**FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE**

The adoption of sustainable agricultural practices by smallholder farmers in Ethiopian highlands: An integrative approach

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**Abstract:** The adoption of Sustainable Agricultural Practices (SAPs) remains high on the policy and research agenda in most of sub-Saharan Africa. This paper adopts an integrative approach to investigate how psycho-social and socioeconomic factors influence the uptake of SAPs by smallholder farmers in Ethiopian Highlands. The study applies the Theory of Planned Behavior theoretical framework, as well as the Ordered Probit model and Partial Least Squares Structural Equation Modeling (PLS-SEM) to model farmers' adoption decisions. The results show that socioeconomic factors such as access to agricultural loans and off-farm income, household labor availability and livestock ownership increase the probability of adopting two or more SAPs. The results further show that farmers' intentions and personal norms significantly influence the number of SAPs adopted at farm-level. These results imply that efforts to promote the widespread adoption of SAPs by smallholder farmers should focus on enhancing farmers' access to agricultural loans and off-farm income, through increased integration into the non-farm rural economy and addressing liquidity constraints through affordable rural financing schemes. The adoption of SAPs would greatly enhance farmers' ability to implement SAPs. Our results also suggest that efforts to achieve widespread uptake of sustainable practices should focus on raising farmers' general awareness and knowledge to change their perceptions and attitudes towards sustainable farming practices.

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**ABOUT THE AUTHOR**

My research interests focus on the interface between agricultural production and the natural resource base, with particular interest in exploring sustainable pathways to enhancing agricultural productivity and intensification, without compromising on equally important social, ecological and welfare goals. I have done research in Zimbabwe, Malawi, Zambia Ethiopia, Mozambique and the United States, working with international research institutions such as the International Maize and Wheat Improvement Centre (CIMMYT) and the International Livestock Research Institute (ILRI). My quest is to understand why smallholder farms have remained small in terms of scale economies, level of technological innovations, degree of commercialization or the general lack of zeal in adopting new and “better” farming systems. With the IPCC projecting a gloomy picture of climate change and its impacts on smallholder agriculture, I have also developed a keen interest in understanding the reasons why many African smallholder farmers are seemingly reluctant to adopt and invest in climate-smart practices agriculture and known adaptation strategies.

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**PUBLIC INTEREST STATEMENT**

Sustainable agricultural practices (SAPs) are farming practices such as conservation tillage, soil and water conservation, legume crop rotations, improved seed varieties and use of animal manure. These practices are part of the packages that seek to improve agricultural productivity while minimizing negative impacts on the environment. However, the uptake of these practices by smallholder farmers has generally been sluggish in most sub-Saharan Africa. This research investigates the factors that would facilitate or hinder farmers’ ability to implement SAPs on their farms. Our results indicate improving farmers’ access to agricultural loans and off-farm income, as well as interventions to increase livestock ownership and access to labor resources; would greatly enhance farmers’ ability to implement SAPs. Our results also suggest that efforts to achieve widespread uptake of sustainable practices should focus on raising farmers’ general awareness and knowledge to change their perceptions and attitudes towards sustainable farming practices.
can further be enhanced by raising farmers' general awareness and knowledge to change their perceptions and attitudes towards sustainable farming practices.

Subjects: Environment & Agriculture; Development Studies, Environment, Social Work, Urban Studies; Social Sciences; Development Studies

Keywords: Ethiopia; ordered probit; structural equation model; sustainable agricultural practices (SAPs); theory of planned behavior (TPB)

1. Introduction

Over the past decade, there have been several efforts to promote sustainable intensification of smallholder farming systems (Barnes, Lucas, & Maio, 2016; Mutyasira et al., 2018a). Several sustainable agricultural practices (SAPs), including conservation tillage, soil and water conservation, legume crop rotations, improved seed varieties and use of animal manure (Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013, Kassie, Zikhali, Pender, & Köhlin, 2010; Teklewold, Kassie, & Shiferaw, 2013) have been promoted by research and development organizations to promote climate-smart agriculture, restore soil health and bolster resilience of smallholder farming systems. Yet, the adoption of conservation practices is lagging among smallholder farmers in many parts of the world (Kassie et al., 2009; Somda et al., 2002; Wollni, Lee, & Thies, 2010). Consequently, a substantial amount of attention has been paid to factors that influence the adoption of conservation practices by farmers. Meta-analytic reviews have shown that a wide range of socioeconomic, institutional and agro-ecological factors influences farm-level adoption decisions (Knowler & Bradshaw, 2007).

