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E J E D

# External debt servicing, foreign exchange constraint and import demand: evidence from Ethiopian economy

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**Abstract**

*This study shows empirical evidence about the effects of external debt servicing on the foreign exchange reserve of the country and tests whether foreign exchange availability of the country affects the import demand. A yearly basis data starting from 1982 up to 2021 is employed. The required data are retrieved mostly from the World Development Indicator (WDI) database of the World Bank. In analyzing the data, the auto regressive (ARDL) technique of econometric estimation is used. The long-run result shows that repayment of foreign borrowing is insignificant in affecting the foreign exchange reserve of the nation. However, foreign aid, foreign borrowing and export growth are significant in increasing the foreign exchange reserve of the country. A sufficient supply of foreign currency in an economy is important to deal against instability and uncertainty of foreign capital flows. So, the government of Ethiopia can enhance the foreign exchange reserve through capital inflows and export growth. The findings from the import demand function of Ethiopia show that the foreign currency reserve is significant in driving import demand of the country. It is known that import enables unfettered access to capital goods from abroad and for improving the domestic welfare. So, the government should have stable and sufficient foreign exchange reserves to finance import of goods and services from abroad.*

**Keywords/Phrases**: Ethiopian economy, External debt servicing, Foreign exchange reserve, Import demand

## 1 Introduction

Different economic development theories highly emphasize that developing countries, in general, are trapped by a vicious circle of poverty, which accounts for the existence of low levels of income, which results in low saving and investment activity in the nation. This implies that there are only little prospects of future growth in per capita income and development of the industrial sector which arises from lower level of investment. Therefore, existence of this situation does not stop at one period since it involves a vicious circle in which poverty and low development lead to more poverty and underdevelopment (Todaro & Smith, 2012).

External debt financing is viewed as a mechanism to escape from the poverty trap and relieve bottlenecks in the development process for many developing countries. In practice, there are sound theoretical reasons why it may be entirely rational for developing countries to borrow from abroad (Ghatak, 2005). To some extent, the accumulation of external borrowing for developing countries arises from their interest in stabilizing the domestic financial market through foreign currency reserves. In this regard, external borrowing contributes to increasing the foreign exchange reserve of developing countries. However, the effect of foreign borrowing in developing countries might not be reflected directly rather first, it boosts the foreign exchange accumulation of countries and could lead to economic growth and more import demand since import of goods and services re-

quires the availability of foreign exchange reserve in the economy. But, this borrowing, in turn, results in repayment, including the interest, which is difficult for most developing countries because developing countries are characterized by foreign exchange constraints combined with the high import of capital goods and heavy types of machinery (Obsfeld *et al*., 2008).

Ethiopia is among those developing countries that borrow from the rest of the world such as the Western World and China, to finance the saving-investment gap, export-import gap, and tax-government spending gap. This borrowing result in repayment of the debt, including interest for the lender country, and Ethiopia has been paying a substantial amount of foreign currency over the last few decades. For instance, the country is paying a total of external debt to different lender countries and institutions, which amounts to 30.4 Million USD in 1990 with a foreign exchange reserve of 202 Million USD; paid 138.6 Million USD in 2000 with a foreign exchange reserve of 490 Million USD; paid 88.3 Million USD in 2005 with foreign exchange reserve of 1.04 Billion USD, paid 1.8 Billion USD in 2010 with foreign exchange reserve of 2.2 billion USD, paid 1.4 USD in 2015 with foreign exchange reserve of 3.8 Billion USD, paid 2.1 Billion USD in 2018 with foreign exchange reserve of 3.9 Billion USD(World Bank, 2021). Hence, the main debate here is "Has external debt servicing eroded foreign exchange accumulation of Ethiopia?" and "Does the country's limited foreign exchange accumulation affect its import demand?" Hence, the need of this study is to answer the above two main questions and draw harmonized policy implications regarding the issues.

The empirical findings by Obstfeld *et al*. (2008) for 134 countries and Aizenman *et al*. (2016) for 100 countries from advanced, emerging, and developing economies concluded that the increase in foreign exchange reserve is a response to domestic financial protection (exchange rate stability) and to get relaxed from policy trilemma*. A study by Ayunku and Markjackson (2020) found that external debt servicing is insignificant in affecting the foreign exchange reserve of the Nigerian economy. On the other hand, various research works are done to show how the growth performance of nations is affected by the availability of foreign exchange reserves. In this regard, Lensik (1995), Tariq *et al*. (2013), Cheng (2013), and Krušković & Maričić (2015) tried to answer the question "Why do countries accumulate foreign exchange reserve?" Those studies confirm the positive impact of the supply of foreign currency on growth. However, all the above studies neglected the impact of the supply of foreign currency on import demand. Specifically, in Ethiopia, no one is devoted to the impact of foreign currency supply on import demand. Moreover, although empirical investigations are done to assess the effect of external borrowing on foreign currency supply, some of research cannot devote to figuring out the effects of repayment of external borrowing on the supply of foreign currency in Ethiopia.

Hence, this study aims to assess how the accumulation of foreign currency is affected by the external debt repayment practice of Ethiopia and, in turn, how this foreign exchange reserve affects the country's import demand by using ARDL technique of estimation This might help to draw alternative policies and import strategies with the prevailing foreign exchange constraint in the country.

## 2 Materials and Methods

### 2.1 Data Source and Type

To achieve the objectives of this study, a secondary type of macroeconomic data ranging from 1982 to 2021 is collected mostly from the World Development Indicator (WDI) database of the World Bank.

### 2.2 Model specification and method of data analysis

In analyzing time series studies, a new model, which was first developed by Pasaran, Shin, and Smith (2001), can give various advantages over other time series estimation techniques. This newly developed model is known as an autoregressive distributive lag model and can give a valid, unbiased, and reliable output because of the following advantages. This approach can be used as mixture of variables that are stationary in level and first difference. *Second*, it is

* Trilemma refers to the situation where a particular nationis unable to design monetary policy with fixed exchange rate policy and capital flows (Aizenman *et al*., 2016).

more suitable for small sample size data in time series regression (Pesaran *et al*., 1998; Narayan, 2005). *Third*, it deals with even some of the endogenous independent variables. (Pesaran *et al*. 1998). *Fourth*, this technique uses only a single reduced form equation, which is impossible in other co-integration estimation techniques.

According to Green (2003), the simple generalized ARDL $(p, q)$ equation can be shown as:

$$\begin{aligned} Y_t = {} & C + \gamma T + \alpha_1 Y_{t-1} + \ldots + \alpha_p Y_{t-p} + \\ & \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_q X_{t-q} + \\ & \theta D + U_t \end{aligned} \tag{1}$$

Based on the above generalized equation, the two equations of this study which are going to be estimated are specifies as follows.

**Equation one**: A composition of traditional and financial stability models used by Obstfeld *et al*. (2008) is applied to show how the foreign exchange reserve is affected by external debt servicing. Moreover, according to Gosselin and Parent (2005), foreign reserve function can be affected also by economic size which can be real GDP growth rate, export volume, external borrowing.

Hence, the foreign exchange reserve function can be expressed as:

$$FER = f(GDPgr, EB, AID, Ex) \tag{2}$$

Where, $EB$ is external borrowing has its counterpart of repaying. As a result, external debt servicing (EDS) should be included in the model. $AID$ is foreign official aid; $Ex$ is export, which is a proxy for structure of the economy. Then the final foreign exchange reserve equation can be expressed as:

$$FER = f(GDPgr, EB, EDS, AID, Ex) \tag{3}$$

Then, the auto regressive form of equation three which is going to be estimated can be expressed as:

$$\begin{aligned} \Delta FER_t = {} & \beta_0 + \theta_1 GDPgr_{t-1} + \theta_2 EB_{t-1} + \\ & \theta_3 EDS_{t-1} + \theta_4 AID_{t-1} + \theta_5 Ex_{t-1} + \\ & \sum_{j=1}^{n} \beta_{1j} \Delta GDPgr_{t-1} + \sum_{j=1}^{n} \beta_{2j} \Delta EB_{t-1} + \\ & \sum_{j=1}^{n} \beta_{3j} \Delta EDS_{t-1} + \sum_{j=1}^{n} \beta_{4j} \Delta AID_{t-1} + \\ & \sum_{j=1}^{n} \beta_{5j} \Delta Ex_{t-1} + U_t \end{aligned} \tag{4}$$

**Table 1.** Measurement and source of dependent and independent variables for equation one

| Variable | Code | Measurement | Expected Sign | Data source |
|---|---|---|---|---|
| Foreign exchange reserve | FER | Foreign exchange reserve in USD at time t | | World Development Indicator |
| Real GDP | GDPgr | Growth rate of real GDP at time t | + | World Development Indicator |
| External debt | EB | External borrowing in USD at time t | + | World Development Indicator |
| External debt servicing | EDS | External debt servicing in USD at time t | - | World Development Indicator |
| Aid received | AID | Net official aid received in USD at time t | + | World Development Indicator |
| Total Export | EX | Total export in USD at time t | + | World Development Indicator |

$U_t$ is the error term of the function;

$n$, is the lag length of the auto regressive process of the equation;

$\Delta$ stands for the first difference operator;

$\theta_1$, $\theta_2$, $\theta_3$, $\theta_4$, $\theta_5$ are long run parameters the function; and

$\beta_{1j}$, $\beta_{2j}$, $\beta_{3j}$, $\beta_{4j}$, $\beta_{5j}$ are short run parameters of the function.

**Equation two**: To show whether the country's foreign exchange constraint is affecting import demand or not, a simple open economy model is used, and the import demand function, which is presented based on the theory of balance of payment and national income identity equation as follows. The national income equation states that national income is expressed as:

$$Y = f(C, I, G, X, M) \tag{5}$$

Where, $Y$- national income, $C$- consumption, $I$- investment, $G$- government spending, $X$- export value

and $M$- import. By rearranging equation five above, import demand is expressed as:

$$M = f(Y, I, G, X) \quad (6)$$

Export is one source of income for import and it can be explained by the availability of foreign exchange reserves. Then, by expanding the above function and including other variables according the country's context and economic literature, the following import demand equation can be specified.

$$M = f(PCI, RP, FER, REER) \quad (7)$$

Where $M$ is import as a share of GDP, $PCI$ is per capita income (a proxy for national income), $RP$ is the relative price, which is a share of domestic price to the world price, $FER$ is foreign exchange reserve, and $REER$ is the real effective exchange rate.

Then, the auto regressive form of equation seven to be estimated is expressed as:

$$\begin{aligned}\Delta M = {} & \beta_0 + \theta_1 PCI_{t-1} + \theta_2 RP_{t-1} + \theta_3 FER_{t-1} + \\ & \theta_4 REER_{t-1} + \sum_{j=1}^{n} \beta_{1j} \Delta PCI_{t-1} + \\ & \sum_{j=1}^{n} \beta_{2j} \Delta RP_{t-1} + \sum_{j=1}^{n} \beta_{3j} \Delta FER_{t-1} + \\ & \sum_{j=1}^{n} \beta_{4j} \Delta REER_{t-1} + U_t\end{aligned} \quad (8)$$

**Table 2.** Measurement and source of dependent and independent variables for equation two

| Variable | Code | Measurement | Expected Sign | Data source |
|---|---|---|---|---|
| Import Demand | M | Total import as a share of GDP at time t | | World Development Indicator |
| Per Capital Income | PCI | Per capital income in USD at time t | +/- | World Development Indicator |
| Relative price | RP | A share of domestic price to world price at time t | + | World Development Indicator |
| Foreign exchange reserve | FER | Foreign exchange reserve in USD at time t, | + | World Development Indicator |
| Real effective exchange rate | REER | Real effective exchange rate at time t, | - | World Development Indicator |

$U_t$ is the error term of the function;

$n$, is the lag length of the auto regressive process of the equation;

$\Delta$ stands for the first difference operator;

$\theta_1$, $\theta_2$, $\theta_3$, $\theta_4$, $\theta_5$ are long run parameters the function; and
$\beta_{1j}$, $\beta_{2j}$, $\beta_{3j}$, $\beta_{4j}$, $\beta_{5j}$ are short run parameters of the function.

For both equations, to test whether there is co-integration between the dependent and independent variables, a bound testing approach is used, which is proposed by Pesaran, Shin, and Smith (2001).

The hypotheses of the test can be presented as:

$H_0$: $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$, implies no co-integration among the variables.

$H_1$: $\theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq 0$, shows co-integration among the variables

## 3 Results and Discussion

### Discussion of Findings

Foreign exchange reserve and import demand equations are specified for the Ethiopian economy, and the results of both equations are discussed intensively. In doing this, pre-estimation and diagnostic tests are employed before the findings.

### 3.1 Foreign Exchange Reserve Equation of Ethiopia

#### 3.1.1 Unit Root Testing

In this model, unit root testing is necessary to check that none of the variables should be stationary at the second difference and beyond. In doing this, the result for unit root testing for the foreign exchange reserve equation is presented as follows. Both Augmented Dicky-Fuller (ADF) and Philips-Perron (PP) tests are used.

The result shows that the real GDP growth rate and external borrowing are stationary at level, and the remaining variables are stationary at first difference. Such a result is a strong justification for employing the autoregressive regression technique for the foreign exchange reserve function.

**Table 3.** Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test results

| Variables | Augmented Dickey Fuller (ADF) and Phillps Perron (PP) Test | | Decision |
|---|---|---|---|
| | ADF | PP | |
| | T-statistics | T-statistics | |
| FER | -6.587295*** | -7.716360*** | I (1) |
| GDPgr | -3.683762** | -4.397673*** | I (0) |
| EB | -3.877499** | -3.326784** | I (0) |
| EDS | -5.047035*** | -4.137477*** | I (1) |
| AID | -6.835964*** | -6.828706*** | I (1) |
| Ex | -5.007812*** | -4.960542*** | I (1) |

Note: *** and ** indicates significance at 1% and 5% level of significance.

Source: Own computation using EViews 9.0

### 3.1.2 Bound testing approach of co-integration for foreign exchange reserve function

To test whether there is a co-integration between the foreign exchange reserve and its explanatory variables; a bound testing approach is used. The result for checking this long-run co-integration between the foreign currency supply and its explanatory variables is presented in the table below.

The value of the $F$-statistic (9.71) is greater than the upper bound critical values at a significance level of 5%. This implies that there is a long-run relationship between the foreign exchange reserve and other independent variables in the function. This represents a co-integrated foreign exchange reserve function in Ethiopia.

**Table 4.** Bound testing result for equation 1

| **Bounds Testing Result** | | |
|---|---|---|
| Null Hypothesis: No long-run relationships exist | | |
| **Test Statistic** | **Value** | **K** |
| $F$-statistic | 9.709534 | 5 |
| | | |
| **Critical Value Bounds** | | |
| **Significance** | **Lower Bound** | **Upper Bound** |
| 5% | 2.62 | 3.79 |
| 1% | 3.41 | 4.68 |

Source: output from E-views 9 econometric software.

### 3.1.3 Other pre-estimation tests for foreign exchange reserve function of Ethiopia

The following diagnostic tests are undertaken in order to check the before estimating the foreign exchange reserve equation of Ethiopia.

The table below implies that there is no serial correlation problem in the function at a 5% level of significance, and the functional form test also confirmed that the model is well specified and there is no problem of omitted variable bias. The normality test reveals that the errors are normally distributed, and there is no heteroscedasticity problem in the foreign exchange reserve function.

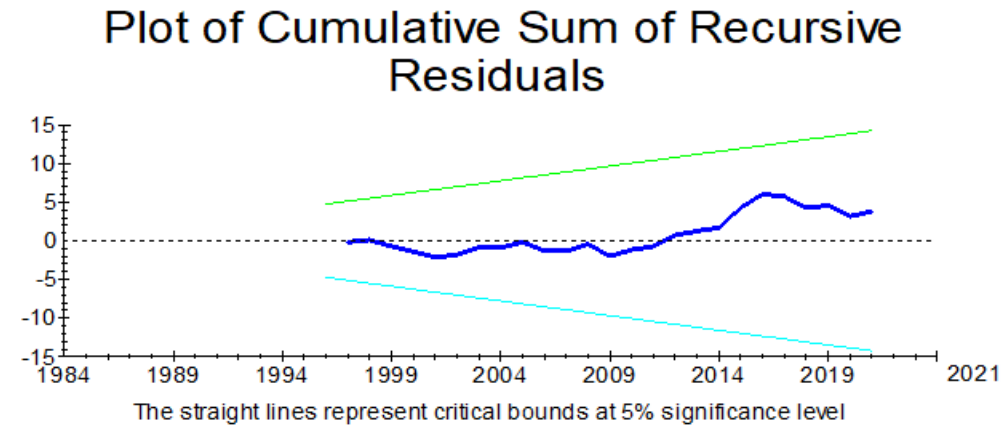
The model stability is checked using the CUSUM and CUSUM square tests suggested by Pesearon and Shin (1997). The test statistics of these stability tests can be graphed, and hence, we can also identify whether there is a structural break problem.

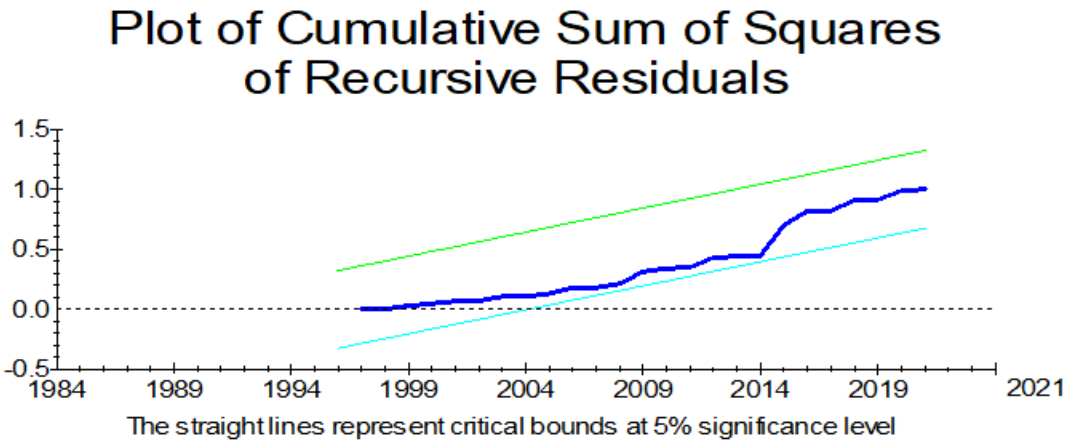
**Table 5.** Pre-estimation diagnostic tests result for the foreign exchange reserve function

| Test statistics | LM version | *F* version |
|---|---|---|
| Serial Correlation | CHSQ (1) = 2.5521[.110] ** | *F* (1, 25) = 1.7999[.192] ** |
| Functional Form | CHSQ (1) = .24652[.620] ** | *F* (1, 25) = .15859[.694] ** |
| Normality | CHSQ (2) = .40651[.816] ** | Not applicable |
| Heteroscedasticity | CHSQ (1) = 2.6427[.104] ** | *F* (1, 36) = 2.6907[.110] ** |

Source: Output from Microfit 4.1 ARDL (0, 0, 1, 1, 2, 2).

Note: 5% level of significance is used.




The above two plots of graphs show that the recursive residual static curves for the foreign exchange reserve equation move between the critical bounds at a 5% level of significance. This implies that the model, which shows short-run and long-run relationships, is stable, and there is no structural break problem in the model.

### 3.1.4 Long run and short run estimates of foreign exchange reserve equation of Ethiopia

After making sure that there is long-run co-integration between foreign currency supply and its explanatory variables, it is possible to estimate the function. In doing this, the following table summarizes the long-run estimation result for the foreign exchange reserve function of Ethiopia.

**Table 6.** Long-run and short-run estimates of foreign exchange reserve equation

| Method: ARDL | | | | |
|---|---|---|---|---|
| Model selected: ARDL (0, 0, 1, 1, 2, 2) | | | | |
| **Variables** | **Coefficients** | **Standard error** | ***t*-statistics** | ***p*-values** |
| **Long-run coefficients** | | | | |
| GDPgr | -17502.6 | 8225028 | -0.0021280 | 0.998 |
| EB | 0.064788 | 0.020606 | 3.1441 | 0.004*** |
| EDS | -0.29866 | 0.28472 | -1.0489 | 0.304 |
| AID | 0.45467 | 0.073786 | 6.1620 | 0.000*** |
| Ex | 9.35E+07 | 1.92E+07 | 4.8796 | 0.000*** |
| C | -1.18E+09 | 2.03E+08 | -5.8140 | 0.000 |
| **Short-run coefficients** | | | | |
| D(GDPgr) | -17502.6 | 8225028 | -0.0021280 | 0.998 |
| D(EB) | 0.15199 | 0.033061 | 4.5974 | 0.000*** |
| D(EDS) | 1.6047 | 0.48382 | 3.3166 | 0.002*** |
| D(AID) | -0.16780 | 0.16400 | -1.0232 | 0.315 |
| D(Ex) | 5.44E+07 | 3.27E+07 | 1.6661 | 0.106 |
| D(C) | -1.18E+09 | 2.03E+08 | -5.8140 | 0.000*** |
| ECM-1 | -0.78726 | 0.16434 | -4.79043 | 0.000*** |

Note: *** and ** indicates the rejection of a null hypothesis of statistical insignificance of the coefficients at 1%, and 5% levels of significance.

Source: Output from Microfit 4.1

The long-run estimates show that foreign borrowing, official foreign aid, and the export sector are strongly significant in affecting the foreign exchange reserve of Ethiopia. This result is consistent with a theory of capital flows. That is, a rise in foreign borrowing is one of the mechanisms to finance funds from abroad and directly increases the foreign currency availability. Another reason is foreign borrowing is likely to lead to greater investment activity in domestic and abroad, which, in turn, might affect the volume of trade. This confirms the finding by Andriyani *et al*. (2020). This result is also consistent with the short-run result. However, borrowing cannot be a persistent way to increase foreign exchange reserves since it can cause serious difficulties. External borrowing beyond the threshold level might cause a debt trap, economic instability, limited fiscal space, vulnerability to external shocks, and low opportunities for private sector growth. Managing borrowing levels and ensuring debt sustainability are crucial for developing countries to ensure long-term economic stability. So, borrowing to increase the foreign exchange reserve of a country should be managed carefully. If the central bank wants to increase the foreign currency reserve, especially during a crisis period, it should seek to identify and utilize other sources of foreign exchange reserve enhancement mechanisms.

Export and foreign aid are strongly significant and favorably influence the foreign currency supply of the country. This is because the export of goods and services is a way to fund sources from abroad in the form of foreign currency. So, countries with abundant natural resources should increase their export in terms of volume and diversification to accumulate a sufficient amount of foreign currency. This finding is also parallel with the findings by Rahmawati and Setyowati (2018) and Andriyani *et al*. (2020). This is one of the reasons why Ethiopia and other sub-Saharan African countries have accumulated substantial foreign currency supply in recent years, mostly from the export sector as well as foreign aid flows although it is not at a satisfactory level. But both

export and foreign aid are found to be insignificant in the short run.

The speed of adjustment of any disequilibrium towards long-run equilibrium, which can be shown by the error correction coefficient, is significant. This estimated error correction coefficient for the foreign exchange reserve equation in Ethiopia implies a high speed of adjustment to equilibrium after a shock. Approximately 78.72% of the disequilibrium from the previous year's shock converges back to the long-run equilibrium in the current year.

In the long run, GDP growth rate and external debt servicing are insignificant in affecting the foreign currency reserve of a country. The insignificant effect of external debt servicing on the foreign currency supply of the country might be because of the huge amount of concessional loans over recent decades. But, in the short run, external debt servicing is significant in affecting the foreign exchange reserve of the country. The GDP growth rate is also insignificant in affecting foreign currency accumulation of the country both in the short run and the long run, which is inconsistent with the findings of Kashif and Thiyagarajan (2017). This result implies that Ethiopia is unable to build up foreign currency reserves from a pro-growth approach.

### 3.2 Import demand equation of Ethiopia

The second function to be estimated in this study is the import demand equation. Before presenting the long-run estimates of all parameters, the necessary pre-and post-estimation tests are checked as follows.

#### 3.2.1 Unit root testing

The unit root test result for the import demand function is presented in table 7 below.

The result shows that relative price (RP) is stationary at level and other variables are stationary at first difference. Like that of the former foreign exchange reserve function, the unit root test result of the import demand function implies a strong justification for employing the autoregressive (ARDL) regression technique.

**Table 7.** Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test results

| Variables | Augmented Dickey Fuller (ADF) and Phillps Perron (PP) Test | | Decision |
|---|---|---|---|
| | ADF | PP | |
| | T-statistics | T-statistics | |
| M | -5.275265*** | -5.266011*** | I (1) |
| PCI | -3.265249** | -3.229117** | I (1) |
| RP | -5.262737*** | -5.267288*** | I (0) |
| FER | -6.587295*** | -7.716360*** | I (1) |
| REER | -5.580210*** | -5.635874*** | I (1) |

Note: *** and ** indicates significance at 1% and 5% level of significance.
Source: Own computation using EViews 9.0

#### 3.2.2 Bound testing approach of co-integration for import demand equation of Ethiopia

The import demand function of Ethiopia is tested for the existence of co-integration between the import demand and its explanatory variables by using a bound testing approach. The result for checking this long-run co-integration between the import demand and its explanatory variables is presented in table 8 below.

Table 8 shows that the value of the $F$-statistic (6.84) is greater than the upper bound critical values at a significance level of 5%. This implies that there is the existence of a long-run relationship between import demand and other independent variables in the function. This represents a co-integrated import demand function in Ethiopia.

**Table 8.** Bound testing result for import demand function in Ethiopia

| **Bounds Testing Result** | | |
|---|---|---|
| Null Hypothesis: there is no long-run relationship between the variables | | |
| **Test Statistic** | **Value** | **K** |
| *F*-statistic | 6.846409 | 4 |
| **Critical Value Bounds** | | |
| **Significance** | **Lower Bound** | **Upper Bound** |
| 5% | 2.62 | 3.79 |
| 1% | 3.41 | 4.68 |

Source: output from E-views 9 econometric software.

### 3.2.3 Diagnostic testing for import demand equation of Ethiopia

The following diagnostic tests are presented for import demand function of Ethiopia.

