# Analysis of Dairy Farm Management Practices and Drivers of Technology Adoption: Insights from Central Highlands of Ethiopia

Abrham Seyoum Tsehay[1]

## Abstract

This study is focused on analysing dairy technology adoption and associated factors among rural households in Basona Werana Woreda, North Shewa zone of Amhara Region. The study selected 252 households using multi-stage sampling technique. Both descriptive and econometric analyses were employed to analyse the data collected using structured interview. Multivariate Probit regression model was applied to examine the derivers of dairy technology adoption in the study area. The study showed mixed results in terms of households adopting the different components of dairy technology. Predominant portions of the sample households adopted one or more of the improved housing conditions, improved feed and regular vaccination by 84.86%, 54.76% and 79.28%, respectively. However, in terms of utilization of the technologies, a significant proportion of adopters practiced a low level of utilization in each of the cases. Contrary to the results above, only 44.84% and 24.21% of the sample households adopted improved breeds and Artificial Insemination services, respectively. The multivariate probit regression results showed that livestock asset in TLU, awareness and training about dairy technology, education of the household head, dairy farm experience, and membership to farmers' cooperatives had positive and significant effects on the adoption of dairy technologies while household size and dependency ratio have negative influence on the adoption of dairy technologies. The study sheds light on the need to develop farmers' cooperatives, training and education as well as family planning tailored to the context of rural households in order to enhance dairy technology adoption in the study area.

[1]Center for Rural Development, College of Development Studies, Addis Ababa University, Addis Ababa Ethiopia. E-Mail: abrham.seyoum@aau.edu.et, POBox: 1176, Addis Ababa University, Addis Ababa, Ethiopia

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## 1. Introduction

In most of the developing nations, agriculture is mainly driven by traditional technologies resulting in low productivity and deprivation of rural households. However, the adoption of agricultural technologies has been instrumental in changing this reality in many parts of the world. Enhancing technology adoption, however, requires a clear awareness and understanding of its definitions and concepts. Various researchers defined adoption differently. Rajesh (2016) describes technology adoption as one of the mature areas of research in information system. According to Feder et al. (1985), adoption is an integration of an innovation into farmers' activity for a period of time; in this regard farmers may not be longer in the adoption process because of different constraints like institutional, personal and social reasons. Carr (1999), defines technology adoption as a stage of selecting a technology by an individual or group of people. According to Rogers (1983), adoption is defined as a mental process through which an individual passes from knowledge of innovation (from knowing or hearing about the innovation) to the final decision to adopt or reject the technologies. This study adopts the latest definition.

The national economies and the livelihood of rural communities in Sub-Saharan African countries are largely dependent on livestock production (Tilahun and Gebregiorgis, 2016). Ethiopia has a huge potential for development, particularly in its livestock sector.

It has the largest livestock population in Africa and the fifth largest in the world. According to the Ethiopian Central Statistical Agency (Central Statistical Agency, 2021), the country has 70.3 million cattle, 42.9 million sheep, 52.5 million goats and 8.1 million camels. The livestock sector contributes nearly 20 percent of the total GDP and accounts for about 35 to 40 percent of agricultural GDP (World Bank, 2017). The Ethiopian highlands, with their moderate climate, are particularly conducive to cattle rearing.

Dairy production is an important component of livestock farming in Ethiopia. The huge and diverse livestock population, varied and favorable agro-ecology for dairying, increasing demand for dairy products in urban and peri-urban areas, long-standing culture of dairy products consumption, and favorable policy are indicators of the importance and potential of dairying in the country. Despite the country's potential for dairy development, productivity of indigenous livestock genetic resources in general is low, and the direct contribution it makes to the national economy is limited (Azage et, al., 2013). Reports indicate that indigenous breeds make up about 97.4% of the total cattle population in the country followed by hybrid and exotic breeds, which make up 2.29% and 0.31%, respectively (Central Statistical Agency, 2020). Even though Ethiopia's agroecology is favorable for dairy production, the sector remains predominantly traditional, with smallholder farmers producing 98% of the milk (Ayza & Olikamo, 2020). This underdevelopment and the low-level of technology adoption among small-scale dairy farmers substantially limit the contribution of the sector to the national economy in general and the rural households' livelihood in particular. According to projections by the Ethiopian Public Health Association, Ethiopia's population is expected to reach 133.5 million by 2032 and 171.8 million by 2050 (Alemayhu & Yihunie, 2014). This demographic growth underscores a critical need for food security and hence necessitating a greater focus and investment in the livestock sector in general and dairy production in particular. The Ethiopian dairy sector is a strategic priority for the Government of Ethiopia, which has mainstreamed the SDGs into its national and sectoral development agenda. Recently, the government of Ethiopia launched its ten years' national development plan where the livestock sector is one of the major focus areas. Despite decades of previous efforts to disseminate dairy technologies in Ethiopia since the 1960s, the rate of adoption by smallholder farmers has remained low (Feyissa et al., 2023). Consequently, widespread adoption of dairy technologies by smallholders is crucial for achieving the plans envisioned by the Government.