Most empirical studies have generally focused on the economic factors influencing farmers’ ability to adopt SAPs (Kassie et al., 2013; Teklewold et al., 2013; Wollni et al., 2010). Relatively less research has focused on understanding farmers’ willingness to invest in SAPs and the intrinsic factors influencing farmers’ conservation behavior (Mills et al., 2017). Behavioral approaches have pointed out the inadequacies of the traditional economic approaches to understanding farmer’s conservation behavior, particularly given that conservation-related decisions are not always made on an economically rational basis (Burton, 2004; Chouinard et al., 2008; Neill & Lee, 2001; Stern, 2000). There are suggestions that non-economic and intrinsic factors such as farmers’ attitudes, norms and stewardship motives may influence individual decision-making processes (Lynne, Shonkwiler, & Rola, 1988), and hence interventions to promote SAPs must target changing farmer’s behavior (Clayton & Myers, 2010; Schultz, 2011). Thus, behavioral approaches have been used to examine farmers’ pro-environmental behavior (Ahnström et al., 2009; Quinn & Burbach, 2008; Wilson, 1996), uptake of conservation technologies (Beedell & Rehman, 1999; Lynne et al., 1995), uptake of organic farming (Läpple & Kelley, 2013) and general perceptions toward SAPs (Füsün Tatlıdil, Boz, & Tatlıdil, 2009).

Understanding farmers’ conservation behavior is complex. Developing a clear picture on the drivers and processes shaping the uptake of SAPs therefore requires a strong understanding of the psycho-social factors influencing farmers’ willingness to adopt SAPs, and the socioeconomic factors affecting their ability to implement these practices on their farms. This study adopts an integrative approach, examining how both socioeconomic and psycho-social factors, such as attitudes and personal norms, influence adoption of SAPs by smallholder farmers in Ethiopia. The findings will assist in the design of more effective policy instruments to remove adoption hurdles as well as crafting tailored extension services that resonate with realities of the farmer and thus help foster behavioral change. We use the theory of planned behavior (TPB) as our framework to understand the main behavioral constructs underpinning farmers’ behavior regarding SAPs. Structural equation modeling techniques are used to derive summated indices of the behavioral latent variables, as well as to examine their significance in explaining farmers’ intentions. An ordered probit regression model is used to examine the relative importance of socioeconomic and psycho-social variables as predictors of the number of SAPs adopted by farmers.
The following section discusses the study's theoretical framework, dissecting the key psychological constructs influencing intentions. Section 3 summarizes the estimation procedure and econometric techniques employed in the study. Section 4 describes the study area and data collection techniques. The main results of the study are detailed in Section 5, while Section 6 concludes with main implications of the research for policy.

2. Theoretical framework

The study uses the TPB (Ajzen, 1991) as the main theoretical framework to analyze farmers’ general attitudes toward sustainable farming practices. The theory argues that a person’s intention (INT) is a good predictor of their actual behavior. According to this theory, a person’s attitude (ATT) toward a behavior, subjective norms (SN) and their perceived behavioral control (PBC) are the key antecedents of INT (Figure 1). ATT is the extent to which a person has a favorable or unfavorable evaluation of a behavior. Subjective norm refers to an individual’s perceived social pressure to perform a certain behavior. It comprises beliefs about social expectations and the motivation to comply with those expectations. Finally, PBC is the extent to which an individual feels able to perform the behavior (Ajzen, 1991). This component addresses the issue of incomplete volitional control over individual actions (Armitage & Conner, 2001). Empirically, the model is specified as follows:

$$ INT = \beta_1 ATT + \beta_2 SN + \beta_3 PBC + \epsilon $$  

(1)

where the $\beta$s are empirically estimated weights or path coefficients depicting the relative importance of each of the three constructs and $\epsilon$ is the error term. The parameters can be derived from multiple regression in a structural equation model. The relative importance of ATT, SN and PBC will vary across contexts and type of behaviors under consideration (Ajzen, 1991). Generally, INT is stronger when individuals exhibit positive attitudes, face favorable social environments and have confidence in their ability to perform a given behavior (Ajzen, 2011). Also, the greater the INT, the more likely one is to perform a behavior in question (Läpple & Kelley, 2013).

The key strength of the TPB is its applicability to a variety of behaviors in different contexts (Ajzen, 2011; Meijer et al., 2015). Its overall validity and usefulness has been confirmed by several meta-analytic reviews (Armitage & Conner, 2001; Godin & Kok, 1996). This paper thus focuses mostly on the TPB constructs, but also incorporates insights from other behavioral theories such as the Value-Belief-Norm theory (Stern et al., 1999), which focuses on how internalized values and moral norms (personal norms) influences individual behavior; and the Technology Acceptance Model (Davis, 1989), which explains an individual's technology acceptance as a function of perceived usefulness and perceived ease of use.