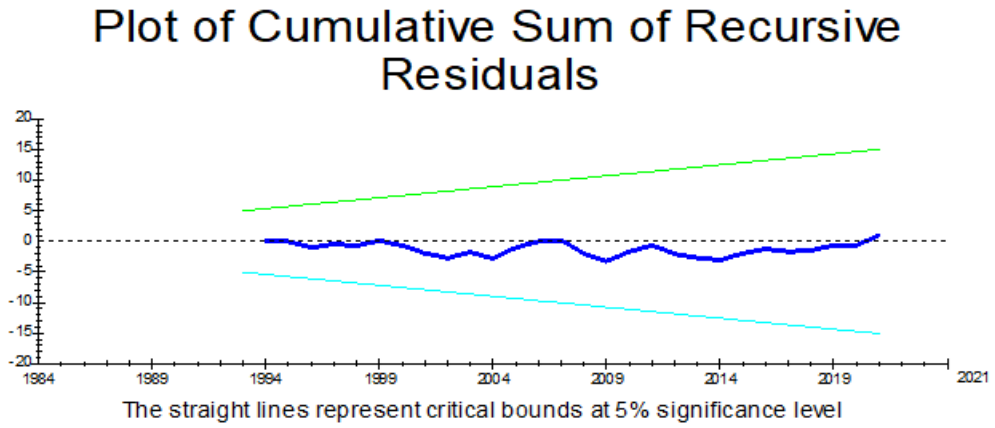
The result in Table 9 above implies that there is no serial correlation problem in the function at a 5% level of significance, and the functional form test also confirmed that the model is well specified and there is no problem of omitted variable bias. The normality test reveals that the errors are normally distributed, and there is no heteroscedasticity problem in the import demand function of Ethiopia.

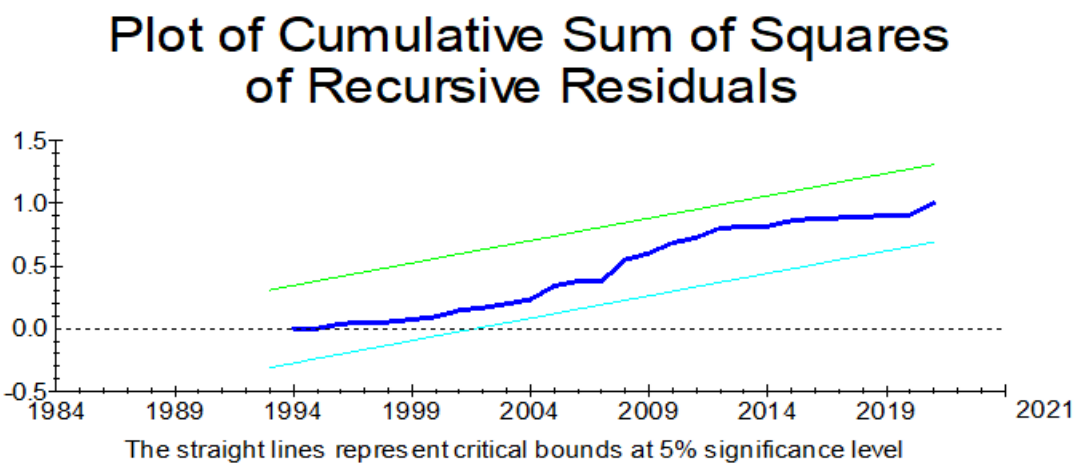
**Table 9.** Pre-estimation diagnostic tests result for import demand function of Ethiopia

| **Test statistics** | **LM version** | ***F* version** |
|---|---|---|
| Serial Correlation | CHSQ (1) = 1.2504[.263] ** | *F* (1, 28) = .95269[.337] ** |
| Functional Form | CHSQ (1) = .013297[.908] ** | *F* (1, 28) = .0098011[.922] ** |
| Normality | CHSQ (2) = .67625[.713] ** | Not applicable |
| Heteroscedasticity | CHSQ (1) = .330624[.861] ** | *F* (1, 36) = .028948[.866] ** |

Source: Output from Microfit 4.1 ARDL (2, 0, 0, 1, 1) .5% level of significance is used

The following plot of graphs is showing the stability and structural problem test for the import demand function in Ethiopia.






The recursive residual static curves for the import demand equation imply that the residual curves move between the critical bounds at a 5% level of significance. This implies that the model, which shows short-run and long-run relationships, is stable, and there is no structural break problem in the model.

### 3.2.4 Long run and short run estimates of import demand function of Ethiopia

After making sure that there is an existence of cointegration between import demand and its explanatory variables, it is possible to estimate the function. In doing this, the following table summarizes the long-run and short-run estimation results for the import demand function in Ethiopia.

**Table 10.** Long-run and short-run Estimates of the import demand equation

Method: ARDL

Model selected: ARDL (2, 0, 0, 1, 1)

| **Variables** | **Coefficients** | **Standard error** | ***t*-statistics** | ***p*-values** |
|---|---|---|---|---|
| **Long-run coefficients** | | | | |
| PCI | -0.13204 | 0.049339 | -2.6762 | 0.012** |
| RP | 1.0468 | 1.0454 | 1.0013 | 0.325 |
| FER | 0.2027E-7 | 0.6834E-8 | 2.9665 | 0.006*** |
| REER | -0.019265 | 0.051816 | -0.37180 | 0.713 |
| C | 40.8159 | 7.5747 | 5.3885 | 0.000*** |
| **Short-run coefficients** | | | | |
| D(PCI) | -0.45161 | 0.13724 | -3.2907 | 0.002*** |
| D(RP) | -0.021853 | .0037493 | -5.8285 | 0.000*** |
| D(FER) | 0.17323 | 0.17575 | 0.98569 | 0.332 |
| D(REER) | -0.024949 | 0.0099976 | -2.4955 | 0.018** |
| D(C) | 6.7549 | 2.1256 | 3.1779 | 0.003*** |
| ECM-1 | -0.68041 | 0.14305 | -4.75644 | 0.000*** |

Note: *** and ** indicates the rejection of a null hypothesis of statistical insignificance of the coefficients at 1%, and 5% levels of significance.

Source: Output from Microfit 4.1

The result from estimates of the import demand function for Ethiopia presented in Table 10 shows that in the long run, foreign currency reserve is significant in increasing the aggregate import demand of the country. Keeping other things constant, a 1 unit increase in foreign currency reserve at the national bank results in a 0.2 unit rise in import demand of the country. This implies that a substantial amount of financing of foreign exchange reserves is allocated for imports. This is because an increase in foreign exchange reserves increases the purchasing power of the country and provides stability in international transactions without disruptions. This finding is consistent with a study Made by Vacu (2021) and Farayibi (2016) and inconsistent with the study done by Vacu and Odhiambo (2019). This call for a sufficient amount of foreign currency reserve is important to increase imports, which in turn enables countries with constrained production capacity, to unfettered access to capital goods from abroad and to improve domestic welfare. But in the short run, it is found to be insignificant in affecting the import demand in Ethiopia.

Both in the short run and the long run, per capital income is significant in negatively affecting import demand in Ethiopia. Keeping other things constant, a 1 unit rise in per capital income of the country results in a 0.13 unit fall in import demand of the country. Following the conventional demand imperfect substitution theory, the consumer's objective is to maximize utility subject to a budget constraint. In other words, the import demand function is primarily determined by the income of the importing country and the relative price of goods. This finding might be because as per capital income is improved, domestic investment can be expanded, and infant domestic industries become strong and competitive at the international level, which can substitute imported items from abroad by enabling them to be produced in domestic. Moreover, an increase in per capital income can increase domestic production, domestic saving and investment, shift in consumer preferences, and those in turn can reduce aggregate import demand of the country. This result is consistent with Narayan and Smyth (2005) and inconsistent with a study by Vacu and Odhiambo (2020).

The speed of adjustment of any disequilibrium towards long-run equilibrium, which can be shown by the error correction coefficient, is significant. This estimated error correction coefficient for the import demand function in Ethiopia implies a high speed of adjustment to equilibrium after a shock. Approximately 68.04% of the disequilibrium from the previous year's shock converges back to the long-run equilibrium in the current year. Although the relative price of goods and services and the real effective exchange rate are found to be significant in negatively affecting the aggregate import demand, in the long run, both are insignificant in affecting the import demand function of Ethiopia. This might be because of price inelastic nature of Ethiopia's imported items from the rest of the world.

## 4 Conclusion and Implications

Based on the results, it can be concluded that export growth, foreign borrowing, and foreign aid can significantly increase the foreign exchange reserves of a country in the long run. This is because of the theory of capital flows. The result can be generalized to argue that a sufficient amount of foreign currency reserve may be due to foreign trade and capital inflows. But in the long run, external debt servicing and GDP growth rate are insignificant in affecting the foreign currency reserve of Ethiopia. This might be because of the huge amount of concessional loans over the last decades and the inability to build up foreign currency reserves from a pro-growth approach in Ethiopia. It is known that reserving a sufficient amount of foreign currency in an economy is essential to deal with the instability and uncertainty of external capital flows. The implication of this result is the government of Ethiopia can enhance the foreign exchange reserve through capital inflow, such as borrowing and working on export growth. The government policy should be designed by focusing on increasing exports in terms of volume and diversification.

However, borrowing cannot be a persistent way to increase foreign exchange reserves since it can cause severe difficulties, especially during a crisis when it becomes almost impossible to refinance. Borrowing above the threshold level can lead to a debt trap, economic instability, limited fiscal space, vulnerability to external shocks, dependence on foreign lenders, and reduced opportunities for private sector growth.

Managing borrowing levels and ensuring debt sustainability are crucial for developing countries to ensure long-term economic stability and growth. So, foreign borrowing should be managed carefully, and most of the time it is not recommended as a persistent way of gaining foreign exchange reserves from abroad.

The findings from the import demand function of Ethiopia show that in the long run, per capita income is negatively affecting the aggregate import demand equation of the country. This is because an increase in per capital income can increase domestic production, domestic saving and investment, shift in consumer preferences, and those in turn can reduce aggregate import demand of the country. However, foreign exchange reserves are strongly significant in positively affecting the import demand of the country because an increase in foreign exchange reserves increases the purchasing power and provides stability in international transactions without disruptions. So, the government should have a stable foreign exchange reserve to finance the import of goods and services from abroad since import enables unfettered access to capital goods from abroad and to improve the domestic welfare and human development.

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**Conflicts of Interest**

The authors declare no conflicts of interest regarding the publication of this paper.

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# Assessing spatial accessibility of bus stops and user satisfaction with transportation services: a case of Dilla Town, South Ethiopia Region, Ethiopia

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**Abstract**

*Bus stop accessibility is a vital component of a successful transportation system. This study aimed to investigate the network characteristics of bus stop locations and evaluate bus service users' satisfaction. The road networks were digitized from aerial photographs and the locations of the bus stops were collected by Handheld GPS to assess the accessibility of bus stops. Additionally, an administered questionnaire related to service quality was collected to evaluate the bus transportation service quality provided by Dilla University. Network analysis techniques were employed to analyze the spatial distribution and accessibility of bus stops. The bus stop coverage ratio index was determined from the ideal access coverage and the actual access coverage of bus stops. The SCRI result indicates Getsmart Bus stop has the highest value (0.96), suggesting that it has a high level of functionality for its surrounding area. On the other hand, the bus stop with the lowest value (0.60) is 'Molla Golja'. The findings of the study highlighted significant variations in bus stop coverage, indicating differences in accessibility among the stops. The questionnaire survey results showed that passengers were not generally satisfied with the bus service. In summary, the network analysis is useful for identifying areas with low accessibility and areas where improvements are needed.The significance of this study extends beyond providing solely to the needs of Dilla University administrators for creating a more efficient and user-friendly transportation system for their workers and the wider community. It is useful for the Dilla Town Administrative Road Transport Office and other organizations seeking to improve transportation systems.*

**Keywords/Phrases**: Accessibility, Bus stop, Dilla Town, Network analysis, Passengers satisfaction

## 1 Introduction

Public transportation is an essential mode of transportation in urban areas. It plays a crucial role in fostering sustainable and efficient urban mobility (Ambrosino *et al*., 2016; Pojani & Stead, 2015), providing a viable alternative to private vehicles,and reducing traffic congestion (Liu *et al*., 2017). It promotes social inclusion by ensuring affordable and accessible transport options for all, irrespective of income and ability (Kett *et al*., 2020; Pereira *et al*., 2017).

Access to public transport plays a vital role in an individual's ability to carry out daily activities effectively. Transportation infrastructure and land use systems are essential to model accessibility in a given area (Yigitcanlar *et al*., 2007). Urban transportation planning encompasses information regarding bus stops, road networks, transport routes, and their frequencies (Martínez *et al*., 2014). The absence of bus stops at the peripheries of town leads to humble accessibility on foot (Hernandez & Titheridge, 2016). When bus stopsare easily accessible, it becomes more convenient for people to use public transportation (Borhan

*et al*., 2019), leading to increased ridership and reduced reliance on private vehicles (Jansuwan *et al*., 2013). This, in turn, can have several positive impacts on the community and the environment. Convenient bus stops encourage a modal shift from private vehicles to public transportation. By ensuring that bus stops are strategically located within communities, close to residential areas, workplaces, educational institutions, and commercial centers, people are more likely to choose buses as a preferred mode of transport (Chakour & Eluru, 2013). This accessibility is determined by how close the passenger's origin or destination is to the nearest transit stop (Pan *et al*., 2017; Wang *et al*., 2011), which can be reached by walking a 400-meter distance as an acceptable standard (Daniels & Mulley, 2013). Overall, the accessibility of Bus stops significantly impacts passenger convenience and their ability to utilize public transportation services effectively (Litman, 2015).

The success of any organization hinges on the quality of services provided. Service quality is the critical link between customer expectations and their actual perception of the service received (Gilaninia *et al*., 2013). Nowhere is this more evident than in the realm of public transportation. Imagine the frustration and disappointment when reliability falters, pushing away both existing and potential clients. Universities, in particular, face the critical challenge of ensuring the reliability and comfort of their bus services, all while ensuring that drivers' attitudes are up to par. These factors, as highlighted by the insightful works of (Md Yusof *et al*., 2014; Osman & Sentosa, 2013), remain constant concerns in the pursuit of excellence.

The Ethiopian Higher Education sector needs significant improvements in service quality despite ongoing efforts by universities (Lemmalodesso, 2012). Various complaints from the university community have emerged, highlighting issues such as inadequate availability and reliability of buses, substandard bus facilities, unsatisfactory attitudes of bus drivers, long waiting times, and a lack of prompt responses to concerns (Oljira, 2022; Phooriphokhai & Jitpraphai, 2016). To ensure the effective utilization of public transportation services, it is crucial to assess the satisfaction of passengers, particularly the Dilla University workers.

While several studies have been conducted in Ethiopia to assess bus service satisfaction (Aniley & Negi, 2010; Belay & Kenei, 2019; M. Girma & Woldetensae, 2022; Lemmalodesso, 2012; Mammo, 2010; Oljira, 2022; Woldeamanuel & Woldetensae, 2021), they have often overlooked the crucial factor of spatial accessibility of bus stops, which plays a significant role in shaping passenger experiences.

By integrating the evaluation of spatial accessibility with service user satisfaction, the study aimed to provide a more comprehensive understanding of transportation services. This approach allowed for a deeper assessment of how convenient and easily accessible bus stops contribute to passenger convenience, time efficiency, and safety. It is useful for the Dilla Town Administrative Road Transport Office and other organizations seeking to improve transportation systems.

## 2 Materials and Methods

### 2.1 Description of the Study Area

Dilla town, located between $10^0 14'$ North latitude and $38^0 10'$ East longitude (Minota, 2014), serves as the administrative center of the Gedeo Zone in the South Ethiopia Region. It is situated approximately 359 km away from Addis Ababa city and is renowned for its local coffee industry (Girma & Wube, 2014). 11 bus stop locations in the town are spread along different routes, as shown in Figure 1. Dilla University, a public institution, is also based in Dilla town. As of 2023, the Human Resource Directorate Office reported a total of 5,376 academic and administrative employees at the university.

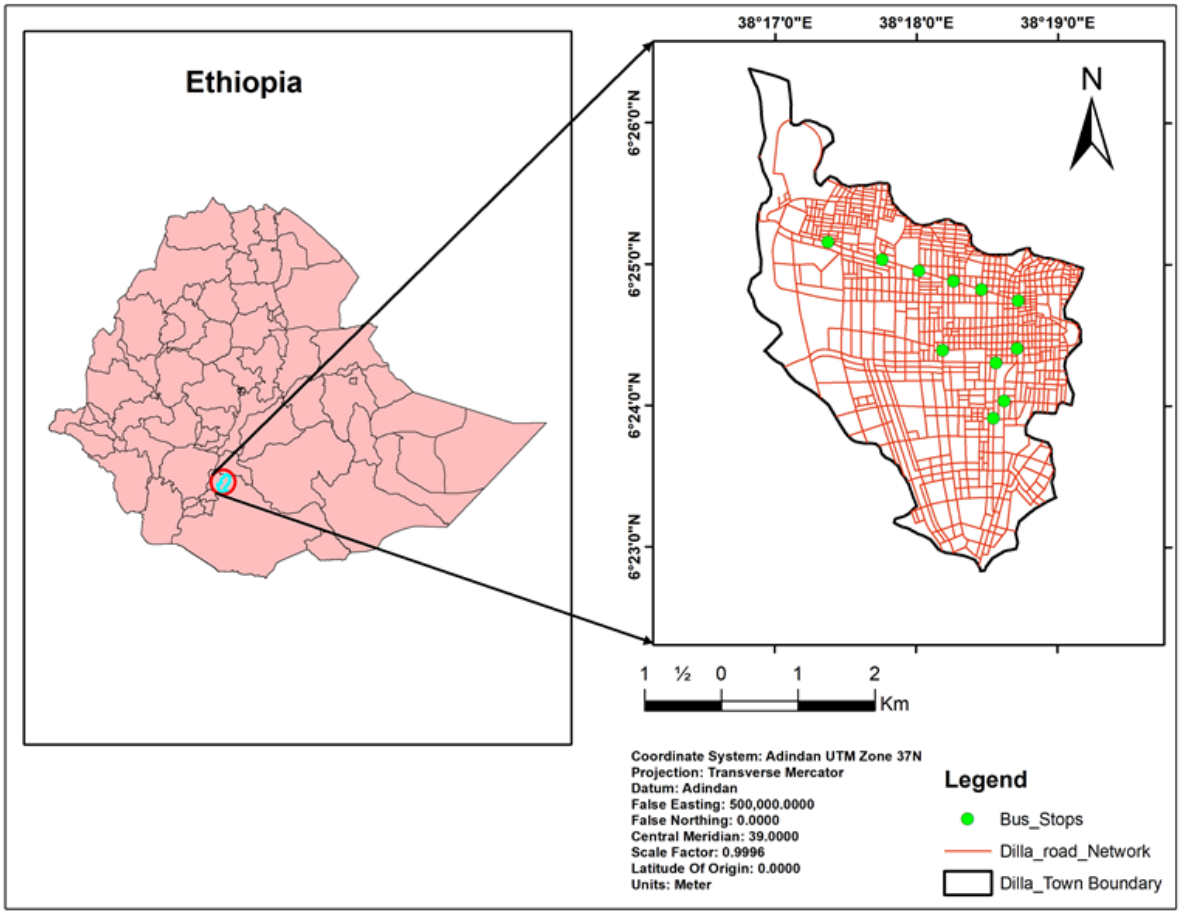


**Figure 1.** Study area map showing the distribution of bus stops

### 2.2 Data Source and Method of Data Collection

To assess the accessibility of bus stops in Dilla Town, the survey employed primary data collection techniques. The researcher utilized a Handheld GPS device to gather the coordinates (X and Y) of eleven bus stops located within the town boundaries along the bus route, aiming to assess the spatial accessibility of the stops. The names of each bus stop utilized in this research were taken from prominent landmarks in the respective area. Before digitizing the road networks, the aerial photographs were first georeferenced to align them with the known coordinate system. Additionally, orthorectification was applied toremove distortions caused by terrain relief. The preprocessed aerial photographs were used for the digitization of Dilla Town road networks using ArcGIS Pro. The road network topology was initially created, followed by a correction and validation process to assurance accuracy and consistency. Subsequently, the network dataset was generated by integrating the topologically refined road networks with the gathered GPS points, enabling the determination of the service area.Furthermore, we have developed structured questionnaires to evaluate users' satisfaction with the bus transportation service offered by the university. The details of data used in this study are shown in Table 1.

**Table 1.** Data and Data Source

| Data | Data source | Purpose |
|---|---|---|
| GPS Point | Field survey | To locate the existing bus stop |
| Aerial Photograph | Dilla Town municipality | To digitize road networks (for network analysis) |
| Questionnaires | Researchers | To assess the user's satisfaction |

### 2.3 Sample Size and Sampling Method

The target population for the study was Dilla University workers, faculty and administrative workers who rely on the university's bus service for transportation. The researchers selected 384 workers out of 5376. The objective was to gather feedback and opinions from experienced bus users working at the university. The participants were chosen using stratified random sampling to address the involvement of both academic and administrative workers in the survey and provided informed consent after receiving a pretested interviewer-administered questionnaire. All statistical analyses were performed using SPSS 22.0 software.

### 2.4 Determining Accessibility of Bus Stops

Bus stop access coverage is used to evaluate the Bus stop position from the area included in the polygon and the road network lying within the polygon. The Ideal stop access coverage can be determined by creating a simple circular buffer with a standard threshold around each bus stop using the equation (1), which overestimates the coverage access (Foda & Osman, 2010), ignoring the actual road network near the stops. On the other hand, the Actual Area Coverage (AAC) is a complete polygonal representation surrounding all road segments within a 0.4 km radius of the bus stops (Daudu *et al*., 2022). The computation of AAC involves generating service areas using network analysis methods.

$$IAC = \pi r^2 \tag{1}$$

Where: IAC - Ideal Area Coverage and $r$ - Buffer radius; 0.4km.

The Ideal Stop Accessibility Index (ISAI) is determined by calculating the road network density within a circular buffer. This is achieved by dividing the total length of the road network by the area of the circular buffer, as expressed in the equation (2). On the other hand, the Actual Stop Accessibility Index (ASAI) is calculated by dividing the total length of the road network by the area of the generated polygon (Foda & Osman, 2010). This relationship is mathematically represented by an Equation (3).

$$ISAI = \frac{\sum LI}{IAC} \tag{2}$$

$$ASAI = \frac{\sum LA}{AAC} \tag{3}$$

$$SCRI = \frac{ISAI}{ASAI} \tag{4}$$

Where: ASAI- Actual Stop Area Index, ISAI- Ideal Stop Area Index, SCRI- Stop Coverage Ratio Index, LI- Ideal Length of road segments within 0.4km buffer, LA- Actual Length of road segments within 0.4km, IAC- Ideal Area Coverage, AAC- Actual Area Coverage. The overall methodology of the study is presented in the flowchart (Figure 2).

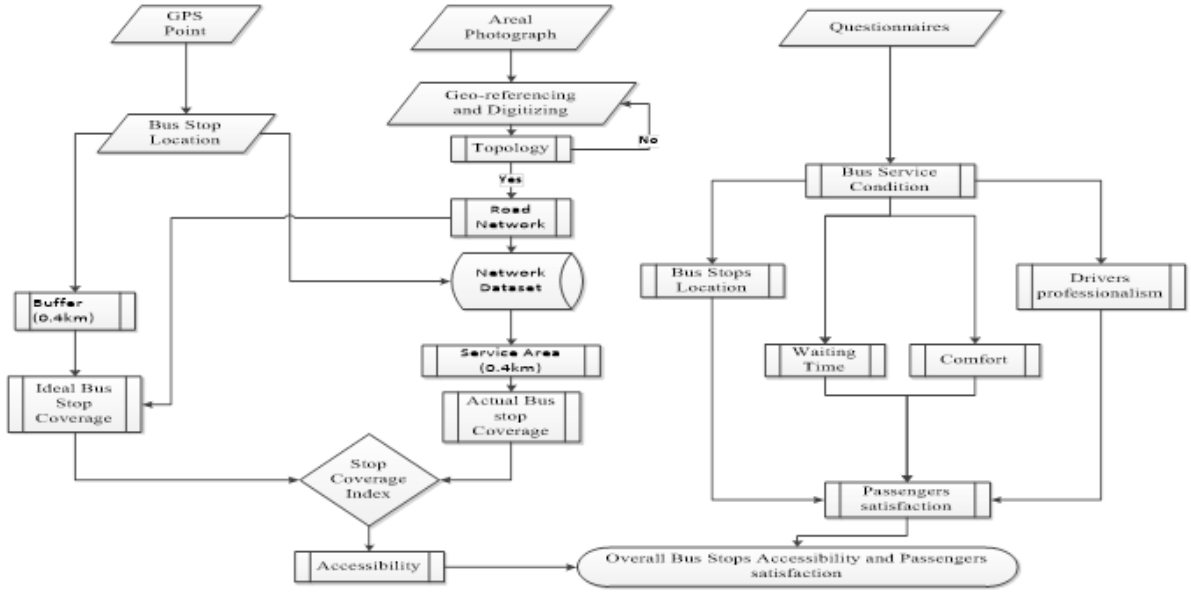


**Figure 2.** The general workflow of the study

## 3 Results

### 3.1 Ideal and Actual Bus Stop Access Index (ASAI and ISAI)

Figure 3a and Figure 3b show the actual service area and ideal service area. A 0.4km buffer was generated around each 11 Bus stop to calculate ASAI. Since the Radius of the buffer is similar, the ideal area coverage is 0.503 km$^2$. Within this area, the total length of each segment was computed. The total length of access roads across the bus stop is 106.721 km; reachable within the ideal area coverage. The Mazoria station has the highest length of accessible road, which is 12.685 km. On the other hand, the Hospital Bus stop has the lowest length of accessible roads, which is 8.581km compared to other stations. The result of ISAI indicated that Molla Golja station has the lowest index of 15.250 km/km$^2$ while Mazoria has the highest index (25.219km/km$^2$).

The Gedeo Zone Higher Court station has the highest actual area coverage (0.427 km$^2$),whereas the Sunshine bus stop has the lowest area coverage (0.183 km$^2$). The result of ASAI indicated that Molla Golja station has the lowest index of 15.25 km/km$^2$ while Mazoria has the highest index (42.401km/km$^2$). The details of the statistics are found in Table 2.

