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Research Article

# Economic Analysis of Minimum Tillage on Small Holder Farmers Income in East Wollaga and West Shoa Zone, Oromia National Regional State, Ethiopia

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## Abstract

Particularly crop production in Ethiopia is characterized by intensive tillage and especially these resource poor farmers w
limited access to draft power were more affected by thus repeated tillage. Survey was conducted to determine benefits
minimum tillage practices and to identify factor affects adoption of minimum tillage practice for teff production in East Woll
and West Shoa zone of western Oromia region of Ethiopia. The Survey was conducted in four districts of the zone namely D
and Sibu Sire from East Wollaga zone, Liban Jawi and Bako Tibe districts from West Shoa zone. Furthermore, the survey w
carried out with 205 farmers in four districts where minimum tillage (MT) practice was expected to be relatively high. In
study the minimum tillage practice was calculated to profit 1.8 birr for each 1 birr of costs than for conventional tillage (1.3 bi
A logistic regression was used to estimate how marginal changes in household characteristics affect the probability of
adoption. Farmers who have never tried MT have less access to training and credit access. They were also having high fam
size, with old age than adopter. To promote the adoption of MT, policymakers and concerned stakeholders should consider sm
holder farmers' age, family size, access to training and credit aspects for promotion of minimum tillage practices.

## Keywords

Tillage Practices, Adoption of MT, Conservation Agriculture, Teff Production

## 1. Introduction

The practice of the conservation agriculture (CA) in general and minimum tillage practices in particular have spread widely to many parts of the world. For instance, the increase from 45 million hectares in 1999 to 111 million hectares in 2009 [1]. Conservation agriculture is heralded to increase yields and reverse land degradation in Sub-Saharan Africa [2]. Furthermore, due to animal for traction reduced by disease in the mid-1990s have created major initiatives to promote minimum tillage (MT) practices to the Africa smallholders since 1996 [3].

In Ethiopia, Sasakawa Global 2000 (SG-2000) introduced CA closely with the Ministry of Agriculture in 1998 including MT practice [4, 5]. The three principles of Conservation Agriculture are: minimum or no tillage, permanent organic soil cover, and crop rotation and minimum tillage were a known practice of CA [6]. This is due to typically emphasized during promotion [2].

Particularly crop production in Ethiopia is characterized by

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intensive tillage [7]. In Ethiopia farmers plow their land from two to six times per planting depending on the crop that is to be planted [8], four to eight times to minimize weed and pest infestations [9]. Teff fields are ploughed up to six times and especially these resources poor farmers with limited access to draft power were more affected by thus repeated tillage [10]. The MT practice is beneficial for farmers who do not have draft animals that spent about 50% of their harvest for ox rent [11].

Minimum tillage reduces labor hours (for men) by 28.6% for land preparation than conventional tillage [12]. Whereas, labor hours (for females) increasing by 40% for weeding resulting labor shift negatively impacted females in the households [13]. Continuous practice of minimum tillage has been increasing maize yields by at least 12% [13]. Another advantage of MT, the early crop harvest associated with the minimum tillage system was highly beneficial for small-holder farmers for early harvest to coincide with the cyclical period of severe household food deficits and high grain prices in local markets [14].

Some earlier studies evaluate the cost benefit of the programme by comparing the MT with conventional only in experimental site in the study area, which is not equal to actual results obtained by farmers from their farm [12, 13]. So, this study expected to address this gap with the following objective to identify and quantify costs and benefits of minimum tillage practice versus conventional, to identify factors affecting use of minimum tillage practice and to assess the gender labor contribution in crop production by implementing minimum tillage practices in the study area.

# 2. Methodology

## 2.1. The Description of the Study Area

This study was conducted in Diga and Sibu Sire from East Wollaga zone, Liban Jawi and Bako Tibe districts from West Shoa zone. First, Diga district is located 340 km west of Adis Abeba and 12 KM west of Nekemt, capital city of East Wollaga. The district has altitude between 1300-2250 masl and an annual rainfall of 1200-2100 mm. The soil in the district was loam soil type. The major crops grown in the area are Maize, sorghum, and Teff. Secondly, Sibu sire district is located 280 km west of Adis Abeba and 50 KM East of Nekemt, capital city of East Wollaga. The district has an average altitude of 1820 masl and an average annual rainfall of 1700 mm. Using herbicide for minimum tillage increase from year to year for instance around 52,000 lit pre-emergence herbicides were distributed in 2022 year in the district. Loam soil type was the major soil type of the districts. The major crops grown in the area are Maize, Teff and Finger millet.

