Hindawi
Applied and Environmental Soil Science
Volume 2023, Article ID 9418258, 13 pages
https://doi.org/10.1155/2023/9418258

Research Article

Smallholders' Conservation Agriculture Adoption Decision in Arba Minch and Derashe Districts of Southwestern Ethiopia

Lemlem Tajebe Lejissa,[1] Feyera Senbeta Wakjira,[2] Agena Anjulo Tanga,[1] and Tesfaye Zeleke Etalemahu[2]

[1]*Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia*
[2]*College of Developmental Studies, Centre for Environment and Development, Addis Ababa University, Addis Ababa, Ethiopia*

Correspondence should be addressed to Lemlem Tajebe Lejissa; lemlemtajebe@gmail.com

Received 14 October 2022; Revised 1 March 2023; Accepted 7 March 2023; Published 16 March 2023

Academic Editor: Francesco De Mastro

This study examines smallholder farmers' conservation agriculture (CA) adoption decisions from a soil management perspective in two semiarid areas of southwestern Ethiopia. The analysis was based on a survey of 392 household heads in each of the mixed maize/sorghum/teff + *Moringa stenopetala* of Derashe district and maize/teff + banana fruit tree in Arba Minch Zuriya district farming systems. Two groups of smallholders that practice different land management, i.e., conservation agriculture and conventional tillage, were selected. A binary logistic regression model was used to answer the question of factors that determine smallholders' initial decision to adopt CA. Nine explanatory variables including the age of the household head, level of formal education, family size, size of total landholding in hectares, size of livestock owned in the tropical livestock unit, farming experience, net income from annual + perennial crops, provided extension service by development agents, and lack of access to small-scale irrigation were included in the analysis. The study result revealed that nonpracticing groups have higher schooling, farmland holding, and livestock relative to CA-practicing households. Households with increasing age, schooling, total livestock holding, and higher net per annum income were less likely to practice CA. However, the CA practicing decision was high with an increase in extension service and lack of access to small-scale irrigation. Though CA with the *Targa-na-Potayta* mulching technique is an age-old practice in the Derashe area, the impact of extension service has indispensable benefits in extending the knowledge to younger smallholders.

1. Introduction

Agriculture remains one of the most critical sectors for African economies [1], and its success is heavily influenced by soil and water management, among other factors. In many parts of Africa, inappropriate land use, poor land management, and lack of appropriate inputs have led to soil erosion, biodiversity loss, declining productivity, and food insecurity [2, 3]. Like many other African countries, Ethiopia's economy depends mainly on subsistence rainfed agriculture. Traditional cultivation practice is an essential livelihood source for over 80% of the population, contributing about 42% of the gross domestic product (GDP) and more than 80% of its exports [4]. Using a small parcel of land, smallholders produce over 90% of the main crops for the nation [5]. Despite its role, with an average population growth rate of 2.6% [6], most smallholders suffer from food insecurity and poverty due to excessive reliance on traditional, nature-dependent, and low-productive agriculture. Eradicating extreme poverty without adequately addressing land degradation is highly unlikely [7].

The Ethiopian government has carried out various land management practices on cultivated land, including contour (level) bunds, hillside terraces with afforestation, and hillside closures over the past five decades to restore land productivity [8]. Sasakawa Global 2000, the Sustainable Land Management Programme, and other related projects have increasingly promoted soil and water management through

conservation agriculture (CA) in Ethiopia [9]. CA is defined as soil management practices that minimize disturbance to the soil structure, composition, and biodiversity [10–12]. As used in this article, CA refers to soil management combined with zero-till, plants mulched using an indigenous technique, and intercropping practices on the undisturbed soil within the partitioned land. The crop is planted directly into the preceding year's crop residue on the soil surface for the entire season. In Nepal, the Terai plains lie at the lowest altitude (<1,000 m.a.s.l.) and support 20% of the agricultural land, which is conducive to growing up to three crops, rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.)-rice, rice-wheat, and rice-maize (*Zea mays* L.), a year if irrigation facilities are present [13].

In Ethiopia, many smallholders use conventional tillage (CT) since the decision to adopt CA is influenced by socioeconomic, institutional, and biophysical factors [9, 14]. The formal education of household heads, family size, age, frequent contact with development agents, and smallholders' average income have all been major influencing factors for practicing CA [15]. In addition, livestock ownership has an impact on CA, as farmers with easy access to traction animals are less inclined to switch to minimum tillage [16]. Furthermore, the massive demand for animal fodder may reduce their interest in practicing CA [17].

Derashe and Arba Minch Zuriya are neighboring districts with contrasting tillage and soil management practices; however, both dominantly cultivate maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in common. In the early years, Derashe district residents suffered from soil erosion, rainwater shortages, and soil moisture stress [18]. As a result of erratic rainfall as well as smallholders' traditional tillage practices lacking appropriate soil management practices, the situation became critical. These factors led to the invention of CA, using an indigenous moisture conservation technique known as *Targa-na-Potayta*. In this technique, own farm input is used for mulching and decomposed crop residue is used as a nutrient supplement [18–20]. In this land management system, only the cob of maize or the head of the sorghum harvest is taken and leaves the stalk in the field to minimize nutrient mining from biomass removal. Uprooted maize/sorghum stalks layered in such a way serve as moisture-conserving mulch from which nutrients can be released for the next crop. After practicing the technology, the problem of soil moisture stress and soil erosion was significantly reduced.

Smallholders in the neighboring Arba Minch Zuriya district practice CT using mineral fertilizer and over-irrigating their fields with flooding [21]. Even though chemical fertilizer use has enhanced crop productivity and soil fertility, excessive use has resulted in a decline in the soil organic matter (SOM) content and a consequent decline in soil quality [22]. Besides, in the Arba Minch area, over-irrigation using lake water leaches nutrients from the soil. The state has increased the rate of salinization and thus removed more banana fields from production [21]. Despite all the benefits of CA, smallholders have had a low adoption rate in the Arba Minch Zuriya district.

A large body of research has focused on the importance of CA for soil fertility from own farm input use, sustainable crop productivity, and household income [17, 23, 24]. Smallholders' CA practice decisions are less studied than their acquired benefits, and there are few universal factors that can explain their decisions [25]. Many studies attribute CA acceptance to several empirically derived farmer characteristics without considering the farmers' decision process (rationally weighing the economic constraints, the information diffusion process, and the utility of adopting the new technology). Therefore, the current study attempted to understand factors that limit CA adoption decisions among the neighboring Derashe and Arba Minch Zuriya districts.