Several studies have explored the dairy sector in Ethiopia. Some of the studies are focused on the state of the dairy sector, dairy management system, genetic make-up, the prevalence of animal diseases and their economic burden on households (Abegaz, 2022; Chebo et al., 2014; Firdessa et al., 2012; Mohammed et al., 2015; Tilaye Teklewold, 2019). Some other studies have been conducted examining the status of dairy technology adoption and major factors affecting the adoption of dairy technology in Ethiopia (Abdinasir Ibrahim Bulale., 2000; Abreham Assefa et al., 2021; Gezie et al., 2014). Still the remaining few studies have made attempts to show the impact of dairy technologies adoption on households' livelihood (Korir, 2023; Melesse & Jemal, 2012), and poverty and food security (Derbe et al., 2023; Mekuria et al., 2017).

Against this backdrop, this study aims at analyzing dairy farm management practices and drivers of dairy technology adoption in Basona Werana Woreda, North Shewa Zone of Amhara Region. The study contributes to the existing literature in three ways. First, the research contributes to bridging literature gap in examining the status of dairy farm management practices and rate of diary technology adoption by households practicing mixed agriculture in central highlands of Ethiopia. Second, in addition to looking at individual dairy technologies piece by piece, this study differs from previous studies in that it looks at dairy technology adoption as a package of five different technologies namely improved breeds, artificial insemination, improved feeds, vaccines and improved housing conditions in a holistic manner. Third, since smallholders adopt one or more of the technologies for improving their livelihoods, the adoption decisions of households for these technologies are inseparable and hence apparently correlated. Therefore, to account for this problem, Multivariate Probit model is applied in this study as opposed to most previous studies that applied binary probit/logit and multinomial logit models for analyzing determinants of dairy technology adoption in Ethiopia. As such, this research has also a methodological contribution to previous studies carried out in the topic.

Therefore, based on theoretical and empirical expositions, the conceptual framework of this study is depicted in Figure 1. Demographic, socio-economic, institutional and community characteristics are considered to affect the choice of farmers in adopting dairy technologies. In this study, dairy technologies comprise of a set of five different components relevant to local context and the adoption of each of these technologies depends on the effects of multiple factors shown in Figure 1 below.

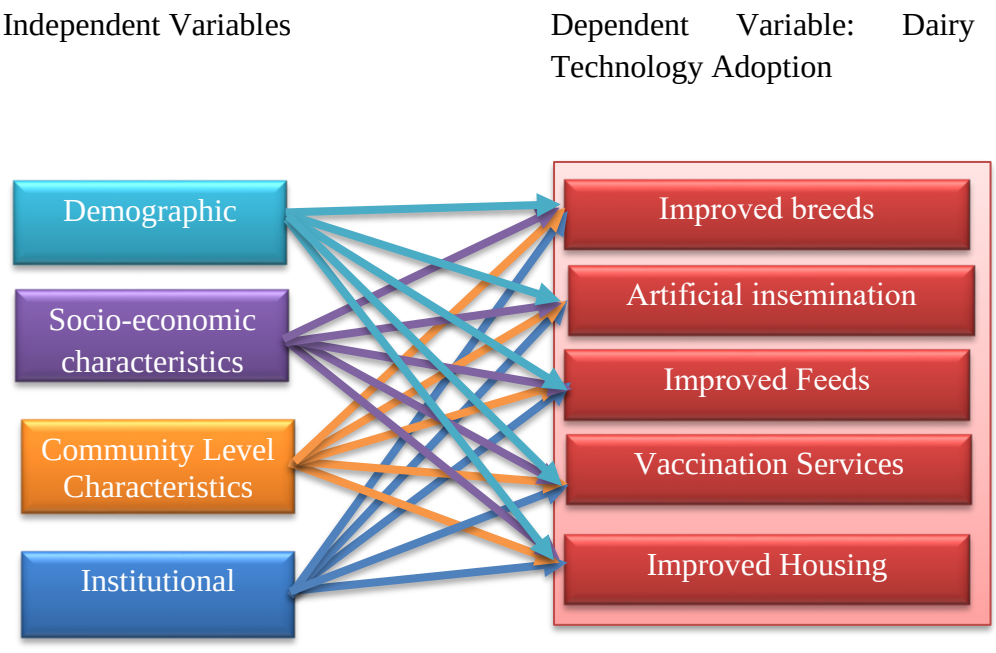


Figure 1: Conceptual Framework of the Study
Source: Author's Illustration (2023)

# 2. Materials and Methods

## 2.1 Study Area Setting

Basona Werana Woreda is one of the districts in North Shewa Zone of the Amhara region surrounding Debre Berhan town, the capital of North Shewa Zone. It was formerly named Debre Berhan Zuria Woreda. It is bordered by Angolalla Tera on the south, Oromia region on the south west, Siyadebrina Wayu on the west, Moretna Jiru on the northwest, Mojana Wadera on the north, Taramaber on the northeast and Ankober on the east.

The study area is located 130 km north of Addis Ababa, the capital city of Ethiopia. It is located between 9038'00''-09041'00" North Latitude and 39030'00'-39032'00" East longitude (Ministry of Agriculture (MoA), 2016). Based on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), this woreda has a total population of 120,930, an increase of 7.81% over the 1994 census, of whom 61,924 are men and 59,006 women; 1,219 or 1.01% are urban inhabitants. According to CSA July 2023 projections for Zones and Woredas, Basona Werana has estimated total population of 147,375 out of which 75,011 are males and 72,364 are females. With an area of 1,208.17 square kilometers, Basona Werana has a population density of 100.09, which is less than the Zone average of 115.3 persons per square kilometer. A total of 27,753 households were counted in this woreda, resulting in an average of 4.36 persons to a household, and 26,918 housing units. The majority of the inhabitants practiced Ethiopian Orthodox Christianity, with 99.93% reporting that as their religion (CSA, 2020).