![Figure 1. Representation of Ajzen's theory of planned behavior.](https://doi.org/10.1080/23311932.2018.1552439)
3. Estimation procedure

The first stage of the modeling process involves estimation of the partial least squares structural equation modeling (PLS-SEM) to examine the relationship between the three TPB constructs. TPB constructs are latent, and thus cannot be observed or measured directly. Instead, a set of measures are derived from a list of questions to act as indicators for an underlying latent variable. The structural equation model therefore comprises an outer sub-model, which specifies the relationships between the latent variables and their observed indicators; an inner sub-model is then added, which assesses the relationship between the dependent and independent latent variables along with their respective path coefficients (Wong, 2013). A partial least square approach to structural equation modeling is adopted in this paper because it makes no assumptions about data distribution (Sarstedt et al., 2014). The model maximizes the variance explained and minimizes the overall error term (Hair, Ringle, & Sarstedt, 2011).

The second stage involves estimating an econometric model to assess the relative importance of socioeconomic and psycho-social variables in explaining farmers’ behavior and uptake of SAPs. The behavioral constructs of the TPB, whose indices are developed from the structural equation model explained earlier, are included as independent variables in the model along with a set of socioeconomic variables synthesized from economic theory and related studies (Knowler & Bradshaw, 2007). The number of SAPs adopted by the farmer is used as the dependent variable in the model, thus circumventing problems associated with defining a cutoff point between adoption and non-adoption (D’souza, Cyphers, & Phipps, 1993; Wollni et al., 2010). An ordered probit model is used for empirical estimation given the ordinal nature of the dependent variable (Daykin & Moffatt, 2002). While a Poisson regression model would be a natural choice for count data, its underlying assumption that all the events have same probability (Wollni et al., 2010) makes it unsuitable for modeling the adoption of SAPs. The adoption of SAPs is likely to follow a path whereby the probability of adopting the first technology will be different from that of the second and subsequent technologies given that the farmer would have gained experience from the previous technologies and probably developed more positive ATT toward SAPs in general.

Empirically, the model is estimated in a random utility framework (Greene & Hensher, 2008), in which the dependent variable depicts whether the farmer adopts none \( S_i = 0 \), one \( S_i = 1 \), two \( S_i = 2 \), three \( S_i = 3 \), four \( S_i = 4 \) or five \( S_i = 5 \) different SAPs. Following Wollni et al. (2010), we assume that farmer \( i \) choose to adopt a certain number of SAPs to maximize an underlying utility function \( U_i \):

\[
U_i = V_i(\beta' x_i) + u_i \text{ for } i = 1, \ldots, n.
\]  \hspace{1cm} (2)

Where \( V \) is the observed portion of the utility function, \( x_i \) is a vector of exogenous covariates, \( \beta \) is a vector of parameters to be estimated. Finally, the unobserved portion of utility function is represented by independently and identically distributed (i.i.d) random error \( u_i \) with mean zero (Wollni et al., 2010). While the utility level of an individual farmer \( U_i \) is unobserved, a latent utility is observed in discrete form through a censoring mechanism (Daykin & Moffatt, 2002):

\[
S_i = 0 \text{ if } U_i \leq \alpha_1, \\
S_i = 1 \text{ if } \alpha_1 < U_i \leq \alpha_2, \\
S_i = 2 \text{ if } \alpha_2 < U_i \leq \alpha_3, \\
S_i = 3 \text{ if } \alpha_3 < U_i \leq \alpha_4, \\
S_i = 4 \text{ if } \alpha_4 < U_i \leq \alpha_5, \\
S_i = 5 \text{ if } U_i > \alpha_5
\]  \hspace{1cm} (3)

Where \( \alpha_1 < \alpha_2 < \alpha_3 < \alpha_4 \) are unknown cutoff or threshold parameters that are estimated using \( \beta \). The parameter \( \beta \) does not contain an intercept term since the intercept term is normalized to zero, allowing the threshold parameters to be free parameters (Daykin & Moffatt, 2002). Assuming the random error, \( u_i \), is normally distributed (Wollni et al., 2010), the following probabilities can be derived:
where \( \Phi(\cdot) \) is the standard normal cumulative distribution function. The parameters \( \alpha \) and \( \beta \) are estimated by maximum likelihood using the following log-likelihood function:

\[
L = \sum_{i=1}^{n} \sum_{s=1}^{j} \log(\Phi(\alpha_j - \beta x_i) - \Phi(\alpha_1 - \beta x_i))
\]

Since the coefficients of the ordered probit regression model are difficult to interpret (Greene & Hensher, 2008), we estimated the marginal effects of change in the regressors on the adoption probabilities. Following Chen et al. (2002), the marginal effects are estimated as follows:

\[
\frac{\delta(S_i = j)}{\delta x_n} = \left[ \Phi \left( \alpha_{j-1} - \sum_{a=1}^{a} \beta_a x_n \right) - \Phi \left( \alpha_j - \sum_{a=1}^{a} \beta_a x_n \right) \right] \beta_n
\]

where \( j \) represents the number of SAPs adopted by the farmer.