Thirdly, Bakko Tibe district is located 250 km west of Adis Abeba and has an average altitude of 1700 masl and an average annual rainfall of 1267 mm. The major crops grown in the area are Maize and Teff. Loam soil type was the major type of the soil in the district. More than 44,000 lit of non-selective herbicides were distributed in the year of 2022. Fourthly, Liban Jaw districts was newly established districts of West Shoa zone, located 161 km west of Adis Abeba and 50 km from Ambo capital city of West Shawa zone and has an average altitude of 2000 masl and an average annual rainfall of 1350mm. Loam soil and clay soil type were the main soil type of the districts.

## 2.2. Source of Data

To provide insights prior to the main sampling, discussions were made with districts' experts from the respective district office of agriculture to make clear the purpose of the study and seek their assistance. The questionnaires were designed to collect both qualitative and quantitative data. Focus group discussion and key informant interview were held with 5-10 farmers, DA and experts in the three kebeles of study area before respondents' interview. Primary data were collected from the sample households. Secondary data on explanation of the study area, soil type, major crops grown, and other issues were collected from published and unpublished documents and reports from relevant organizations.

## 2.3. Sampling Techniques

Multi-stage sampling was employed to select households to be included in the survey. In the first stage, potential zone were selected. In the second stage, 4 districts (Diga and Sibu Sire from East Wollaga zone, Liban Jawi and Bako Tibe disricts from West Shoa) were purposively selected based on the potential by practicing minimum tillage from selected zones. In addition, based on the potential, 8 kebeles were selected in the third stage. Teff producers' farmers were selected purposively in each kebele at the fourth stage. Those Teff producers' farmers were stratified into farmers adopt minimum tillage and non-adopters were selected at fifth stage.

In the final stage, a total of 205 households were randomly selected from these four Kebeles, with the number of households selected from each kebele proportional to the number of the households in the kebeles' in relation to the practices.

## 2.4. Data Analysis

### 2.4.1. Descriptive Statistics

In this study, descriptive statistics such as mean, standard deviation, percentages and frequency of occurrence were used along the econometric model to analyze the collected data. The Chi-square test was made to compare dummy explanatory variables and t-test for continuous explanatory variables were used to see the statistical difference between the two groups' mean of adopting and non-adopt of minimum tillage practice of respondents.

To conducting cost benefit analysis, a comparison was drawn between user and non-user of MT in the study area focusing on the teff crop production. The costs and benefits associated with each input of practices in the farmers' plots of teff crop and sales of its outputs with market price of 2022 year at farm gate were calculated. Costs of fertilizer and labor for land preparation (person-days and oxen day) were the major input used for the cost analysis. Other production inputs used could be estimated held constant. Example, all weeding by all farmers was conducted by post-harvest herbicide like 2, 4-D with nearly similar dose of application.

### 2.4.2. Econometric Analysis

The second section deals with the analysis of determinants of households' adoption of minimum tillage practice. A binary logistic regression model was applied to answer the factors that influence MT practice. Logistic function was selected since it approximates the cumulative normal distribution [15]. 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 [16].

$$Pi = \frac{1}{1 + e\text{-}ZI} = \frac{e\text{-}ZI}{1 + e\text{-}ZI}$$

Where, in the notation, Pi represents the probability that an individual will make a certain choice in this study, whether the *i*th farmer practice MT or not, e denotes the base of natural logarithms which is approximated at 2.718, and *Zi* is a function of explanatory/independent variables (*Xi*) and expressed as follows: If Pi is the probability of the *i*th farmer to adopt MT, given then (1 − Pi) is the probability of the *i*th farmer to not adopt the practices:

$$\text{Ln}\left(\frac{pi}{1-pi}\right) = \beta_0 + B_1x_{1i} + \beta_2X_{2i} + \ldots + \beta_mX_{mi}$$

$$Zi = \beta_0 + B_1x_{1i} + \beta_2X_{2i} + \ldots + \beta_mX_{mi}$$

## 3. Results and Discussion

### 3.1. Socio Economic Characteristics of Households

The data collection conducted from two categories 130 (64%) adopter and 75 (36%) of non-adopters of MT practices. Many of respondents 192 (94 percent) were males. Creditworthiness of a farmer shows that only 23% he/she can borrow the required capital necessary to generate the expected gross income from the categories of adopter. with another 66% saying access to credit was limited from the total sampled households (Table 1).