The study Woreda is dominantly inhabited by ethnic Amhara and Orthodox Christians. North Shewa Zone has large production of cereal and pulse crops. In the area, cereals like teff, wheat, burley, maize, sorghum, millet and pulses as well as different types of beans, peas and lentils are very dominant products of the farmers. The rural households practice mixed farming and it is one the areas in Ethiopia where the dairy sector has a big potential. The Woreda is one of the dairy belts in

Ethiopia where the Ethiopian government considers target areas for dairy sector development by providing training, dairy technology, improved heifers and the like.

## 2.2 Research Approach and Data

The philosophical worldview of this research is a pragmatic research paradigm, which allows the use of meta-methodology and maximizes the benefits of using a combination of methodologies (Ormerod, 2006). The research approach is predominantly quantitative. Given that the research has several objectives and employs various research techniques, the research design is therefore a mix of descriptive and explanatory research designs.

The research is primarily quantitative and relies on primary data sources. To complement the primary data and substantiate the results, secondary sources such as government documents, articles and theses were also consulted. Moreover, this study utilizes structured interviews as method of data collection, supplemented by field observations before and during the survey.

## 2.3 Sampling Design

This research is conducted at household level and hence targets smallholders engaged in mixed agriculture in Basona Werana Woreda, which is one of the 10 woredas of North Shewa Zone of Amhara National Regional State. In this Woreda, there are 30 rural kebeles and one urban center, namely Debre Berhan Town, which is the capital of the zone. The research follows a multi-stage sampling technique. In the first stage, Basona Werana Woreda was selected purposively since it is located in one of the major milksheds in the country. In the second stage, two rural kebeles, namely Bakelo and Birbisa, were selected randomly among the rural kebeles from the woreda. In the third and

final stage, households were selected from each kebele using systematic random sampling proportional to size.

To determine the sample size for this research, Yamane (1967) formula is employed as shown below:

$$n = \frac{N}{1 + Ne^2} = 227$$

where, n denotes the desired sample size, e is set at ± 6% level of precision; and N is the size of the total population (N=1234) from which the sample is drawn. Therefore, based on the sample size determination formula given above, the sample size of 227 farm households was determined for the study. To account for the possible missing response values due to non-sampling errors, following (Naing et al., 2006), 15% contingency was assumed from the total sample to achieve the required accuracy. Accordingly, a total sample of 262 farm households was determined as the total sample size. Out of which, 198 and 64 households were from Bakelo and Birbisa kebeles respectively based on proportional sampling to the size of households in the kebeles. Though the study is confined to one study woreda and may not represent central highlands of Ethiopia, the results of the study would provide valuable insights and have important implications to wider areas in central highlands of Ethiopia.

## 2.4 Methods of Data Analysis

Both descriptive and econometric analyses have been employed to address the objectives of the study. In addition to the use of descriptive statistics to provide an overall picture of the sample smallholders, multivariate probit regression model was used to analyse the determinants of dairy technology adoption.

***Measuring Adoption of Dairy Technology***: The types and functions of dairy technologies might vary from place to place. However, in this study, adoption of dairy technologies includes improved breeds, Artificial Insemination (AI), recommended feed, vaccination and improved housing conditions. It is captured by a set of binary indicators

depending on whether households adopt each of the specific technologies or not.

***Determinants of Dairy Technology Adoption***: Multivariate Probit Model (MVP) is applied for analysing the determinants of technology adoption by dairy producers as technology adoption is captured by a set of dummy variables of whether dairy producers adopt a particular technology or not. These technologies include adoption of improved breeds, Artificial Insemination (AI), improved breeds, vaccines, and improved housing. Multivariate Probit model has superiority over other models in capturing the possibility of practicing more than one dairy technology hence capturing the correlation of households' decisions for the different technologies, which otherwise might not be addressed by other competing models. Multivariate Probit Model was first proposed by Ashford and Sowden (1970) and further extended by Chib and Greenberg (1998). In Ethiopia, the MVP model has been used to study a variety of topics, including land management technology adoption (Dessalegne et al., 2024); market outlet choice (Habtamu et al., 2020; Tarekegn et al., 2017); climate change adaptation (Dessalegn et al., 2023); and adoption of biogas digesters (Berhe et al; 2017). Accordingly, the MVP model is found suitable and applied for analyzing the determinants of dairy technology adoption.

We follow the general specification of Multivariate Probit model as illustrated by (Greene, 2000):

$$y_m^* = x_m'\beta_m + \varepsilon_m, y_m = 1\ if\ y_m^* > 0, 0\ otherwise, m = 1, \dots, M,$$

$$E[\varepsilon_m | x_1, \dots, x_M] = 0$$

$$Var[\varepsilon_m | x_1, \dots, x_M] = 1$$

$$Cov[\varepsilon_j \varepsilon_m | x_1, \dots, x_M] = \rho_{jm}$$

$$(\varepsilon_1, \dots, \varepsilon_M) \sim N_M[0, R]$$

where x is a matrix of covariates consisting of independent variables, $\beta$ is a matrix of unknown regression coefficients and $\varepsilon_m$ is residual error. R is the variance-covariance matrix.