4. Study area and data

Ethiopia is generally classified into 18 major agro-ecological zones and 49 sub-zones (Tesfa & Mekuria, 2014). The highland regions in Ethiopia are characterized by soils of high agricultural potential, as well as relatively steady rainfall, ranging from 600 to 2,700 mm per year. However, the same areas are characterized by land degradation and soil erosion, attributable to overgrazing, deforestation and high population densities in general (Pender et al., 2001; Tesfa & Mekuria, 2014). Hence, the study area provides an excellent case study for investigating the uptake of SAPs by farmers. The study was conducted in four regions of Ethiopian highlands—Tigray, Amhara, Oromia and the Southern Nations, Nationalities, and Peoples (SNNP), representing the South Tigray, North Shewa, Bale and Hadjia zones, respectively. Climatic conditions vary across regions. The Tigray region, for instance, is generally characterized by frequent droughts, while Oromia and SNNP regions generally have relatively good agro-ecological potential. The Amhara region, located in the central and north-western part of Ethiopia, receives annual rainfall ranging from 300 mm in the east to over 2,000 mm in the west (Benin, 2006; Headey, Dereje, & Taffesse, 2014).

The study was conducted in four regions of Ethiopian highlands. A cross-sectional survey of 600 smallholder farmers was carried out in Endamehoni, Basona-Worena, Sinana and Lemo woredas (districts) of Tigray, Amhara, Oromia and the SNNP regions, respectively (Figure 2). Three kebeles (wards), which are the smallest administrative unit in Ethiopia, were selected in each of the four districts. These included two of International Livestock Research Institute (ILRI)’s Africa RISING research wards, and one non-project wards. A total of 12 wards were therefore selected based on opportunities for sustainable intensification. A total of 50 households were randomly selected in each village, based on farmer lists provided by government extension officers and ILRI field facilitators in the respective wards. Overall, a total sample of 600 households was surveyed across the four regions.

Data collection was done using a structured questionnaire, and household interviews were administered by a team of government extension officers and ILRI field facilitators. Table 1 provides summary statistics of the variables used in the subsequent analysis.

The questionnaire included a list of statements based on the constructs of the TPB model, which were used to elicit information on farmers’ attitudes toward SAPs, the perceived social pressure to adopt SAPs, PBC over use of SAPs, as well as their overall intentions implement SAPs on their farms.
Figure 2. Study areas.

Figure 3. Indicator loadings and path coefficients of key behavioral constructs.
ATT was measured directly by four questions on the instrument (ATT1, ATT2, ATT3, ATT4). The four questions asked the farmer the degree to which they agreed with the notion that using SAPs increased farm yields, incomes, soil fertility and the farmer’s reputation in community. Subjective norm was captured by four items (SN1, SN2, SN3, SN4) referring to the opinions of important people and fellow farmers in the community, as shown in Table 2. PBC was measured by three items (PBC1, PBC2, PBC3) capturing the extent to which farmers were confident in their ability to implement SAPs on their farms. Finally, INT was measured by a three of statements (INT1, INT2, INT3) that capture a person’s readiness to adopt SAPs. These questions were worded following (Ajzen, 2002) recommendation. In total, 14 questions directly based on the theory were used to create indices of each of the four constructs. Farmers’ responses to these measurement items were captured on a 5-point Likert scale which ranged from 1 = strongly disagree to 5 = strongly agree, indicating the degree to which they agreed with the set of statements. Table 2 provides descriptive statistics of the measurement items used in the study.

5. Results

5.1. Psycho-social factors influencing farmers’ sustainability behavior

The first step in PLS-SEM involved the assessment of the reliability and validity of the key latent variables and indicators. This preliminary diagnostic step showed that all the indicators used were high in individual indicator reliability, indicating that they loaded higher in their respective constructs than they would in other constructs (Table A1). Table 3 shows the Cronbach’s alpha, composite reliability and average variance extracted (AVE) measures for each of the four constructs.

