm production data collected between 2000 and 2006 by ISD (Institute for Sustainable Development). ISD's[2] primary objective for collecting this data was to investigate the impact of compost on crop production and soil fertility. The dataset covered 8 districts and 19 villages in the Tigray region, including the Ofla wereda. Of the 19 villages, 17 are located in drought-prone areas of the southern, eastern, and central zones of Tigray. The soils are poor and rainfall is erratic in these areas. ISD only collected agronomic data and grain and straw yields for 11 crops from 974 plots. The FAO crop-sampling method was used to collect yield data from those plots which had received compost, chemical fertilizer, and no inputs (control plots).

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[2] The Institute of Sustainable Develoment (ISD) promotes organic agriculture in Ethiopia. It also has the responsibility of providing information and training on making compost and its application, and recording grain and straw yields data during harvest in collaboration with farmers.

Three one-meter-square plots were harvested from each field to reflect the range of conditions of the crop. All of the crop management practices, including the amount of compost and fertilizer application, were decided by the farmers themselves. The average amount of compost application ranged from 5–15 tons/hectare, depending on availability of materials (Edwards et al. 2007). Fertilizer was 0–275 kg/hectare—the average is 40 kg/hectare. (Kassie et al. 2008). The average-per-hectare cost of applying compost is about ETB 370, whereas commercial fertilizer (DAP and urea) is about ETB 594[3] (S. Edwards, Director, Institute of Sustainable Development, Addis Ababa, personal communication, November 2008).

3. Estimation Results

In this section, we present the stochastic dominance analysis and multinomial logit-adoption model results. The stochastic dominance analysis was used to investigate the impact of compost on crop productivity while the multinomial logit model was used to investigate factors that determined the decision to adopt compost, conservation tillage, and/or a combination of both.

3.1 Stochastic Dominance Analysis

For the purposes of this analysis, we focused on four major crops (wheat, barley, teff,[4] and hanfets (mixture of barley and wheat) and compared yield distributions obtained from plots using compost, chemical fertilizer, and no inputs (control). The outcome variable is the physical grain yield (ton/hectare) of the respective crops. Figures 1–4 show cumulative density functions for yields obtained from compost, chemical fertilizer, and control plots.

As illustrated in the figures, for all crops the yield cumulative distribution with compost is entirely to the right of the chemical fertilizer and control yield distributions, indicating that yield with compost unambiguously holds first-order stochastic dominance over chemical fertilizer and control plots.

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[3] ETB = Ethiopian birr. ETB 1 = US$ 0.09, using January 11, 2009, exchange rate.

[4] Teff is a small grain crop widely consumed in Ethiopia and is the main ingredient in *injera* (the common pancake-like staple).

Figures 1–4. Stochastic Dominance Analysis of the Impact of Compost on Crop Productivity

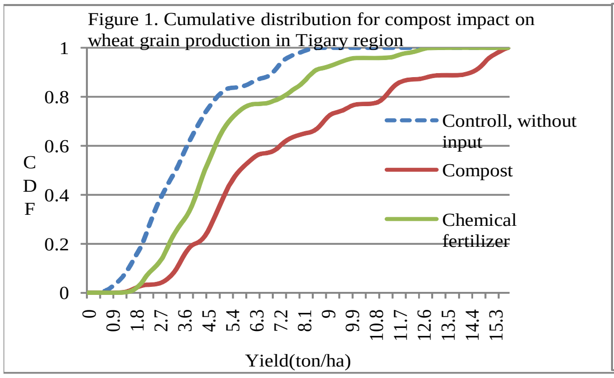
Figure 1. Cumulative distribution for compost impact on wheat grain production in Tigary region

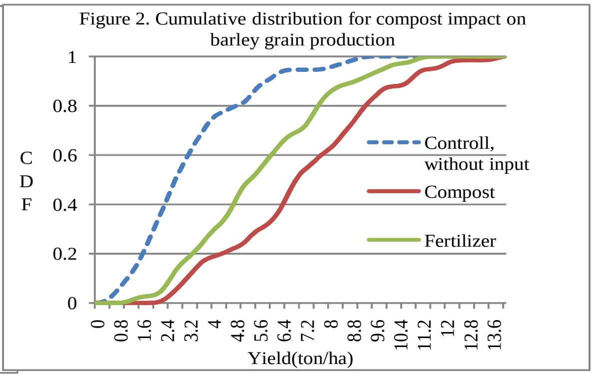
Figure 2. Cumulative distribution for compost impact on barley grain production