The marginal effects of independent variables on the propensity to adopt a certain dairy technology is calculated as follows:

$$\frac{\partial P_i}{\partial x_i} = \varphi(x'\beta)\beta_i, i = 1,2,3, \dots, n$$

where $P_i$ is the likelihood of event $i$ which increases/decreases the possibility of adopting different dairy technologies by households, and $\varphi(.)$ is the standard univariate normal density distribution function.

## 2.5 Descriptions of Variables

The descriptions of both the dependent and independent variables are presented below. The independent variables include those factors that are important in influencing a household's decision for dairy technology adoption in the study area.

Table 1. Descriptions of dependent and independent variables

| Variable | Description |
|---|---|
| ***Dependent Variable*:** | |
| Adoption of Improved Breeds | A binary variable referring to the status of households' improved breeds adoption where 1 is adopter and 0 otherwise. |
| Adoption of Artificial Insemination | A binary variable referring to the status of households' artificial insemination adoption where 1 is adopter and 0 otherwise. |
| Adoption of Recommend Feed | A binary variable referring to the status of households' recommended feed adoption where 1 is adopter and 0 otherwise. |

| Variable | Description |
|---|---|
| Adoption of Vaccination | A binary variable referring to the status of households' adoption of vaccination services where 1 is adopter and 0 otherwise. |
| Adoption of Improved Housing Condition | A binary variable referring to the status of households' adoption of improved housing conditions where 1 is adopter and 0 otherwise. |
| ***Independent variables*:** | |
| Sex of the Household Head | It is a dummy variable referring to the sex of the household head where 1 is female and 0 is male. |
| Age of the Household Head | A discrete variable referring to the age of the household head in years. |
| Education of the Household Head | It is a categorical variable referring to the household head's education level where 1 is illiterate, 2 is having informal education and 3 is with formal education. |
| Dairy Experience | It is a discrete variable referring to the household's experience in dairy farming in years. |
| Access to Credit | It is a dummy variable capturing the status of access to credit over the last 2 year where 1 is yes and 0 otherwise. |
| Membership to farmers cooperatives | A dummy variable for being member of the farmers' cooperatives where 1 is yes, and 0 otherwise. |
| Access to training on dairy technology | A dummy variable referring to the status of household members' access to training where 1 is yes and 0 otherwise. |
| Awareness on dairy technology | A dummy variable referring to status of household members awareness to dairy technology where 1 is yes and 0 otherwise. |

| Variable | Description |
|---|---|
| Household size | A count variable referring to the number of members in a household. |
| Dependency Ratio | A continuous variable measured as the ratio of the number of dependent household members over number of independent household members. |
| Livestock holding in TLU | A continuous variable referring to the total asset of livestock owned by the household measured in tropical livestock units (TLU). |

Source: Author's compilation.

# 3. Results and Discussion

The research was conducted in Basona Warena Woreda of North Shoa Zone in Amhara National Regional State. From the interview of 262 households, who are engaged in dairy farming, 252 (96%) of the sample was found to be usable for analysis and hence only 10 (4%) of the respondents were made void due to different types of non-sampling errors. Hence, the response turnout is within the margin of the contingency given and the sample data is adequate for analysis. The questionnaire is adopted from internationally accepted and tested instruments of dairy farm management and dairy technology adoption. Besides, the instruments of the data have passed through different phases of comments and revisions by professionals and experts in the area and thus assuring the reliability and validity of the data.

## 3.1 Descriptive Statistics

### 3.1.1 Descriptions of Categorical Variables

The descriptive results of categorical variables show that household heads in the study area are predominantly males and married similar to other parts of the country (see Table A in the appendix). More than

44% of the household heads have some formal education while 36.11 and 19.44 percent of the households are illiterate and have some informal education respectively. Households in the study are mainly engaged in on-farm activities while their involvement in off-farm and non-farm activities is limited, which is less than one-third and 14% of the total sample, respectively.

In the study area, 41.27% of the households participate in irrigation practices showing that irrigation practices are common in the study area. It is known that access to financial services is limited in developing countries like Ethiopia. This is exemplified by the figures show in Table A in the appendix. Only 10.32% percent of the households took credit over the last 2 years and only 12% of the sample households received remittances over the last year. The findings also show that a little less than a quarter of the sample households in general are members of farmers cooperatives.

### 3.1.2 Descriptions of Continuous Variables

The results of the data analysis show that the mean age of household heads is 50 and those who attended formal education have completed an average school year of close to 7 Grade. The average household size in this study is close to 5, which is exactly comparable to the national average of about 5 members per household (International Labor Organization, 2021).

Table 2: Description of continuous variables (N= 252)

| Variables | Frequency (Percent) |
|---|---|
| Head Age (years) | 49.45 (12.54) |
| Highest years of schooling completed by the head | 6.55 (2.38) |
| Household size (number) | 4.67 (1.88) |
| Size of Crop Land Owned (ha) | 0.96 (0.72) |
| Livestock holding in TLU (index) | 6.40 (3.43) |

| | |
|---|---|
| Crop diversification (index) | 0.32 (0.33) |
| Distance to nearest Market (walking minutes) | 52.68 (28.71) |

Source: computed from Survey Data (2023)

The average size of crop land owned by households is equivalent with 0.96 ha national average farmland size per household, which is by far higher compared to 0.49 ha for Tigray, and Southern Nations and Nationalities Region and a little bit lower than the average landholding size of 1.09 ha and 1.15 ha for Amhara and Oromia regions respectively (Headey et al., 2014). The average livestock holding of sample households is 6.4 in TLU while crop diversification index based on Herfindahl's formula is found to be 0.32 which is in the lower middle category. Finally, it takes close to 53 minutes for households to reach to the nearby market when walking the distance.