From the results, both the Cronbach’s alpha and composite reliability, which are alternative measures of internal consistency and reliability, showed high internal consistency among all the constructs (Hair et al., 2011). Generally, the closer these values are to 1, the greater the internal consistency of the indicators (items) in the constructs (Gliem & Gliem, 2003). The AVE shows high levels of convergent validity, except for the SN, which is slightly lower than the acceptable threshold of 0.5 (Sarstedt et al., 2014). However, the Fornell–Larcker Criterion (Fornell & Larcker, 1981) asserts that discriminant validity is achieved when the square root of AVE is greater than its inter-construct correlations. The Fornell–Larcker Criterion results (Table A2) show that discriminant validity was well established across all the constructs. Other diagnostic tests include the variance

| Table 1. Descriptive statistics of socioeconomic variables used in analysis |
|---------------------------------------------------------------|
| **Variable** | **Description/units** | **Mean** | **Std. Dev.** |
|-----------------|-------------------------|-----------|--------------|
| Dependent variables |
| Soil and water conservation | 1 = Adapted; 0 = Not adopted | 0.540 | 0.50 |
| Legume crop rotations | 1 = Adapted; 0 = Not adopted | 0.74 | 0.44 |
| Organic manure | 1 = Adapted; 0 = Not adopted | 0.75 | 0.43 |
| Conservation tillage | 1 = Adapted; 0 = Not adopted | 0.08 | 0.27 |
| Improved varieties | 1 = Adapted; 0 = Not adopted | 0.76 | 0.43 |
| Independent variables |
| Agricultural loans | 1 = Access; 0 = No access | 0.25 | 0.44 |
| Tropical livestock units (TLU) | Unit | 4.93 | 2.83 |
| Off-farm income | Ethiopian Birr | 3554.99 | 8678.99 |
| Group membership | 1 = Member, 0 = No | 0.53 | 0.50 |
| Land size | Hectares | 1.80 | 1.66 |
| Farming experience | Years | 23.77 | 12.02 |
| Household labor | Number of people | 2.28 | 1.26 |
inflation factor (VIF) to ascertain degree of multicollinearity. Ideally, VIF values of 5 or lower are desirable to avoid the collinearity problems (Hair et al., 2011). These results indicate that both the inner and outer model VIF values were less than 5 (Table A3).

### Table 2. Descriptive statistics of psycho-social variables used in analysis

| Construct          | Items | Description                                                                 | Mean | Std. Dev. |
|--------------------|-------|-----------------------------------------------------------------------------|------|-----------|
| Attitude           | ATT1  | I think SAPs increase my crop yields                                         | 4.41 | 0.60      |
|                    | ATT2  | I think SAPs increase farm incomes                                          | 4.36 | 0.61      |
|                    | ATT3  | I think SAPs improve a farmer’s reputation in community                     | 4.11 | 0.69      |
|                    | ATT4  | I think SAPs improve fertility of my soil                                   | 4.42 | 0.57      |
| Subjective norm    | SN1   | Most farmers important to me apply SAPs on their farms                      | 3.62 | 0.90      |
|                    | SN2   | People important to me would think that using SAPs would be a good idea    | 3.82 | 0.83      |
|                    | SN3   | Most farmers in my community expect me to use SAPs on my farm               | 3.62 | 0.83      |
|                    | SN4   | When it comes to choosing farming practices, I want to be like other farmers in my community | 3.67 | 0.92      |
| Perceived behavioral control | PBC1  | I would be able to practice at least one of the SAPs                         | 4.13 | 0.70      |
|                    | PBC2  | I have the resource to implement SAPs                                        | 3.71 | 0.97      |
|                    | PBC3  | I have the knowledge to try out or practice SAPs                             | 3.81 | 0.88      |
| Intention          | INT1  | I intend to use SAPs                                                         | 4.08 | 0.62      |
|                    | INT2  | I will try to adopt at least one of the SAPs                                 | 4.17 | 0.61      |
|                    | INT3  | I am planning to adopt SAPs                                                  | 4.08 | 0.69      |

Note: respondents were asked to rate their agreement on all measurement items using a 1–5 scale.

### Table 3. Cronbach’s alpha, composite reliability and average variance extracted

|                          | Cronbach’s alpha | Composite reliability | Average variance extracted |
|--------------------------|------------------|-----------------------|----------------------------|
| Attitude                 | 0.80             | 0.87                  | 0.63                       |
| Intention                | 0.85             | 0.91                  | 0.77                       |
| Perceived behavioral control | 0.59             | 0.79                  | 0.55                       |
| Subjective norm          | 0.68             | 0.78                  | 0.47                       |
Having established the validity of the structural model, the next step was to examine the path coefficients and to test the theoretical relationships (Figure 3). The inner model path coefficients suggest that PBC has the strongest effect on farmers’ intentions to implement SAPs (0.51), followed by A (0.26), and SN (0.03).