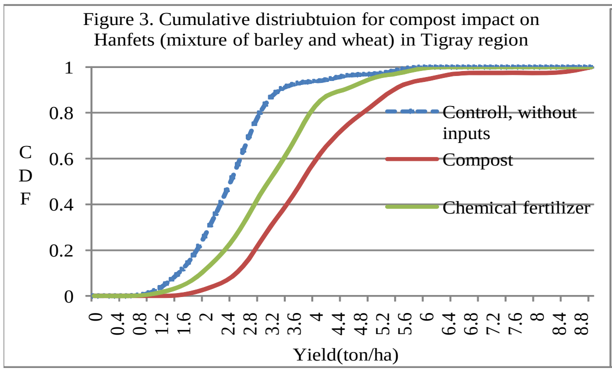
Figure 3. Cumulative distriubtuion for compost impact on Hanfets (mixture of barley and wheat) in Tigray region

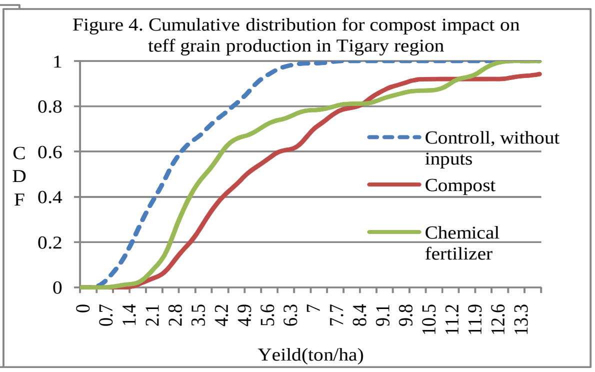
Figure 4. Cumulative distribution for compost impact on teff grain production in Tigary region

The non-parametric Kolmogorov-Smirnov statistics test for first-order stochastic dominance (or the test for the vertical distance between the two cumulative density functions) also confirmed this result (see table 2 below). Interestingly, compared to control plots and plots that used chemical fertilizer, plots with compost gave higher yield levels. Furthermore, except for hanfets crops, yield distribution of plots with chemical fertilizer dominated yield distributions of control plots, i.e., plots with no input (table 2).

Table 2. Kolmogorov-Smirnov Statistics Test for First-Order Stochastic Dominance

Crop	**Treatments**		
	Compost + control	***Compost + fertilizer***	***Fertilizer + control***
Barley	0.355 (0.000)***	0.192 (0.008)***	0.241 (0.000)***
Wheat	0.484 (0.000)***	0.384 (0.000)***	0.270 (0.000)***
Teff	0.591 (0.000)***	0.195 (0.003)***	0.396 (0.000)***
Hanfets	0.363 (0.000)***	0.330 (0.000)***	0.132 (0.407)

Note: *** significant at 1%

The foregoing analysis revealed an interesting finding: adoption of sustainable or organic farming practices, such as the use of compost, is not inferior in terms of its impact on yields to the use of chemical fertilizers. In fact, as the results showed, use of compost can lead to significantly higher yields. This means that adoption of organic technologies presents multiple benefits—reduced production costs, environmental benefits, and at the same time increased yields. Given these potential benefits, what constrains farmers from adopting such technologies? And, if they decide to adopt, what determines their choice of organic technology? We attempted to answer these questions by estimating a multinomial logit model as outlined in the discussion of the econometric strategy we pursued. We discuss the results in section 4.

3.2 Multinomial Logit Model Results

Table 3 below gives the multinomial logit-estimation results for the impact of both plot and socio-economic characteristics of the household on the decision to adopt a given farming practice. The base outcome is adopting neither of the practices, i.e., $j=0$. This implies that the ensuing discussion of the results focuses on the impact of the explanatory variables on a specific choice relative to no adoption. The model was tested for the validity of the independence of the irrelevant alternatives (IIA) assumptions, using the Hausman test for IIA. The test failed to reject the null hypothesis of the independence of the adoption of organic farming technologies, suggesting that the multinomial logit specification is appropriate to model adoption of organic technologies.