### 3.1.3 Dairy Technology Adoption and Utilization

In Ethiopia, dairy production is generally a subsistence smallholder-based industry with relatively few small and medium commercial dairy farms. In 2019, close to 6.7 million dairy cows produced an estimated 3.6 billion liters of milk nationally, out of which over 95% are from local breeds (Central Statistical Agency, 2021). However, Ethiopian dairy yield is much lower by any standard. Hence, to satisfy the growing need for milk and milk products in Ethiopia, there is a need for adoption of relevant technologies in the dairy sector. In this study, the adoption of dairy technologies includes adoption of improved livestock breed, Artificial Insemination Service (AIS), recommended feed, improved housing conditions and veterinary services. The findings of the survey for sample households in the study area revealed the following results for each technology component.

#### A) Adoption of Breed Component

In Ethiopia, about 95% of the milk produced in the country is from local breeds (Central Statistical Agency, 2021). In fact, the adoption of improved breeds is increasing over the years. In this survey, only 44.8%

of the sample households own one or more improved livestock breeds while the remaining majority (55.2%) of the households did not adopt improved breeds and own only local breeds. The result concurs with a study conducted by (Mekuria et al., 2017) in Gudo Beret Watershed, North Shewa, where he found that 74.6% of the cattle are local breeds while only the rest 25.4% are improved breeds indicating that the adoption of improved breeds in central highlands of Ethiopia are still at low levels.

**B) Adoption of AIS Component**

Reproductive efficiency of the dairy herd is important for the economic success of the dairy operation. One of the most important reproductive technologies of the dairy industry is artificial insemination (AI), which reduces the incidence of sexually transmitted diseases among cattle and increases the use of genetically superior sires to improve performance of the herd. Though it is now close to seven decades since crossbreeding activities were started in Ethiopia, the proportion of both hybrid and exotic breeds is not greater than 2% out of 60.4 million heads of cattle (Central Statistical Agency, 2020). The reality is not much different in the study area, where only less than a quarter of the households adopted AIS, out of which 49.2% of households have low level of adoption. This figure is in agreement with 23.53% adoption of AI in Eastern Tigray studied by Gebre et al. (2022). A study conducted by Korir (2023), on the contrary, showed high level of AI for breeding in a study conducted in urban, peri-urban and intermediate rural areas located within a 60km radius of Addis Ababa, the capital city of Ethiopia. This study has shown as high as 86% of smallholder dairy farms have adopted AI for breeding.

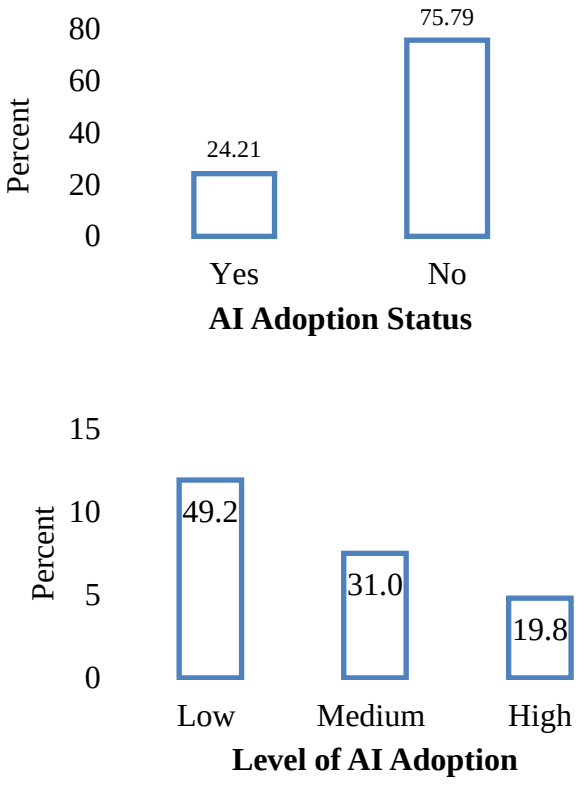


Figure 2: Status and level of adoption of Artificial Insemination (AI) component

Source: computed from Survey Data (2023)

### C) Adoption of Feed Components

Dairy cattle feed improvement is an integral part of the dairy sector development both at national and household levels. In the Ethiopian highlands, the traditional feeding system for dairy cattle is mainly based on the use of crop residues and natural pasture hay/grazing supplemented with a little or no concentrate. Feed resources are not only of low quality, but also do not last for the whole year (Kebede et al., 2017). In Basona Werana Woreda, about 55% of the households

adopt one or more of the recommended feed indicating high level of awareness of the importance of feed in dairy production. Among the most frequently used feed technologies in the study woreda, standardized crop and hay supplement are the leading ones adopted by 59.92% and 58.33% of the sample households respectively while forage legumes are used only by about one-third of the households. In addition, more than 46% percent of the sample households apply two or more of the recommended fodders in combination for their livestock feeding. In terms of intensity of utilization of improved feed, 70.7% of the households adopted a medium and low scale of utilization of the technology while only 15.1% and 5.2% of the households have high and very high rate of adoption.