**Table 2.** ISAI, ASAI, and SCRI Values for Bus Stops

| Station Name | $\sum LI$(km) | IAC(km$^2$) | ISAI(km/(km$^2$) | $\sum LI$(km) | AAC(km$^2$) | ASAI(km/ km$^2$) | SCRI |
|---|---|---|---|---|---|---|---|
| Get smart | 8.619 | 0.503 | 17.135 | 5.308 | 0.267 | 19.843 | 0.864 |
| Sunshine | 10.196 | 0.503 | 20.269 | 5.306 | 0.183 | 29.073 | 0.697 |
| TTC | 9.136 | 0.503 | 18.164 | 5.338 | 0.282 | 18.928 | 0.960 |
| Babbo | 9.644 | 0.503 | 19.172 | 3.851 | 0.169 | 22.730 | 0.843 |
| Biruk | 11.675 | 0.503 | 23.211 | 7.236 | 0.239 | 30.229 | 0.768 |
| Delight | 10.042 | 0.503 | 19.963 | 6.120 | 0.269 | 22.741 | 0.878 |
| Hospital | 8.581 | 0.503 | 17.060 | 7.579 | 0.297 | 25.544 | 0.668 |
| Gedeo Zone Higher Court | 9.857 | 0.503 | 19.597 | 9.360 | 0.427 | 21.929 | 0.894 |
| Lamberet | 8.615 | 0.503 | 17.128 | 5.433 | 0.208 | 26.181 | 0.654 |
| Mazoria | 12.685 | 0.503 | 25.219 | 11.131 | 0.263 | 42.401 | 0.595 |
| Molla Golja | 7.671 | 0.503 | 15.250 | 3.820 | 0.193 | 19.776 | 0.771 |

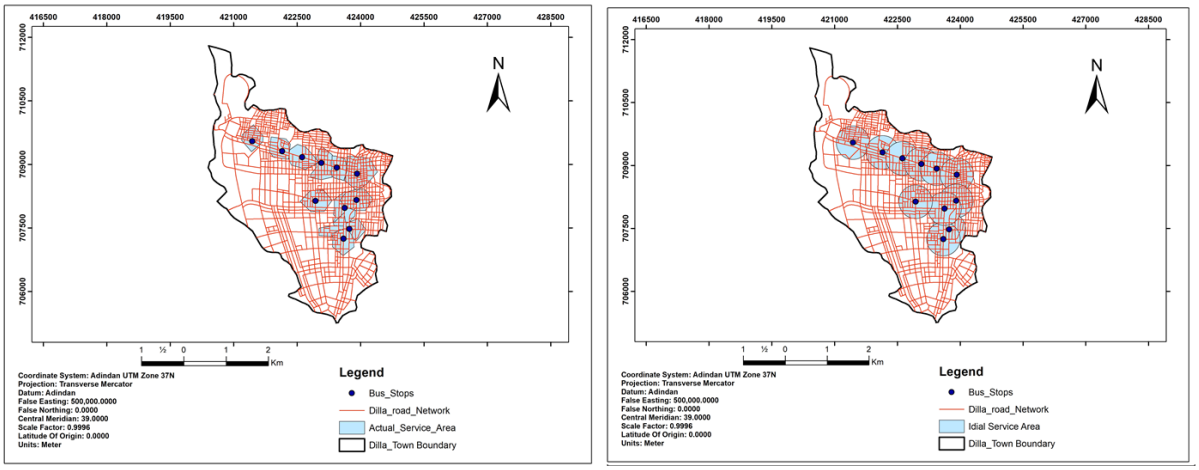


**Figure 3.** Actual bus stop access (left) and Ideal bus stop access (right)

### 3.2 Stop Coverage Ratio Index (SCRI)

The SCRI for all 11 stations was calculated by dividing the ISAI by ASAI using the equation [4]. As shown in the (Table 2), the values of SCRI are between 0 and 1. When analyzing the SCRI results for the these stations, it was found that the TTC Bus stop exhibited the highest SCRI value (0.96%). This result indicates that the stationprovides better

accessibility to its surrounding area, making it more convenient for transport users to reach their destinations.

The other stations also demonstrated varying levels of access coverage. For example, the station named "Get Smart" had an SCRI value of 0.864%, indicating a relatively high level of accessibility. On the other hand, "Molla Golja" bus stop had the lowest SCRI value of 0.595% (Table 2), suggesting that it provides lower access coverage when compared to other bus stop locations.

### 3.3 Analysis for Overall Satisfaction Level

In this study, passengers' satisfaction level was measured by how much they were satisfied with the quality of transportation service experienced at Dilla University. The factors examined were the convenience of the location of bus stops, waiting time, denied entry onto buses due to full seats, and the driver's level of professionalism. The majority of respondents (40.95%) reported that the location of bus stops was very convenient, while a small percentage (1.90%) found it inconvenient, suggesting a need for improvements in this area. The largest group of respondents (45.71%) reported waiting for more than 15 minutes for buses, indicating dissatisfaction with the waiting times. On the other hand, 18.10% of the respondents reported waiting less than 5 minutes (Table 3), which suggests a positive experience in terms of waiting time.

The results indicate that 39.05% of the respondents reported frequent cases of being denied entry onto buses due to full seating. A slightly lower percentage (32.38%) reported experiencing this issue somewhat frequently. However, 20.95% of respondents stated that they rarely encountered this problem, indicating a relatively positive experience. The majority of respondents (43.81%) rated the driver's level of professionalism as good, while a similar percentage (42.86%) rated it as average. A smaller group of respondents (13.33%) perceived the driver's professionalism as poor, indicating room for improvement in this area (Table 3).

**Table 3.** Passenger's satisfaction for service provision of Dilla University, Dilla, Ethiopia, 2023 (n = 384)

| Variables | Category | Frequency | Percent % |
|---|---|---|---|
| Convenience of bus stops | Very inconvenient | 99 | 25.7 |
| | Inconvenient | 7 | 1.9 |
| | Neutral | 70 | 18.1 |
| | Convenient | 51 | 13.3 |
| | Very convenient | 157 | 40.9 |
| Waiting time (minutes) | < 5 | 70 | 18.1 |
| | 5-10 | 11 | 2.86 |
| | 10-15 | 128 | 33.3 |
| | >15 | 176 | 45.7 |
| Denied entry onto buses due to full seats | Very frequently | 150 | 39.0 |
| | Somewhat frequently | 124 | 32.3 |
| | Rarely | 81 | 20.9 |
| | Almost never | 29 | 7.62 |
| Driver's level of professionalism | Poor | 51 | 13.3 |
| | Average | 165 | 42.8 |
| | Good | 168 | 43.8 |

## 4 Discussion

In this study, the network characteristics of bus stop locations in Dilla Town were analyzed and evaluated the bus service conditions through questionnaires. In this study, the analysis employed a scale of 0 to 1.0 SCRI, where the bus stop's accessibility decreases as the value approaches 0 and increases as the value approaches 1.0 (Daudu *et al.*, 2022). Based

on the result of SCRI, the bus stop with the highest value (0.960) is the one named 'Getsmart', indicating a high level of functionality for its surrounding area. On the other hand, the bus stop with the lowest coverage index is 'Molla Golja', with a coverage index of 0.595, less functional to its surrounding area when compared to other stations. The finding of this study is consistent with previous studies conducted in Nigeria, in which the highest SCRI value is 0.972 and the lowest is close to 0.163 (Daudu *et al*., 2022). The bus stops on the main road from Dilla University's main campus and the Odaya campus to Dilla Roundabout are better connected and more accessible to other parts of the network. On the other hand, the outlying areas on the road from Molla Roundabout to Chuchu and residential neighborhoods need additional accessible bus stops.

The convenience of the location of bus stops is a crucial factor for passengers (Chen *et al*., 2015; Nguyen, 2020). While 40.95% of the respondents consider the bus stop locations to be very convenient, 25.71% specifies the need for improvements in this area. This result is supported by studies aimed at assessing passengers' satisfaction and revealed that the locations of the bus stops are crucial factors for stakeholders to prioritize the placement of bus stops to satisfy the needs of customers (Litman, 2008; Liu *et al*., 2017).

The maximum waiting time for the bus transportation service should be in the range of 10-20 minutes (Armstrong-Wright, 1993). However, the majority of the respondents (45.71%) reported waiting for the bus more than 15 minutes. However, there is a positive aspect that 18.10% of respondents reported waiting times of less than 5 minutes, recommending that some individuals have had a satisfactory experience in this regard. The dissatisfaction is consistent with previous research conducted in Oslo, Norway, which specifies that reduced reliability and increased travel time are associated with decreased satisfaction with travel experiences (Lunke, 2020). Another study conducted in Addis Ababa city reported that 32.86% of the respondents wait for more than 20 minutes to get service, which is above the standard (Weldeamanuel, 2019)

Another significant issue identified in the results is denyingentrance into buses due to absence of seats. Several respondents (39.05%) stated experiencing this problem regularly, is a challenge that needs to be addressed. While it is positive that 20.95% encountered this issue rarely, efforts must be made to find solutions that minimize instances of overcrowding and ensure that passengers are not left waiting for the next bus due to capacity constraints.

Regarding the driver's level of professionalism, the majority of respondents (43.81%) rated it as good, while a comparable percentage (42.86%) rated it as average. Although these ratings indicate generally satisfactory performance, it is concerning that a notable portion of respondents (13.33%) perceived the driver's professionalism as poor. This signifies the need for continuous training and monitoring to ensure consistent service quality and professionalism among bus drivers (Shaaban & Kim, 2016).

## 5 Conclusion

This study analyzed the network characteristics of bus stop locations in Dilla Town using a GIS and evaluated the bus service conditions through questionnaires. The study employed the Service Coverage Ratio Index (SCRI) to assess the functionality and accessibility of bus stops. The study found that bus stops located on the main road between Dilla University's main campus and the Odaya campus and those near Dilla Roundabout, had more accessible bus stops than other parts of the network. In contrast, the outlying areas along the road from Molla Roundabout to Chuchu and residential neighborhoods had no accessible bus stop, indicating a lack of access to bus services. This highlights the need to improve bus service in these areas to enhance connectivity and accessibility. These findings emphasize the importance of addressing the shortcomings in the bus service to meet the needs of the community.

This study contributes significant information to the scientific community by analyzing the spatial distribution of bus stops in Dilla Town and evaluating the conditions of bus services. It not only provides information regarding the accessibility of bus stops throughout the town but also offers valuable information about the distribution of bus services in different areas. These findings can serve as a basis for future research and can guide transportation authorities in similar contexts to optimize bus stop locations and enhance overall bus service quality.

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**Conflicts of interests**

We disclose no conflicts of interests

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# Land use land cover change and expansion of Eucalyptus plantations in Senan District, northwest Ethiopia: analysis of potential factors

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**Abstract**

*Farmers in Ethiopia's highlands are rapidly converting their agricultural land into Eucalyptus plantations, which may have socioeconomic and environmental implications for local communities. This study aims to assess the expansion of Eucalyptus tree plantations at the expense of other land use practices in Northwest Ethiopia, specifically in the Senan district, and the factors that contribute to it. Data was collected from 332 (166 Eucalyptus planter and 166 non-planter) households and analyzed using the binary logit model. Land use and land cover change in the study area were investigated using Landsat satellite images of four periods (1990, 2000, 2010, and 2021). The land use and land cover classes were categorized using a supervised classification method. The findings revealed a decrease in cropland from 58.4% in 2010 to 38.1% in 2021, whereas the vegetation cover, predominantly consisting of Eucalyptus, experienced an increase from 16.8% to 26.5% during the same period. The results of the binary logit analysis indicate that the age of the household head, the size of the farmers' land, and savings had a positive and significant impact on the adoption of Eucalyptus plantation, while the family size of households, educational status, livestock ownership, and the fertility level of farmers' land had a significant negative effect on Eucalyptus plantation. Therefore, it is recommended to conduct comparative studies to assess the impact of Eucalyptus plantations on the livelihoods of farmers, ensuring that their well-being is improved as a result..*

**Keywords/Phrases**: Driving factors, Ethiopia, Eucalyptus, GIS, Land-use change

## 1 Introduction

Eucalyptus is the most widely planted tree species in the world (Abebe *et al*., 2019). Over the last century, it has spread rapidly throughout the world. In the 1890s, it was introduced to Africa, specifically Ethiopia (Jaleta *et al*., 2016).

Zenebe (2016) noted that in terms of livelihoods, Eucalyptus plays an important role in addressing food security. Besides, according to Elli *et al*. (2019), the availability of fuelwood is one of the most important contributions of Eucalyptus to food security. Cooking, for example, is the most common method of ensuring food utilization through high nutritional absorption from food, and 2.4 billion people use fuelwood to cook.

Despite the numerous benefits of eucalypt plantations, particularly in East Africa, where most people rely on wood for construction and fuel, there is still some criticism. Eucalyptus tree users, growers, environmentalists, researchers, and policymakers have different views on the economic, social, and environmental sustainability of the species. The majority of concerns raised are related to the environmental impact, particularly concerning soils, water, and biodiversity (FAO, 2011). On the contrary, according to Sembiring *et al*. (2020) and Silenat & Fikadu

(2018), Eucalyptus is a plant that has many environmental benefits, including the ability to reduce the risk of forest fires, floods, and erosion, be more efficient with water use, make nature more natural, restore land degradation or unproductive land, and the growth of these plants has long-term potential for biodiversity. On the other hand, Zenebe (2006) stated that Eucalyptus hurts yield and inhibits undergrowth. However, almost all the firewood, building materials for houses, farm implements, and other materials in the village are made from Eucalyptus. As a result, the benefits outweigh the negative impacts, which can be mitigated by planting Eucalyptus in areas that are unsuitable for agriculture and spacing them widely apart, even in farmlands and borders.

Even though Eucalyptus plantations are generally criticized, farmers in Ethiopia, particularly in the northwest highlands, including the Senan district have converted their cropland into Eucalyptus plantations (Amare *et al*, 2021). Previous studies have identified various factors associated with the expansion of Eucalyptus plantations in Ethiopia. For instance, the age of the household head (Gebreegziabher *et al*., 2010; Tegegne *et al*., 2018), the education level (Kebede, 2017; Asabeneh & Yoseph, 2022), sex of the household head (Zenebe *et al*., 2020), family size (Setiye & Mulatu, 2016), wood demand (Tola, 2010), land degradation (Berihun & Habtemariam, 2017), the need for immediate cash (Tola, 2010), adaptability to wider agro-ecological zones, affordable cost of production (Gashaw *et al*, 2023). and low labor requirements for management (Berihun & Habtemariam, 2017) have all been identified as significant factors influencing land use patterns and the expansion of Eucalyptus plantations in Ethiopia. These factors play a significant role in shaping land use patterns and the expansion of Eucalyptus plantations in Ethiopia. However, it is important to acknowledge that these factors may vary in different contexts.

While previous studies have provided some insights into the conversion of croplands to Eucalyptus plantations in Ethiopia, including the Senan district, there is a lack of adequate research, specifically focusing on the land use and land cover change in this district and the reasons behind the conversion. Amare *et al*. (2022) highlighted that smallholder farmers in the northwestern highlands, including the Senan district, have recently started converting their croplands to Eucalyptus plantations. However, their study was conducted across three districts and did not separately analyze the driving factors specific to the Senan district. Therefore, this study assesses the land use land cover change and the factors that motivate farmers to convert their croplands into Eucalyptus plantations in the Senan district.

## 2 Materials and Methods

### 2.1 Description of the Study Area

Senan is located in the East Gojjam Zone of the Amhara Region, Ethiopia, which lies within the range of $10^0$25’13" N and $10^0$40’30" N latitudes and $37^0$40’ E and $37^0$50’20" E longitudes (Lakachew, 2022). The district has 19 kebeles; 17 rural and 2 urban kebeles. The altitude within the district varies from 2300 meters to 4154 meters. Notably, Mount Choqe, known as the ’water tower of Ethiopia,’ is located in this district, serving as the highest point in the district and the East Gojjam Zone, reaching an elevation of 4154 meters above sea level (Senan District Communication Affairs Office, 2021).

Approximately 25% of the land in the district consists of plateau and plain surfaces, while mountains and hills make up around 60%, and valleys account for approximately 15% of the landform. Eucalyptus globules are the dominant vegetation in the study area (Senan District Communication Affairs Office, 2021).

According to the Central Statistical Agency of Ethiopia’s 2007 national census, this district has a total population of 98,939 people.

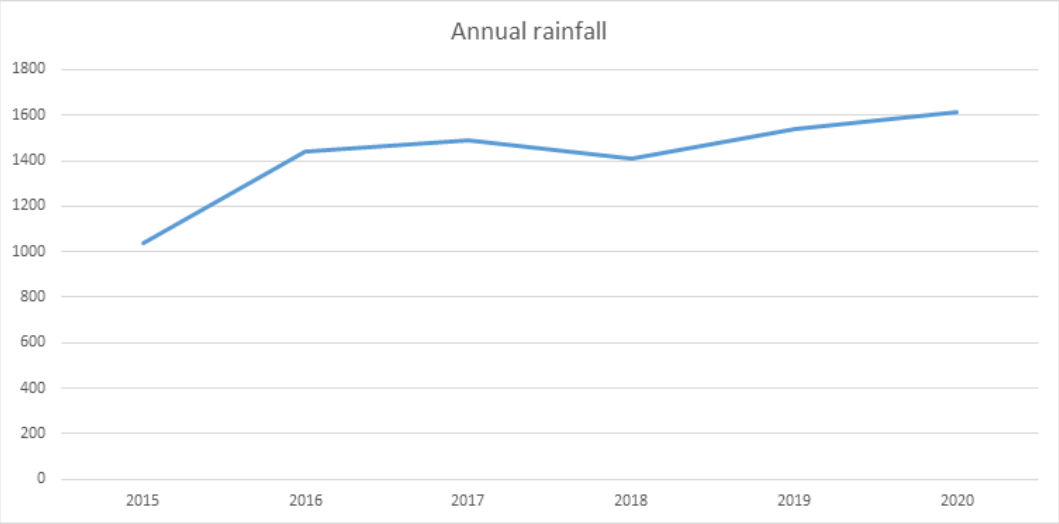


**Figure 1.** Annual Rainfall of Senan District (2015-2020)(CSA, 2022)

The daily average temperature is 15 degrees Celsius and the annual rainfall in the district is between 900-1500 mm (Central Statistics Agency, 2022).

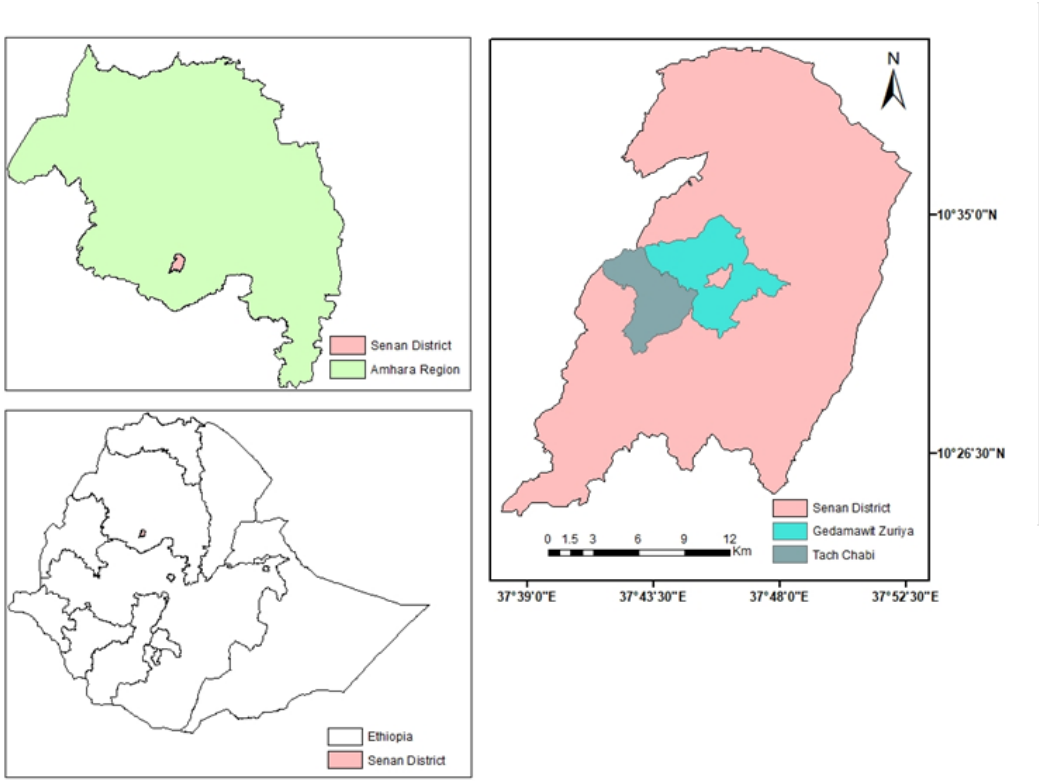


**Figure 2.** The location map of the study area

## 2.2 Data Sources and Processes

This study used both primary and secondary data sources. The primary data were collected using questionnaires, personal observations, key informant interviews, focused group discussions, and surveys using GPS instruments, whereas the secondary data were collected from satellite images and various organizations' documents and reports.

### Questionnaire

The researchers collected quantitative data using a questionnaire from 166 households that had planted Eucalyptus and 166 households that had not planted Eucalyptus. The questionnaire was translated into the local language, Amharic, before being pilot-tested.

### Personal Observations

We conducted field observations by walking through the district with agricultural office experts in the area. This method assisted us in comprehending the expansion of Eucalyptus plantations. The observation was also carried out at the district's local marketplace, where we asked questions and took notes on what we had seen, further enhancing our understanding of the situation.

### Key Informant interviews and focus group discussions

To understand the determinants of Eucalyptus plantations from their experiences and opinions, thirteen farmers were interviewed and four focus group discussions were held with purposefully selected elderly farmers and agricultural bureau officers. Saturation was used as a criterion for deciding when to stop collecting qualitative data.

### Satellite Image

Landsat satellite images of the study area were acquired from the United States Geological Survey (USGS: https://earthexplorer.usgs.gov) for four periods (1990, 2000, 2010, and 2021). 1990, 2000, and 2010 images were Landsat 4-5 Thematic Mapper, whereas the 2021 image was a Landsat 8 Operational Land Image and Thermal Infrared Sensor (OLI/TIRS). The images were extracted in Tiff data format during January. This is the time when there is clear sky season in the study area, and important to detect vegetation. Moreover, this time is important to reduce atmospheric and radiometric problems. The detailed feature of the four Landsat satellite images is indicated in table 1.

### Ground Control Points

Data collected by satellite sensors should be validated and compared to reality using reliable ground truth data. Therefore, real-world data were gathered using a hand-held GPS instrument for model validation and accuracy evaluation. To have the proper spectral value for each class, training data from the field was gathered to create a land-use land-cover map. Google Earth Pro image was also employed to validate the land use land cover result.

**Table 1.** Sources of secondary data

| No. | Data Type | Sensor | Date of acquisition | Path/Row | Resolution | Source |
|---|---|---|---|---|---|---|
| 1 | Landsat image | TM | 07/01/1990 | 169/053 | 30m by 30m | USGS |
| 2 | Landsat image | TM | 19/01/2000 | 169/053 | 30m by 30m | USGS |
| 3 | Landsat image | TM | 14/01/2010 | 169/053 | 30m by 30m | USGS |
| 4 | Landsat image | ETM+ | 28/01/2021 | 169/053 | 30m by 30m | USGS |

## 2.3 Sample Size Determination and Sampling Technique

The choice of the Senan district as the study area was driven by the presence of extensive Eucalyptus plantations within the region. Since the population of the study area is small, the modified formula of Cochran, which is designed for a small population, was used.

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

Here, $n_0$ is Cochran's sample size recommendation, $N$ is the population size, and $n$ is the new, adjusted sample size. Hence, the sample size will be:

$$n = \frac{385}{1 + (385 - 1)/2392} = 331.89 = 332$$

To ensure representative coverage, a multistage sampling technique was employed. First, the seventeen rural kebeles of the district were categorized into two distinct agro-climatic groups: nine woinadega (sub-tropical) and eight dega (temperate) dominated kebeles. Then, the kebeles of Gedamawit and Tach Chabi were selected from each group. Households

within the selected kebeles were stratified based on ownership of Eucalyptus plantations. Employing a proportionate stratified sampling technique, 166 planters and 166 non-planters were selected proportionately from both planters and non-planters within each kebele. Agricultural experts of the two kebeles assisted us in collecting data from households that plant and do not plant Eucalyptus trees.

### 2.4 Data Analysis

Preparing digital images for human interpretation is known as digital image processing (Bakker *et al*., 2001). Pre-processing procedures have been carried out after downloading and extracting the satellite image. These include atmospheric rectification, layer stacking/merging, gap-filling, image mosaicking, clipping, and other image enhancement pre-processing procedures that were used to enhance the quality and interpretability of the image so that the images are appropriate and prepared for further analysis.

The development of thematic maps involves classifying the satellite image. The subjects could range from general categories to in-depth analyses of specific groups (Schowengerdt, 2007). Images were composed in different ways to identify surface features in the study area. True color composite known by RGB 321 for Landsat 4-5 TM where band 3 reflects red, band 2 reflects green band 1 reflects blue color combination, and RGB 432 combination for Landsat 8 ETM+ were used to conduct the classification.

The land use classifications were conducted by using the maximum likelihood supervised classification. 155 training areas for all spectral classes were developed composing each information class to be identified by the classifier. Based on prior research (Agenagnew *et al*., 2019; Aramde *et al*., 2014) in the area and observations (ground truthing) made by the researcher, the following classification schemes were developed as follows.

**Table 2.** LULC classes used for classification

| No. | Classes | Description |
|---|---|---|
| 1 | Settlement | Scattered settlements with houses separated from one another. |
| 2 | Cropland | This category includes area allotted for annual rain-fed and irrigated cultivation. Lands mostly used for cereal production in subsistence farming. Potato, barley, and beans are the main crops produced in the district. They farm using oxen and horse ploughs in the most traditional way. |
| 3 | Grassland | Area predominantly covered by small grasses with a small proportion of shrub and trees. |
| 4 | Vegetation | This unit includes a collection of plant species. Eucalyptus is the prominent species in the area. |
| 5 | Shrub land | Dominated land with isolated small trees always with a lower range of grass. |

Calculation of the area in hectare and percent of the resulting LULC types for each study year and subsequently comparing the results were used as a major data analysis method to identify the change from cropland to vegetation. ERDAS IMAGIN and ArcGIS 10.8 software were used to make this analysis.