Table 3. Multinomial Logit Estimates

	Compost		Conservation tillage		Both	
Variable	***Coeff.***	***Std. error***	***Coeff.***	***Std. error***	***Coeff.***	***Std. error***
Socio-economic characteristics						
Male	-1.99**	0.79	19.60***	0.92	2.21**	1.11
Age	-0.01	0.03	-0.06***	0.02	-0.06***	0.02
Dependents	-0.23	0.18	-0.20**	0.10	-0.17	0.12
Household labor	-0.14	0.42	0.40**	0.20	0.36	0.24
Religious education	0.39	1.06	-0.53	0.67	-0.31	0.76
Formal education	1.41*	0.73	0.14	0.39	0.25	0.47
Farmer organizations	0.90	0.77	1.46***	0.47	1.24**	0.58
Extension	1.95**	0.85	1.00**	0.40	1.09**	0.51
Livestock	0.20**	0.10	0.05	0.05	0.06	0.07
Farm size	0.31	0.42	0.54***	0.20	0.39	0.25
Market distance	0.16	0.16	0.06	0.09	-0.07	0.12
Plot characteristics						
Ownership	1.38*	0.78	0.41	0.34	1.29**	0.50
Distance	0.64	0.44	0.51*	0.26	0.43	0.33
Flat or moderate slope	-1.26	0.78	-0.74**	0.37	-1.35***	0.52
Fertile soil	0.56	0.62	0.20	0.36	-0.16	0.45
Black soil	-0.57	0.61	0.65*	0.36	0.25	0.42
Moderately deep soil	-0.68	0.86	0.38	0.41	-0.74	0.57
Shallow soil	0.52	0.71	0.50	0.43	0.40	0.50
Degradation	-0.32	0.64	0.14	0.34	0.02	0.42
Number of observations	348					
Pseudo R2	0.23					
LR chi2(54)	168.60***					
Log likelihood	-287.18					

Notes: Base outcome = no adoption; * significant at 10%; ** significant at 5%; *** significant at 1%

The results suggested that both socio-economic and plot characteristics are significant in conditioning the households' decisions to adopt sustainable agricultural production practices. While there is heterogeneity with regard to factors influencing the choice to adopt compost and/or conservation tillage, our results suggested that significant determinants of adoption can be broadly classified into social characteristics of household head, labor intensity, access to information, wealth, and plot characteristics, which include whether or not the household owned the plot.

There is a heterogeneous impact of the gender of the head of the household on adoption decisions regarding the two practices. Specifically, we found that households with a male head are less likely to adopt the use of compost, while they are more likely to either adopt conservation tillage or combine it with the use of compost. While some researchers have found that male-headed households are more likely to adopt sustainable agricultural technologies (Adesina et al. 2000), our results underscored the need to avoid generalizing the impact of gender on farm technology adoption, emphasizing that the impact of gender on technology adoption is technology-specific. In this area, it seems male-headed households had a comparative advantage in conservation tillage, while female-headed households enjoyed an advantage in the use of compost. Still, with the characteristics of the household head, we found a negative and significant impact of age on the likelihood of adopting conservation tillage, as well as combining it with compost. This could suggest that younger farmers are more likely to try innovations and, in addition, they might also have a lower risk aversion and longer planning horizon to justify investments in technologies whose benefits are realized over time. The results also suggested the need to develop gender- and age-specific technologies instead of blanket recommendations of technologies, regardless of the characteristic of the farmers to encourage adoption of sustainable agricultural practices.

Labor issues seem to be of more concern in the decision to adopt conservation tillage. Specifically, the probability of adopting conservation tillage, relative to no adoption, increased with the number of household members who actively provided farm labor. This is in line with the descriptive statistics results, where about 69 percent of conservation tillage adopters reported that conservation tillage adoption was labor intensive. This is not surprising because stubble is tilled during the peak period of one of the agricultural activities, crop harvesting. This underscores the importance of labor availability to technology adoption, consistent with findings by Caviglia and Kahn (2001) and Shiferaw and Holden (1998). In such circumstances, it is important to consider strengthening and structuring the existing local labor-sharing mechanism. On the other hand, this probability declined with the number of dependents in the household, capturing the intuitive expectation that the time spent caring for dependents shifts labor away from adoption activities.