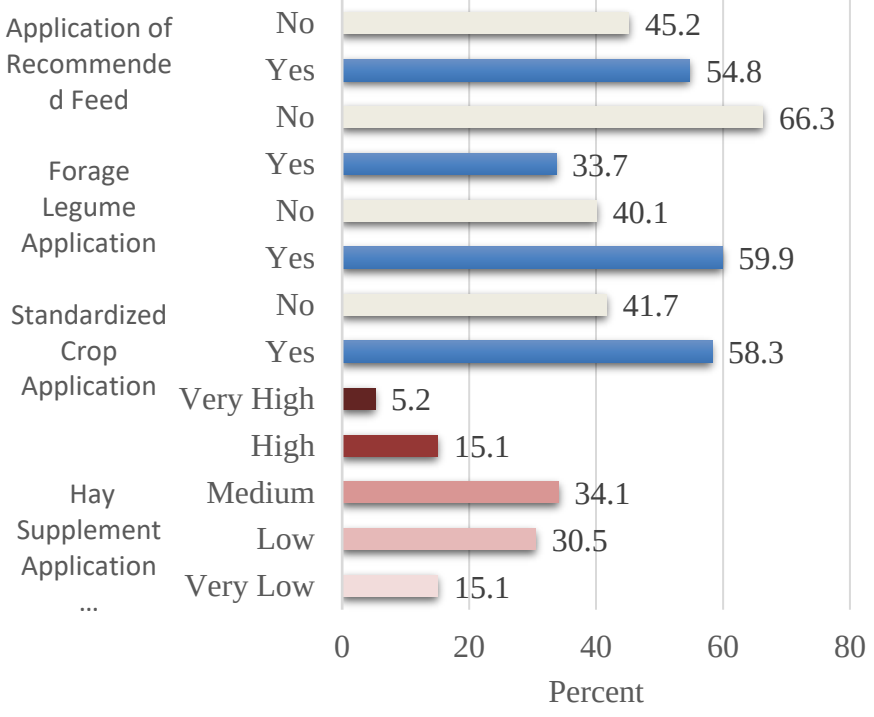


Figure 3: Adoption and intensity of utilization of recommended feed (N=252)

Source: computed from Survey Data (2023)

**D) Adoption of Housing Components**

The adoption of breed, feed and AIS technology in dairy production improvement should be complemented with better housing condition to fully realize their benefits. Improvement of housing conditions is not an easy task for smallholder dairy producers in Ethiopia given their traditional way of living and requirements of huge cost and effort to realize it. In this study, housing condition has been captured by four parameters such as conditions of feeding trough, floor, roof and side wall as well as current condition of housing. The result shows that a significantly higher proportion of the dairy producers (88.49%, 92.06%, 81.17% and 84.86%, respectively) have adopted each of the four housing improvement technologies. However, in all of these components of housing improvement, most of the households have poor scale of housing improvement followed by moderate and good scales, respectively. A study by Korir (2023) have shown that adoption of improved housing even in Addis Ababa and its vicinity is very limited and only a quarter of the smallholder dairy farms have adopted the technology.

Table 3: Adoption and intensity of utilization of housing improvement technologies

| No | Item Description | N (%) | Poor | Mod-erate | Good | Total |
|---|---|---|---|---|---|---|
| 1 | Feeding trough (width, depth, smoothness) | 29 (11.51) | 97 (38.49) | 97 (38.49) | 29 (11.51) | 252 (100) |
| 2 | Floor (slope) | 20 (7.94) | 103 (40.87) | 91 (36.11) | 38 (15.08) | 252 (100) |
| 3 | Roof and Side Wall (ventilation) | 47 (18.73) | 83 (33.07) | 69 (27.49) | 52 (20.72) | 251 (100) |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | Current condition of housing (feeding trough, gutter, floor, side walls and roofing) | 38 (15.14) | 102 (40.64) | 65 (25.90) | 46 (18.33) | 251 (100) |

Source: Computed from survey data (2023)

**E) Adoption of Veterinary Service Components**

Veterinary services in Ethiopia are largely provided by the woreda livestock office with clinics located in every Kebele or one serving not more than three Kebeles. These clinics supply drugs, vaccines and provide animal health related training and advisory services to farmers in their jurisdiction. The service is often constrained by lack of work force, supplies and other resources. The private sector is also increasingly being involved in the veterinary service. The National Veterinary Institute (NVI) produces vaccines and provides distribution support services. It produces vaccines for 16 types of diseases. In general, these services are insufficient in terms of supply as compared to demands especially from smallholders located all over the country. The primary problem is the lack of capacity to produce some essential vaccines, which are not produced at present (Tilaye, 2019). Reports indicate that only 45% of the country has veterinary service coverage (Shapiro et al., 2017). In the study area, more than 79% of the households have indicated that they have access to regular vaccination services while only one-fifth of the households do not have access to the services. Again, from those who have access to regular vaccination services, 91.63% and 8.37% of the households have access to disease preventing and disease curing vaccination services, respectively. Moreover, most of the households rated the current use of vaccination against disease prevalence as moderate and poor with the proportion of

48.61% and 33.07% respectively while only 12.35% of the households rated it as good. The level of access to vaccination goes up to as high as 94% in a study conducted by Korir (2023) in urban, peri-urban and intermediate rural areas with a 60 km radius of Addis Ababa.