2. Theories of CA Practicing Decisions

The current study focuses on two paradigms or conceptual models employed to explain the decision of smallholders to accept and practice novel technology: (i) the innovation diffusion model and (ii) the economic constraints model. The innovation diffusion model, also called transfer of technology (TOT), follows the initial work of Rogers [26].

Innovation diffusion occurs when innovation is communicated over time through specific channels among the members of a social system [26]. This model sees change as a linear process. In this model, innovations generated by smallholders and/or agricultural research are passed down to farmers through extension agents and/or respected smallholders (these are farmers who implement a given technology and become far more profitable with comparing the majority; in most areas, they are named as model farmers) in the area. Thus, extension agents and/or respected smallholders act as modes of communication, and most farmers are recipients of innovation. The diffusion of innovations is composed of four components: (i) innovation, (ii) the communication channel, (iii) time, and (iv) a social system. However, the model's weakness is that it defines individuals according to their behavior without considering factors that influence their behavior. In addition, the assumption is that innovative technology should be used unless it is hindered by the lack of effective communication [27].

The economic constraints paradigm postulates that farmers aim to maximize utility and that uneven resource endowments lead to observed adoption patterns of novel technology [27, 28]. The model emphasizes the role of economic factors at the individual level in determining practicing decisions, and the lack of access to these resources could affect practicing the technology [24]. However, this model allows only strictly rational and informed behavior and fails to capture the effects of individual perceptions of innovation. This perception is determined by personal characteristics (human values, education, and experience), physical factors of the land, and institutional factors, e.g., raising awareness through extension [29].

Overall, the technology-practicing decision illustrates that the practice of innovation encompasses a set of phases or levels, such as cognitive, normative, and action-oriented, that govern it. Recognizing these levels will aid in

understanding the prerequisites for successive steps in the conservation agriculture technology practicing decisions in Derashe and Arbba Minch Zuriya districts (Figure 1).

2.1. Conceptual Framework of the Study. Practicing CA technologies is viewed as a variable representing farmers 'behavioral changes in accepting technologies [31]. However, the uptake of the latest technology is a process and can be influenced by socioeconomic, institutional, and physical factors [14, 15, 34]. Characteristics of the household head such as age, formal education level, farming experience, total land holding, annual income from farming activities, and total livestock holdings, farming experience, annual net income, lack of access to small-scale irrigation, and extension service are selected variables in the current study expected to affect CA practicing decisions (Figure 2).

2.1.1. Independent Variables and Their Expected Outcomes. The independent variables that were used in the study are given in Table 1. It shows the independent (explanatory) variables, their description, and the expected outcome of the dependent variable.

3. Methodology

3.1. Description of the Study Sites. The study was carried out in the Arba Minch Zuriya and Derashe districts in the southwestern region of Ethiopia (Figure 3). Arba Minch Zuriya is one of the 14 Gamo Zone districts with 18 Kebeles (Kebele is the smallest administrative unit of Ethiopia, similar to a neighborhood or a localized and delimited group of people). It is about 505 km south of Addis Ababa, the capital city of Ethiopia. The district lies between 37°23′51.37″ Eastern longitude and 5°55′16.24″ Northern latitude. Its elevation ranges from 1250 to 2600 m.a.s.l. [34]. In the last ten years, the district received a total annual rainfall of 892 mm, with maximum and minimum temperatures of 30.4 and 15.6°C, respectively [21]. Among the total Kebeles, the study was conducted in two neighboring Kebeles, namely, Zeyse Eligo and Zeyse Wezeqa.

Derashe district is 525 km away from Addis Ababa and geographically located between 5°35′25″ Northern latitude and 37°12′41.00″ Eastern longitude (USGS, 2020). The elevation ranges from 1250 to 2300 m.a.s.l. [34]. The area receives a total annual rainfall of 952.1 mm, about 261.2 mm in the long rainy season (June–September) and about 413.8 mm in the short rainy season (March–May) [35]. Most parts of the Southern region are considered short-rainy season (Belg (crops harvested between Megabit (March) and Nehase (August) are considered part of the Belg season crop [36])) growing areas with rainfall reaching its peak during April/May and daytime temperature near its maximum. The Belg growing season is also marked by erratic rainfall patterns (in terms of amount, distribution, onset, and cessation). From the total of 19 Kebeles, Walessa and Holte Kebeles were purposively selected based on an intensive land management culture and their adjacency to the selected Kebeles of Arba Minch Zuriya district.

Agriculture is the mainstay of the community in the selected *Kebeles*. The major types of crops grown in Holte and Walessa *Kebeles* are maize (*Zea mays*), sorghum (*Sorghum bicolor*), *teff* (*Eragrostis tef*), and haricot beans (*Phaseolus vulgaris*) in integration with *Moringa stenopetala* trees in an agrisilviculture system. The local communities of Derashe are hard-working people in Ethiopia where all the household members spend their days in the field, ensuring they have successful crops [37]. Given their commitment to the harsh environment, they may be regarded as among the most capable managers of the arid ecosystem. In Zeyis Eligo and Zeyis Wezequa Kebeles of Arba Minch Zuriya district, maize, teff, sweet potato (*Ipomoea batatas*), haricot beans (*Phaseolus vulgaris*), cassava (*Manihot esculenta*), and vegetables mixed with mango (*Mangifera indica*), and banana fruit trees (Musa Sps.) are commonly practiced as fruit tree-based agroforestry.

3.2. Description of Conservation Agriculture in the Study Area. Derashe is located in southwest Ethiopia with unpredictable and inadequate rainfall; hence, crop production was threatened by chronic soil moisture stress [18]. Short rainwater quickly evaporates due to soil-water evaporation exacerbated by the high temperature at low altitudes. Runoff coming from the nearby higher altitude sloping and undulating terrain also causes soil erosion, reduces soil fertility and productivity, and increases the risk of drought and food insecurity for a long time. To relieve the problem, hundred plus years ago, after many trials, they invented a novel soil moisture conservation structure using crop residues as mulch, locally known as *Targa-na-Potayta* (Figure 4).