Access to information on new technologies is crucial to creating awareness and attitudes towards technology adoption (Place and Dewees 1999). In line with this, we found that access to agricultural extension services, indicated by whether or not the household had contact with an extension agent, impacted adoption of all technology choices positively. Contact with extension services gives farmers access to information on innovations, advice on inputs and their use, and management of technologies. In most cases, extension workers establish demonstration plots where farmers get hands-on learning and can experiment with new farm technologies. Consequently, access to extension is often used as an indicator of access to information (Adesina et al. 2000; Honlonkou 2004).

Another indicator of information, that shapes management skills or simply human capital, is the amount of formal education (as opposed to no education at all), which increases the probability of using compost relative to not adopting any conservation practice at all. This could suggest that using compost is relatively knowledge-intensive and, thus, that management skills are crucial in its adoption. It has been argued that farmer associations and unions constitute important sources of information available to farmers (Caviglia and Kahn 2001). Our results confirmed this: we found that a household’s membership in at least one farmers’ organization significantly increased the likelihood that the farmer would practice conservation tillage, as well as the likelihood that the farmer would use both compost and conservation tillage. These results underscore the role of public policy in encouraging the adoption of sustainable agricultural practices.

In addition, we found evidence that livestock ownership limited the adoption of compost, while a household’s total landholdings limited the adoption of conservation tillage (as well as combining the two practices). This suggests that poverty significantly limits technology adoption. Wealth intuitively affects adoption decisions since wealthier farmers have greater access to resources and may be better able to take risks. It must be acknowledged, however, that the wealth measures we used might be confounded with other factors related to adoption. For example, using livestock ownership as an indicator of wealth may be compromised by the fact that oxen provide draft power as well as manure (which, as organic matter, is a component of compost). Furthermore, as the data showed, farmers who compost have more livestock compared to tillage adopters and this result could imply that the opportunity cost of crop residue is smaller for tillage adopters than compost adopters. The size of total landholdings, on the other hand, although measuring farmers’ wealth, could also suggest economies of scale in production using conservation tillage, as well as indicating the social status of the household—both of which could influence the farmers' ability to obtain credit. (Even though in Ethiopia, credit markets are highly imperfect.) All the same, these results suggest that policies to alleviate poverty and increase crop productivity among farmers will impact the adoption of sustainable agricultural practices positively.

Given the fact that the benefits from investing in both compost and conservation tillage accrue over time, this inter-temporal aspect implies that secure land access or tenure will impact adoption decisions positively. In our analysis, we used plot ownership as a proxy for assured land access. Our results revealed that this particularly has a positive impact on the decision to use compost and the decision to combine composting and tillaging. Ownership of the plot increases the assurance of future access to the returns of investments. In the same vein, the positive impact of distance from the homestead to the plot on the decision to adopt either conservation tillage or compost could reflect the fact that plots further away present tenure security challenges because they are more difficult to monitor; consequently, farmers might invest more in them as a way of securing tenure.

Sustainable agricultural systems are intuitively site-specific (Lee 2005). This is further confirmed by our finding that plot characteristics influence the decision to adopt conservation tillage, as well as to combine it with the use of compost. In particular, we found that the likelihood of households choosing to practice conservation declined with the perceived slope of the plots. This could reflect the fact that plots with steeper slopes are more prone to soil erosion, which necessitates adoption of farming techniques, such as conservation tillage, since they are meant to mitigate soil erosion and subsequent nutrient losses. The plot slope impacted the decision to combine the use of compost and conservation tillage in a similar way. We also found that conservation tillage is more likely to be practiced on plots with predominantly black soils, indicating the role of soil type and quality in influencing adoption decisions. Interestingly, plot-specific characteristics did not seem to impact the decision to adopt only the use of compost. These results imply that, for sustainable agricultural practices to be successful, they must address site-specific characteristics since these condition the need for adoption as well as the type of technology adopted.