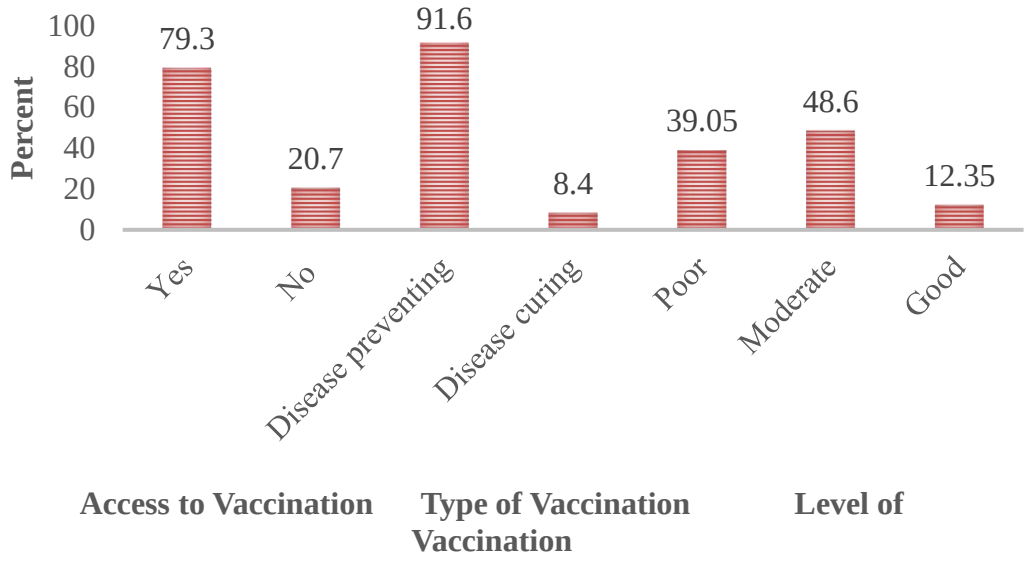


Figure 4: Adoption and level of access to veterinary services in the study area (N=251)

Source: Computed from survey data (2023)

## 3.2 Econometric Regression Results

In addition to understanding the status of households in terms of demographic, socio-economic and livelihood characteristics, it is important to unravel the factors behind their adoption of dairy technologies in the study area. Five packages of dairy technology have been identified namely improved breeds, AIS, recommended feed, vaccines and improved housing technologies. Since households adopt one or more of these technologies, a multivariate probit regression model is applied to account for capturing overlapping consensus in the

decision of households to adopt more than one technology and hence accounting for the correlation of error terms across equations than undertaking a separate probit regression model for the decision of households to adopt each of the dairy technologies. The MVP regression has given robust results showing the model results are overall significant at 1 percent. A crucial test for determining whether Multivariable probit model is preferred over separate probit regressions or not is the test of dependence. The test of dependence is a likelihood ratio test that follows a chi-square distribution where the null hypothesis asserts that the error terms of each of the separate probit regressions are independent (no significant correlations among themselves).

The test result shows that the null hypothesis is rejected with one precent significance in favor of the multivariate probit model, which is approved to handle the problem of significant correlations among the error terms. The test result is shown in the appendix. The overall significance of the model is attested by the significance of the Wild Chi2 reported in Table 4. Multicollinearity problem is checked with *collin* command in Stata and the VIF values are found to be below 2 for each of the variables indicating that the model doesn't suffer from multicollinearity problem. Robust options are also applied to account for the possible problem of heteroscedasticity in the model. Following all applicable tests conducted, the results of the MV Probit regression is reported in Table 4 below.

Table 4: Multivariate Probit Regression Results of Determinants of Diary Technology Adoption in the Study area

| Descriptions of variables | Adoption of Improved breed | Adoption of AIS | Adoption of recommended feed | Adoption of vaccines | Adoption of better housing technologies |
|---|---|---|---|---|---|
| Sex of household head (0 male) | -0.173(0.22) | -0.231(0.24) | 0.081(0.21) | 0.287(0.23) | -0.251(0.24) |
| Age of household head (years) | 0.007(0.01) | -0.006(0.01) | 0.003(0.01) | -0.000(0.01) | -0.000(0.01) |
| Education of the household head (Base: illiterate) | | | | | |
| Informal education | -0.431(0.28) | 0.230(0.29) | 0.027(0.27) | 0.870(0.33)*** | 1.306(0.40)*** |
| Formal education | -0.250(0.22) | 0.571(0.23)** | 0.527(0.22)** | 0.388(0.23)* | 0.341(0.25) |
| Experience in dairy farming (years) | 0.002(0.01) | 0.023(0.01)* | 0.035(0.01)*** | 0.007(0.01) | 0.099(0.02)*** |
| Equb Participation (Base: Not member) | 0.130(0.22) | -0.115(0.22) | 0.050(0.22) | -0.104(0.23) | 0.176(0.25) |
| Access to Credit (Base: no access) | -0.143(0.31) | -0.308(0.38) | 0.240(0.29) | -0.060(0.31) | -0.223(0.39) |
| Cooperative membership (Base: not member) | 0.062(0.23) | -0.431(0.23) | 0.598(0.24)*** | -0.350(0.24) | 1.076(0.35)*** |
| Training on dairy technology (Base: No training taken) | 0.505(0.22)** | 0.534(0.21)** | 0.947(0.21)*** | 0.024(0.23) | 0.059(0.24) |
| Awareness on dairy technology (Base: Not aware) | 1.182(0.21)*** | 0.475(0.22)** | 0.278(0.21) | 0.273(0.23) | -0.152(0.25) |
| Household size (number) | -0.113(0.07)* | 0.043(0.06) | -0.014(0.05) | 0.100(0.07) | -0.148(0.07)* |
| Dependency Ratio | 0.025(0.15) | -0.479(0.16)** | 0.044(0.14) | -0.115(0.15) | 0.186(0.21) |
| Livestock Asset (TLU) | 0.076(0.03)** | 0.064(0.03)** | 0.115(0.03)*** | 0.144(0.04)*** | 0.074(0.04)* |
| constant | -1.134(0.57)** | -1.694(0.60)*** | -1.974(0.53)*** | -0.860(0.56) | 0.093(0.59) |
| Loglikelihood | -522.8.761 | | | | |
| Number of Observations | 247 | | | | |
| Wald Chi2 (60) | 229.06 (Prob > chi2 = 0.000) | | | | |