Targa-na-Potayta is a mulch arrangement technique where maize and sorghum residues are mulched in the field in a rectangle shape, roughly 60 cm × 80 cm, with continuing patterns [37]. It is arranged so that the more extended parallels are known as "Targa" and the shorter transverse residue stems form a rectangular partition, "Potayta." One large *Targa-na-Potayta* can use 0.17 ha of land and is known as "*Apha*." They separate each "*Apha*" using a ditch/trench, and a total of 6 *Apha* can be found in one hectare of land. When water ponds on the surface of one Potayta follow a high rainfall, they open the rectangular crop residue and pass it to the next Potayta, and if one Apha (consisting of one long structure of *Targa-na-Potayta*) is ponded, then they pass it into the trench/ditch that connects the next *Apha* (Figure 4).

The structure helps to

(i) Improve rainwater use efficiency
(ii) Reduce soil erosion and improve soil fertility
(iii) Reduce soil compaction
(iv) Moderate soil temperature
(v) Give higher and stable yields
(vi) Save inputs and reduce cost of cultivation [17]

Farmers use a metal stick called a "Totale" to plant by counting their steps with minimal tillage. Weeds are continuously controlled, cleared by hoeing, and used as residue. They do not allow a single weed in their crops.

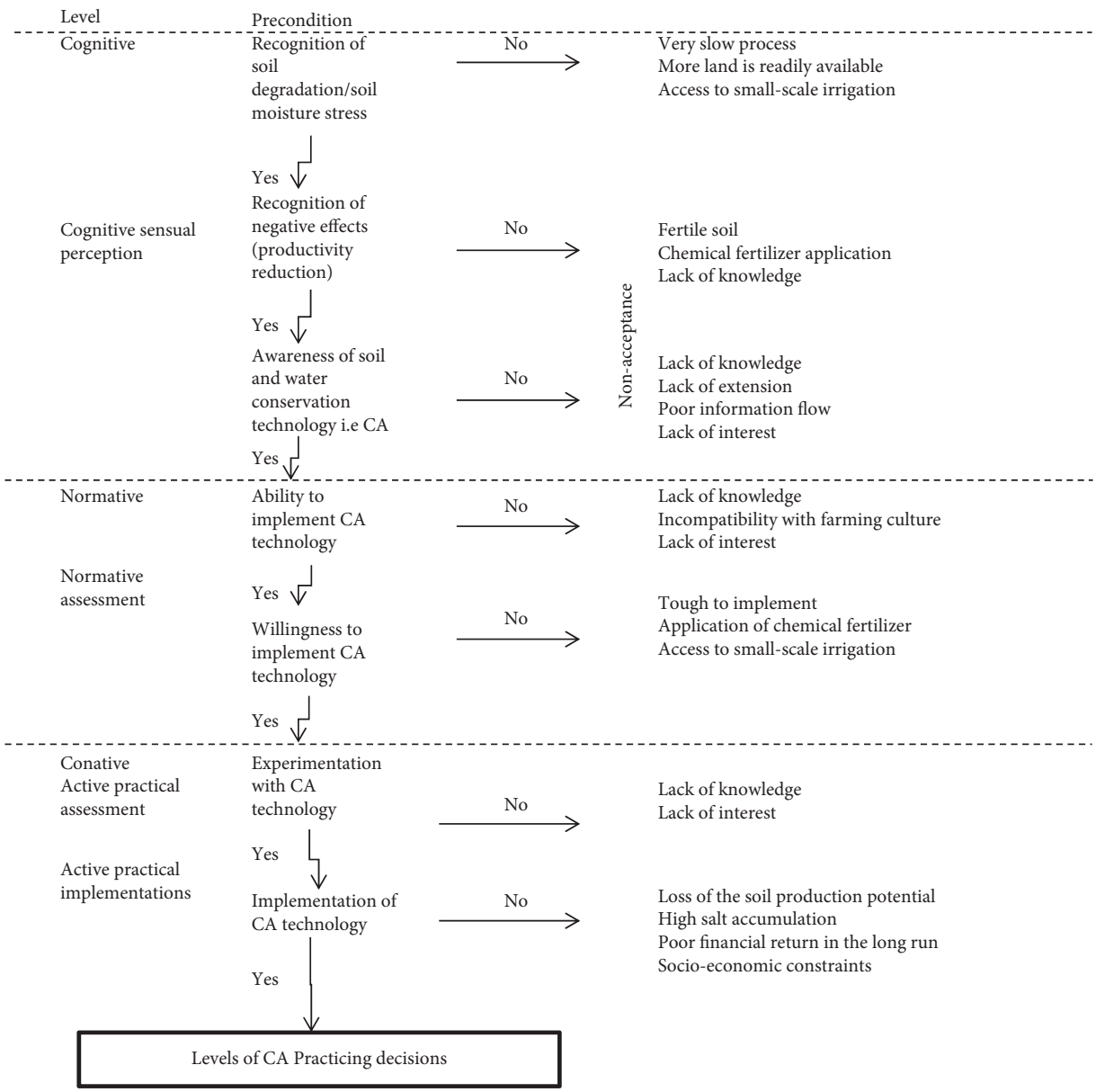

Figure 1: Levels and preconditions of the practicing process adapted from [30].

3.3. Sampling Technique. Derashe and Arba Minch Zuriya districts are neighboring districts with distinct cultures and languages and fall under different administration zones. In all Kebeles of Derashe district, *Moringa stenopetala* trees are cultivated with maize, sorghum, and teff with various intercropping intensities, and crop rotation is widely practiced. The Derashe people use the leaves of the *M. stenopetala* tree as a staple and nutritious vegetable in the semiarid rift valley, adding to the food system for the dietary requirements of children and mature people. The leaves are harvested every afternoon, added to the three meals, and mixed with sorghum or maize flour when cooking the local food"kurkufa." Meanwhile, the residents of the bordering Arba Minch Zuriya district practice contrasting farming systems where banana and maize crops are integrated into separate plots but located close to each other using CT. The nearby Wezeqa River partly irrigates this cropping system. However, moisture stress also occurs in the dry season when all farmers struggle to irrigate their crop fields simultaneously. Despite the moisture stress during the dry spell, farmers in the Arba Minch Zuriya district do not tend to learn and practice the adjacent Derashe district's moisture conservation and nutrient management skills. In the current study, consultation with the district agricultural office experts was made before selecting appropriate Kebeles.