### 2.5 The Binary Logit Model

To assess the drivers of Eucalyptus plantations in the study area, the dependent variable was categorized into two qualitative parts: whether or not to have Eucalyptus plantations. Therefore, a binary logit econometrics model was employed to examine the factors that influence farmers' decisions to plant Eucalyptus trees. In binary logistic regression analysis, the dependent variable must be categorical (it can be coded as 0 and 1) (Cokluk, 2010).

The functional form of logit model is specified as follows, according to Gujarati (2003);

$$P_i = E\left(Y = \frac{1}{X_i}\right) = \frac{1}{1 + e^{-(\beta_1 + \beta_2 X_i)}} \qquad (1)$$

For ease of exposition, we write as

$$P_i = \frac{1}{1+e^{-z_i}} = \frac{e^z}{1+e^z} \quad (2)$$

Where, $Z_i = \beta_1 + \beta_2 X_i$.

If $P_i$, the probability of owning Eucalyptus plantation, is given by (2), then (1 - $P_i$), the probability of not owning Eucalyptus plantation, is

$$1 - P_i = \frac{1}{1+e^{z_i}} \quad (3)$$

Therefore, we can write

$$\frac{P_i}{1-P_i} = \frac{1+e^{z_i}}{1+e^{z_i}} \quad (4)$$

Now, $\frac{P_i}{1-P_i}$ is simply the odds ratio in favor of owning Eucalyptus plantation - the ratio of the probability that a household will own the plantation to the probability that it will not own it. Finally, taking the natural log of equation we obtain:

$$L_i = ln\left(\frac{P_i}{1-P_i}\right) = Z_i = \beta_0 + \beta_1 X_i + \beta_2 X_2 + ... + \beta_n X_n \quad (5)$$

$$Z_i = \beta_0 + \beta_1 X_i + \beta_2 X_2 + ... + \beta_n X_n \quad (6)$$

$\beta_0$ is an intercept; $\beta_1$, $\beta_2$ ... $\beta_n$ are slopes of the equation in the model; $L_i$ = is log of the odds ratio, which is not only linear in $X_i$ but also linear in the parameters; $X_i$ = is vector of relevant household characteristics

If the disturbance term ($U_i$) is introduced, the logit model that has been used to analyze drivers of Eucalyptus plantation in this study becomes:

$$Z_i = \beta_0 + \beta_1 X_i + \beta_2 X_2 + ... + \beta_n X_n + U_i \quad (7)$$

**Table 3.** List of independent variables in drivers of Eucalyptus plantations

| Independent variables | Description | Expected Effect |
|---|---|---|
| Age of household head (years) | Continuous | + |
| Sex of Household head | Female = 0, Male = 1 | - |
| Marital status of household head | Married= 1, Otherwise = 0 | + |
| Education level of household head (years) | Continuous | + |
| Family size (number) | Continuous | - |
| Farm size (Ha) | Continuous | + |
| Farm fertility (%) | Continuous | - |
| Livestock ownership (TLU) | Continuous | - |
| Membership of cooperatives | Not a member = 0, Member = 1 | + |
| Savings | No savings = 0, Have savings= 1 | + |
| Access to savings and credit service | No access = 0, Have access = 1 | + |

## 3 Results and Discussions

### 3.1 Land Use and Land Cover Analysis

The analysis comprises the land use land cover analysis and the factors behind the expansion of Eucalyptus plantations. As the classification scheme indicated, cropland, grassland, vegetation settlement, and shrub land area are the major LULC classes of the study periods. The classified images were acquired when crop harvesting had already been completed, farmlands appeared bare, and grasslands looked relatively bright in color.

Figure 3 shows the land use land cover classes of the study area in 1990, 2000, 2010, and 2021. For 1990, 2000, 2010, and 2021, five major LULC types (cropland, vegetation, settlement, grassland, and shrubland) were classified. The result reveals that there is a recent land-use change, especially in cropland and vegetation cover.

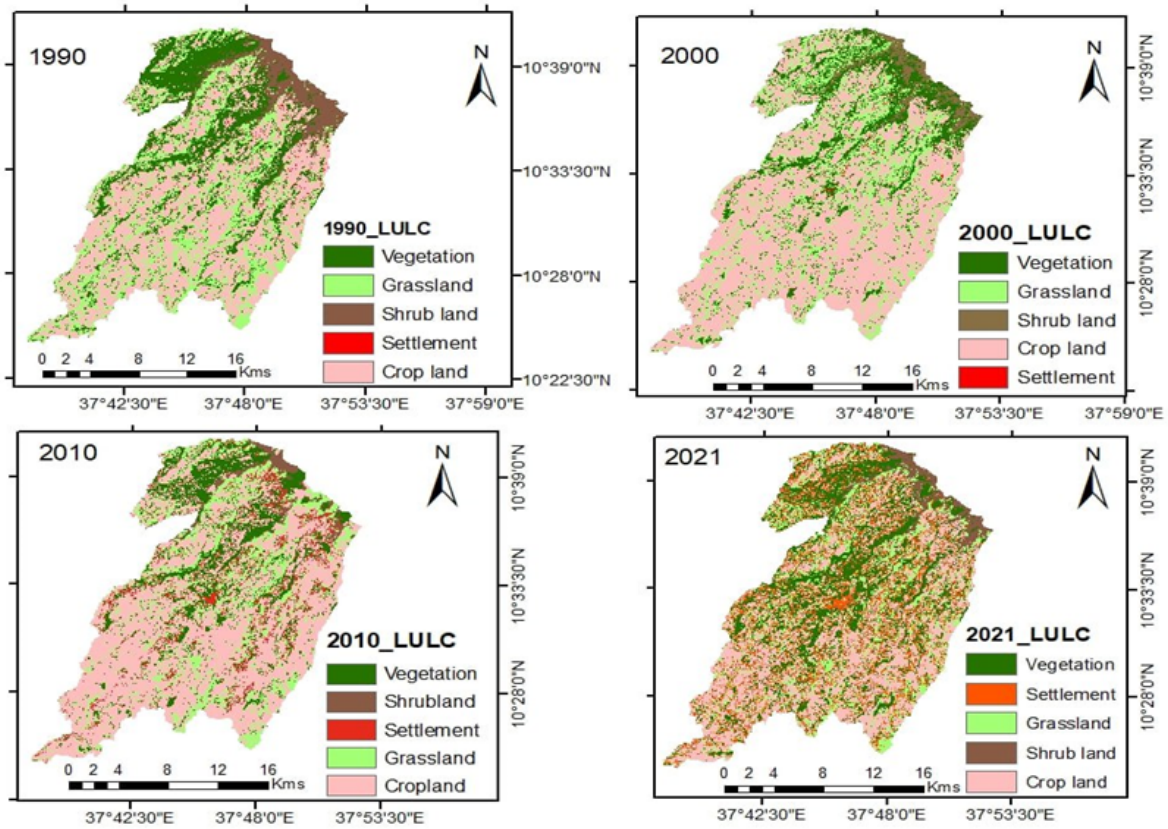


**Figure 3.** Land use land cover map of Senan district (1990, 2000, 2010, and 2021)

**Table 4.** LULC classes and their spatial extent with the observed changes over time

| LULC classes | 1990 | | 2000 | | 2010 | | 2021 | |
|---|---|---|---|---|---|---|---|---|
| | Area (ha) | Percent | Area (ha) | Percent | Area (ha) | Percent | Area (ha) | Percent |
| Crop land | 19750 | 45.2 | 25049 | 57.4 | 25500 | 58.4 | 16647 | 38.1 |
| Vegetation | 10408.5 | 23.8 | 7456 | 17.1 | 7294 | 16.8 | 11558 | 26.5 |
| Grassland | 10151.6 | 23.3 | 9406 | 21.6 | 6911 | 15.8 | 6297 | 14.4 |
| Settlement | 110.9 | 0.3 | 128 | 0.3 | 2334 | 5.4 | 6996 | 16.1 |
| Shrub land | 3215 | 7.4 | 1597 | 3.6 | 1597 | 3.6 | 2138 | 4.9 |
| Total | 43636 | 100.0 | 43636 | 100.0 | 43636 | 100.0 | 43636 | 100.0 |

The LULC classification result shows that cropland increased from 45.2 % in 1990 to 57.4 % in 2000 and 58.4 % in 2010, but it decreased to 38.1 % in 2021. On the contrary, the vegetation cover decreased from 23.8 % in 1990 to 17. 1% in 2000 and 16.8% in 2010, but it increased from 16.8% in 2010 to 26.5% in 2021. According to our observation and the focus group discussion result, the highest proportion of the vegetation cover in the Senan district is the Eucalyptus plantation, which has been expanded recently.

The focus group discussion result also confirmed that a significant number of farmers has been converted their cropland into Eucalyptus plantations during the last 10 years.

The change matrix (1990-2021) shows that the highest proportion of land was converted from cropland to vegetation. This change is mainly because farmers have changed their farmland into Eucalyptus plantations. From 2010 to 2021, the conversion of cropland

to vegetation experienced the most significant rate of change, with a total of 3,353 hectares, equivalent to 13% of the initial cropland, transformed into vegetation. Based on personal observation, almost all forests of the area are Eucalyptus. The key informant interview also approved that farmers are aware of the economic advantage of Eucalyptus and tried to cover their cropland with this plant.

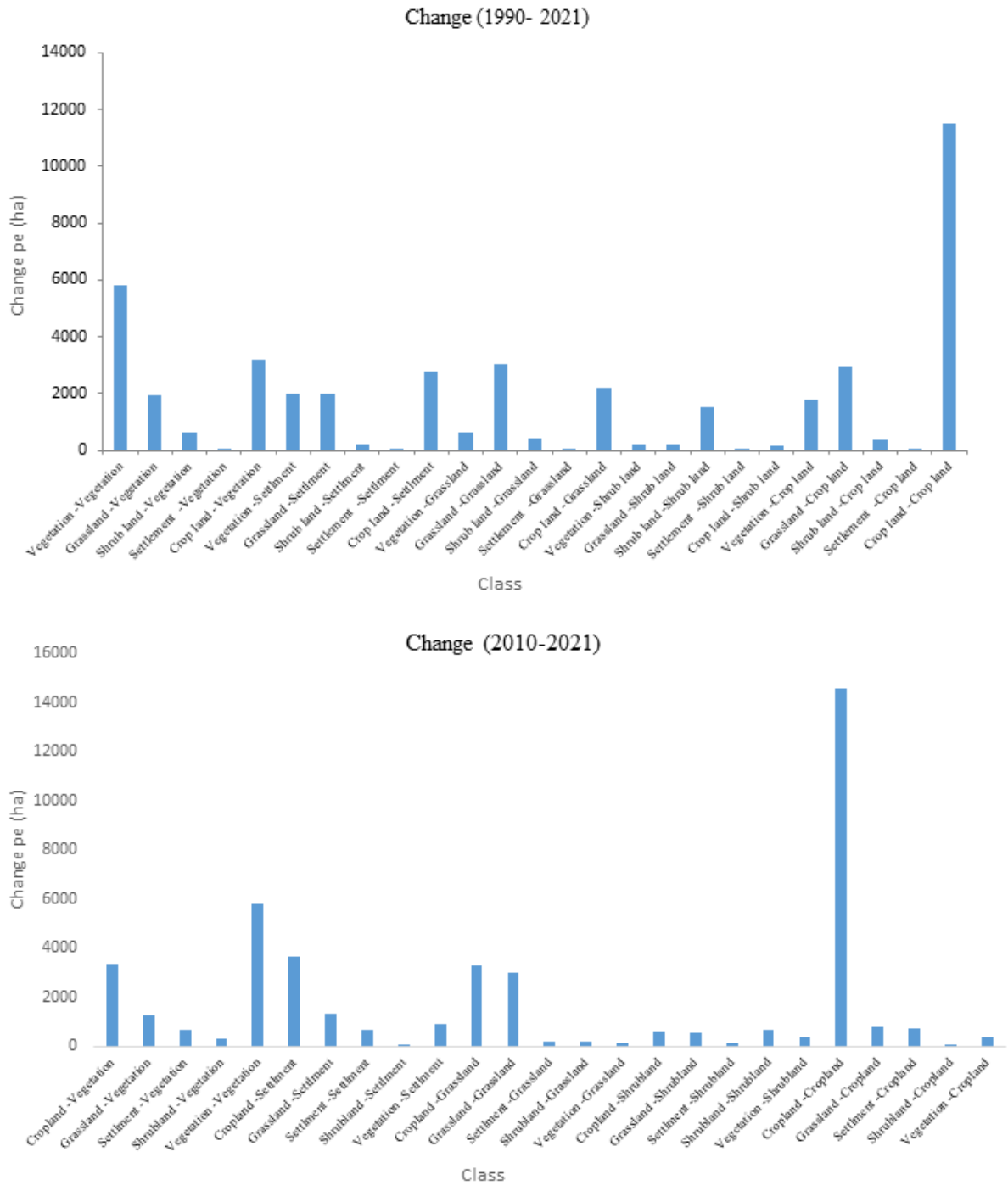


**Figure 4.** shows the calculated change detection matrix, in percent, covers the change of the whole study period from 1990 to 2021 and from 2010 to 2021

### 3.2 Factors Affecting Eucalyptus Tree Plantation

#### Binary logit model result

**Table 5.** Llogistic regression results

| Explanatory variables | B | S.E. | Wald | Sig. | Exp(B) |
|---|---|---|---|---|---|
| Sex of household head | -.185 | 1.091 | .029 | .865 | .831 |
| Age of household head | .169 | .031 | 29.382 | .000*** | 1.184 |
| Marital status | 5.701 | 6.104 | .872 | .350 | 299.189 |
| Educational Status | -1.730 | .465 | 13.833 | .000*** | .177 |
| Livestock ownership (TLU) | -.385 | .140 | 7.601 | .006*** | .681 |
| Farm size in hectare | 3.039 | .548 | 30.766 | .000*** | 20.883 |
| Family size (adult equivalent) | -.957 | .203 | 22.203 | .000*** | .384 |
| Farm fertility | -2.204 | .497 | 19.665 | .000*** | .110 |
| Membership of cooperatives | .363 | .604 | .362 | .548 | 1.438 |
| Having savings | 1.453 | .432 | 11.300 | .001*** | .234 |
| Access to saving and credit service | .850 | .449 | 3.583 | .058 | 2.340 |
| Constant | -8.738 | 6.409 | 1.859 | .173 | .000 |

Land Use and Land Cover (LULC) are influenced by a variety of factors, encompassing both natural processes and human activities (Terefe *et al*, 2019). We categorized the driving factors and implications of land use land cover change and expansion of Eucalyptus plantations in the Senan district into four broad categories based on the result of the binary logistic regression model, the focus group discussion, and key informant interview result, as described below.

### 3.3 Socio-demographic Characteristics

Studies by Gebreegziabher *et al*. (2010), Tegegne *et al*. (2018), and Zenebe *et al*. (2020) have all found that age, gender, and education are factors that increase the likelihood and number of trees planted by farmers. However, according to Arragaw & Woldeamlak's (2018) findings, tree-planting activity is negatively influenced by the education level of the household. On the other hand, Tefera & Kassa (2016) noted that household size has a positive and significant influence on the adoption of Eucalyptus plantations by farmers. In relation to this, the binary logit results of this study show that the age of the household head positively and significantly affected the Eucalyptus plantation, while family size of smallholder and educational status had a significant negative effect on the Eucalyptus plantation. This result means that as the age of the household head increases, the likelihood of adopting a Eucalyptus plantation also increases by a factor of 1.18. The key informant interview also reveals that farmers' motivation and decision to plant Eucalyptus trees increases as their age increases. This is because tree planting does not require much labor force. Therefore, elders prefer to plant Eucalyptus trees to practice crop production. Furthermore, since Eucalyptus plantations do not demand more labor than crop production, female-headed households in the study area prefer planting Eucalyptus to crop production.

According to the binary logistic regression model, the exp (b) value for family size is 0.38, indicating that the odds of adopting the Eucalyptus plantation decrease by a factor of 0.38 for every one-unit increase in family size. The focus group discussions also revealed that farmers with large families are less likely to plant Eucalyptus trees, which negatively affects their decision-making. In contrast, households with fewer family members tend to use their farmlands to grow Eucalyptus because it is less labor-intensive than crop production. However, one of the key informant interviewees noted that even households with large families experience labor con-

straints due to increasing school enrolment rates in the Senan district, which has led to a shift towards Eucalyptus plantations that require less labor. This finding aligns with previous studies, such as Asabneh *et al*. (2023), which found that family size has a detrimental impact on adopting Eucalyptus tree plantations. Based on the results of the focus group discussions and key informant interviews, it was found that female-headed households with smaller family sizes tended to choose Eucalyptus planting over other crops due to its low labor requirements. A widow female-headed household also stated "*My husband was a hard-working farmer who was capable of working day and night. But after I lost him, I turned the cropland into the Eucalyptus plantation because no one can help me on the farm*."

### 3.4 Economic Drivers

The decision-making process of farmers regarding Eucalyptus tree planting is influenced by resource ownership, including access to land, labor, livestock, agricultural inputs, and market opportunities. Asabeneh & Yoseph (2022) stated that planting Eucalyptus trees offers a considerably better return on investment than growing crops and raising animals. Other previous studies, (Kebede, 2017; Setiye & Mulatu, 2016; Zenebe *et al*., 2020; Dereje *et al*., 2011), on the other hand, emphasized that the size of the farmland owned by farmers is a crucial factor in determining their decision to plant Eucalyptus trees. Gebreegziabher *et al*. (2010) found that the number of cattle owned by households had a significant negative impact on the likelihood of participating in Eucalyptus plantations. The findings of the binary logistic regression model in the study area also confirmed that the total land size and savings had a positive and significant effect on Eucalyptus plantations, while livestock ownership had a negative effect. The odds ratio of livestock ownership and farm size indicates that holding all other variables constant, the decision of smallholder farmers to adopt Eucalyptus plantation decreases by a factor of 0.68 times as livestock ownership increases by 1, while the likelihood of Eucalyptus plantation increases by a factor of 20.8 times as the farm size of households' increases by 1. Interviewees also reported that farmers with a large number of cattle do not have Eucalyptus plantations because Eucalyptus trees are not used for animal grazing, unlike crop residues. As Setiye & Mulatu (2016) described the farmers who have small landholdings prefer to produce crops and other purposes like growing fruits and vegetables than growing Eucalyptus trees. The family who has a large landholding uses their land for diversifying the source of income like growing crops, fruit, tree planting, vegetables, and animal rearing.

Farmers may choose to plant Eucalyptus on marginal land that has limited potential for crop production. The binary logistic regression model and focus group discussions indicate that farmers are less likely to adopt Eucalyptus plantations on highly fertile land. Moreover, one of the interviewees said that:

"*I do have four temad (one hectar) land. The two temad are very fertile but the remaining two temad are not suitable for crop production. That's why I planted Eucalyptus trees on the plot of land which is not fertile*."

The findings of the focus group discussion revealed that farmers plant Eucalyptus to make a lot of money at a time so that they will be able to either construct a house, pay school fees to their children, or move to urban areas.

Moreover, Belay *et al*. (2021) also revealed that the growing need for fuelwood, construction, and cash for various purposes are the primary economic drivers behind the planting of Eucalyptus plantations.

### 3.5 Environmental Drivers

Senan is one of the districts in the Amhara Region of Ethiopia, which is predominantly Dega and is not suitable for producing high-value products like Teff. Therefore, the farmers preferred to plant Eucalyptus than to produce low-value products like potatoes.

Moreover, according to Yusuf (2016), Tola (2010), and Dereje *et al*. (2011) land degradation and depletion of natural vegetation are also the driving factors of Eucalyptus plantations. The key informant interviewees described that land degradation is the most common problem in the district, which is usually related to soil acidity. Concerning this, Hailu & Getachew (2011) stated that Ethiopia's highland areas are experiencing an increase in soil acidity.

These issues are the result of continuous cropping and the use of acidifying fertilizers. The logit result reveals that farm fertility level and Eucalyptus plantation have a negative and significant relationship. According to the interview and focus group discussion, reduced crop yield because of declining soil fertility made farmers convert their cropland into Eucalyptus plantations.

### 3.6 Properties of the Eucalyptus Species

According to Tefera & Kassa (2017), coppicing ability, straight pole growth, quick growth and thus shorter maturity period, multiple uses of the wood, low labor required for management, and drought, disease, and pest resistance are important characteristics of the species. These characteristics are also one of the farmers' driving factors in planting Eucalyptus in the Senan district. One of the interviewees stated that:

"*Eucalyptus is a good species because it saves my time and labor; it teaches me to save a lot of money; it is free from natural hazards; unlike crops, it is not consumed by animals which make it easy to have the plantation*."

The focus group discussion participants also stated that shorter growing seasons and higher biomass, increasing price of farm input such as fertilizer and improved seed, the negative effects of nearby Eucalyptus plantation shades on a crop, and other farmers' successful experiences are some of the factors related to the properties of the species.

In relation to this, an interviewee emphasized that "*the shade of my neighbors' Eucalyptus plantation on my cropland affects its productivity. Hence, I was obligated to convert my cropland into a Eucalyptus plantation even though I did not want to do that*."

Silenat & Fikadu (2018) also stated that Eucalyptus plants are typically taller than other plants of equal age due to their rapid growth, and their shade may affect nearby crops by reducing the sunlight required for growth. Moreover, Gashaw *et al* (2023) described that the detrimental effects that Eucalyptus plantations have on nearby cropland made farmers convert their cropland into Eucalyptus tree plantations.

## 4 Conclusion

The results indicated a decline in cropland area from 58.4% in 2010 to 38.1% in 2021, while there was an increase in vegetation cover, primarily Eucalyptus, from 16.8% to 26.5% over the same time frame. This is mainly caused by socio-demographic characteristics of the household, economic factors, environmental factors, and the characteristics of the Eucalyptus species, such as the availability of large plots of land for ownership, infertile agricultural land, a small labor force, a shorter growing period, the species' shading impacts, and easily accessible market opportunities are responsible for the rapid expansion of Eucalyptus plantation in the study area. As a result, agricultural experts should provide support to farmers through various land-use planning strategies that take into account their socio-demographic, economic, and environmental elements and the country's land-use policy. Moreover, comparative studies should be conducted to make sure the livelihood of farmers is improved due to Eucalyptus plantations.

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### Conflict of Interest

The authors declare that there is no conflict of interest.

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# Economic efficiency in maize (*Zea mays* L.) production of small holder farmers in Amhara Regional State, Ethiopia

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**Abstract**

*Ethiopian agriculture is explained by low productivity, caused by a combination of demographic economic, constraints, and other factors such as-policy factors, drought, war, lack of basic infrastructure, etc. To improve this problem many of the researchers are focusing only on technical efficiency. So, technical and allocative efficiency are important in improving the productivity gains from existing technology. A multi-stage sampling technique was employed. The study was conducted using cross-sectional data. From 366 households randomly selected. The stochastic frontier function was used to estimate the level of technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE), whereas the Tobit model was used to identify factors affecting efficiency level. The mean TE, AE, and EE were 90.3%, 59.9%, and 76.4%, respectively. The Tobit model results revealed that Gender distance to market, access to credit, training, extension service, seed Variety, and group membership had a significant positive effect on TE, while household size and education level had a negative significant effect on TE. Age, gender, group membership, training, extension service, and seed variety had a positive significant effect on AE, however, household size had a negative significant effect on AE. Moreover, age, gender, group membership, training, extension service, and seed variety had a positive significant effect on EE. However, household size, experience, and distance to market had a negative significant effect on EE. The results showed that there is an opportunity to increase the efficiency of maize production in the study area through improving seed. Therefore, the policies and strategies in development and research may act on these variables to increase the efficiency level of maize producer farmers.*

**Keywords/Phrases**: Cobb-Douglas, Efficiency, Maize, Production, Stochastic frontier, Tobit model

## 1 Introduction

Agriculture is the main economic activity in Ethiopia. According to the United Nations Development Program (UNDP, 2015) two third of the people in developing countries are living in rural areas. Agriculture is the main source of subsistence and income for the majority of the rural people; many of them are small-scale farmers. Farmers in developing countries are depending on farm income and experience a hand-to-mouth way of living. This is because of technological backwardness, rapid population growth, and low productivity of livestock (FAO, 2014).

Agriculture is a dominant sector in Ethiopia that has contributed to the livelihoods of about 85% employed, about 85% labor force, accounts about 45% of the GDP, and for foreign exchange currency about 86% (FDRE, 2016). Accordingly, the government of Ethiopia has taken initiatives that are meant to support achievement, which can be assured by improving efficiency through reducing losses and improving market performance.

Ethiopian agriculture is characterized by low productivity due to technical and socio-economic factors. Mostly, the farmers with the same resources are producing different per hectare output because of management inefficiency inputs, limited use of

modern agricultural technologies; obsolete farming techniques, poor complementary services such as extension, credit, marketing, and infrastructure, poor and biased agricultural policies in developing countries like as Ethiopia (WFP, 2012).

Maize is the single most important crop in terms of the number of farmers engaged in cultivation and crop yield, and cereals account for 65 percent of the agricultural value added, equivalent to about 30 percent of the national GDP (Shahidur *et al*., 2010). The smallholder farmers that comprise about 80 percent of Ethiopia's population are both the primary producers and consumers of maize (Dawit *et al*., 2008). The role of maize is central to agricultural policy decisions as a prime staple food for food security and the overall development of the agricultural sector. The Ethiopian government has put a lot of effort into promoting agricultural productivity and efficiency of smallholder farmers (Jema, 2008) since agriculture continues to be the dominant sector in Ethiopia's economy. Maize production can increase either through the introduction of modern technologies or by improving the efficiency of inputs with existing technologies. These two are not mutually exclusive because the introduction of modern technology could not bring the expected shift of production frontier if the existing level of efficiency is low. This result implies the need for the integration of modern technologies with improved levels of efficiency (Kinde, 2005).

Economic efficiency in this study refers to the ability of a farmer to produce the maximum possible output at a minimum feasible cost by utilizing the resources they already have most optimally. It encompasses both allocative and technical efficiencies. A proper analysis of the economic efficiency of farmers requires the estimation of both technical and allocative efficiencies. Therefore, this study analyzed the economic efficiency of maize production of smallholder farmers, enhanced efficiency would contribute to improved well-being and sustainable farming for a large segment of Dega Damot *Woreda*, West Gojjam Zone of Amhara Region.

According to previous research in Ethiopia, there also exists a wide cereal yield gap among the farmers that might be attributed to many factors such as lack of knowledge and information on how to use new crop technologies, poor management, climate factors, and others (Sisay *et al*.,2015).