Bootstrapping was used to obtain $t$-statistics to test the statistical significance of both the indicators (outer model) and structural model constructs (inner model). Two-tailed $t$-tests of significance at 5% level were carried out, with $t$-statistic values larger than 1.96 indicating significance. Table 4 shows results of the structural path significance tests. The hypothesized path relationship between ATT and INT, and the relationship between PBC and INT, were both statistically significant at 5% level while the relationship between SN and INT was not significant. Therefore, farmers’ attitudes and their PBC are both moderately strong predictors of farmer’s intentions to adopt SAPs. Subjective norm does not seem to have a direct effect on farmers’ intentions to use SAPs. Bootstrapping was also used to derive $t$-statistics in the outer model, and the results showed that all the factor loadings were statistically significant at 5% level. The full results are provided in Figure A1.

5.2. Determinants of SAPs adoption

The study investigated the key factors influencing the uptake of SAPs by farmers. The majority of the farmers’ revealed that access to farming knowledge and advice (38.5%), access to agricultural credit (20%), availability of land (23.2%), availability of labor (8.4%) and access to farm equipment and tools (3.1%), as well as security of farm tenure (2%) would influence their decisions to implement SAPs on their farm.

An ordered probit econometric model was estimated to identify the factors influencing the number of SAPs adopted, as a proxy for extent of adoption. Model was estimated using maximum likelihood in STATA. The likelihood ratio test \( \chi^2(12) = 107.61, p = 0.000 \) indicated that the null hypothesis, that slope coefficients are jointly equal to zero, was rejected. The results of the ordered probit model are presented in Table 5.

The results show that the number of SAPs adopted by households increases with access to agricultural loans. Having access to agricultural loans increases the probability of adopting more than two SAPs increases by 7.4%; the cumulative of the probabilities of adopting two, three, four and five SAPs (Table 5). Access to off-farm income was also found to have a significant positive impact on the number of SAPs adopted by farmers, although the marginal effects were quite small. These results are consistent with a-priori expectations. One of the critical barriers to successful adoption and scaling up of sustainable farming practices and technologies is the fact that they often require significant initial investments while benefits could be realized in a few seasons (Giller et al., 2009). Improved access to loans and off-farm income should help alleviate liquidity constraints and thus enhance access to complimentary technical, mechanical and capital inputs (Deressa et al., 2009; Mutyasira et al., 2018b).

| Relationship                        | Path coefficient | $T$-statistic |
|-------------------------------------|------------------|---------------|
| Attitude effect on intention        | 0.26             | 5.78**        |
| Perceived behavioral control effect on intention | 0.51             | 11.29**       |
| Subjective norm effect on intention | 0.03             | 0.80          |

** indicates significance at 5%
Table 5. Ordered probit results

| Variables          | Coefficients | Std. Err. | Prob (Y = 0|X) | Prob (Y = 1|X) | Prob (Y = 2|X) | Prob (Y = 3|X) | Prob (Y = 4|X) | Prob (Y = 5|X) |
|--------------------|--------------|-----------|---------|---------|---------|---------|---------|---------|---------|
| Agricultural loans | 0.226**      | (0.120)   | 0.005*  | 0.016*  | 0.021*  | 0.006   | 0.037*  | 0.010   |
| TLU                | 0.0955***    | (0.021)   | 0.002***| 0.003***| 0.004*  | 0.002   | 0.007***| 0.002***|
| Off-farm income    | 1.49e-05*    | (7.60e-06)| 0.000*  | 0.000*  | 0.000** | 0.000   | 0.000*  | 0.000*  |
| Group membership   | 0.494***     | (0.106)   | 0.008***| 0.018***| 0.019***| 0.008   | 0.032***| 0.009***|
| Land size          | -0.271***    | (0.037)   | 0.004***| 0.007***| 0.008***| 0.005   | 0.012***| 0.004***|
| Farming experience | 0.00308      | (0.004)   | 0.000   | 0.001   | 0.001   | 0.000   | 0.001   | 0.0003  |
| Household labor    | 0.0735*      | (0.041)   | 0.002   | 0.006*  | 0.007*  | 0.001   | 0.013*  | 0.003*  |
| Personal norms     | 0.260***     | (0.094)   | 0.005** | 0.014***| 0.016***| 0.004   | 0.029***| 0.007** |
| Intention          | 0.127**      | (0.053)   | 0.003** | 0.008** | 0.009** | 0.002   | 0.016** | 0.004** |
| Constant cut1      | -0.478       | (0.395)   |         |         |         |         |         |         |
| Constant cut3      | 1.143***     | (0.386)   |         |         |         |         |         |         |
| Constant cut4      | 1.991***     | (0.391)   |         |         |         |         |         |         |
| Constant cut5      | 3.518***     | (0.411)   |         |         |         |         |         |         |
| Observations       | 452          |           |         |         |         |         |         |         |