Using a structured household survey, the study collected production and income data for significant perennial and annual crops for three consecutive cultivation seasons. The sampling procedure was performed using a multistage sampling technique. The study populations were all the households in each study site that cultivate banana + maize/teff in Arba Minch Zuriya and *Moringa stenopetala* + maize/

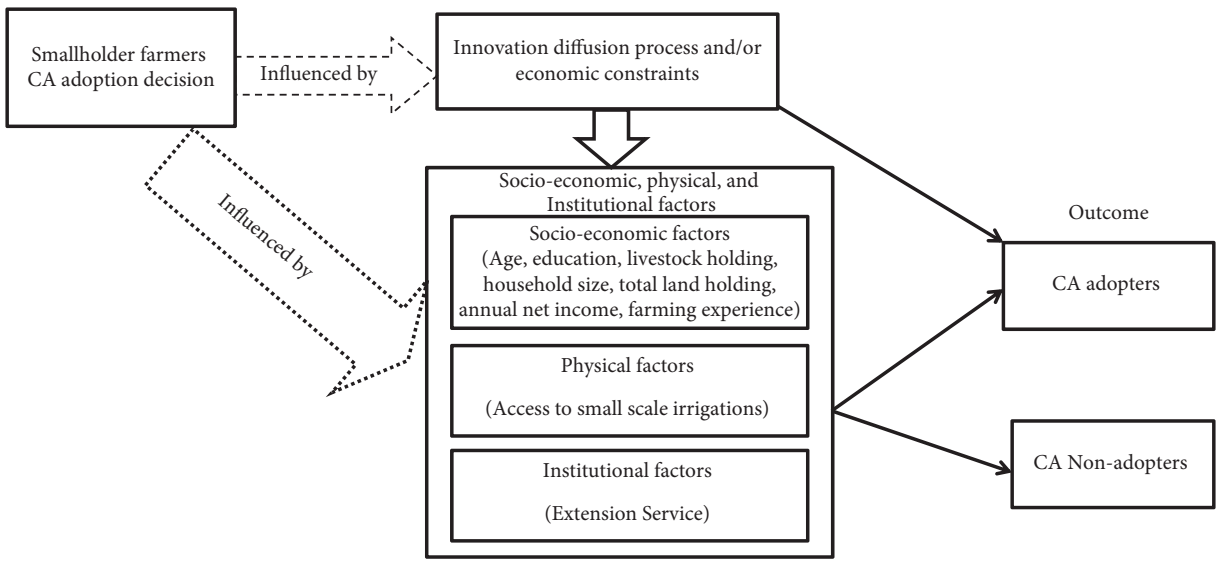

Figure 2: Conceptual framework adapted from Zeleke [33].

teff/sorghum in Derashe districts. We calculated the total household of the four Kebeles [38] and developed an equation to yield a representative sample for proportions:

$$n_0 = \frac{Z^2 * p * q}{e^2}. \quad (1)$$

This is valid, where n_0 is the sample size, Z^2 is the abscissa of the normal curve that cuts off an area α at the tails $(1-\alpha)$ equals the desired confidence level, e is the desired level of precession, p is the estimated proportion of an attribute that is present in the population, and q is $(1-p)$. Based on the formula, the calculated minimum sample size was 384:

$$Z = 1.96, p = 0.5, e = 0.05. \quad (2)$$

When the population size is known (finite), the formula is as follows:

$$n = \frac{n_0}{1 + n_0 - 1/N}, \quad (3)$$

where n_0 is Cochran's sample size computed using the formula for the ideal sample size and N is the size of the population.

$$n = \frac{384}{1 + 384 - 1/7502} = 365.7 \approx 366. \quad (4)$$

Therefore, the data were collected from 392 proportionally allocated household heads (HHHs) in the four districts stratified based on tillage practices.

3.4. Methods of Data Collection. The primary data were collected using structured questionnaires administered to farm households, key informant interviews, and field observations. An organized questionnaire was developed to capture information about farmers' socioeconomic, physical, and institutional characteristics. Four key informant interviews were conducted, one in each study Kebele, with carefully selected elderly farmers who have relevant experience and opinions about the topic. Field observations were also used to cross-check the information gathered by the questionnaire survey and key informant interviews. Field observations and informal discussions with farmers and key informants were continuous processes during the entire duration of the research.

3.5. Methods of Data Analysis. A logistic regression model was applied to analyze the determinants of farmers' CA practice decisions in the two study districts. The model helps to estimate the probability of farm households practicing CA using various independent variables. STATA version 14 was used to analyze the collected data from all surveyed households.

3.5.1. Econometrics Model

(1) Determinants of Farmers' Decision to Practice CA. A binary logistic regression model was applied to answer the factors that influence CA practice using the *Targa-na-Potayta* mulching technique. The model describes the relationship between a dependent variable and a set of independent variables. The dependent variable was binary or dichotomous and had only two groups: practicing and nonpracticing, whereas the explanatory variables could be continuous, categorical, or dummy [39]. The logistic function was selected since it approximates the cumulative normal distribution [40]. Most technology-practicing studies have used the logistic regression model to analyze dichotomous practicing decisions in which the dependent variable is binary: 1, if the household head is practicing; otherwise, it is 0 [41]. As a result, the probability of practicing CA is as follows:

Table 1: Definition of independent variables, which were included in the econometric model and expected sign.

Variable codes	Description	Types of variables	Unit of measurements	Expected sign (s)
Adoption	CA adoption	Dummy	1 = adopter and 0 = nonadopter	
AGE	Age of the HHH	Continuous	Measured in years	+
EDU	Formal educational level of the HHH	Continuous	The level of formal education	+
FAMSIZE	Family size in adult equivalent (in number)	Continuous	Number of family member	+
TLANDHOLD	Total land holding	Continuous	Measured in hectare	+
TLU	Total livestock holding of the HHH	Continuous	Measured in tropical livestock unit (TLU)	−
EXP	Farming experience (in years)	Continuous		+
NETINCO	Annual net income from annual + perennial + crops in ETB	Continuous	Measured in Ethiopian birr	−
IRRIGATION	Lack access to small-scale irrigation	Dummy	1 = yes and 0 = no	+
EXTEN	Extension visit	Dummy	1 = yes and 0 = no	+

Source: by authors; (+/−) indicates a positive or negative relationship with the dependent variable.