Many of the researchers are focusing only on technical efficiency; understating the benefit that could be derived by producers from the importance of the overall performance of how farmers allocate their resources in response to price incentives, is an important determinant of the profitability of the farming enterprise. So, technical and allocative efficiency are important in improving the productivity gains from existing technology. However, as to the knowledge of the researcher, there is no study done on the economic efficiency of smallholder maize producers in the study area. Hence, there is a need to fill the existing knowledge gap by addressing issues related to technical, allocative, and economic efficiencies of smallholder farmers' maize production in the study area by providing empirical evidence on smallholder resource use efficiency. Therefore, the present study is useful in formulating appropriate policies and research information for reducing the level of economic inefficiency with the objectives of measuring the level of technical, allocative, and economic efficiencies of maize production and identifying factors affecting them in the study area.

Therefore, this study answers the following objectives:

1. To measure the level of economic, technical and allocative efficiency in maize production by small holder farmers in the Dega Damot *Woreda*, West Gojjam Zone.

2. To identify the major determinants that affect efficiencies in maize production in the study area.

## 2 Materials and Methods

### 2.1 Description of the Study Area

Dega Damot is one of the *Woreda*s in the West Gojjam zone, Amhara Region of Ethiopia. It is Part of the Mirab Gojjam Zone, located 399 km away from the capital city of Ethiopia (Addis Ababa). Dega Damot is bordered on the south by Dembecha, on the southwest by Jabi Tehnan, on the west by Kuarit, and the north and east by the Misraq Gojjam Zone. Dega Damot has a population density of 183.27, which is greater than the Zone average of 158.25 persons

per square kilometer. A total of 33,336 households were counted in this *Woreda* resulting in an average of 4.57 persons per household and 32,497 housing units. The largest ethnic group reported in Dega Damot is Amhara (99.95%). Amharic is spoken as a first language by 99.97%. The *Woreda* is also characterized by a good climate for most of the year, with annual rainfall between 900 ml and 1200 ml (CSA, 2007). Maize is one of the major staple crops grown in the poorest and most food-insecure regions of Ethiopia, like Dega Damot *Woreda*. The crop is produced under adverse conditions such as low input use and marginal lands. The climate of Dega Damot *Woreda* is most favourable for the cultivation of a wide variety of crops like maize, sorghum, teff, wheat, barley, bean, and pea, oil seeds (vegetable and fruit).

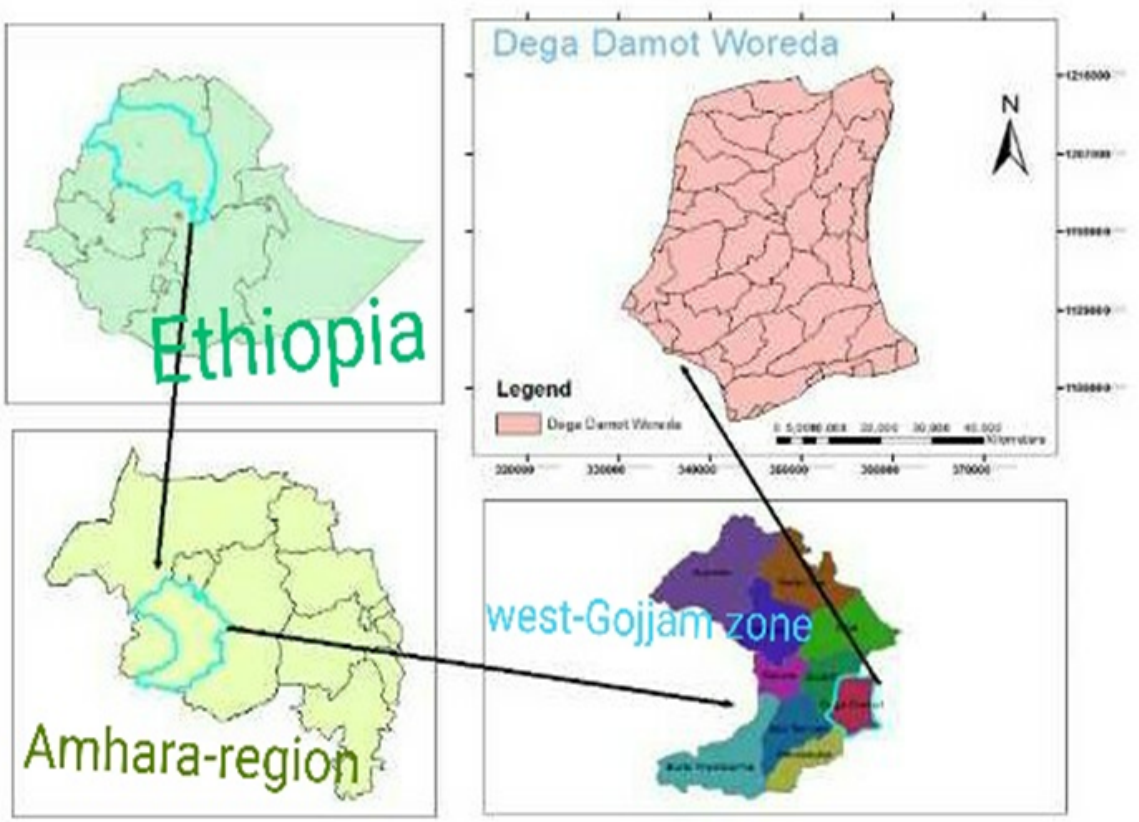


**Figure 1.** Map of the study area (Source: Ethio-GIS, 2018)

## 2.2 Method of Data Collection

Primary and secondary data were used for this study. Primary data was collected from the 2017/18 cropping season using personally administered questionnaires. To collect primary data through structural questionnaires, the study involved 366 respondents. Interviews were conducted to obtain in-depth qualitative information. Structured interviews were conducted with four extension agents, one from each *Kebele*. Through Focus Group Discussion (FGD), this was conducted to obtain individuals' impressions and concerns about maize production. Focus groups allow for interactions between the researcher and the participants and among the participants. The group was composed of four farmers from each *Kebele*.

## 2.3 Sample Size Determination and Sampling Technique

A multi-stage sampling technique was employed to analyze the economic efficiency of smallholder maize producers. In the first stage, Dega Damot *Woreda* was purposively selected for the study because of the presence of a large number of maize-producing households and the extent of maize production in the study area. In the second stage, Dega Damot *Woreda* comprises 32 *Kebeles*. From these, 27 rural *Kebeles* are major maize-producing *Kebeles*. Since the research focuses basically on maize pro-

duction, maize producer *Kebeles* are the major target areas for the sample selection. In the third stage, out of 27 *Kebeles*, four *Kebeles* are selected randomly due to homogeneity in maize production of all *Kebeles*. Finally, based on the list of households of the *Kebeles* who produced maize during the 2017/18 production year, 366 sample farm households were selected from the total households of four *Kebeles* by using systematic random sampling (SRS) technique based on probability proportional to size (PPS).

### 2.3.1 Sampling Size Determination

According to Dega Damot *Woreda*s agricultural and rural development office, the total household in the four rural *Kebeles* is 4370. The researchers used a formula developed by Yamane (1967) with a precision level of, ±5 (because the target population is homogeneous).

$$n = \frac{N}{1+N(e^2)}$$

Where, $N$ = designates total number of households in four *Kebeles* $n$ = the sample size whom the researcher used $e$ = designates maximum variability or margin of error 5% (0.05).

Thus, $N = 4370$, $e = 0.05$

Therefore, $n = 366$

Based on this approach, a total of 366 farmers from the four *Kebeles* proportional to the size sampling technique were selected. Out of 27 *Kebeles*, 4 rural *Kebeles* were randomly selected, out of which respondents were taken as a sample based on the procedures described below.

**Table 1.** Summarize on Sample size per *Kebele*

| ***Kebele*** | **Maize producing households** | **Sample size (*n*)** |
|---|---|---|
| Geshet Slassie | 1290 | 108 |
| Arefa Debtera | 1242 | 104 |
| Damot Tsion | 1015 | 85 |
| Feresbet Mikael | 823 | 69 |
| Total | 4370 | 366 |

## 2.4 Method of Data Analysis and Interpretation

The data collected from different sources were analyzed using descriptive statistics and econometric methods. The descriptive analysis was used to summarize some important characteristics of the sample households. The descriptive method includes tables, simple ratios, percentages, frequencies, standard deviations, *etc*.

In the econometrics analyses, a stochastic frontier model (SFM) and a two-limit Tobit regression model were used. The purpose of using the econometric method was to estimate the effects of inputs on maize output, to measure the economic efficiency of maize production by using the stochastic frontier production model with maximum likelihood estimation, and factors that affect the economic efficiency of smallholder maize producers by using two-limit Tobit model in Dega Damot *Woreda*. The qualitative data was also summarized and presented to supplement the result of the quantitative analysis. The data was analyzed using the Frontier 4.1c program and STATA software.

### Model Specification and Estimation Procedures

A stochastic frontier production model proposed by Battese and Coelli (1995) by the original models for Aigner, *et al*. (1977) and Meesuen and van den Broeck (1977) was applied to cross-sectional data to estimate the effects of input on maize output using maximum likelihood estimation. In this study, the stochastic production function was used for its key features that the disturbance term is composed of two parts *i.e*., a two-sided and symmetric term and a one-sided component.

### Cobb-Douglas stochastic frontier production function Model

Either a Cobb-Douglas (CD) or Translog (TL) functional form for the production functions. In this

study, only CD model was specified and the most appropriate model is selected based on log-likelihood ratio tests.

For Cobb-Douglas production function defined over $N$ inputs,

$$Y = AX_1^{\beta_1} X_2^{\beta_2} \ldots\ldots XN^{\beta_N}$$

Where, $Y$ = yield of maize and $X_i$ = different variable of inputs ($i$ = 1, 2, 3, ..., $N$)

The measure of returns to scale, RTS, representing the percentage change in output due to a proportional change in use of all inputs, is estimated as the sum of output elasticities for all inputs.

The specific Cobb-Douglas production model estimated is given.

$$Y_i = \beta_0 * \prod_{i=1}^{n} X_i \beta_i * e^{(v_i - u_i)}$$

By transforming it into double log-linear form

$$lnY_i = ln\beta_0 + \sum_{i=1}^{5} lnX_i + (V_i - U_i)$$

Where, $Y_i$ represents maize yield harvested and $X_i$ represents maize inputs by $i^{th}$ farmer (Land, Oxen, Seed and Fertilizer). Whereas $\beta_0$, $\beta_1$, $\beta_2$, $\beta_3$, $\beta_4$, and $\beta_5$ the regression parameters to be estimated and ln= natural logarithm. From the error term component ($V_i - U_i$), $V_i$ is a two sided ($-\infty < V < \infty$) normally distributed random error ($v \sim N\,[0, \sigma^2 v]$) that represents the stochastic effects outside the farmer's control (e.g., weather, natural disasters, and luck), measurement errors, and other statistical noise while Ui is a one-sided ($u_i \geq 0$) efficiency component which is independent of vi and is normally distributed with zero mean and a constant variance ($\sigma^2 u$) allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

**Stochastic frontier Cobb-Douglas cost function**

In order to estimate farm level overall economic efficiency, the stochastic frontier cost functions model is specified as follows:

$$C_i = h\,(Y_i, P_i, \alpha_i) + \varepsilon_i$$

Where, $C_i$ is the total production cost, $Y_i$ stands for output produced, $P_i$ is price of input, $\alpha_i$ represents the parameters of the cost function to be estimated and $\varepsilon_i$ is the error term. Since, inefficiencies are assumed to add to costs, error components, therefore, have positive signs.

**Tobit Model with Maximum Likelihood Estimation**

The estimation of the Tobit Model is the censored regression model, also called the Tobit model, to pay respect to Tobin (1958), who was the first to introduce censoring in economics. The most common censored regression model is the Tobit model, which expresses the observed level in terms of an underlying latent variable. A Tobit is a censored regression model in which the dependent variable is observed only if it is above or below some cut-off level. A two-limit Tobit model is a censored normal regression model where the dependent variable is continuous, and its range is constrained both from above and below by cut-off point.

The dependent variable lies in a double-bounded range (*i.e.*, between zero and one). The use of the Tobit model is intuitive because the parameter estimates are biased and inconsistent if OLS is used (Gujarati, 2004). In the model the dependent variables are economic efficiency (technical and allocative efficiency) scores which will be regressed against the common independent variables (age of the household head, experience in maize production, education, gender, household size, access to credit, distance to market, extension service, group membership, family income training and seed varieties). A number of explanatory variables were expected to influence the economic efficiency (technical and allocative efficiencies) directly or indirectly.

In measuring the factors affecting economic efficiency levels, a two–limit Tobit regression model was used. The estimated efficiency scores were regressed on a set of socio-economic, institutional, demographical, and other factors that were assumed to be important determinants of efficiency. The Tobit regression model was considered more appropriate since the values of the dependent variables (efficiency scores) lay within a certain interval (0, 1).

Three separate equations for determinants of technical, allocative, and economic efficiency were estimated using a two-limit Tobit model with the de-

pendent variable as the technical, allocative, and economic efficiency indices, respectively. Following Amemiya (1981), Waluse (2011), Essa *et al*. (2011), and Endrias *et al*. (2013), the two-limit tobit model was defined as:

$$Y_i\text{*EE, TE, AE} = \beta_0 + \sum_{j=1}^{12} \beta_i Z_{ij} + U_i$$

Where *Yi** is the latent variable representing the efficiency scores, $\beta_0$, $\beta_1$, ..., $\beta_{12}$ are parameters to be estimated, and EE, TE, and AE are economic, technical and allocative efficiency of the $i^{th}$ farmer, respectively. $Z_i$ is demographic, socioeconomic and institutional factors that affect efficiency level. And, $\mu_i$ is an error term that is independently and normally distributed with mean zero and variance $\sigma^2$ ($\mu_i \sim$ IN 0, $\sigma^2$).

### 2.5 Diagnostic Tests

#### 2.6.1. Test for Heteroskedasticity

Heteroscedasticity Test is a situation in which the assumption of equal variance of residuals in the classical linear regression model is violated. In this situation, the estimators are unbiased but inefficient, and the estimates of the variances are biased, leading to invalid tests of significance results (Maddala, 1992). The first step in addressing the problem of heteroscedasticity is to determine whether or not heteroscedasticity exists. There exist several tests for heteroscedasticity detection, among others, the Koeker Basset, the PBPG, the White's, and the Breusch-Pagan tests as listed by Gujarati (2004). A test for heteroskedasticity was done to verify the assumption of constant variance. The Breusch-Pagan /Cook-Weisberg test for heteroscedasticity was used. To correct for heteroscedasticity, the robust option was used in the MLE regressions for both models (Baum, 2006).

#### 2.6.2 Multicollinearity

The data was also tested for multicollinearity. Test for the presence of multicollinearity in the models was performed using the Variance Inflation Factor (VIF). Multicollinearity is a situation when the independent variables are highly inter-correlated.

According to Gujarati (2004), the value of VIF more than ten is usually considered an indicator of serious multicollinearity and should be excluded from the model. The multicollinearity test for both continuous and dummy variables at the same time was done using the Variance Inflation Factor (VIF) to check the multicollinearity problem among all variables entered in the model. In addition, multicollinearity tests of continuous and dummy variables were checked using the variance inflation factor and contingency coefficient, respectively.

## 3 Result and Discussion

### 3.1 Estimating the Result of the Production and Cost Function

The maximum likelihood estimates (MLE) of the parameters of the stochastic frontier production function for maize farmers are presented in Table 1. The values of output Elasticity of all input variables are positive and have a significant influence on maize output growth except Labour. This suggests that as labour increases, maize production decreases. This result could mean that using more labour on a fixed size of land might lead to labour redundancy and a labour surplus whose withdrawal would leave output virtually unchanged.

**Fertilizer** (chemical and organic) is a major land augmenting input that improves the productivity of existing land by increasing yield per unit area. The coefficient of fertilizer used by farmers has a positive relationship with maize output and is significant at a 1% level. It is indicated that a 1% increase in the amount of fertilizer in kg would increase maize yield by (11.1%). Other input remains constant. This type of relationship is, however, expected where the available fertilizer is efficiently applied in terms of rate along with other inputs to avoid diminishing return to fertilizer. This result is consistent with the findings of Netabirabose (2017). Fertilize had a positive impact on productivity and was statistically significant at 1% and 5% level;

**Table 2.** The Maximum Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Production Function

| Variable | Parameter | Coefficients | Std. Error | Z | *p*-value |
|---|---|---|---|---|---|
| **Constant** | $\beta_0$ | 5.45 | 0.187 | 29.19 | 0.000 |
| ln(land) | $\beta_1$ | .244 | 0.0858 | 2.84 | 0.005 |
| ln(labor) | $\beta_2$ | 0.0163 | 0.0684 | -0.24 | 0.811 |
| ln(seed) | $\beta_3$ | 0.103 | 0.046 | 2.27 | 0.023 |
| ln(oxen) | $\beta_4$ | 0.219 | 0.086 | 2.55 | 0.011 |
| ln(fertilizer) | $\beta_5$ | 0.111 | 0.036 | 3.09 | 0.002 |
| | | | | | |
| $\ln\sigma^2 v$ | | -3.737 | 0.211 | -17.83 | 0.000 |
| $\ln\sigma^2 u$ | | -4.086 | 0.784 | -5.21 | 0.000 |
| $\sigma v$ | | 0.153 | 0.016 | | |
| $\sigma u$ | | 0.130 | 0.051 | | |
| $\sigma^2$ | | 0.040 | 0.009 | | |
| $\lambda$ (lambda) | | 0.848 | 0.066 | | |
| $\gamma$ (gamma) | | 0.522 | | | |

Note: *, **, *** significant at 10%, 5% and 1% level of significance, respectively

**Land** (farm size) is another variable worth mentioning. The coefficient of land was also found to be positive and significant at a 1% level. The highest coefficient of output to land (24.4%) indicated that land is the main determinant of maize production in the study area. Maize production is relatively sensitive to land. This implies that a one percent increase in farm size used in hectare increases the maize output by about (0.244) percent while other inputs remain constant. This implies the 1% statistical significance level for farm size also implies that the influence of changes in farm size on production efficiency was very important. This means that there is scope for increasing output by expanding farm size. This result is similar to the findings of Tarekegn (2017), who revealed farm size to be significantly related to cumin output.

**Oxen**: in most developing countries like Ethiopia, oxen are the main source of draft power to perform activities like ploughing and sowing crops. The estimated coefficient of oxen days (one oxen-day is equivalent to eight working hours) was found to be positive and significant at the 5 level. The positive sign implies that using more ploughs can increase the output of maize. As a result, a 1 percent increase in the number of oxen per day will result in a (21.9%) percent increase in the maize output, keeping other inputs constant. This finding is consistent with the study of Getachew (2017) and Bealu *et al*. (2013).

**Seed**: seed also showed a positive effect on maize productivity according to the findings and significance at a 5% level. As a result, other things kept constant, a 1% increase in seed amount in kg will lead to a (10.3%) % increase in maize output. Hence, it might be better to use improved and certified maize seeds to increase their maize output. This finding is consistent with the study of Bealu *et al*. (2013) and Tarekegn (2017) seed is the most vital input for crop production.

Wald $Chi-square$ statistic = 752.41 and Probability = 0.000, since the Wald $Chi-square$ statistic is significant at 1% level, we reject the null hypothesis that there is the absence of inefficiency in favour of the presence of inefficiency. To check whether technical inefficiency effects are absent, we may use the important test, and the important parameter of log-likelihood in the half-normal model is $\lambda = \sigma u/\sigma v$. If the value of $\lambda$ is equal to 0, there are no technical inefficiency effects, and all deviations from the frontier are due to noise (Aigner, Lovell, & Schmidt, 1977). The estimated value of $\lambda$=0.848 is significantly different from 0, and the null hypothesis that there are no inefficiency effects is rejected at a 1%

significance level.

The results of Maximum Likelihood estimates of variance parameters explain that the variance parameter gamma ($\gamma$) is the ratio of variance of farm-specific technical efficiency to the total variance of output and has a value between zero and one.

$$\gamma = \frac{\sigma^2 u}{\sigma^2 u + \sigma^2 v} = 0.522$$

Therefore, it can be concluded that there is inefficiency in the production of maize. The estimated value of $\gamma$ was 0.52, which indicated that about 52% of total variation in maize farm output was due to technical inefficiency. Thus, 52% of the variation in composite error term was due to the inefficiency component. This result also suggests that about 48% of the variation was due to random shocks outside the farmer's control. For instance, weather conditions/temperature during the maize production process. If technical inefficiencies among maize producers are minimized, there can be optimization of maize output.

### 3.2 Efficiency Scores

Frontier version 4.1c computer program was used to estimate technical efficiency (TE) and cost efficiency (CE). Cost efficiency is the ratio of observed cost to the optimum cost.

**Table 3.** Summary Statistics of Efficiency Measures

| Types of efficiency | Min | Max | Mean | Std. deviation |
|---|---|---|---|---|
| TE | 0.755 | 0.963 | 0.903 | 0.342 |
| AE | 0.309 | 0.826 | 0.599 | 0.865 |
| EE | 0.526 | 0.909 | 0.764 | 0.120 |

TE (Technical efficiency), AE (Allocative efficiency), and EE (Economic efficiency)

Accordingly, cost efficiency will always range from 1 to infinity, while technical, allocative, and economic efficiency will always be bounded between 0 and 1. But to keep the discussion in line with technical efficiency from the production function and cost efficiency from the cost function, calculate economic efficiency to take the inverse of cost efficiency allocative efficiency obtained from technical and economic efficiencies is estimated as follows: AE = EE/TE. After estimating the stochastic frontier production and cost functions, respectively. The mean scores of technical, economic, and allocative efficiency from the sample farm of Dega Damot *Woreda* were 90.3%, 76.4%, & 59.9%, respectively. The minimum technical, allocative, and economic efficiency scores for the sampled farms were 0.755 %, 0.309%; & 0.526 %, respectively. The maximum allocative technical and economic efficiency scores for the sampled farms were 96.3%, 82.6%, & 90.9%, respectively.

### 3.3 Determinants of Efficiency among Maize Producers in the *Woreda*

In measuring the factors affecting economic efficiency levels, a Two–limit Tobit regression model was used. The estimated efficiency scores were regressed on a set of socioeconomic, institutional demographical, and factors that were assumed to be important determinants of efficiency. The major interest behind measuring TE, AE, and EE levels is to know what factors determine the efficiency level of individual farm households and to come up with development and policy recommendations that improve their efficiency. The TE, AE, and EE scores derived from the model were regressed on socioeconomic, demographic, and institutional variables that explain variations in inefficiency across farm households using the Tobit regression model.

#### 3.3.1. Determinants of Technical Efficiency

According to Table 4, the result shows that estimates from a tobit regression of socio-economical, demographical, and institutional factors effect of technical efficiency scores in the study area. The variables were found to be Age, gender, education level, experience, household size, group membership, training, distance to market, extension service, access to credit, family income, and seed variety.

**Table 4.** Two–limit Tobit model technical efficiency result

| | | Robust | | |
|---|---|---|---|---|
| **Technical efficiency** | **Coefficient** | **Standard error** | *t* | *P* >\|t\| |
| **Constant** | 0.866 | 0.0103 | 83.67 | 0.000 |
| age | 0.00014 | 0.0003 | 0.49 | 0.625 |
| gender | 0 .0121 | 0.0037 | 3.25 | 0.001 |
| education | -0.0046 | 0.0016 | -2.90 | 0.004 |
| hhsize | -0.0014 | 0.00080 | -1.71 | 0.088 |
| famincome | 3.98e-07 | 3.61e-07 | 1.10 | 0.271 |
| experience | -0.00035 | 0.00040 | -0.87 | 0.387 |
| dismarket | 0.00045 | 0.00015 | 2.99 | 0.003 |
| acccredit | 0.0229 | 0.0030 | 7.53 | 0.000 |
| groupmm | 0.0106 | 0.0030 | 3.51 | 0.001 |
| training | 0.0079 | 0.0030 | 2.63 | 0.009 |
| extsservice | 0.008 | 0.0029 | 2.56 | 0.011 |
| seedvariety | 0.009 | 0.0036 | 2.57 | 0.011 |
| Number of obs = | 366 | | | |
| LR $Chi^2$ (12) = | 242.49 | | | |
| Prob > $Chi^2$ = | 0.0000 | | | |
| Log likelihood = | 833.19002 | | | |
| Pseudo $R^2$ = | -0.1703 | | | |

Note: significant at 10%, 5% and 1% level significance, respectively

According to this study, the Tobit model is results for each significant variable are discussed as follows:

The gender of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, the result shows that the sex of the household head from (0=F, 1=M) increases the probability of technical efficiency of farmers by about 1.2 percent. It also implies that male-headed households are more technically efficient than female-headed households. The possible explanation is that male household heads might have better practical experiences in farming. Also, one might argue that female household heads are too occupied with domestic activities and have little time for the management of their maize plots, which leads to low technical efficiency levels. This result is consistent with the findings of Muluken (2014).

**Group membership**: Technical efficiency was also influenced by a maize farmer who participated in a producer cooperative/group. Due to this finding, group membership of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, an increase in group membership to farmers' cooperatives also increases the probability of technical efficiency. Farmers who were members of farmers' cooperatives improved their technical efficiency levels by 1.057 percent compared to those who failed to join farmer groups, assuming that other variables are kept constant. This result is consistent with the findings of Bealu, *et al.* (2013).

**Distance to market**: theoretical distance to market is hypothesized that the distance of maize production to the market was negatively related to technical efficiency. Households located nearer to the factor markets showed higher technical efficiency than those located in remote areas. However, the findings

of the unexpected result were distance to the market of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was found to be significant at a 1% level.

From the marginal effect result, an increase in the distance to the market by one kilometre leads to an increase in the farmer's probability of technical efficiency by about 0.045 percent, with other variables being constant. Therefore, farmers have to get inputs easily and communication channels have to be improved to get a better level of technical efficiency. This result is in disagreement with Ntabakirabose (2017) and Bealu *et al*. (2013) that this finding was negatively related and significantly affected technical efficiency.

**Access to credit** is an important element in agricultural production systems. It allows the producer to satisfy their cash needs induced by the production cycle. The amount of credit increases farmers' efficiency because it temporarily solves the shortage of liquidity/working capital. In this study, the amount of credit was hypothesized in such a way that farmers who get more amount of credit at the given production season from either formal or informal sources were expected to be more efficient than those who get less amount of credit. In the study access to credit in the household head showed a positive effect on technical efficiency (TE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, According to the findings, a household head having access to credit increases the probability of technical efficiency by about 0.75%. This result is consistent with the findings of Netabirbose (2017) and Musa *et al*. (2014).