4. Conclusions and Policy Implications

The viability of the agricultural production systems in Ethiopia, as in many semi-arid areas in developing countries, is highly constrained by inadequate nutrient supply, depletion of soil organic matter, and soil erosion. This problem is further compounded by an increasing population which is not accompanied by technological and/or efficiency progress. Efforts by the government to promote adoption of chemical fertilizers have not been successful, owing largely to escalating fertilizer prices and production and consumption risks associated with fertilizer adoption. Given these constraints, it can be argued that sustainable agricultural production practices create a win-win situation: farmers are able to reduce production costs (by relying on renewable local or farm resources), it provides environmental benefits, and at the same time it increases yields.

In this paper, we used plot-level data from the semi-arid region of Tigray, Ethiopia, to investigate the factors influencing farmers' decisions to adopt sustainable agricultural production practices, with a particular focus on the adoption of compost and conservation tillage. By identifying significant characteristics associated with adoption of these practices, we can better inform policies that promote adoption of sustainable agricultural production practices. Furthermore, the use of stochastic dominance analysis supports the contention that these sustainable farming practices enhance productivity, further validating the need to investigate factors that influence adoption of these practices.

While there is heterogeneity with regard to factors that influence the choice to adopt compost and/or conservation tillage, our results underscored the importance of both plot and household characteristics on adoption decisions. Our findings imply that public policy can affect adoption of sustainable agricultural production practices. In particular, we found that poverty limits adoption which suggests that polices aimed at alleviating poverty will impact adoption decisions positively. In addition, the significant and positive impact of access to information indicates that public policies aimed at improving access to information (as well as the quality of these sources) will help promote adoption of organic farming practices.

Moreover, we found evidence that such public polices should acknowledge the fact that there may be gender differences in adoption of different technologies, and that the age of the household head (whether affecting aversion to risk and/or life-cycle dynamics) will have a differential impact on adoption, depending on the type of technologies. In the same light, availability of household labor conditions the choice of technology adopted, given that the labor requirements differ from technology to technology. Thus, public policy should factor in the impact of these socio-economic characteristics.

We found evidence for the significance of land rights in influencing adoption and that its impact varies from technology to technology. This indicates that assurance of access to future returns is vital in adoption decisions and, thus, policies should strive to create security of tenure among farmers.

In addition, the significance of plot characteristics indicated that the decision to adopt specific technologies is site-specific and, as such, public policy should be informed by analyses of how different sustainable agricultural practices are conditioned by plot characteristics. So, the next interesting research question is to analyze how plot characteristics affect the productivity implications of different practices.

References

Adesina, A.A., D. Mbila, G.B. Nkamleu, and D. Endamana. 2000. “Econometric Analysis of the Determinants of Adoption of Alley Farming by Farmers in the Forest Zone of Southwest Cameroon,” *Agriculture, Ecosystems and Environment* 80: 255–65.

Byerlee, D., D.J. Spielman, D. Alemu, and M. Gautam. 2007. “Policies to Promote Cereal Intensification in Ethiopia: A Review of Evidence and Experience.” International Food Policy Research Institute Discussion Paper 00707. Washington, D.C.: IFPRI.

Caviglia, J.L., and J.R. Kahn. 2001. “Diffusion of Sustainable Agriculture in the Brazilian Rain Forest: A Discrete Choice Analysis,” *Economic Development and Cultural Change* 49: 311–33.

Croppenstedt, A., M. Demeke, and M.M. Meschi. 2003. “Technology Adoption in the Presence of Constraints: The Case of Fertilizer Demand in Ethiopia,” *Review of Development Economics* 7(1): 58–70.

Dercon, S., and L. Christiaensen. 2007. “Consumption Risk, Technology Adoption, and Poverty Traps: Evidence from Ethiopia.” World Bank Policy Research Working Paper 4527. Washington, D.C.: World Bank.

D’Souza G., D. Cyphers, and T. Phipps. 1993. “Factors Affecting the Adoption of Sustainable Agricultural Practices,” *Agricultural Resource Economics Review* 22(2): 159–65.

EEA/EEPRI (Ethiopian Economic Association/Ethiopian Economic Policy Research Institute). 2006. “Evaluation of the Ethiopian Agricultural Extension with Particular Emphasis on the Participatory Demonstration and Training Extension System (PADETES).” Addis Ababa, Ethiopia: EEA/EEPRI.