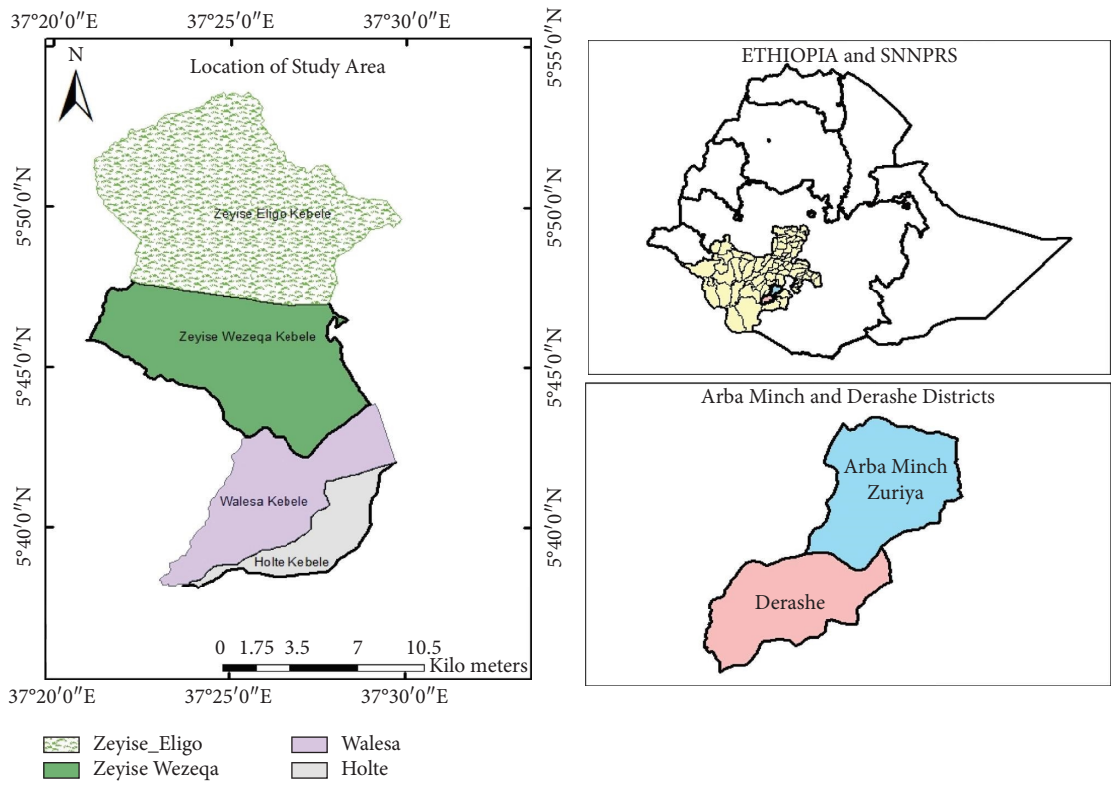

Figure 3: Map of Arba Minch Zuriya district, Zeyse Eligo, and Zeyse Wezeqa Kebeles; Derashe district, Holte and Walessa Kebeles.

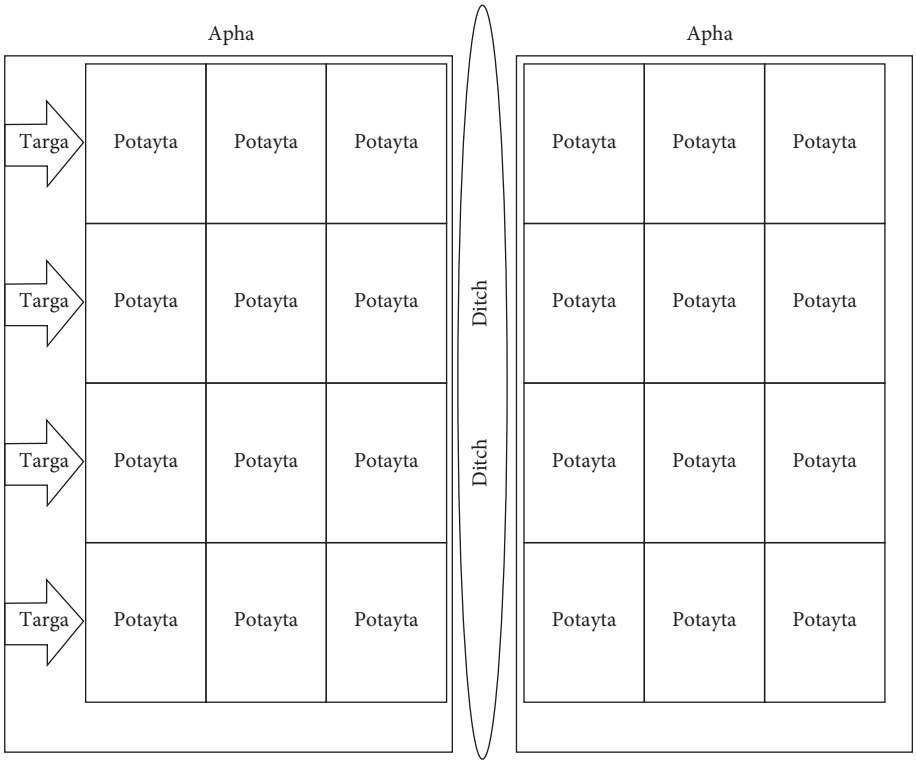

Figure 4: Schematic representation of Apha constituting *Targa-na-Potayta*, an indigenous mulching technique in Derashe district.

$$P_i = \frac{1}{1 + e^{-Z_i}} = \frac{e^{Z_i}}{1 + e^{Zi}}, \quad (5)$$

where, in the notation, $\mathbf{P_i}$ represents the probability that an individual will make a certain choice in this study, whether the ith farmer practice CA or not, **e** denotes the base of natural logarithms which is approximated at 2.718, and Z_i is a function of *e*xplanatory/independent variables (X_i) and expressed as follows:

$$Z_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_m X_{mi}. \quad (6)$$

If $\mathbf{P_i}$ is the probability of the ith farmer to adopt CA, given by (equation (5)), then $(\mathbf{1} - \mathbf{P_i})$ is the probability of the ith farmer to not adopt the traditional CA:

$$1 - P_i = \frac{1}{1 + e^{Z_i}}. \quad (7)$$

Dividing (5) by (7), we obtain

$$\frac{P_i}{1 - P_i} = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{Z_i}, \quad (8)$$

where $P_i/1 - P_i$ is simply the odds ratio (likelihood) in favor of the ith farmer to practice to the probability to not practice it.