**Training**: Training is an essential tool in building the managerial capacity of the household head. Household heads that get training related to crop production and marketing or any related agricultural training are hypothesized to be more efficient than those who did not receive training. Training farmers on maize crops was essential because it could improve farmers' skills regarding production practices and related aspects. Several farmers in the study areas received training on maize for a few days mainly on production practices and the importance of using improved packages. Due to the findings, training of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the number of farmers who attended training in maize production increases the probability of technical efficiency of farmers by about 0.79 percent than farmers who did not attend it. This result implies that farmers with training were technically more efficient than farmers without training. This result is consistent with the findings of Netabirbose (2017 and Bealu *et al*., (2013).

**Seed variety**: The seed variety of the household head showed a positive effect on the technical efficiency (TE) of the maize farms and was significant at a 1% level. From the marginal effect result, Farmers using improved seed Varieties of the household head increased the probability of the technical efficiency of the farmers by about 0.91%; other variables were kept constant. Farmers who used improved seed at least on one of their plots are technically more efficient than others. Seed variety is a dummy variable that represents whether the farmer adopted improved seed practice. It was hypothesized that farmers who practiced seed variety could be more efficient than their counterparts, as it helps to increase output by improving seed verity required for maize production and may result in a reduction in costs. This result is consistent with findings of Bealu, *et al*, (2013).

Education level of the household head showed a negative effect on the technical efficiency (TE) of the maize farms in the study area and it was significant at a 1% level. From the marginal effect result, as years spent in school increased, the probability of technical efficiency of farmers decreased by 0.45%, and other variables remained constant. This result is consistent with the findings of Getachew, *et al*. (2017). According to the result reported by Alemu *et al*. (2009), education decreases efficiency. The argument is as the level of a farmer's education increases, he or she may get better opportunities outside the farming sector. Ultimately, this reduces labor availability for maize production in the household thereby lowering efficiency. And Adesina and Djato (1996) have views on the effect of education on efficiency. They contend that educated farmers may not necessarily be more efficient than uneducated farmers since uneducated farmers may have acquired more farming experience and knowledge

than their educated counterparts and may be more efficient technically. Contrary to these arguments, evidence from Battesse and Coelli (1995) shows that education enhances the ability to utilize available technology and increases the efficiency of farmers. These studies reported are unexpected result of a negative relationship between technical efficiency and education.

This result is in disagreement with the findings of Mustefa *et al.* (2014), Muluken (2014), and Bealu *et al*. (2013). This study showed positive and significant impact of education on all types of efficiencies. It confirmed the importance of education in increasing the efficiency of production. It is a variable that is expected to increase managerial ability and lead to good decisions in farming. Because of their better skills, access to information, and good farm planning, literate farmers are better able to manage their farm resources and agricultural activities and are willing to adopt improved production technologies than illiterate ones.

**Household size** (family size) of the household head showed a negative effect on the technical efficiency (TE) of the maize farms in the study area, and it was significant at a 10% level. From the marginal effect result, a one-person increase in household size would decrease the probability of technical efficiency of farmers by about 0.14 percent, with other variables being constant. This result was due to households with large numbers of family members were not able to use appropriate input combinations due to a shortage of cash. Musa *et al*. (2014), Essilfie *et al*. (2011), and Belete *et al*. (2014) also had similar findings, and their argument was based on the fact that large household size increases the population pressure on the farmer's limited resources due to increases in household spending.

**Extension service** affected technical efficiency level positively and significantly at 1% level. From the marginal effect result, Maize farmers who accessed extension services pointed out a higher level of technical efficiency by 0.75% than those who failed to access the services. Other variables are kept constant. The positive estimated coefficient for contact with extension workers implies that efficiency increases with the number of visits made to the farm household by extension workers. Extension services reveal that farmers, who have access to extension services, have implemented relatively more crop diversification than those who did not have access to extension services. Extension workers have technical knowledge of crop production and improved production management practices that can assist farmers in implementing their crop diversification decisions. Therefore, appropriate and adequate extension services should be provided. This result is consistent with the findings of Ahmed *et al.* (2013, Netabirbose (2017, Desale (2017), Daniel (2016), and Bealu *et al*. (2013).

### 3.4 Determinants of Allocative Efficiency

According to table 5 result shows that estimates from a tobit regression of socio-economical, demographical and institutional factors effects of allocative efficiency scores in the study area.

According to the results, nine in twelve variables were found to have a significant contribution to allocative efficiency. Allocative efficiency as mentioned earlier is another important part of the total productivity of farms. Optimal use and allocation of inputs may potentially be an aspect that could improve the overall productivity of farms.

Gender of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was found to be significant at a 1% level. From the marginal effect result, the result shows that the sex of the household head from (0=F, 1=M) increased the probability of allocative efficiency of farmers by about 3.57% when other factors were kept constant. It also implies that male-headed households are more allocative efficient than female-headed households. This may be because allocative efficiency requires greater knowledge and skill gathered over time, which increases the capacity of farmers for optimal allocation of resources and technology.

**Table 5.** Two–limit Tobit model Allocative efficiency result

| | | Robust | | |
|---|---|---|---|---|
| **Allocative efficiency** | **Coefficient** | **Standard error** | *t* | *P* >\|t\| |
| **Constant** | 0. 4245 | 0.0410 | 10.34 | 0.000 |
| age | 0.00295 | 0.00112 | 2.63 | 0.009 |
| gender | 0.03578 | 0.0146 | 2.45 | 0.015 |
| education | -0.01065 | 0.00709 | -1.50 | 0.134 |
| hhsize | -0.0061 | 0.0030 | -2.06 | 0.040 |
| famincome | 2.90e-06 | 1.22e-06 | 2.38 | 0.018 |
| experience | -0.0035 | 0.0016 | -2.22 | 0.027 |
| dismarket | -0.00102 | 0.00073 | -1.41 | 0.159 |
| acccredit | -0.01145 | 0.013 | -0.88 | 0.379 |
| groupmm | 0.0517 | 0.013 | 3.84 | 0.000 |
| training | 0.0553 | 0.012 | 4.49 | 0.000 |
| extservice | 0.03108 | 0.013 | 2.45 | 0.015 |
| seedvariety | 0.0463 | 0.014 | 3.35 | 0.001 |
| Number of obs = | 366 | | | |
| R $Chi^2$ (12) = | 153.53 | | | |
| Prob > $Chi^2$ = | 0.0000 | | | |
| Log likelihood = | 326.92949 | | | |
| Pseudo $R^2$ = | -0.3068 | | | |

The age of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was significant at a 5% level. According to the marginal effect result, as the age of the household head increased by a year, the probability of allocative efficiency increased by 0.30%, when other factors were kept constant. This indicates that the older farmers are more efficient than the younger ones. This may be because allocative efficiency requires knowledge and skill gathered over time, which increases the capacity of farmers for optimal allocation of resources and technology. This suggested that older farmers were more efficient than their young counterparts. The reason for this may probably be that the farmers become more skillful as they grow older due to cumulative farming experiences. This is consistent with the findings of Daniel (2016).

Family income of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was significant at a 5% level. From the marginal effect result, a unit increase in the family income owned by a household increased the probability of allocative efficiency by about 0.00029 percent when other variables were kept constant. As these family incomes increase positively, the efficiency of farmers improves. This result is because the availability of family income shifts the cash constraint outwards and enables farmers to make timely purchases of those inputs that they cannot provide from on-farm income. Therefore, it enables farmers to maximize their output by allocating efficiently at an efficient cost of production. The result is in line with the findings of Hasen (2011), Abebayehu (2011), and Mustefa (2014).

**Household size** (family size) of the household head showed a negative effect on the allocative efficiency (AE) of the maize farms in the study area, and it was significant at a 5% level. From the marginal effect result, a one-person increase in household size would decrease the probability of allocative efficiency of farmers by about 0.61 percent when other variables are constant. This might be because farmers with

large family sizes had less good capacity for optimal allocation of resources. This result is consistent with the findings of Daniel (2016) and Hika (2016).

Group membership of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms in the study area, and it was significant at a 1% level. From the marginal effect result, Farmers who were members of farmers' co-operatives improved their allocative efficiency levels by 5.16 percent compared to those who failed to join farmer groups, assuming that other variables are kept constant. Theoretically, membership in social organizations helps producers in achieving efficiency. This result is consistent with the findings of Waluse (2012) and Bealu (2013).

Extension service was also found to affect allocative efficiency (AE) level positively and significantly at a 5% level. From the marginal effect result, According to the findings, maize farmers who accessed extension services pointed out a higher level of probability of allocative efficiency by 3.11% than those who failed to access the services. Besides, the frequency of extension contact was an important factor that affected the allocative efficiency of farmers in the study area. This result was due to new skills and information farmers learned from development agents. This result is consistent with the findings of Mustefa (2014), Tarekegn (2017), Desale (2017), Daniel (2016), and Bealu (2013). From the marginal effect result, increasing extension contact by a single day increases the possibility of maize market participation by 0.47%.

Experience: The effect of farming experience, usually measured in the number of years the farmer has been involved in maize farming, is one of the socio-economic factors that has been given greater attention in many stochastic production function literature. Experience significantly affected the allocative efficiency (AE) of the sampled households at a 5% level of significance. From the marginal effect result, as the farming experience increased by one year, the probability of allocative efficiency of farmers decreased by 0.34 when other factors were kept constant. However, the sign of the coefficient for allocative efficiency is negative and contradictory to the expectation. Its negative sign might be due to farmers having more experience in farming may not be responsive to modern input combinations that minimize their costs.

Farmers with many years of production experience have higher capital accumulation than those farmers who have little experience. Therefore, once the farmer accumulates capital, the desire for farming might be weak, and he will shift to other business activities instead. So, this might lead to decreasing efficiency of smallholder farmers in maize production. This result is in line with the earlier research findings of Getachew (2017), Musemwa *et al* (2013), Hika (2016), and Gosa (2014).

Training of the household head showed a positive effect on the allocative efficiency (AE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the number of farmers who attended training in maize production increases the probability of allocative efficiency of farmers by about 5.53 percent than farmers who did not. It can be concluded that training enabled them to use inputs in a cost-minimizing input ratio. This result is in line with the finding of Nejuma (2012).

Seed verity of the household head showed a positive effect on allocative efficiency (AE) of the maize farms and was significant at a 1% level. From the marginal effect result, farmers using improved seed variety of the household head increase the probability of the allocative efficiency of the farmers by about 4.63% when other variables remain constant. This result is consistent with the findings of Bealu *et al*, (2013). The use of improved seeds will also increase efficiency.

### 3.5 Determinants of Economic Efficiency

According to the results, ten in twelve variables were found to have a significant contribution to economic efficiency.

Gender of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 1% level. The marginal effect result shows the sex of the household head from (0=F, 1=M) increases the probability of economic efficiency of farmers by about 4.36 percent. Male-headed farm households were more likely to make market-oriented decisions than female-headed households. This result was because female-headed households were exposed to resource constraints for crop production.

**Table 6.** Two–limit Tobit model economic efficiency result

| | | Robust | | |
|---|---|---|---|---|
| **Economic efficiency** | **Coefficient** | **Standard error** | *t* | *P* >\|t\| |
| **Constant** | 0.6345 | 0.0279 | 22.70 | 0.000 |
| age | 0.00224 | 0.00081 | 2.75 | 0.006 |
| gender | 0.0437 | 0.1028 | 4.26 | 0.000 |
| education | -0.00625 | 0.0048 | -1.31 | 0.192 |
| hhsize | -0.0043 | 0.0021 | -2.09 | 0.037 |
| famincome | 1.89e-06 | 8.50e-07 | 2.23 | 0.027 |
| experience | -0.00338 | 0.00108 | -3.11 | 0.002 |
| dismarket | -0.0011 | 0.00049 | -2.22 | 0.027 |
| acccredit | -0.0118 | 0.0087 | -1.35 | 0.177 |
| groupmm | 0.0385 | 0.0090 | 4.23 | 0.000 |
| training | 0.0433 | 0.0084 | 5.13 | 0.000 |
| extservice | 0.0285 | 0.0086 | 3.32 | 0.001 |
| seedvariety | 0.03079 | 0.0092 | 3.32 | 0.001 |
| Number of obs | = | 366 | | |
| LR $Chi^2$ (12) | = | 196.34 | | |
| Prob > $Chi^2$ | = | 0.0000 | | |
| Log likelihood | = | 450.24502 | | |
| Pseudo $R^2$ | = | -0.2788 | | |

The age of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the farmer's age by one year increases the level of probability of economic efficiency by 0.22% when other variables were kept constant. Therefore, the older farmers are the more economically efficient. The results show that the aged head of household is more efficient and produces the output efficiently. This result ensured that aged households have more experience and use their past learning in the production process to produce more output with a given level of inputs efficiently. This result is consistent with the findings of Tarekegn (2017) and Nejuma (2012).

Family income of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 5% level. From the marginal effect result, a unit increase in the family income owned by a household increased the probability of economic efficiency by about 0.0002 percent when other variables were kept constant. The result was consistent with Solomon (2014).

Household size (family size) of the household head showed a negative effect on the economic efficiency (EE) of the maize farms in the study area, and it was significant at a 5% level. From the marginal effect result, one person increases the household size of a household head and decreases the probability of economic efficiency by about 0.43 percent when other variables were kept constant. Household size is an unexpected sign in economic efficiency; a possible reason for the expected might be that a larger household size guarantees the availability of family labor for farm operations to be accomplished in time. At the time of peak seasons, there is a shortage of labour, and hence households with large family sizes would deploy more labour to undertake the necessary farming activities, like ploughing, weeding, and harvesting on time than their counterparts and hence, they are more efficient in maize production.

Group membership of the household head showed a positive effect on the economic efficiency (EE) of the maize farms in the study area, and it was significant at a 1% level. From the marginal effect result, Farmers who were members of farmers' cooperatives increased the probability of economic efficiency of farmers by about 3.84 percent compared to those who failed to join farmer groups, keeping other variables constant.

Farmer membership in farmer cooperatives is used as a proxy for measuring the role of social organization in the production process. Farmers who are members of farmer cooperatives receive more viable information on production technologies than farmers who are not. As a result, they experiment and apply new production technologies, and hence, they are more efficient in maize production. This result is consistent with the findings of Waluse (2012) and Bealu (2013).

Extension service was also found to affect economic efficiency (EE) level positively and significantly at the 1% level. From the marginal effect result, according to the findings, maize farmers who accessed extension services pointed out a higher probability of economic efficiency by 2.85% than those who failed to access the services when other variables remained constant. This result might be due to the information obtained from extension workers had the power to increase the awareness and know-how of farmers towards technologies and efficient utilization of the existing resources to decrease their inefficiency and wastage of resource use. That is, farmers who had more extension contact during the cropping period were economically more efficient than those who had less extension contact during the cropping period. Thus, the frequency of extension contacts with development agents is crucial to increasing the economic efficiency of maize production in the study areas. Farmers who had more contact with such agents improved their access to improved inputs and farming management practices, thereby increasing their production efficiencies. This result is consistent with the findings of Desale (2017), Daniel (2016), and Bealu (2013).

**Experience on farming** unexpectedly, the coefficient of farming experience of farmers on maize production negatively affected the economic efficiencies (EE) of farmers significantly at a 1 % level of probability. The marginal effect result, as the farming experience increased by one year, the probability of economic efficiency of farmers was decreased by 0.34 when other factors remained constant. Its negative sign might be due to those farmers having more experience in farming not being responsive to modern inputs combination that minimizes their costs. They may be experienced more on their traditional technology, which consumes more money and time. However, the sign of the coefficient for economic efficiency is negative, which is contradictory to our expectations. Farmers with many years of production experience have higher capital accumulation than those who have little experience. Therefore, once the farmer accumulates capital the desire for farming might be weak, and he will shift to other business activities instead.

**Distance to the market** of the household head showed a negative effect on the economic efficiency (TE) of the maize farms and was significant at a 5% level. The marginal effect result revealed that an increase in the distance to the market by one kilometer reduced the level of probability of economic efficiency by about 0.11 percent, and other variables remained constant. This implies that since the farmers are far from the market, their inefficiency increases because it incurs more costs to transport inputs and outputs, transaction costs, and market information. This result is consistent with the findings of Essa (2011), Hassen (2011) and Musa *et al*(2015).

Training of the household head showed a positive effect on the economic efficiency (EE) of the maize farms and was significant at a 1% level. From the marginal effect result, an increase in the number of farmers who attended training in maize production increases the probability of economic efficiency of farmers by about 4.32 percent than farmers who did not. This result suggests that farmers who attended training in maize production-related courses are supposed to be more efficient than those who did not, but the result of this study states otherwise. This result also indicated that farmers who attended training in the study area were more efficient than farmers who did not.

The seed variety of the household head showed a positive effect on the economic efficiency (EE) of

the maize farms and was significant at a 1% level. From the marginal effect result, Farmers using improved seed Variety of the household head increase the probability of economic efficiency of a farmer by about 3.07 percent when other variables were kept constant. This result is consistent with the findings of Essa (2011), Nejuma (2012), and Bealu *et al*, (2013). The impact of improved maize varieties on economic efficiency is very high. Most improved varieties released by agricultural research institutes worldwide have proven to be high-yielding vis-a-vis traditional varieties.

## 4 Conclusion and Recommendations

This study was conducted to estimate Technical efficiency, Allocative efficiency, and Economic efficiency and to identify factors affecting economic efficiency among maize Producer households in Dega Damot *Woreda*, Amhara Regional State, Ethiopia.

The agricultural outputs could be increased either through the introduction of modern technologies or by improving the efficiency of inputs. This implies the need for the integration of modern technologies with improved levels of efficiency.

Several studies have dealt with the technical efficiency of farmers in developing countries. However, many of the researchers focused only on technical efficiency. So, technical and allocative efficiency are essential in improving the productivity gains from existing technology. Also, there was no study on the economic efficiency of smallholder maize producers in the study area. The estimates of the Tobit regression model also showed that among the total variables, nine (sex of household, education level, distance to market, access to credit, household size, extension service, group membership, training and seed Variety) were statistically significant in affecting the level of technical efficiency, whereas, nine variables (household head age, family income, gender, household size, experience, group membership, training, seed variety and extension service) significantly influence allocative efficiency of maize production. Moreover, the result of the model also revealed that ten (Age, gender, group membership, training, extension service, distance to market, experience, household size, family income, and seed variety) factors were important in influencing the economic efficiency of households in the study area. The study results also revealed that there is considerable variability in all efficiency scores of sample households in the production of maize in the study area. Therefore, less efficient farmers increase their efficiency level by adopting the practices of relatively efficient farmers in the area. So, based on the results, suggestions are made for increasing the productivity and efficiency of maize production. Therefore, based on the findings of this study, policy implications are made to enhance resource use efficiency and increase maize productivity in the study area.

A high level of financial support should help to acquire necessary inputs for maize production and expand extension services for easy adoption of technology and implementation of inputs used. Attainment level is an important factor in TE, AE, and EE, the key policy implication is that appropriate policy should be designed to provide adequate and effective basic educational opportunities for farmers in the study area. The government should invest in and encourage credit service provider satisfaction to solve problems associated with the utilization of credit.

Policies and strategies that improve extension services could help raise the efficiency of maize production. Hence, the number of visits by households to extension agents should be increased through subsequent training programs.

Further, given the complementarities of extension services, the expansion of basic and functional educational provisions in rural areas must be considered a key strategy for achieving increased Smallholder household agricultural productivity.

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### Conflict of Interest

The authors declare that they have no known competing financial interest or personal relationship that

could have appeared to influence the work reported in this paper.

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# Ethnobotanical survey of traditional medicinal plants used to treat human ailments in Arero District, Borena Zone, Ethiopia

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## Abstract

*Pastoralist communities have traditionally possessed extensive knowledge regarding the plants and grazing areas in their vicinity, acquired through continuous practice and meticulous observation. As members of the Borana pastoralist communities, the people residing in the Arereo District utilize a variety of plant resources found in their rangelands. In order to evaluate the traditional use of medicinal plants in treating human ailments in Arero District, Borena Zone, an ethnobotanical study was conducted. The primary objective of this study was to document the medicinal plants employed by the local community. Fifty-one key informants were purposefully selected to participate in the study. Data was obtained through the use of questionnaires, focus group discussions, and field observations. In the study area, a total of forty-four medicinal plant species belonging to thirty-six genera and twenty-four plant families, were identified and documented. These plants were reported to be used in the treatment of thirty-five different human ailments. Among the various plant parts used for medicinal purposes, roots were found to be the primary source of remedies (47.7%), followed by leaves (13.6%). Of the remedies documented, 59.7% were prepared for internal use, with oral consumption being the most common method (53.73%). Additionally, 40.3% of the remedies were intended for external applications. The decoction was the predominant method of remedy preparation, accounting for 41.8% of the remedies known in the study area. The findings indicated that the local community possessed valuable knowledge regarding the use, preparation, and application of medicinal plants for the treatment of human ailments. However, it was also noted that certain medicinal plants in the study area, such as Vachellia nilotica and Vachellia tortilis, were reported to be locally threatened. It is crucial to pay adequate attention to prevent further threats to these medicinal plants and to conserve them, along with the associated local knowledge. Efforts should be made to safeguard the medicinal plant resources in the study area, ensuring their sustainable use and preservation for future generations.*

**Keywords/Phrases**: Borena, Human ailments, Indigenous knowledge, Medicinal plant, Traditional healers

## 1 Introduction

Plants play a crucial role in the lives of human beings, providing essential resources for their well-being and fulfilling their basic needs. The utilization of plants by humans can be traced back to the process of domestication, which originated about 10,000 years ago (Martin, 1995). Over time, indigenous communities have developed their own specific knowledge regarding the use, management, and conservation of plants in their local environments. This indigenous knowledge (IK) is continuously adapted to changing circumstances, passed down through generations, and deeply intertwined with cultural values (Cotton, 1996).

Ethiopia is recognized for its rich plant biodiversity, boasting approximately 6,000 species of higher

plants (Hedberg *et al*., 2009). Throughout various regions of the country, people have long relied on medicinal plants to treat human and animal ailments. Traditional Ethiopian medicine has relied heavily on the use of plants for centuries (Debela *et al*., 1999; Fullas, 2007), becoming an integral part of Ethiopian society due to its long-standing practice (Kaba, 1998). In fact, it has been estimated that around 80% of Ethiopians rely on traditional herbal remedies (Abebe, 1996). The high prevalence and interest in medicinal plants in Ethiopia can be attributed to their acceptability, accessibility, and biomedical benefits (Abebe, 2001).

The southern and southwestern regions of the country, known for their biological and cultural diversity, exhibit a particularly rich diversity of medicinal plants (Tadesse & Demissew, 1992). Knowledge and services related to traditional medicinal plants are passed down from family members, neighbors, and communities, ensuring their continuity across generations (Yirga, 2020).

Traditional healers and those who have benefited from these practices have been the primary disseminators of information regarding medicinal plants and their applications (Punjani, 2010). However, the restricted availability of this knowledge to the wider public has led to its concealment, making traditional medicinal plant knowledge and skills more hidden (Abbink, 1995). Consequently, the potential loss of this valuable knowledge looms as traditional healers and elderly community members pass away.

In Ethiopia, the documentation of local knowledge concerning traditional medicinal plants and their uses remains incomplete (Abbink, 1995; Getahun, 1974). As much of this knowledge is transmitted orally from one generation to the next, the disapproval of traditional medicine practitioners jeopardizes the future preservation of the country's cultural heritage (Kibebew, 2001).

The Borana pastoralists, with their diverse cultures, unique traditional practices, and distinct livelihood systems, utilize a variety of plants for traditional medicines, food, forage, construction materials, household implements and utensils, firewood, and more, much like other ethnic groups in Ethiopia. Additionally, certain plant species hold ritual and commercial significance and provide shade.

The Arero District, situated within the pastoralist areas of Borana, boasts a wealth of indigenous medicinal plant knowledge. Community members often rely on herbal remedies derived from medicinal plants to address a wide range of human ailments. However, the knowledge held by the community has been largely overlooked by researchers. The indigenous knowledge associated with the use and practices of medicinal plants in this region remains poorly documented, limited to traditional healers and a select group of community members. This situation poses a significant risk to the future preservation of medicinal plants, traditional knowledge, and their utilization. Therefore, the objective of this study was to assess and document the medicinal plants used in the treatment of human diseases and associated practices in the Arero District.

## 2 Research Methodology

### 2.1 Description of the Study Area

The study was carried out in Arero District, Borana Zone, Southern Ethiopia, as described by the Dalle (2020). Arero District is situated approximately 660 km south of Addis Ababa. Geographically, the district is located between $38^0$15' - $39^0$30' East longitude and $3^0$45' - $5^0$15' North latitude (Figure 1). It covers a total area of 3660 km$^2$ and exhibits a diverse landscape characterized by plains, undulating topography, hills, and gorges. The elevation of Arero District ranges from 700 to 1,600 meters above sea level.

The study area, as mentioned by the Dalle (2020), is primarily recognized for its semi-arid agroclimatic conditions. It experiences a bimodal rainfall pattern. Based on data obtained from the National Meteorological Agency (NMA, 2021) for the Yaballo Meteorology Station, the mean annual rainfall and temperature in the area are recorded as 603 mm and $20^0$C, respectively.