***Table 1.*** *The Relationship of the Different Dummy Variables to MT Practices.*

| Variables | Category | MT adopter | | Non adopter | | Total % | X2 |
|---|---|---|---|---|---|---|---|
| | | frq | % | Frq | % | | |
| Total sample size | Adopter | 130 | | | | 64 | |
| | Non adopter | | | 75 | | 36 | |
| Sex | Male | 118 | 58 | 74 | 36 | 94 | |
| | Female | 5 | 3 | 8 | 4 | 6 | |
| Training received | yes | 65 | 32 | 11 | 6 | 37 | 34.15*** |
| | no | 66 | 33 | 63 | 31 | 63 | |
| Having access to credit | yes | 47 | 23 | 21 | 11 | 34 | 3.87 |
| | No | 79 | 39 | 58 | 29 | 66 | |
| Belongs to a farmer in cooperatives | yes | 88 | 43 | 41 | 20 | 63 | 10.69*** |
| | no | 36 | 18 | 40 | 20 | 37 | |
| Having extension support for MT practices | Yes | 79 | 39 | 23 | 12 | 50 | 12.89*** |
| | No | 48 | 24 | 55 | 27 | 50 | |

Source: Own survey, 2022

## 3.2. Access to Extension Services

The major complain of respondents was "the chemical changed from time to time, and nobody can be perfect of its effectiveness from time to time" The farmers required technical advice from extension worker starting from what type of chemical was effective to buy. According to Table 1, from category of adopter 79 (39%) of respondents indicated that they have a technical extension services form extension workers whereas 24% have no technical assistance for MT practices. From the non-adopter the majority 55 (27%) have no technical support from extension concerning the practice. There was statistically significant relationship between having technical support for MT practices not having.

The average age of minimum tillage adopters was 40.7 years with having 7 persons of total family size. However, the average age of non-adopters was 46 years with 6.5 persons family size and there was statistical difference between the two groups' mean of age at 1% probability level of significance. The total income of the respondent obtained per year was other important factor hypothesized for the household decision to adopt MT practice (Table 2). This table also showed that, sample households earned an average income of 74320 Ethiopian Birr per annum for the sample household adopt MT and 33421 for non-adopter. There was statistically significant difference between the two groups in terms of total income at 1% probability level of significance.

***Table 2.*** *the Relationship of the Different Continuous Socio-Economic Variables to MT Practices (Adopter).*

| NO | Variable | Adopter (mean) | Non adopter (mean) | Total | T- test |
|---|---|---|---|---|---|
| 1 | Age of the household head (years) | 40.7 | 46 | 43.4 | 3.1*** |
| 2 | Education of the household head | 4.8 | 4 | 4.5 | 1.27 |
| 3 | Number of family members | 7 | 6.5 | 6.8 | 1.25 |
| 4 | Livestock owned (TLU) | 7.2 | 6.7 | 6.9 | 0.68 |
| 5 | Total farm size (ha) | 1.8 | 1.7 | 1.8 | 0.47 |
| 6 | Household yearly income | 74320 | 33421 | 55887 | 3.32*** |

Source: Own survey, 2022

## 3.3. Household Access to Oxen

***Table 3.*** *The distribution of Sample HH Heads by Numbers of Oxen.*

| No | Numbers of oxen | Number of sample households | Percent |
|---|---|---|---|
| 1 | Zero | 28 | 13.7 |
| 2 | One | 51 | 24.9 |
| 3 | Two | 81 | 39.5 |
| 4 | Three and more | 45 | 22 |
| | Total | 205 | 100 |

Source: Own survey, 2022

Oxen has a long history in Ethiopia and was probably first used for land preparation particularly well suited to Teff cultivation than other crops because of its small seeds [10] and to minimize weed and pest infestations [9]. Access to oxen can be seen to be more important than land size in the Ethiopian context; because without the oxen, the land cannot be cultivated [17]. In the study area, according to Table 3, about 28 (13.7%) sampled household have no oxen, 51 (24.9%) have only one draft oxen, 81 (38.5%) own a pair, and the rest of the households own three and more oxen for draft purpose. This showed that more than 38% of the farmers have got the oxen through *hidhata* system with other farmers or by borrow one or two oxen for cultivation. According to [18] reduced tillage was the coping strategies for the poor farmers constrained by a shortage of oxen.