*** p < 0.01, ** p < 0.05, * p < 0.1
Farmers’ membership in farmer groups and other producer associations was found to positively influence the number of SAPs adopted on farms. If a household has a member who belongs to a farmer group, their probability of adopting two or more SAPs increases by 6.8%. Farmer groups and commodity associations act as platforms for social networking and learning where farmers can share their knowledge, know-how and experiences with SAPs, which can positively influence perceptions and therefore adoption of these practices. By nature, some of the SAPs tend to be knowledge-intensive (Giller et al., 2009; Wall, 2007), and thus social learning will be crucial in shortening the learning curve. For instance, social capital was found to be a critical driver behind the adoption of water conservation practices by small-scale farmers in central Chile (Jara-Rojas, Bravo-Ureta, & Díaz, 2012). Also, related to this result, we found that availability of household labor resources positively influenced the number of SAPs adopted by farmers. The results showed that each additional unit of family labor increases the probability of adopting two or more SAPs by 2.4%. This result is consistent with studies that have shown how labor constraints impede the adoption of sustainable agricultural technologies, a typical example being the case of System of Rice Intensification in Madagascar (Moser & Barrett, 2003).

Tropical livestock units (TLU) had a positive and significant effect on the number of SAPs adopted by farmers. Each additional increase in TLU owned by the households increases the probability of adopting two or more SAPs by 1.4%. The positive contribution of livestock to using sustainable farming practices most probably comes through the increased availability of animal traction, which enables farmers to mechanize conservation tillage through implements such as direct seeders, reduce labor drudgery in erosion control activities such as gathering stones for stone bunds, as well as improved availability of animal manure. Also, households who own more livestock are likely to have more income from sales of livestock and livestock products. This income could be used to purchase improved seeds and other complimentary inputs. However, farm size was found to have a negative effect on the number of SAPs adopted by farmers. The results indicate that households who have smaller landholdings have a higher probability of implementing more than two SAPs. Although this is contrary to several studies that show how larger farms have a greater propensity to implement soil management and conservation practices (Reig-Martínez, Gómez-Limón, & Picazo-Tadeo, 2011), this result could imply that smallholder farmers in Ethiopia are implementing SAPs such as improved varieties, legume intercropping and rotations as agricultural intensification strategies in response to land constraints. A similar result was found in Tanzania where households who owned less land were more likely to adopt conservation tillage and legume intercropping (Kassie et al., 2013).

Perhaps the most interesting result of this study is the significance of the psychological factors. Results showed that INT was a strong predictor of the number of SAPs that farmers implemented on their farms. This result fits well within the psycho-social and behavioral literature that has demonstrated significance of intentions as a predictor of actual behavior (Armitage & Conner, 2001). Our results show that a unit increase in the magnitude of INT increases the probability of adopting two or more SAPs by 3.1%. The INT variable reflected farmers’ attitudes toward and their PBC over implementation of SAPs. Therefore, the broader implication is that if farmers view SAPs favorably and are confident that they have the knowledge and resources to try them out on their own, then there would be strong intentions to adopt SAPs (Wauters et al., 2010). However, if farmers believe that SAPs are not compatible with the farming systems they are accustomed to and that adopting SAPs would require making huge changes in their current practices (Giller et al., 2009), this could result in reluctance to adopt SAPs. This implies that changing farmers’ perceptions and attitudes toward sustainable farming practices is central in the quest to promote the widespread adoption of SAPs. Increased awareness, field schools and on-farm demonstrations of alternative sustainable practices and technologies should assist in this regard.

Personal norm was another psychological variable included in the model. It captured the extent to which a farmer felt the conviction and obligation to implement SAPs as a farmer, land owner or community member. Our results suggest that personal norm was positively and significantly linked
to the number of SAPs adopted by farmers. A unit increase in the strength of farmers’ intrinsic drive to incorporate sustainable practices on their farms increases the probability of adopting two or more SAPs by 5.6%. This is consistent with observations in some studies that farmers could be driven by stewardship motives to adopt sustainable farming practices (Chouinard et al., 2008; Hayes & Lynne, 2004).