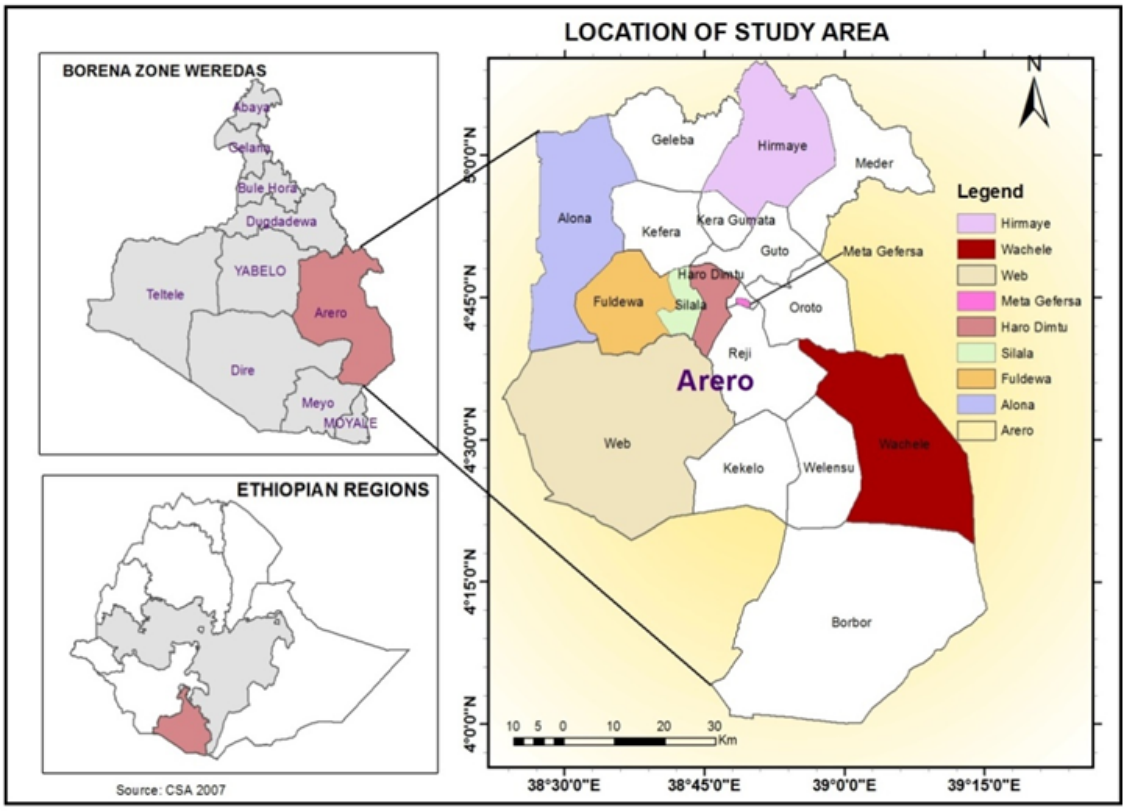


**Figure 1.** Map of the study area (right), Ethiopia (bottom left), Borena Zone (top left)

## 2.2 Sampling

For the sampling process, a total of fifty-one traditional healers (37 male and 14 female) residing in eight *Kebeles* within Arero District were purposefully selected, following the approach outlined by Martin (1995). The selection of traditional healers was based on information acquired from the elderly and local community leaders in the respective *Kebeles*. In accordance with the "Rule of Thumb'' for purposive sampling, which suggests a sample size of at least 10% of the population or 30 for smaller populations, a sample size of 30% of the total traditional healers (170) in the study area was deemed appropriate. Consequently, a proportional number of traditional healers from each *Kebele* were included in the sample (Table 1). The selection of key informants was based on their profile, experience, and history of practice.

**Table 1.** Number of traditional healers in the study area and sampled

| Name of the *Kebeles* | Number of traditional healers in the *Kebele* | Number of traditional healers sampled |
|---|---|---|
| Alona | 20 | 6 |
| Fuldowa | 16 | 5 |
| Silala | 23 | 7 |
| Haro-dimtu | 21 | 6 |
| Mata-Gafarsa | 24 | 7 |
| Wachile | 24 | 7 |
| Web | 19 | 6 |
| Hirmaye | 24 | 7 |
| Total | 171 | 51 |

### 2.3 Ethnobotanical Data Collection

To collect ethnobotanical data, standard methods of ethnobotanical techniques and herbarium preparation, as described by the Martin (1995) and Alexiades (1996), were employed. The techniques used included focus group discussions with various groups of people, including traditional healers, *Kebele* authorities, and elderly community members (both male and female). Semi-structured interviews with traditional healers and field observations were also conducted. The primary source of ethnobotanical data was the interviews conducted with the traditional healers.

During the interviews, the following information was gathered from the informants: human ailments treated by traditional healers using medicinal plants, local names of medicinal plants used for specific ailments, plant parts used for preparing remedies, methods of remedy preparation and administration, knowledge transfer related to medicinal plants, and threats to medicinal plants.

In addition to the interviews, a focus group discussion was conducted to rank the preference of medicinal plants for snake bites, which is a frequently occurring incidence in the area. The discussion also included topics such as knowledge transfer and threats to medicinal plants.

### 2.4 Data Synthesis or Analysis

Descriptive statistics were utilized to summarize and describe the collected ethnobotanical data, with percentages and frequencies used for data presentation. Microsoft Excel 2016 was employed to organize quantitative data, calculate proportions, and create tables and graphs. For the analysis of qualitative data obtained through interviews and focus group discussions, NVIVO 12, a software for qualitative data analysis, was utilized.

According to the traditional healers, snake bites were reported as the most prevalent incidence among community members seeking traditional medication. The preference ranking of five medicinal plants used for preparing remedies for snake bites was conducted by seven key informants, following the methodology outlined by Martin (1995). During the focus group discussion, the informants compared the given medicinal plants based on their knowledge of their effectiveness in treating the illness and assigned scores ranging from 1 to 5, with 5 indicating the most effective and 1 indicating the least effective. The scores assigned to each medicinal plant species were then totaled to determine the overall rank of preference.

Furthermore, a direct matrix ranking, a more complex version of preference ranking (Martin, 1995; Cotton, 1996), was performed to assign scores to seven medicinal plants reported to have multiple uses in addition to their medicinal value. The seven multipurpose plant species included *Boscia mossambicensis*, *Grewia tembensis*, *Grewia villosa*, *Lanea rivae*, *Pappea capensis*, *Vachellia nilotica*, and *Vachellia tortilis*. These plants were reported to be used for various purposes in the study area, such as forage, medicine, traditional cleansing, construction of houses or corrals, firewood, charcoal, farm and household implements, shade, rituals, and wild edible food. Seven randomly selected key informants (traditional healers) were asked to score each multipurpose plant based on its uses. The attributes considered were medicinal use, firewood, charcoal, construction, live fence, and fodder. Each key informant independently assigned scores ranging from 0 to 5 (where 0 = not used, 1 = less used, 2 = moderate, 3 = good, 4 = very good, and 5 = the best) for each medicinal plant in relation to its preferred uses. The scores given for each attribute and corresponding multipurpose plant species were summed up to obtain a total score for each plant. The seven multipurpose plant species were then ranked based on their respective total scores.

## 3 Results and Discussion

### 3.1 Demographic Feature of Informants

In this study, a total of informants participated. Among them, 72.54% were male, while 27.45% were female. The informants were categorized into three age groups for the collection of basic ethnobotanical data. Specifically, 7.84% were between 20 and 35 years old, 31.37% were between 36 and 55 years old, and 60.78% were above 55 years old (Table 2).

**Table 2.** Demographic profile of the informants

| Demographic Attributes | Characteristics | Male | Female | Total | Percentage (%) |
|---|---|---|---|---|---|
| **Sex:** | Female | - | 14 | - | 27.45 |
| **Sex:** | Male | 37 | | - | 72.54 |
| **Age group:** | 20-35 years | 4 | - | 4 | 7.84 |
| | 36-55 years | 7 | 9 | 16 | 31.37 |
| | Above 55 years | 26 | 5 | 31 | 60.78 |
| **Literacy:** | Illiterate | 30 | 12 | 42 | 82.35 |
| | Literate | 7 | 2 | 9 | 17.64 |
| **Livelihood category:** | Agropastoralist | 4 | 2 | 6 | 11.76 |
| | Pastoralist | 33 | 12 | 45 | 88.24 |

### 3.2 Species Composition of Medicinal Plants

The plant family with the highest number of medicinal plant species in this study is Fabaceae, which includes eleven species. This is followed by Solanaceae with four species, Euphorbiaceae with three species, and Anacardiaceae, Apocynaceae, Capparidaceae, Cucurbitaceae, and Tiliaceae with two species each. Additionally, sixteen other families were represented by one species each (Table 3).

The ecological success of the Fabaceae family can potentially be attributed to its ability to form root nodules containing nitrogen-fixing bacteria, although it is important to note that not all Fabaceae species fix nitrogen. This finding aligns with the results of previous studies conducted by Hunde (2001), Teklehymanot & Gidey (2007), Amenu (2007), Tolosa (2007), Yineger & Yewhalaw (2007), and Tamene (2011), where the family Fabaceae also emerged as the predominant family of medicinal plants in their respective study areas.

**Table 3.** Plant families, number of medicinal plant species and proportions

| Plant family | Species richness | Percentage | Plant family | Species richness | Percentage |
|---|---|---|---|---|---|
| Fabaceae | 11 | 25.0 | Ascelpiadaceae | 1 | 2.3 |
| Solanaceae | 4 | 9.1 | Asparagaceae | 1 | 2.3 |
| Euphorbiaceae | 3 | 6.8 | Asteraceae | 1 | 2.3 |
| Anacardiaceae | 2 | 4.5 | Balantaceae | 1 | 2.3 |
| Apocynaceae | 2 | 4.5 | Boraginaceae | 1 | 2.3 |
| Capparidaceae | 2 | 4.5 | Ebenaceae | 1 | 2.3 |
| Cucurbitaceae | 2 | 4.5 | Lamiaceae | 1 | 2.3 |
| Tiliaceae | 2 | 4.5 | Plumbaginaceae | 1 | 2.3 |
| Acanthaceae | 1 | 2.3 | Rutaceae | 1 | 2.3 |
| Aloaceae | 1 | 2.3 | Sapindaceae | 1 | 2.3 |
| Amaryllidaceae | 1 | 2.3 | Sapindaceae | 1 | 2.3 |
| Apiaceae | 1 | 2.3 | Vitaceae | 1 | 2.3 |
| Total | 44 | 100.0 | Total | 44 | 100.0 |

Because of the remote nature of the study area and limited access to medical facilities, pastoralists in the study area heavily rely on traditional remedies (Dale *et al*., 2005). The medicinal plants documented in the current study were utilized for the treatment of 35 different human ailments (see Annex). As the

community in the study area consists of pastoralists, they do not cultivate medicinal plants in gardens. Instead, these medicinal plants are sourced from the wild. Due to the nomadic lifestyle of pastoralists, who move with their cattle in search of pasture and water, there is no practice of cultivating medicinal plants near residential areas.

Among the total documented medicinal plant species in the study area, 47.7% were shrubs, 29.6% were trees, 13.6% were herbs and 9.1% were lianas (Figure 2).

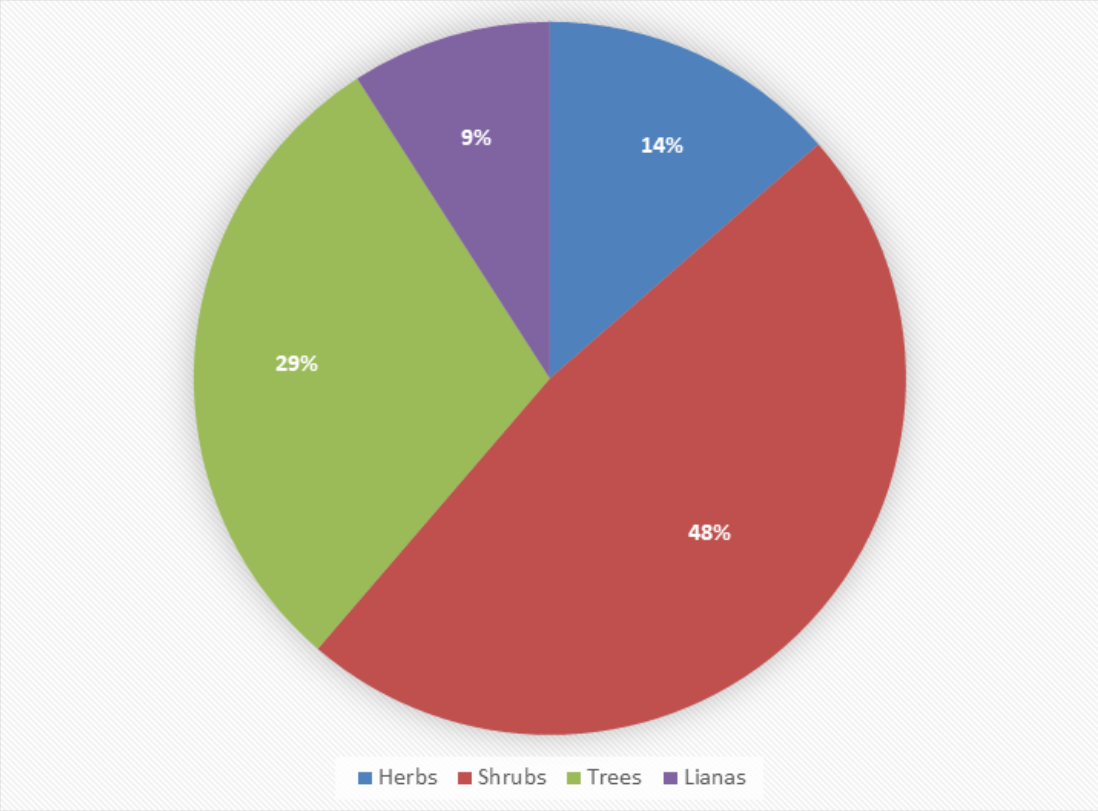


**Figure 2.** Proportion of growth forms of medicinal plants documented in the study area

Shrubby medicinal plant species were found to be prevalent in the study area and were frequently used due to their year-round availability. This finding is consistent with a study conducted by Hunde (2001) in Boosat District, where shrubs ranked first (at 59%), followed by herbs (14%). Similar findings were reported by Tamene (2000) in semi-wet lands of Cheffa area in South Wello, Tolasa (2007) in Gimbi District of western Wellega, Yineger & Yewhalaw (2007) in Sekoru District, and Tamene (2011) in Wondo-Genet Natural Forest and adjacent *Kebeles*, where shrubs were the most commonly encountered forms of medicinal plants. Additionally, Bekele & Ramachandra (2015) identified the widespread utilization of shrubs for medicinal purposes in the Dugda-Dawa and Abaya District of Borana Zone. Their study reported that shrubs, trees, herbs, and climbers accounted for 45.2%, 26.7%, 18.5%, and 9.6% of the total medicinal plants, respectively. However, the findings of Gebre (2005) in Konso Special District of SNNPRS and Amenu (2007) in Ejaji of Chelia District in West Shewa differed from these findings, reporting that herbaceous plants were the most commonly harvested for medicinal purposes. This disparity could be attributed to agroecological variations in these areas.

### 3.3 Medicinal Plant Parts Used for Remedy preparation

Among the medicinal plants documented, roots were widely used for the preparation of remedies, accounting for 47.7% of the total medicinal plants, followed by leaves (13.6%). Medicinal plants with barks being used accounted for 9.1%, while both roots and

leaves were used in 9.1% of cases, and other plant parts accounted for 9.1% (Figure 3). These findings contrast with previous studies conducted by Abebe & Hagos (1991), Tamene (2000), Amenu (2007), Tolosa (2007), and Yineger & Yewhalaw (2007), which found that leaves were the most commonly used plant parts for remedy preparations to treat health problems, followed by roots.

The variation in the relative abundance of herbaceous and woody medicinal plants resulting from agroecological differences and factors such as grazing and encroachment may contribute to these differences. However, it is important to note that the harvesting of plant parts such as roots and barks may have a negative impact on the survival and sustainability of medicinal plants in the study area.

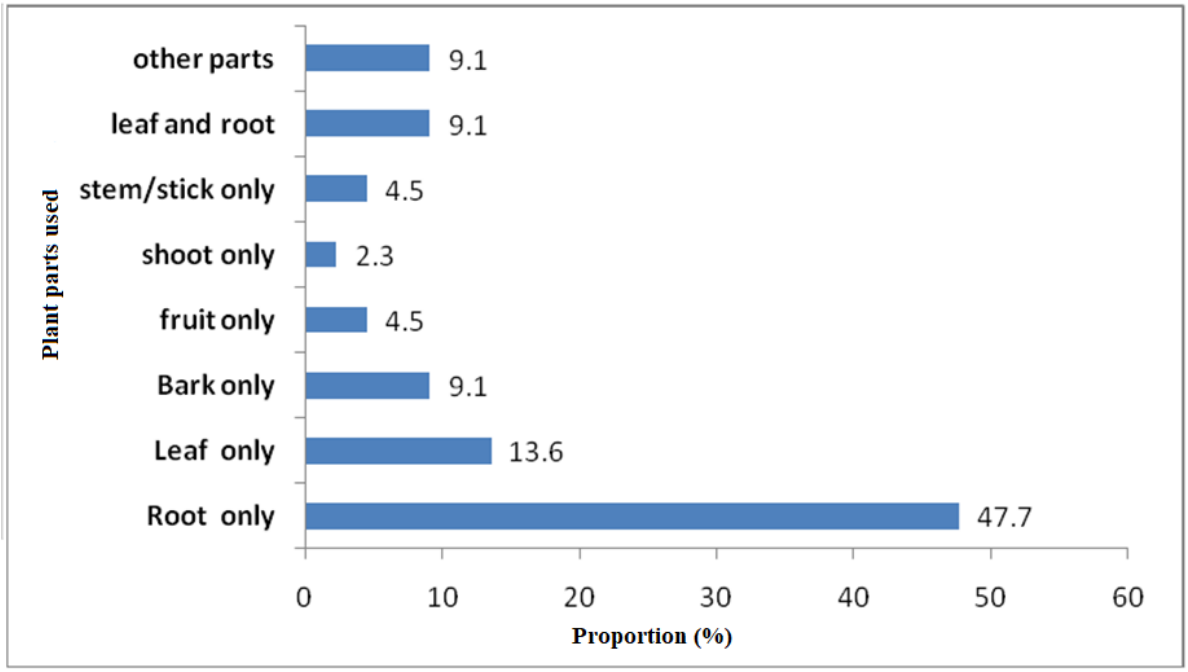


**Figure 3.** Medicinal plants parts used for preparation of remedies

### 3.4 Method of Preparation of Remedies

According to Dale *et al*. (2005), Borana pastoralists extensively utilize the available plant resources in their rangelands. It was observed that certain medicinal plants were used to prepare remedies for multiple diseases. The preparation of remedies from these medicinal plants can involve various methods. For example, a leaf of *Solanum giganteum* is rubbed to treat nasal bleeding, while decoctions from the same plant are used to treat the evil eye. Similarly, the latex at the shoot tip of *Croton macrostachyus* is used to treat *Tenea corporis*, while decoctions from the root of the same plant are used for rabies and snake bites, and the bark of *Croton macrostachyus* is utilized for intestinal parasites. In the current study area, decoction was found to be the most commonly employed method for remedy preparation, accounting for 41.8% of the remedy preparation methods, followed by rubbing, juice extraction, and hot and cold infusions (Figure 4).

It is important to note that the methods of remedy preparation utilized by communities may vary from one place to another or from one district to another. For instance, previous studies conducted by Abebe & Hagos (1991), Tamene (2000), Yineger & Yewhalaw (2007), Amenu (2007), and Tolosa (2007) have reported that pounding and powdering, or crushing and squeezing, were the most commonly used methods for remedy preparation.

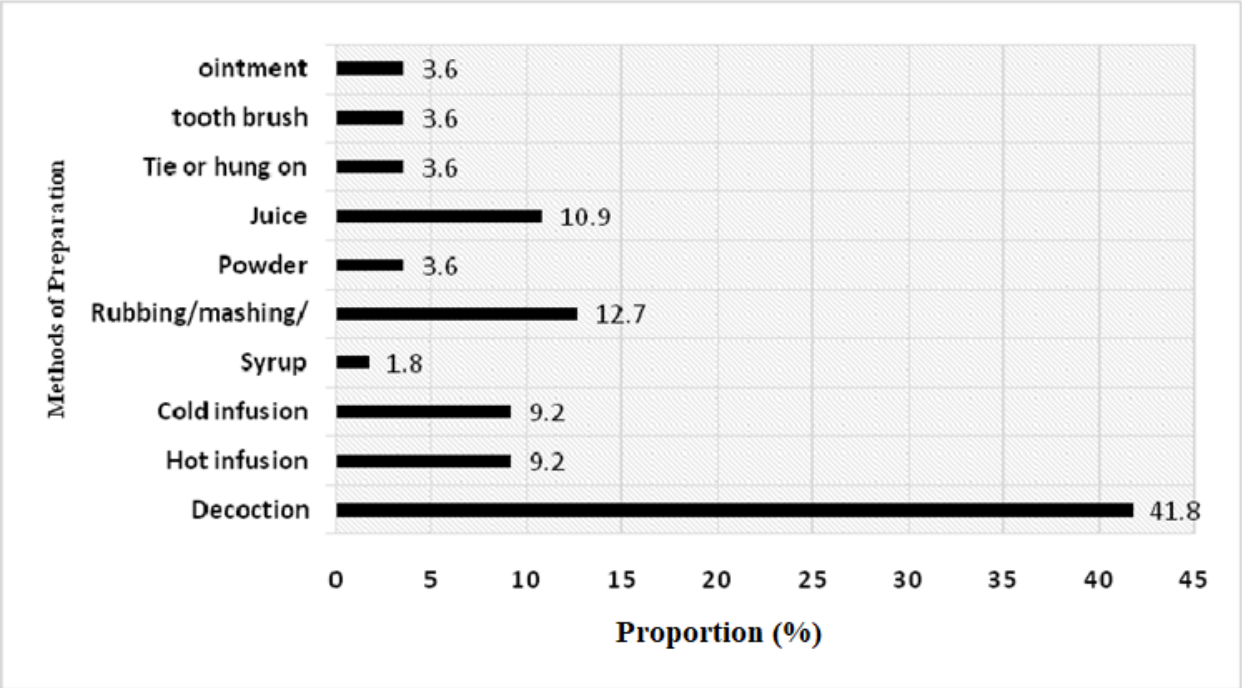


**Figure 4.** Modes of remedy preparations

Remedies in the study area were prepared either from a single medicinal plant or a combination of multiple medicinal plant species. The analysis revealed that 88.46% of the remedies were prepared from a single medicinal plant, while 11.54% were prepared from a combination of plants. This finding aligns with the results of Hunde (2001) and Tolasa (2007), where a higher proportion of remedies were also prepared from a single medicinal plant.

Borana pastoralists extensively utilized the available plant resources in their rangelands (Dale *et al*., 2005). Certain medicinal plants were found to be used for the preparation of remedies targeting multiple diseases. These remedies can be prepared using different methods. For example, the leaf of *Solanum giganteum* is rubbed to treat nasal bleeding, while decoctions from the same plant are used to address the evil eye. Similarly, the latex found at the shoot tip of *Croton macrostachyus* is used to treat *Tenea corporis*, whereas a decoction made from the root of the same plant is employed for the treatment of rabies and snake bites. Additionally, the bark of *Croton macrostachyus* is utilized for addressing intestinal parasites.

Regarding the forms in which medicinal plants were used, the majorities (77.27%) of the encountered plants in the study area were used in fresh form, while 22.73% were used both in fresh and dry conditions (Table 4). This reliance on fresh plant material limits the availability of medicinal plants during different seasons of the year. During the dry season, community members reported having to travel long distances in search of specific medicinal plants, as they were not readily available in the vicinity of their homes.

**Table 4.** List of medicinal plants in the study area used in fresh and both fresh & dry forms

| Medicinal Plants used in fresh form | Medicinal plants used in both fresh and dry forms |
|---|---|
| *Albizia anthelmintica* (A. Rich.) Brongn. | *Acokanthera schimperi* (A.DC.) Schwevinf |
| *Aloe secundiflora* Engl. | *Boscia mossambicensis* Klotzsch. |
| *Asparagus racemosus* Wild. | *Carissa edulis* Vahl. |
| *Balanites aegyptica* (L.) Del. | *Croton dichogamus* Pax |
| *Barleria spinesepala* (Ait.) Benth. | *Croton macrostachyus* Del. |
| *Bidens hildebrandtii* O. Hoffm. | *Ehretia cymose* Honn. |
| *Calpurnia aurea* (Ait.) Benth. | *Euclea divinorum* Heirn |
| *Capparis tomentosa* Lam. | *Grewia tembensis* Fresen |
| *Cissus quadrangularis* L. | *Grewia villosa* Wild |
| *Crinum abyssinicum* Hochst. Ex A. Rich | *Zanthoxylum chalybeum* Engl. |
| *Cucumis dipsaceus* Ehrenb. ex Spach | |
| *Dichrostachys cinerea* (L) Wight et Arn. | |
| *Euphorbia nubica* NE.Br. | |
| *Euphorbia schizacantha* Pax. | |
| *Gnidia stenophylla* Gilg. | |
| *Indigofera volkensii* Taub. | |
| *Kedrostis pseudogijef* (Gilg.) C. Jiffrey | |
| *Lanea revea* (Chiov.) Sacleux | |
| *Ocimum lamiifolium* Hochst. Ex Benth | |
| *Ormocarpum trichocarpum* (Taub.) Engl | |
| *Pappea capensis* Eckl. & Zeyh. | |
| *Plumbago zeylanica* L. | |
| *Searsia tenuinervis* (Engl.) Moffett | |
| *Senegalia brevispica* (Harms) Seigler & Ebinger | |
| *Senegalia mellifer*a (Vahl) Seigler & Ebinger | |
| *Solanum giganteum* Jacq. | |
| *Solanum incanum* L. | |
| *Solanum somalense* Franchet | |
| *Steganotaenia araliacea* Hochst | |
| *Sterculia stenocarpa* H. Winkler | |
| *Vachellia etbaica* (Schweinf.) Kyal. & Boatwr. | |
| *Vachellia nilotica* (L.) P.J.H.Hurter & Mabb. | |
| *Vachellia tortilis* (Forssk.) Galasso & Banfi | |
| *Withania somnifera* (L.) Dunal | |

### 3.5 Routes of Administration of Remedies

Internal routes of administration accounted for the highest proportion (59.7%) compared to external modes of administration (40.3%). Among the internal routes, oral application (53.73%) of remedies was relatively more common. Similarly, painting and washing (7.46% each) were relatively more prevalent among the external routes of administration (Table 5).

For remedies administered orally, it was observed that they were often consumed with milk tea, curdled milk, honey, salts, or '*Maqado*' and sugar. These additional ingredients were used to mitigate the smell, discomfort, potency, and taste of the medicine.