## 3.4. Cost-benefit Analysis of Using MT

Total revenue (TR) was calculated based on the grain yield and market price in the production year. The local market grain price of Teff used was 45 birr per kg at farm get when the data was collected. The average estimated labor price in the study area was 124.6. 6.5 days were estimated to complete 1 hectare during primary tillage however for secondary tillage 5.7 days required through oxen plow for land preparation. The average frequency of plow of land to sow Teff seed (2.4 for MT and 3.9 times for conventional tillage). The average amount of non-selective herbicide used by sampled households was 1.9 liter per plot and its average price was 700:00

birr per plot. Local market DAP and UREA prices per kilogram were 38.68 and 38.39 birr respectively. According to sample respondents, there was an exercise of renting a pair ox including human labor and averagely estimated 308.78 birr per day. As indicated in Table 4, the net income from the plot used for the comparison was 2749.87 and 6772.32 birr for conventional and MT respectively.

*Table 4. Cost-Benefit Analysis of MT and CT Practices.*

| Cost item | Conventional tillage | | | | Minimum tillage | | |
|---|---|---|---|---|---|---|---|
| | units | Unite price (birr) | Qty | Total price | Unite price (birr) | Qty | Total price |
| Average frequency for plow | | | 3.9 | | | 2.4 | |
| Primary tillage (land preparation) | Oxen day | 308.78 | 4.03 | 1244.38 | - | - | - |
| Secondary tillage | Oxen days | 308.78 | 4.03@3.9 | 4853.09 | 308.78 | 3.5@2.4 | 2593.75 |
| Herbicide (pre emergence) | liter | | - | - | 700 | 1.9 | 1330 |
| Herbicide applications | person day | | - | - | 124.6 | 1 | 124.6 |
| Pulverization | person day | 124.6 | 6.5 | 809.9 | 124.6 | 9.93 | 1237.28 |
| Fertilizers DAP | kg | 38.68 | 63.43 | 2453.47 | 38.68 | 64 | 2475.52 |
| UREA | kg | 38.39 | 42.05 | 1614.29 | 38.39 | 27 | 1036.53 |
| Total variable cost | | | | 10975.13 | | | 8797.68 |
| Out put | kg | 45 | 305 | 13725 | 45 | 346 | 15570 |
| Net income | | | | 2749.87 | | | 6772.32 |
| Benefit-Cost ratio’ | | | | 1.3 | | | 1.8 |

Source: Own survey, 2022

If a project has a BCR greater than 1.0, the project is expected to deliver a positive net present value to a farmer. So, in the study the minimum tillage practice expected to profit 1.8 birr for each 1 birr of costs than expected for conventional tillage (1.3 birr) (Table 4).

## 3.5. The Gender Labor Role in Implementing MT Practice

The gender participation in using minimum technology like purchasing herbicide in the household level was assessed in the study area. Major sampled households (69.8%) decide implementing minimum tillage practice on their farm was conducted by both household header and his spouse while 30.2% conducted by male households only. however, according to [23] women must act as leaders in its development and as agents of change and it would be a mistake leaving women behind to fully benefit from new technology. Second, the households these practice MT were asked the question “From family for whom the use of MT was giving more rest and their answers were 36.4% for male HHs and 66.9% for all family members. Lastly, there was hypothesis the reduction of labor from men during tillage has been transferred to women as a burden due to MT increase weeding because, traditionally women’s contribution in weeding is relatively high [19]. Moreover, *h*igher weed pressure with minimal tillage increases labor demand for weeding and it was more than double under reduced tillage than in the conventional tillage (Editor, 2014). In contrast, in the study area weeding of teff crop conducted with application of herbicides (like 2-4D) and the burden of weeding has not transferred to women (Table 5).

*Table 5. The Gender Labor Roles in Implementing MT Practice.*

| No | Category | N | % |
|---|---|---|---|
| 1 | Decision maker to use MT practices | | |
| 1.1 | Male household head | 31 | 30.2 |
| 1.2 | Both (male and his spouse) | 73 | 69.8 |
| 2 | For whom giving more rest in the family | | |
| 2.1 | Male | 40 | 36.4 |

| No | Category | N | % |
|---|---|---|---|
| 2.2 | Female | 3 | 2.7 |
| 2.3 | For all families | 67 | 69.9 |
| 3 | Does the burden of weeding transfer to women (No) due to MT practice | 130 | 100 |

Source: Own survey, 2022

### 3.6. Determinant Factors for Practicing Minimum Tillage

According to Table 6, the findings showed that the model's Log likelihood ($X2$) = -69.23, Wald Chi-square = 55.98, is significant at (P0.00), indicating that the model is well-fitting. Age of household, family size, access to training, access to credit Cooperative member were some of the key determinants of adoption of MT practices. As shown in the model summary Table 6, age influences the practicing MT negatively and significantly at a 5% probability level. The findings found that as the age of the farmers increases the adoption of MT decreases, the finding was like [21] in contrast with [20].