Taking the natural logarithm of the odds ratio in both sides of (8) will result in what is known as the logit model as indicated below:

$$\ln\left(\frac{P_i}{1 - P_i}\right) = \ln\left(\frac{1 + e^{Z_i}}{1 + e^{-Z_i}}\right) = \ln\left(e^{Z_i}\right), \quad (9)$$

$$\ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_m X_{mi}. \quad (10)$$

The model included all responses (392 from each site, including CA adopters and nonadopters). The explanatory variables (X_i) included in the model were the age of the household head (AGE), level of formal education (EDU), family size (FAMSIZE), size of total landholding in hectares (TLANHOLD), size of livestock owned in tropical livestock unit (TLU), farming experience (EXPER), net income from annual + perennial crops (NETINCO), provided extension service by development agents (EXTE), and lack of access to small-scale irrigation (IRRI). Logistic analysis was conducted to determine if the farmer practices CA if practicing group 1 and 0 otherwise. Given the above explanatory variables, the general form of equation (10) was rewritten to represent the likelihood of practicing CA in the two study districts:

$$\begin{aligned}\ln\left(\frac{P_i}{1 - P_i}\right) = {} & \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{EDU} + \beta_3 \text{FAMSIZE} \\ & + \beta_4 \text{TLANHOLD} + \beta_5 \text{TLU} + \beta_6 \text{EXPER} \\ & + \beta_7 \text{NETINCO} + \beta_8 \text{EXTE} + \beta_9 \text{IRRI}_7.\end{aligned} \quad (11)$$

In this study, the above econometric model was used to identify factors that influence the decision to practice CA.

4. Results and Discussion

4.1. Household and Socioeconomic Characteristics

4.1.1. Household Characteristics. Among the total sampled respondents, 97.45 percent were male and 2.55 percent were female household heads, of which 96.7 percent were married. In Ethiopia, men are the head of the house and considered representatives of their families. With an average age of 45, CA adopters and nonadopters were each 44.8 and 45.2 years old, respectively (Table 1). CA practicing and nonpracticing groups have a formal educational level of grade 6. Furthermore, 3.32% of CA and 15.81% of CT participants completed high school. However, studies have shown that higher education levels increase the chances of practicing CA because educated farmers are more likely to ease understanding and be receptive to advancing technology or innovations [42]. Even though the average age, farming experience, and formal education of CT practitioners were substantial, they still used traditional tillage by maresha to till their land. This indicates the need for more understanding/perception about the comparative benefits of CA among CT practicing groups.

The average family size of CA adopters and nonadopters was 6.88 and 6.94 per household (Table 1). Study findings by Sileshi et al. [43] suggest that having a bigger family size increases smallholders' interest in practicing soil and water conservation technologies because they gain additional labor. Households with more members are more likely to adopt it since larger families have more labor available for farm operations, such as weeding, which is critical in CA [24]. However, this assumption only sometimes holds since labor availability depends on how large a household is and the ages and types of persons in that household. In this study, though the total household size was higher for the CT practicing groups, the proportion of economically active members was slightly higher for CA practicing (0.67) compared to CT (0.66). In the Arba Minch Zuriya district, most banana fruit producers use something other than family labor. Instead, they recruit laborers during major agricultural activities because they get massive income from banana fruit marketing. The lack of social, economic, and environmental benefits of CA-trapped CT practicing smallholders in traditional tillage.

The total land holding (which consists of homestead land + land for woodlot + main farmland + grazing land) of CA adopters was higher than that of CT practicing groups. However, CT adopters' main farmland (the land use to cultivate *Moringa stenopetala* + sorghum/maize/teff in Derashe and banana fruit tree + maize/teff in Arba Minch Zuriya district) was significantly enlarged compared to CA. Ntshangase et al. [24] found that farmers with larger pieces of land were less likely to adopt CA technology than those with smaller pieces. The CT groups in the Arba Minch Zuriya district planted bananas on a large plot of land. Even some farmers extend their land to the coast of Lake Chamo. CT

practicing groups had a mean higher net income of 157,980.60 ETB compared to 49,672.86 ETB from annual-+perennial crops (Table 2). This was due to the huge income from banana fruit production and marketing. It was assumed that a higher income meant the farmer could buy farming inputs and engage in CA. Despite this income, most groups that practice CT continue to practice traditional tillage. This is probably because they needed to fully understand the benefits of CA and/or perceived it as exhausting and difficult. Of the total sampled households, 77.4 percent was native to the area and the rest, 22.6 percent, was not native (Table 2). Being native to a particular area increases smallholders' interest in trying novel technologies.

4.1.2. Determinant Factors for Practicing Conservation Agriculture. Seven continuous and two dummy explanatory variables were identified to explain factors influencing practicing CA in Arba Minch Zuriya and Derashe districts. The effects of the independent variables on the log odds of practicing CA are reported as the odds ratio alongside the parameter estimates (β). For an independent variable, the odds ratio (e^{β}) represents the amount by which the odds favoring the decision to adopt CA (adopter = 1) change for a change in that independent variable (Table 3).

(1) *AGE*: The direction of influence of the age variable for practicing CA was predicted to be positive. However, as shown in the model summary table, age influences the practicing CA negatively and significantly at a 5% probability level. The negative coefficient and the odds ratio indicated that other factors held constant; the likelihood of a household in favor of practicing CA decreased by a factor of 0.89 for an increase in age by one year. The endpoint of a 95% confidence interval (CI) of the odds ratio is (0.81, 0.99), suggesting that CA adoption could be decreased as be as little as 0.81 times to as much as 0.99 times as an increase in age by one year. The negative relation of age with practicing CA was due to the considerable labor and energy requirement in structuring *Targa-na-Potayta*.

Similarly, older farmers want to continue their traditional farming practices rather than try more modern and latest technologies. However, young farmers could be more inclined to try innovations with a lower risk averse and a longer planning horizon. This would justify investments in technologies whose benefits are realized over time. The finding was with [44], which showed that older farmers were accustomed to conventional farming methods and were unlikely to change. However, the current finding was contrary to [24], as they revealed that practicing the new technology by older farmers may be attributable due to older access to better resources (for example, land ownership), coupled with experience and knowledge that had been gained over time compared to younger farmers.