6. Conclusions and policy implications
The general lack of spontaneous adoption of SAPs and technologies among smallholder farmers has been a major concern for researchers. Several research enquiries have attempted to understand the factors impeding or facilitating the uptake of SAPs and their continued utilization by farmers on a bigger scale. Research has predominantly focused on economic drivers, with little emphasis on the psycho-social and behavioral factors affecting farmers’ technology preferences and general attitudes toward sustainable farming practices. This study adopted an integrative approach, analyzing how a mix of economic and psycho-social factors affect the adoption of a set of SAPs by smallholder farmers in Ethiopian highlands. The study found that both economic and non-economic factors were significant predictors of the numbers of SAPs that are adopted by farmers. Significant economic drivers of adoption included access to agricultural loans, off-farm income, farmer organizational membership, farm size and household labor resources. Consistent with other studies, the research also found that farmers’ norms and intentions were strong predictors of the number of SAPs they end up adopting on their farms. Although no variable we looked at increased the probability of adopting two or more SAPs by more than 8%, collectively, these findings will be important in the promotion of SAPs and in tailoring current interventions to specific needs of farmers. Interdisciplinary and holistic approaches should form part of effective strategies for promoting SAPs among smallholder farmers, focusing on both economic and psycho-social factors. Strategies to improve adoption rates could include provision of financial incentives to help offset initial investment and opportunity costs, addressing liquidity constraints through promotion of alternative off-farm income sources, strengthening of farmers organization to induce learning-from-peers effects, promoting small-scale mechanization options to address seasonal labor constraints, as well as innovation to enhance the productivity of the livestock sector, probably through improved access to animal health facilities and introduction of improved breeds. Emphasis should also be placed on tailored extension services that provide relevant information on SAPs and thus help dispel common misconceptions and shorten the learning circle.

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Competing Interests
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## Appendix

### Table A1. Indicator loadings across constructs

| Indicator | Attitude | Intention | Perceived behavioral control | Subjective norm |
|-----------|----------|-----------|-------------------------------|-----------------|
| ATT1      | 0.82     | 0.30      | 0.21                          | 0.17            |
| ATT2      | 0.83     | 0.31      | 0.21                          | 0.14            |
| ATT3      | 0.77     | 0.39      | 0.30                          | 0.25            |
| ATT4      | 0.75     | 0.36      | 0.28                          | 0.15            |
| INT1      | 0.33     | 0.85      | 0.50                          | 0.24            |
| INT2      | 0.39     | 0.90      | 0.56                          | 0.22            |
| INT3      | 0.41     | 0.89      | 0.54                          | 0.23            |
| PBC1      | 0.36     | 0.44      | 0.67                          | 0.15            |
| PBC2      | 0.20     | 0.40      | 0.78                          | 0.37            |
| PBC3      | 0.16     | 0.49      | 0.77                          | 0.23            |
| SN1       | 0.24     | 0.07      | 0.14                          | 0.58            |
| SN2       | 0.19     | 0.08      | 0.12                          | 0.61            |
| SN3       | 0.14     | 0.19      | 0.32                          | 0.72            |
| SN4       | 0.16     | 0.26      | 0.25                          | 0.81            |

### Table A2. Fornell–Larcker Criterion analysis for checking discriminant validity

| Construct                  | Attitude | Intention | Perceived behavioral control | Subjective norm |
|----------------------------|----------|-----------|-------------------------------|-----------------|
| Attitude                   | 0.79     |           |                               |                 |
| Intention                  | 0.43     | 0.88      |                               |                 |
| Perceived behavioral control | 0.32     | 0.61      | 0.74                          |                 |
| Subjective norm            | 0.23     | 0.26      | 0.33                          | 0.68            |

The bold figures show that average variance extracted is greater than its inter-construct correlations, which implies discriminant validity.
| Variable                      | VIF |
|-------------------------------|-----|
| ATT1                          | 2.53|
| ATT2                          | 2.61|
| ATT3                          | 1.40|
| ATT4                          | 1.40|
| INT1                          | 1.93|
| INT2                          | 2.27|
| INT3                          | 2.16|
| PBC1                          | 1.12|
| PBC2                          | 1.37|
| PBC3                          | 1.28|
| SN1                           | 1.51|
| SN2                           | 1.51|
| SN3                           | 1.27|
| SN4                           | 1.14|
| Attitude                      | 1.14|
| Perceived behavioral control  | 1.21|
| Subjective norm               | 1.15|

**Figure A1.** Bootstrapping results showing t-statistics.