**Table 5.** Modes of administrations/applications of remedies

| Mode of use | Routs of application | Percentage (%) |
|---|---|---|
| Internal | Oral (solid, semi-solid, or liquid form) | 53.73 |
| | Inhale vapor of decoction, infusion, or smoke | 5.97 |
| External | Chewing & spitting on the affected body part | 5.97 |
| | Steam or vapor bath | 5.97 |
| | Poultice | 2.99 |
| | Hanging | 2.99 |
| | Compressing | 2.99 |
| | Painting or rubbing | 7.46 |
| | Washing | 7.46 |
| | Using the plant as a tooth brush | 4.47 |

Remedies administered by traditional healers often lack precise measurements and standards for preparation and administration. Measurements are often estimated using terms such as hand full, pinch, finger length, or a number of leaves. Oral remedies are measured using units like '*kookii*', '*nyaree*', '*galasa*', and '*Xaasaa*' (cup, glass, or tin). Furthermore, the administration and measurements can vary among different traditional healers. This finding is consistent with the studies conducted by Getahun (1976), Sofowora (1993), and Abebe (1986), which also highlighted the lack of precise measurements and standardization as a drawback in the traditional healthcare system.

Traditional healers believe that if a person is given an overdose of a remedy, consuming milk can counteract its effects. Additionally, adverse effects of traditional medicines can be mitigated or regulated by consuming milk or other additives such as honey, coffee, or tea. Similar results have been reported by Giday *et al*. (2009), Tamene (2000), and Amenu (2007). Abebe (1986) also identified the use of additive substances in the preparation of herbal remedies.

Informants mentioned that there are specific pre- or post-conditions that patients need to fulfill before or after taking certain remedies. Failure to meet these conditions can lead to severe adverse effects or even death. For instance, a patient using *Aloe secundiflora* should avoid consuming meat and milk until the treatment is completed, as it may have fatal effects. There are also situations where patients are advised not to look into water or a mirror, avoid washing or bathing, and expose themselves to the sun for specific periods of time continuously for seven to fourteen days while undergoing treatments for rabies. Similar practices have been reported by Amenu (2007) and Tolosa (2007).

Certain medicinal plants are well-known among community members, while others are kept secret and known only by traditional healers. For example, *Ocimum lamifolium*, *Solanum giganteum*, *Euphorbia schizacantha*, and *Croton macrostachyus* are commonly used at home by community members for preparing remedies to treat febrile illness, nasal bleeding, influenza (common cold), and ringworm, respectively. However, the treatment of other ailments such as evil eye, hemorrhoids, gonorrhea, ulcers, rabies, and snake bites is entrusted to traditional healers who specialize in preparing remedies based on the stage, complexity, and condition of the patients. Similar practices have been reported in the studies conducted by Tolosa (2007) and Tamene (2011). Therefore, depending on the nature or type of health problem, local people in the study area attempt to manage their health issues at home before seeking other options.

The diagnosis and treatment methods employed by traditional healers depend on the specific ailment. When a patient visits a local traditional healer, the practitioner typically conducts an interview and vi-

sually inspects the patient to identify the illness or health problem. The interview focuses on gathering information about the symptoms and the onset of the health problem. The practitioner then visually examines the patient's eyes, tongue, skin color, urine color, body temperature, and checks for sores or wounds before preparing and prescribing remedies.

According to the respondents, three main factors influence their choices for treatment when they fall ill. These factors include the ease of access to treatment, the perceived effectiveness of the treatment, and the cost associated with it. In terms of access, local healers are conveniently located within reachable distances from modern healthcare institutions in the locality.

In this community, there is a traditional rule of 'pay once and be treated until you are cured' that is followed by traditional healers and their clients. This finding is consistent with the study conducted by Tolosa (2007). According to this rule, once payment is made for the treatment of a particular health problem, no further payment is requested by the traditional healer until the patient is cured. Clients typically present coffee beans and chewable tobacco ('*Buna-fi-tambo*') as a gift or payment after receiving treatment from a local healer. This gift is locally known as '*Darara*'. After the patient recovers from their illness, it is customary for them to invite the healer to their home, hold a '*Bunaqala*' ceremony, and receive blessings from the healer. In cases where a patient is unable to make a payment, they may offer a few blades of fresh grass to the healer as a sign of respect and acknowledgment of the treatment. This is known as '*Irressaa*' in the local context. In some regions of the country, monetary payments are made instead. According to the informants, if the practice of '*Darara*' is avoided, they believe that the curative value of the remedies will fail, and the disease may reappear in the patient.

### 3.6 Medicinal Plants Knowledge Transfer

According to the information obtained from the local administration in 3.6 of the study, it was found that there is a higher number of male traditional healers compared to female traditional healers in the study area. The transfer of medicinal plant knowledge and healing practices among traditional healers is typically passed down to a family member or a close relative. However, the choice of individuals for knowledge transfer is not the same among family or community members. In this context, parents (traditional healers) in the study area tend to prefer boys over girls for the transfer of medicinal plant knowledge. This preference is attributed to boys spending more time on farms and fields with their parents compared to girls. Consequently, boys have a better opportunity to learn about various medicinal plants in their locality while engaging in activities with traditional healers.

The informants have indicated that the transfer of medicinal plant knowledge to males holds greater importance compared to females. This belief stems from the assumption that there is a higher likelihood of losing medicinal plant knowledge within the community or village when females marry individuals from outside their community and relocate to other areas. However, there are exceptions where females in the community may have the chance to acquire medicinal plant knowledge from their healer parents and be entrusted to practice healing. This typically occurs when they are trusted by their parents to maintain secrecy about the knowledge and healing practices or when there are no boys in their family. This situation has contributed to a relatively higher number of male healers in the study area. Similar findings were reported by Tamene (2011) and Teklehaymanot & Giday (2006), who noted that traditional knowledge is primarily passed down from a parent to an elder son. Tamene (2011) also observed that female traditional healers tend to stay within close proximity to their residence or village and do not frequently venture far in search of medicinal plants. Thus, the medicinal plant knowledge of female traditional healers is often limited to cultivated plants in their home gardens or those found in the vicinity of their homesteads.

Most traditional healers prefer not to impart knowledge about medicinal plants and healing practices to their family members at a young age. Instead, they select a trusted individual within the family whom they believe will maintain secrecy regarding medicinal plant knowledge and traditional healing practices. Training typically begins when the traditional healer is advanced in age and can no longer travel to search

for medicinal plants in the field. The chosen individual is gradually trained by allowing them to search for and collect medicinal plants from the garden or field, but they are not initially allowed to perform healings.

A person who receives medicinal plant knowledge and healing practice from their healer parent is required to take a solemn oath (referred to as '*Kaku*' locally) to keep all the acquired knowledge about medicinal plants and traditional medications confidential. Finally, the individual who is trained to become a healer receives blessings from their parent or transferrer, which empowers them to administer traditional medicines to patients in need, carrying the curative abilities inherited from their parent.

According to key informants, the transfer of knowledge regarding medicinal plants and traditional medicine in the study area faces challenges due to the lack of interest displayed by most youths in acquiring traditional medicine knowledge. It was mentioned that this disinterest among the younger generation may be attributed to the influence of Western religions, modern education, the proliferation of health centers, and the community's attitude towards modern medicine. These findings align with the works of Gebreegziabher (1991), Hunde (2001), Gebre (2005), and Tolosa (2007), who have reported that older individuals possess relatively more knowledge about medicinal plant use compared to younger members of the same community. This indicates a decline in traditional medicine knowledge, alongside the practice of secrecy. The diminished knowledge among younger community members may be linked to their lack of interest in traditional medicines, which can be attributed to the impact of modernization, including increased access to modern education and health services.

### 3.7 Preference Ranking

Among the medicinal plants used to treat snake bites in the study area, certain plants are more popular and preferred. According to the preference ranking results (Table 6), *Senegalia mellifera* holds the highest preference for treating snake bites. It is ranked first among the five medicinal plants used for this purpose in the area. Following *Senegalia mellifera*, *Dichrostachys cinerea* and *Senegalia brevispica* are ranked second and third, respectively, indicating their relatively high preference. On the other hand, *Kedrostis pseudogijef* and *Searsia tenuinervis* are ranked fourth and fifth, respectively, suggesting their lower preference compared to the other plants.

Not all medicinal plants contain the same content and concentration of chemical compounds or phytochemicals. The preference ranking of medicinal plants based on their efficiency reveals that traditional healers in the study area, drawing from their life experiences, have identified the most effective medicinal plants for addressing specific ailments.

**Table 6.** Preference ranking of medicinal plants used to treat snake bite

| Factors | Informants | | | | | | | Total | Rank |
|---|---|---|---|---|---|---|---|---|---|
| | I1 | I2 | I3 | I4 | I5 | I6 | I7 | | |
| *Senegalia brevispica* | 3 | 2 | 3 | 4 | 3 | 3 | 4 | 22 | $3^{rd}$ |
| *Senegalia mellifera* | 5 | 5 | 4 | 2 | 5 | 5 | 5 | 31 | $1^{st}$ |
| *Dichrostachys cinerea* | 4 | 4 | 5 | 5 | 4 | 4 | 3 | 30 | $2^{nd}$ |
| *Kedrostis pseudogijef* | 1 | 1 | 0 | 3 | 4 | 2 | 1 | 12 | $4^{th}$ |
| *Searsia tenuinervis* | 2 | 3 | 1 | 1 | 0 | 0 | 2 | 9 | $5^{th}$ |

Note: I = Informant

### 3.8 Direct Matrix Ranking

Despite their medicinal value, several medicinal plants in the study area have been reported to serve multiple purposes beyond medicine. These include forage, traditional cleansing, construction of houses and corrals, firewood, charcoal, farm or household implements, shade, rituals, and as a source of edi-

ble wild plants. Based on the direct matrix ranking, *Lanea rivae*, *Vachellia tortilis*, and *Grewia villosa* emerged as the top three preferred medicinal plant species due to their diverse range of uses (Table 7). Conversely, *Vachellia nilotica* received the lowest score and was ranked last, indicating its relatively lower preference compared to other multipurpose plants listed in the table. In terms of total scores in the direct matrix (Table 7), these multipurpose medicinal plants were primarily favored for their forage value, followed by their use in house and corral construction, and as a source of medicine.

**Table 7.** Direct Matrix ranking of seven selected medicinal plants

| Multipurpose plants | Forage | Medicine | Traditional cleansing | House/Corrals construction | Firewood | Charcoal | Farm/House implements | Shade tree | Ritual | Wild edible | Total Score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Boscia mossambicensis* | 21 | 16 | 17 | 24 | 10 | 10 | 6 | 30 | 35 | 0 | 169 | $6^{th}$ |
| *Grewia tembensis* | 31 | 21 | 0 | 21 | 28 | 20 | 22 | 0 | 0 | 30 | 173 | $5^{th}$ |
| *Grewia villosa* | 28 | 35 | 0 | 28 | 17 | 4 | 21 | 0 | 30 | 20 | 183 | $3^{rd}$ |
| *Lanea rivae* | 35 | 30 | 35 | 26 | 13 | 0 | 27 | 0 | 20 | 19 | 205 | $1^{st}$ |
| *Pappea capensis* | 35 | 28 | 0 | 12 | 35 | 12 | 23 | 0 | 0 | 32 | 177 | $4^{th}$ |
| *Vachellia nilotica* | 12 | 13 | 0 | 35 | 15 | 35 | 24 | 28 | 0 | 0 | 162 | $7^{th}$ |
| *Vachellia tortilis* | 22 | 17 | 13 | 35 | 19 | 35 | 20 | 35 | 0 | 0 | 196 | $2^{nd}$ |
| **Total Score** | 184 | 160 | 65 | 181 | 137 | 116 | 143 | 93 | 85 | 101 | | |
| Rank | $1^{st}$ | $3^{rd}$ | $10^{th}$ | $2^{nd}$ | $5^{th}$ | $6^{th}$ | $4^{th}$ | $8^{th}$ | $9^{th}$ | $7^{th}$ | | |

According to Dale *et al*. (2005), Borana pastoralists extensively utilize the available plant resources in their rangelands, with nearly half of the plant species in Borana serving multiple purposes, similar to other regions in the country. While medicinal value is the primary use category for many indigenous rural communities (Coe & Anderson, 1999), it ranks second in importance for the community in the present study area. The local community exhibits a high dependence on plant resources for forage, reflecting the area's predominant livestock production system. This finding aligns with the conclusions drawn by Dale *et al*. (2005).

### 3.9 Threats to Medicinal Plants and Associated Knowledge

Herbal remedies hold significant importance for the rural population in Ethiopia, as modern medications are often inaccessible or prohibitively expensive. Abebe (1996) reported that approximately 80% of Ethiopians rely on traditional herbal remedies, and this also holds true for the pastoralist community in the current study area. Traditional healers in the area express concerns about the gradual decline of some of the most beneficial medicinal plants. Limited efforts have been made to conserve medicinal plants in the study area, as observed by key informants and through personal observations. Human-induced factors, compounded by prolonged dry seasons, pose threats to the survival of medicinal plant species. Livestock grazing, bush encroachments, wood cutting for construction, charcoal production, and firewood collection were identified as major threats to medicinal plants in the area. Among these threats, livestock grazing and charcoal production ranked first and second, respectively, based on their severity (Table 8).

The prevalence of woody medicinal plants (shrubs and trees) in the study area, compared to herbaceous species, suggests that herbs are more vulnerable to various hazards such as livestock grazing, trampling of seedlings, climate change, and encroachment. Traditional healers in the area employ several methods, such as crushing and storing powdered forms of medicinal plants, to preserve the ingredients when they are unable to obtain fresh plants during the dry season. This finding is consistent with the research conducted by Duguma & Mesele (2019).

**Table 8.** Factors threatening medicinal plant

| Factors | Informants | | | | | | Total | Rank |
|---|---|---|---|---|---|---|---|---|
| | I1 | I2 | I3 | I4 | I5 | I6 | | |
| Charcoal production | 5 | 7 | 6 | 7 | 6 | 7 | 38 | $2^{nd}$ |
| Cultural taboo | 2 | 1 | 2 | 1 | 1 | 1 | 8 | $6^{th}$ |
| Firewood collection | 4 | 5 | 5 | 4 | 2 | 3 | 23 | $4^{th}$ |
| House construction | 6 | 4 | 4 | 5 | 3 | 4 | 26 | $3^{rd}$ |
| Livestock grazing | 7 | 6 | 7 | 6 | 7 | 6 | 39 | $1^{st}$ |
| Over utilization | 3 | 3 | 3 | 3 | 5 | 5 | 22 | $5^{th}$ |

Note: I = Informant

Moreover, cultural beliefs and traditional practices in the study area may have an impact on medicinal plants, as well as the associated local knowledge and practices. Key informants have revealed that medicinal plant knowledge and associated practices are often kept secret by traditional healers, with the information being shared only among practitioners. Traditional healers refrain from disclosing the names of medicinal plants or showing the actual plants to patients, believing that the effectiveness of traditional remedies would diminish if patients were aware of the plant sources. In some cases, traditional healers assign names to medicinal plants by adding the prefix '*Qorsa*' to the name of the corresponding illness, aiding in their identification. For example, a plant used to treat Mich is named '*Qorsa Michi*', signifying the medicine for Mich.

Lack of conservation efforts for ethnomedicinal plant species, despite their perceived importance, has also been highlighted by the traditional healers in the study area.

## 4 Conclusion

The pastoral community of Arero District possesses a rich indigenous knowledge of medicinal plants and traditional medicine, which they rely on to address a wide range of ailments. Despite the availability of modern medicine, traditional medicine remains highly valued due to its affordability, accessibility, therapeutic efficacy, and cultural significance. Traditional healers play a crucial role in simplifying healthcare complexities within the community. However, the lack of standardized dosing of remedies should be addressed, as it may pose risks to patients' health, potentially leading to fatal outcomes.

The knowledge of medicinal plants is primarily limited to traditional healers and a few elderly individuals within the community. The secretive nature of medicinal plant knowledge, coupled with gender biases and a lack of motivation, poses a threat to the preservation of local medicinal plant knowledge and practices in the study area. Without appropriate interventions, there is a risk of losing this valuable knowledge in the near future, exacerbated by the oral transmission of knowledge. It is important to recognize that medicinal plants not only serve as a source of traditional medicine but also hold potential for the development of new drugs. However, numerous medicinal plant species are reported to be under threat from factors such as encroachment, climate change, overharvesting, fire, and overgrazing. Traditional healers in the study area have also acknowledged their limited involvement in conservation activities for medicinal plants in their surroundings. To ensure sustainable management of the pastoral system and improve healthcare within the pastoralist

community, development programs should prioritize the sustainable use and conservation of plant resources, with a specific focus on medicinal plants.

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**Conflict of Interest**

The authors declares that there is no conflict of interest.

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## Annex

List of medicinal plant species encountered in the study area, growth form, and use (S = Shrub, T = Tree, H = Herb, C = Climber, WC = Woody Climber)

| Scientific name | Vernacular name | Plant family | Growth form | Plant parts used | Ailments treated | Application |
|---|---|---|---|---|---|---|
| *Acokanthera schimperi* (A.DC.) Schwevinf | Qaraaruu | Apocynaceae | T | Root & Stem | Rabies | Taking an extract/juice of the plant orally. |
| *Albizia anthelmintica* (A. Rich.) Brongn. | Awaachoo | Fabaceae | S | Root | Liver disease, Impotence, & Gonorrhea | Washing body with its decoction, inhaling the vapor, and drinking a cup of it daily for 3-7 days. |
| *Aloe secundiflora* Engl. | Hargeessa | Aloaceae | S | Leaf & Root | Rabies, Sinus, Common cold, Eye disease, & Cancer | Ingesting hot infusion mixed with *Panicum ruspolii* bark for 3-7 days to treat Rabis; ingesting cold infusion & placing few drops of its latex on the head to treat Sinus Common cold, & Eye disease; & ingesting decoction with *Croton macrostachyus* bark for 7 days to treat Cancer. |
| *Asparagus racemosus* Wild. | Sariitii | Asparagaceae | C | Leaf | Skin burns | Rubbing leaf and mounting on a burned area. |
| *Balanites aegyptica* (L.) Del. | Baddanalu'oo | Balantiaceae | T/S | Root | Torn removal and torn wound | Chewing/mashing and mounting on a wound. |
| *Barleria spinesepala* (Ait.) Benth. | Qilxiphee | Acanthaceae | H | Root | Prolonged diarrhea and vomiting | Taking the decoctions with yoghurt or curdled milk. |
| *Bidens hildebrandtii* O. Hoffm. | Abunee | Asteraceae | S | Root & Leaf | Common cold & Skin infection | Ingesting decoction orally to treat Common cold; and washing an infected body parts with cold infusion for 3 days to treat Skin infection. |
| *Boscia mossambicensis* Klotzsch. | Qalqacha | Capparidaceae | T | Bark | Hemorrhoid & Evil eye | Ingesting decoction with juice from *Solanum incanum* root to treat Hemorrhoid; & ingesting tea made from the powder to treat Evil eye. |
| *Calpurnia aurea* (Ait.) Benth. | Ceekataa | Fabaceae | S | Leaf | Ecto-parasites (ticks, mites, bedbugs, fleas) | Washing cloths & beds with the cold infusion mixed with salt. |
| *Capparis tomentosa* Lam. | OgooraGaalaa | Capparidaceae | S | Root | Skin rush and body pain | Inhaling hot infusion vapor, washing infested body part with it, and drinking small amount. |
| *Carissa edulis* Vahl. | Dhagamsa | Apocynaceae | S | Root | Glandular swelling, Headache, & Toothache | Ingesting decoction daily for 7 days to treat Glandular swelling & Headache; and putting hot/boiled root on tooth during the tooth pain. |
| *Cissus quadrangularis* L. | Cophiisoodduu | Vitaceae | WC | Root | Hemorrhoids | Ingesting decoction orally. |
| *Crinum abyssinicum* Hochst. Ex A. Rich | Butewarabesaa | Amaryllidaceae | H | Root | Rabies | Taking a cupful of cold infusion, that was left for 2-3 days, daily for 7 to 14 days. |
| *Croton dichogamus* Pax | Mookofa | Euphorbiaceae | S | Root | Common cold; Allergy | Taking a hot infusion mixed with milk. |
| *Croton macrostachyus* Del. | Makkaniisa | Fabaceae | T | Shoot, Root, & Bark | Rabies; Snake bite, Intestinal parasites including *Tenea corporis*, & Cancer | Rubbing a sap on infected body part until recovery to treat Rabies & Snake bite; and taking decoction orally for 3-7 days to treat *Tenea corporis*, other intestinal parasites, & Cancer. |
| *Cucumis dipsaceus* Ehrenb. *ex* Spach | Buratee | Cucurbitaceae | C | Fruit | Stomachache & Breast ache | Ingest decoction to treat Stomachache; & heating the fruits & painting the hot sap on the injured breast to treat Breast-ache. |
| *Dichrostachys cinerea* (L) Wight et Arn. | Jirimee | Fabaceae | S | Leaf & Root | Wound | Washing the wounded part of the body with a hot infusion |
| *Ehretia cymose* Honn. | Ulaagaa | Boraginaceae | S | Root | Liver disease | Inhaling decoction vapor, wash the body with its water, & drink some amount for 5-7 days. |
| *Euclea divinorum* Heirn | Mi'eessaa | Ebenaceae | T/S | Root | Mitch | Taking droplets of water diluted powder orally. |
| *Euphorbia nubica* NE.Br. | Aannoo | Euphorbiaceae | S | Root, Shoot, & Bark | Rabies, Stomachache, Menstruation irregularity, Gonorrhea, & Common cold | Ingesting decoction mixed with milk to treat these health problems. |

| Scientific name | Vernacular name | Plant family | Growth form | Plant parts used | Ailments treated | Application |
|---|---|---|---|---|---|---|
| *Euphorbia schizacantha* Pax. | Harkeena | Euphorbiaceae | S | Root | Gonorrhea & Common cold | Taking the decoction mixed with milk for 3 days. |
| *Gnidia stenophylla* Gilg. | Aarsaa | Ascelpiadaceae | H | Root | Gonorrhea | Drinking a cup of decoction every morning for 7-14 days. |
| *Grewia tembensis* Fresen | Dheekkaa | Tiliaceae | S | Stem | Magic; Evil spirit | Brushing teeth with stick of the plant when needed |
| *Grewia villosa* Wild | Ogomdii | Tiliaceae | S | Root | Snake bite | Taking cold infusions orally every day till recovery. |
| *Indigofera volkensii* Taub. | Gurbiihoolaa | Fabaceae | H | Leaf | Bleeding due to cut of body part | Mounting mashed leaves on the injured body part. |
| *Kedrostis pseudogijef* (Gilg.) C. Jiffrey | Gaaleeadii | Cucurbitaceae | C | Stem | Snake bite | Applying the exudates on the affected body part for 3 days. |
| *Lanea revea* (Chiov.) Sacleux | Handaraka | Anacardiaceae | T | Bark | Abdominal Pain | Taking the juice extract during the pain. |
| *Ocimum lamiifolium* Hochst. Ex Benth | Hancabbii | Lamiaceae | H | Leaf | Fibril illness | Applying cold infusion on body or drink with coffee until recovery. |
| *Ormocarpum trichocarpum* (Taub.) Engl | Buutiyyee | Fabaceae | T | Root | Intestinal parasite & Ulcerated wound | Taking 1-2 water cups of the decoction orally before having a breakfast for 3 days to treat Intestinal parasite; and applying a chewed root on wound for 3 days to treat Ulcerated wound. |
| *Pappea capensis* Eckl. & Zeyh. | Biiqqaa | Sapindaceae | T | Bark | Rabies & Snake bite | Taking hot infusion orally. |
| *Plumbago zeylanica* L. | Igaaji | Plumbaginaceae | H | Shoot | Glandular swelling | Mounting mashed leaf on swelled part or wound for 2 days in 2–3-days gap. |
| *Searsia tenuinervis* (Engl.) Moffett | Daboobessa | Anacardiaceae | S | Leaf | Skin allergy | Applying juice on infected area at night before bed. |
| *Senegalia brevispica* (Harms) Seigler & Ebinger | Hammareessa | Fabaceae | T | Root | Epilepsy | Applying 2-3 drops of extract/juice through nose |
| *Senegalia mellifera* (Vahl) Seigler & Ebinger | Saphansagurracha | Fabaceae | S | Root | Snake bite | Chewing & spitting juice/extract on an infected body part |
| *Solanum giganteum* Jacq. | Hiddiiloonii | Solanaceae | S | Leaf & Root | '*Dingetegna*', Nasal bleeding, & Evil eye | Rubbing and smelling leaf immediately to treat '*Dingetegna*' & Nasal bleeding; and taking a tea cupful of decoction of root with milk orally twice a day for Evil eye. |
| *Solanum incanum* L. | Hiddiiwaatoo | Solanaceae | S | Root | Evil eye & Hemorrhoids | Ingesting decoction with milk twice a day for Evil eye; and taking decoction orally every morning until recovery to treat Hemorrhoids. |
| *Solanum somalense* Franchet | Hiddiigaagee | Solanaceae | S | Root | Cancer appearing on an external body part | Applying powder on the affected body part. |
| *Steganotaenia araliacea* Hochst | Luqaaluqqee | Apiaceae | T | Root | Menstruation problem (Irregularity) | Mixing 2-3 glasses of decoction with sheep butter ('*dhadhahoola*') and taking orally every morning for up to 3-7 days. |
| *Sterculia stenocarpa* H. Winkler | Qararrii | Sterculiaceae | T | Bark | Nasal bleeding | Tying the bark on head. |
| *Vachellia etbaica* (Schweinf.) Kyal. & Boatwr | . Alqabeessa | Fabaceae | T | Bark | Nasal bleeding | Tying a bark of the plant on head during bleeding. |
| *Vachellia nilotica* (L.) P.J.H. Hurter & Mabb. | Burquqqee | Fabaceae | T | Fruit | Sinus & Ulcerated wound | Ingesting decoction to treat Sinus; & spiting the juice on a ulcerated wound every morning, before breakfast, for 3 days. |
| *Vachellia tortilis* (Forssk.) Galasso & Banfi | Dhadacha | Fabaceae | T | Seed & Latex | Urine retention problem & Asthma | Ingesting decoction of fresh seeds boiled with *Sansevieria ehrenbergii* to treat the Urine retention problem & Asthma. |
| *Withania somnifera* (L.) Dunal | Hiddiixirooftuu | Solanaceae | S | Root | Evil eye | Feeding milk mixed cold infusion to infants. |
| *Zanthoxylum chalybeum* Engl. | Gaddaa | Rutaceae | T | Leaf & Root | Asthma magic | Taking 1-2 cups of syrup orally & brushing teeth with it. |