(2) *EDU*: The direction of influence of the education variable on the adoption of CA was predicted to be positive. However, as shown in the model summary table, education was found to influence CA adoption negatively and significantly at a 5% probability level. Based on the negative coefficients and odds ratios, the increase in the educational level by one year decreased the favor of adopting CA by 0.77, and the 95% confidence interval (CI) of the odds ratio is (0.65, 0.93). This suggests that practicing CA among smallholders could be as little as 0.65 times to as much as 0.93 times lower as the level of education increases by a year. However, some studies have shown that higher education levels increase the chances of practicing CA because educated farmers are more likely to quickly understand and be receptive to novel technology or innovations [24, 25, 42].

(3) *TLU*: The total number of cattle in the tropical livestock unit was statistically significant at a 5% probability level and negatively associated with implementing CA. Keeping other factors constant, the odds ratio in favor of practicing CA decreased by 0.85 as livestock ownership increased by 1 TLU. The negative relation of the livestock size with practicing CA was smallholders choosing to use crop residue as animal fodder, where benefits from livestock are realized over a short period. Jat Sahrawat et al. [17] stated that, in the tropics and subtropics, smallholders prioritize the use of crop residues as cattle fodder due to the high economic and cultural importance of livestock for smallholders. Also, ownership, particularly oxen ownership, reduced the practice of minimum tillage with mulching probably because easy access to traction animals makes it less attractive for farmers to switch to minimum tillage [16].

(4) *NETINCO*: As hypothesized, the net income from annual + perennial plants is significant at a 1% probability level and negatively affects practicing CA. Keeping other factors constant, the odds ratio indicated that, as the increase in the net annual income in one ETB decreases, the favor of adoption by a factor of 0.99, with the endpoints of a 95% confidence interval (CI) of the odds ratio is (−0.000037, −0.000016). This may be due to the increased net income by practicing CT causing farmers' to lack interest in CA since many smallholders desire short-term returns overlooking sustainable land management. However, as the productive potential and annual income from the farmland are reduced, farmers will be more likely to practice CA. The current finding was with Nyanga [44], as the most resource-rich farmers are less likely to practice CA since they did not see any need to practice it. This could be because the relatively wealthy farmers are comfortable with their production levels and do not

Table 2: Descriptive statistics of CA and CT practitioners in Derashe and Arba Minch Zuriya districts.

Variables	CA practitioners ($n = 196$)		CT practitioners ($n = 196$)		Pooled data	
	Mean	%	Mean	%	Mean	%
Age**	44.78		45.18		44.98	
Family size***	7.7		6.9		7.29	
Educational level	5		6.89		6.15	
% Nativity		72		82.7		77.4
Farming exp***	32		25.73		28.83	
Total land holding	2.43		2.39		2.41	
Main farmland***	1.59		2.25		1.92	
Net income in ETB***	49,672.86		157,980.60			

Variables in which practicing and nonpracticing groups have a significant difference: ***at 0.01 and **at 0.05 level of significance.

Table 3: Maximum likelihood estimate of the binary logit model for decisions to practice CA.

Explanatory variables	Coefficient	Robust std. err	Z	$P > \|z\|$	e^{β}	Tolerance	VIF	CC
AGE	−0.11**	0.05	−2.42	0.015	0.89	0.412	2.43	
EDU	−0.26**	0.1	−2.58	0.01	0.77	0.883	1.133	
FAMSIZE	0.18	0.2	0.90	0.4	1.2	0.889	1.125	
TLANHOLD	−0.09	0.315	−0.28	0.78	0.9	0.805	1.242	
TLU	−0.16**	0.06	−2.57	0.01	0.85	0.802	1.246	
EXP	0.13*	0.048	2.6	0.09	1.13	0.375	2.665	
NETINCO	−0.00003***	$5.45E^{-06}$	−4.82	0.000	0.99	0.807	1.239	
EXT	2.95***	0.55	5.31	0.00	19.01			0.707
IRRIGA	4.97***	0.8	6.24	0.00	144.43			
CONS	−0.12	1.75	−0.07	0.95	0.89			

Log likelihood (X^2) = −43.37, Wald Chi-square = 87.75***, and pseudo-R^2 = 0.7957. ***represents statistically significant at 1% level of significance, respectively.

see any need to allocate their resources toward CA. However, the finding was against Marenya et al. [16], as poor farmers were less likely to practice minimum tillage with mulching as compared to more assets owned by smallholders.

(5) *EXT*: As hypothesized, getting extension service is significant at a 1% probability level and positively correlates with practicing CA. Keeping other factors constant, the odds ratio indicated that, as smallholders get information about CA, the favor of practicing will increase by a factor of 19.01, with endpoints of a 95% confidence interval (CI) of the odds ratio (1.86, 4.03). This is due to frequent outreach explaining the contributions of technology to sustainable soil fertility. Crop production will enhance farmers' perception of the benefits of CA and the decision to practice. According to [24, 43], increasing contact with farmers can positively influence CA practice. A study on socioeconomic and institutional factors influencing the practice of CA in Zimbabwe also revealed a positive and significant relationship between extension services in the practice of CA [45].

(6) *IRRIGA*: As hypothesized, the lack of access to small-scale irrigation was significant at a 1% probability level and positively correlated with adopting CA. Keeping other factors constant, the odds ratio indicated that, as smallholders lack access to small-scale irrigations, the favor of adopting CA increased by 144.43, with endpoints of a 95% confidence interval (CI) of the odds ratio (3.4, 6.54). As a result of a lack of small-scale irrigations or poor moisture conditions, CA adopters as innovators used an indigenous mulching technique known as *Targa-na-Potayta*, invented almost a century ago. However, CT practitioners in the Arba Mich Zuriya district have easy access to small-scale irrigation systems. Due to this, smallholders in the area are reluctant to practice CA with indigenous mulching, *Targa-na-Potayta*. Their CA practicing decision would likely increase if they did not have access to an irrigable water source. During the key informant interview, the Derashe area elderly smallholders stated as follows: "the problem of short and erratic rainfall coupled with lack of irrigable water was a critical challenge for the survival of Derashe people for many years. Using our progenitors' *Targa-na-Potayta* technology, which they invented with dedication and a creative mind, greatly reduced the demand for rainwater. The current generation also appreciates them since the technology enhances soil moisture and increases soil fertility and crop productivity." These disclosed smallholders of the Derashe area use

the *Targa-na-Potayta* mulching technique that inherently innovated to relieve the problem of soil moisture stress.