The farmers should make sure how to use these chemicals correctly and according to the label's directions. improper herbicide application could possibly injure crops and reduce weed control. According to [22] some factors to be considered for proper herbicide application are crop growth stage, weed growth stage, environmental conditions, (wind, temperature and moisture), soil conditions (PH and organic matter). Increased access to training showed that a household that received training was more likely to increase adoption of MT. Increased access to loans was associated with an increase adoption of MT similar to [20]. Furthermore, household size has been noted as a predictor in households' decisions to adopt MT practices. Larger family size holders are more declined to accept MT practices (Family size affect adoption of MT negatively).

***Table 6.*** *Determinant of Factors Affecting Practicing of MT.*

| Variables | Coff | Std.err | P>/Z/ |
|---|---|---|---|
| Age | 0.597** | 0.302 | 0.048 |
| Education | 0.379 | 0.596 | 0.525 |
| Farming expr. | 0.0219 | 0.344 | 0.524 |
| Family size | -0.2119** | 0.1035 | 0.041 |
| TLU | 0.0027 | 0.0512 | 0.884 |
| Training | 2.620*** | 0.6325 | 0.000 |
| Credit | 0.8859** | 0.5021 | 0.078 |
| Cooperative member | 1.507*** | 0.4770 | 0.002 |
| cons | -6.042 | 1.475 | 0.000 |

Source: Own survey, 2022
Log likelihood ($X2$) = -69.23, Wald Chi-square = 55.98, and pseudo-$R2$ = 0.288. represents statistically significant at 1% level of significance.

## 4. Conclusion

Data from primary and secondary sources were used to to identify and quantify costs and benefits of minimum tillage practice versus conventional, to identify factors affecting use of minimum tillage practice, to assess the gender labor contribution in crop production by implementing minimum tillage practices in western Oromia, Ethiopia. The study was conducted in Diga and Sibu Sire from East Wollaga zone, Liban Jawi and Bako Tibe districts from West Shoa zone based on the potential by practicing minimum tillage (MT) from selected zones.

The costs-benefits analysis was done by comparison drawn between user and non-user of MT in the study area focusing on the teff crop production. The net income from the plot used for the comparison was 2749.87 and 6772.32 birr for conventional and MT respectively. In addition, the minimum tillage practice has more benefit cost ratio than conventional tillage practices, it expected to profit 1.8 birr for each 1 birr of costs than expected for conventional tillage (1.3 birr). Further, there was hypothesis the reduction of labor from men during minimum tillage has been transferred to women as a burden due to MT increase weeding because, traditionally women's contribution in weeding is relatively high. In contrast, in the study area weeding of teff crop conducted with application of herbicides (like 2-4D) and the burden of weeding has not transferred to women.

A logistic regression model was used to understand the determinant factors that limit smallholders' minimum tillage practice decisions. Farmers who have never tried MT have less access to training and credit access. They were also having high family size, with old age than adopter. To promote the adoption of MT, policymakers and concerned stakeholders should consider small holder farmers' age, family size, access to training and credit aspects for promotion of minimum tillage practices.

## 5. Recommendation

Heavy reliance on tillage for weed control has been cited as a weakness in organic systems and herbicides was used as complementary as external input and using non- selective herbicide as substitute for oxen plow to keep weeds under control before plowing their farmland for implementing minimum tillage practices. So, using the herbicide became popular until a good promotion of biological ways of the practices was done. Further, the major of respondents and members participated in group discussion and paper validation showed that "the herbicide brand changed from time to time, and nobody can be perfect of its effectiveness."

So, the farmers required technical advice from extension worker encouraging biological ways of MT practices like mulching and other practices of conservation agriculture. The government and concerned bodies may also provide the effective information to the suppliers in order to induce them to supply effective herbicides to this study area.

Increased access to training to the farmers from time to time to decrease the negative effect of using chemicals for MT practices.

Increased access of smallholder farmers to loans was associated with an increase adoption of the MT practices.

## Abbreviations

MT Minimum Tillage
CA Conservation Agriculture

## Conflicts of Interest

The authors declare no conflicts of interest.

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