Edwards, S., A. Asmelash, H. Araya, and T.B. Gebre-Egziabher. 2007. “Impact of Compost Use on Crop Production in Tigray, Ethiopia.” Rome: FAO, Natural Resources Management and Environment Department.

FAO 2008. Web site. “Conservation Agriculture.” http://www.fao.org/ag/ca/. Accessed December 16, 2008.

Greene W.H. 1997. *Econometric Analysis.* 3rd ed. Prentice-Hall International, Inc.

Grepperud, S. 1996. “Population Pressure and Land Degradation: The Case of Ethiopia,” *Journal of Environmental Economics and Management* 30: 18–33.

Hagos, F. 2003. "Poverty, Institution, Peasant Behavior, and Conservation Investments in Northern Ethiopia." PhD diss., no. 2003:2. Aas, Agricultural University of Norway, Department of Economics and Social Sciences. http://www.umb.no/ior/publikasjoner/avhandling2003.2.html.

Honlonkou, A.N. 2004. "Modeling Adoption of Natural Resources Management Technologies: The Case of Fallow Systems," *Environment and Development Economics* 9: 289–314.

Hemmat, A., and Taki, O. 2001. "Grain Yield of Irrigated Winter Wheat as Affected by Stubble-Tillage Management and Seeding Rates in Central Iran," *Soil and Tillage Research* 63: 57–64.

Kassie, M., J. Pender, M. Yesuf, G. Köhlin, R. Bluffstone, and E. Mulugeta. 2008. "Estimating Returns to Soil Conservation Adoption in the Northern Ethiopian Highlands," *Agricultural Economics* 38: 213–32.

Kassie, M., M. Yesuf, and G. Köhlin. 2008. "The Role of Production Risk in Sustainable Land-Management Technology Adoption in the Ethiopian Highlands," EfD Discussion Paper 08-15. Washington, D.C.: Resources for the Future.

Lee, D.R. 2005. "Agricultural Sustainability and Technology Adoption: Issues and Policies for Developing Countries," *American Journal of Agricultural Economics* 87(5): 1325–34.

Mas-Colell, A., M.D. Whinston, and J.R. Green. 1995. *Microeconomic Theory*. New York: Oxford University Press.

Mesfine, T., G. Abebe, and A.R.M. Al-Tawaha. 2005. "Effect of Reduced Tillage and Crop Residue Ground Cover on Yield and Water Use Efficiency of Sorghum (*Sorghum bicolor* [L.] Moench) under Semi-arid Conditions of Ethiopia," *World Journal of Agricultural Sciences* 1(2): 152–60.

Negatu, W., and A. Parikh. 1999. "The Impact of Perception and Other Factors on the Adoption of Agricultural Technology in the Moret and Jiru Woreda [districts] of Ethiopia," *Agricultural Economics* 21(2): 205–216.

Place, F., and P. Dewees. 1999. "Policies and Incentives for the Adoption of Improved Fallows," *Agroforestry Systems* 47: 323–43.

SG2000 (Sasakawa Global 2000). 2004. "Proceedings of the Workshop on Conservation Tillage," Melkassa Agricultural Research Center, East Shewa, Ethiopia, April 6, 2004.

Sasakawa Africa Association (2008). Web site. “Country Profile.” http://www.saa-tokyo.org/english/country/ethiopia.shtml. Accessed October 2008.

Shiferaw, B., and S.T. Holden. 1998. Resource Degradation and Adoption of Land Conservation Technologies in the Ethiopian Highlands: A Case Study in Andit Tid, North Shewa,” *Agricultural Economics* 18: 233–47.

Twarog. 2006. “Organic Agriculture: A Trade and Sustainable Development Opportunity for Developing Countries.” In *UNCTAD Trade and Environment Review 2006*. New York and Geneva: United Nations. http://www.unctad.org/en/docs/ditcted200512_en.pdf.

UNCTAD and UNEP (United Nations Conference on Trade and Development and United Nations Environment Program). 2008. “Organic Agriculture and Food Security in Africa: UNEP-UNCTAD Capacity-Building Task Force on Trade, Environment, and Development.” New York and Geneva: United Nations.