Smallholders' new ideas, practices, and technology choices were theorized to be influenced by the innovation diffusion process and/or economic constraints. Referring to various studies, three socioeconomic, institutional, and physical factors were identified, and nine explanatory variables were selected as factors that influence CA adoption decisions. The results showed that age, year of schooling, total livestock holdings, and net per annum income from annual + perennial crops affects CT practitioners' decision to adopt CA. Furthermore, increased extension agent visits and a lack of access to small-scale irrigation forced CA groups to accept the technology from their progenitors and apply it extensively.

In the innovation diffusion model, Rogers [46] emphasized four key variables, namely, innovation, time, communication channels, and the social system. CA using the *Targa-na-Potayta* mulching technique is a unique feature in the Derashe area. Smallholders in the Derashe area adopted this innovation because of its benefits. However, those in the adjacent Arba Minch Zuriya district were not interested in adopting it, even though they were aware of it. Rogers [46] defined innovation as an idea/practice/object perceived as a novel by an individual or other unit of a working group. Therefore, CA with *Targa-na-Potayta* is considered an innovation for the Arba Minch Zuriya district smallholders, since apart from hearing and observing it, they did not practice it on their farmland. CA practice by the neighboring Arba Minch Zuriya district smallholders is slow, and they are still in the first stage of the practicing process, i.e., the awareness stage. According to this study, time alone is not enough to make people accept and embrace novel practices; however, extension agents must play a key role in communication channels. Because their progenitors faced an outwardly overwhelming problem, the Derashe smallholders understood the benefits of CA. Again, families and extension agents also help smallholders practice CA as intensively as their ancestors did.

Rogers [46] also stated the effectiveness of innovation when diffused through a given social system considering their cultural similarities. It is generally accepted that innovation diffusion has a strong location-specific component, with geographical proximity and spatial accessibility as important factors [47]. However, people primarily practice innovation based on subjective values and social norms diffused through interpersonal networks [26]. Innovation can easily be diffused to different areas if the technology is considered appropriate by a certain society. According to Assefa and Gezahegn [48], one of the ways that farm-level productivity can be increased is through the introduction of technology from other areas and transferring it to the farmers. It is possible if and only if practicing groups get appropriate information and the risk-taking behavior of farmers is known in advance. Furthermore, Lanckriet et al. [49] stated in their study on CA that spatial factors are relevant and interpersonal relations play a role. As indicated in their study findings, social networks between different villages play an essential role in innovation, and innovations are derived from kinship, friendship, and marriage, and 39.2% of the CT practicing groups cited these factors as reasons for their knowledge of CA.

Most respondents in the Arba Minch Zuriya district stated that designing/implementing *Targa-na-Potayta* in the plot seemed tedious. However, if there was a problem with access to small-scale irrigation, they indicated their interest in practicing CA. Despite the importance of a social system for easing innovation diffusion, an extension system can scale out innovation outside of a social network. Agricultural research/smallholders are considered the source of innovation, extension agents act as modes of communication, and farmers are recipients of the invention. Farmers' rationality is judged either by adopting or rejecting innovations that are seen as the outcome of an innovation-decision process [50]. In the Arba Minch Zuriya district, the lack of scientifically supported investigation on the importance of CA with *Targa-na-Potayta* makes extension agents hesitant to understand and diffuse the neighboring indigenous practice throughout the community. This slows the diffusion process and keeps farmers trapped in CT.

The study findings showed that CT practicing groups have higher age, schooling, and net per annum income than CA practicing groups. The economic constraints model assumes that individuals strive for profit or utility maximization, but observed adoption patterns are determined by the asymmetrical distribution of resource endowments among individuals [27, 28]. A farmer chooses to adopt a technology if they perceive increased utility from its adoption. That is, adoption will occur if $U1 > U0$, where $U1$ is the utility if technology is adopted and $U0$ is the utility without adoption, and the economic constraints model recognizes the importance of profitability and financial constraints (access to capital, learning costs associated with innovation, or risk). Observing the comparative benefits, CT practicing groups obtained, on average, a higher net per annum income from sole banana fruit production than CA practicing groups' income from annual + perennial crops. The high monthly income from banana fruit production makes smallholders inconsiderate of the sustainable benefits obtained from CA with *Targa-na-Potayta* mulching for soil fertility and productivity.

5. Conclusions

Data from primary and secondary sources were used to assess CA practice decisions in southwestern Ethiopia, Derashe, and Arba Minch Zuriya districts. The study was conducted in 4 adjacent Kebeles (2 from each district) that engage in different tillage and soil management activities. The logistic regression model was used to understand the various determinant factors that limit smallholders' CA practice decisions. In the selected districts, nine independent variables were examined that were supposed to influence CA practice decisions.

The logistic regression findings suggested that households with older age, education, total livestock holdings, and net per annual income were less likely to adopt CA. Increasing extension services and a lack of access to small-scale irrigation systems influenced the decision to practice CA. One of the principal factors preventing Arba Minch Zuriya district smallholder farmers from adopting CA was receiving the most net income per year from banana fruit production. The economic constraint assumes that any rational person intends to maximize profit (utility). Similarly, the primary objective of the smallholders in the area was to enhance income using CT at the expense of the soil. Smallholders focused on the momentary benefits of banana fruit, overlooking sustainable productivity because of the high demand nationwide. Lack of an irrigable water source, soil moisture stress, rainwater shortage, and soil erosion make smallholders in the Dershe district practice CA more intensively with the *Targa-na-Potayta* mulching technique. In the area, the culture of practicing CA and a structured extension system inform smallholders about the importance of CA for sustainable soil and crop productivity. If the government pays careful attention to the importance of soil and water conservation practices, the probability of CA adoption by Arba Minch Zuriya district farmers will increase.

Data Availability

All the data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors are grateful to Ethiopian Environment and Forest Research Institute (EEFRI), Environment Forest and Climate Change Commission (EFCCC), and Addis Ababa University (AAU) for funding this study. The cooperation received from farmers, administrative officials, development agents, and NGOs during data collection is highly appreciated.

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