Source: Computation from survey data (2023). Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The multivariate probit regression came up with interesting results. Livestock assets captured in terms of TLU has positive and significant effect in the adoption of all the dairy technologies signifying that the more livestock asset a household has the better it gets motivated to adopt better dairy technologies, which is in line with Zemarku et al. (2022) and Korir (2023). Similarly, households with heads who have taken training on dairy technology are found to have higher probability of adopting three of the dairy technologies namely improved breeds, AIS and recommended feed compared to those who have not. These results are in line with Bassa (2021), Diro et al. (2016, Getachew et al. (2020), and Jena et al. (2022).

Household heads who have informal education have a higher probability of adopting vaccines and better housing technologies while household heads with formal education have significantly higher probability of adopting AIS, recommended feed and vaccines compared to those households with illiterate heads. These results exemplify the role of both formal and informal education in supporting the decision of households to adopt dairy technologies. This is in agreement with studies such as Claire et al. (2018), Feyissa et al. (2023), Job et al. (2020), Korir (2023), and Tesfaye & Gutema (2022). Similarly, households with more years of experience in dairy farming have higher probability of adopting AIS, recommended feed and improved housing conditions in line with Korir (2023) and Zemarku et al. (2022).

Members of cooperatives have a significantly higher probability of adopting recommended feed and better housing technologies at 10% level of significance. The result concurs with previous studies by Manda et al. (2020) and Mina & Agham (2023). On the contrary, greater household size is associated with lower probability of adopting improved breeds and better housing technologies in accord with Sarah et al. (2021) in affecting the adoption of modern dairy farming in Bangladesh and with Diro et al. (2016) in affecting the extent of dairy technology adoption in Southwest Ethiopia. This result is in contradiction with previous studies such as Bassa, (2021) and Tadese

(2020). The effect of household size on adoption of technology is mixed in the literature. If a greater household size is associated with more dependency ratio, then the burden of caring and feeding dependents creates a huge economic burden on active members of the household thereby negatively affecting the likelihood of households adopting dairy technologies. Another possible explanation could be that a greater household size could discourage adoption of labor-saving technologies. However, if large household size means more breadwinners for the family, then that might boost the capability of the household to buy more technologies. The fact that dependency ratio has a negative and significant effect on the probability of adopting AIS in this research is supportive of the former argument and agrees with Kebebe (2015). Finally, households that have awareness of improved dairy technologies have higher probability of adopting improved breeds and AIS compared to those that do not have awareness supporting previous studies such as Russell and Hoag (2004), Høyer et al. (2019), Kaushik et al. (2023) and Quddus (2013). Other variables were not found to have significant effect in the adoption of any of the technologies.

# 4. Conclusions and Implications

This study is aimed at examining the dairy technology adoption status of rural households in one potential woredas in the central highlands of Ethiopia. Though Basona Werana woreda is one of the milkshed areas in Ethiopia, the extent of adoption is limited in most of the dairy technologies considered in this study particularly improved breeds, vaccination and artificial insemination. Though several decades passed since the introduction of cross-breeding activities in Ethiopia, only less than a quarter of the households adopted artificial insemination, out of which close to half of them have low level of adoption. The findings of the study allude to the need for directing more resources for and focus on increasing the likelihood of dairy technology adoption in the study area and other high potential areas of milk production in the country.

More importantly, the study revealed that the extent of adoption of improved breeds, AIS, improved feeds, vaccines and improved housing condition are all at low levels. Hence, a concerted effort by stakeholders is required to increase the awareness of households about the technologies as well as enhance access of households to those improved services. The multivariate regression results have shown that rural households that have more livestock resources have greater likelihood of adopting improved dairy technologies compared to those that do have less. Thus, dairy farmers need to mobilize financial, human and capital resources to develop their livestock asset so as to leverage the adoption of dairy technology.

Expansion of formal education as well as provision of training tailored to the needs of dairy farmers are crucial for enhancing the adoption of dairy technologies and thereby improving their livelihood outcomes. Besides formal way of improving the awareness and knowhow of farmers to dairy technology, it is equally important to find indigenous and traditional mechanisms and social networks/platforms to boost the adoption of dairy technologies. Cooperatives have understandably key roles in the dairy value chain but the findings also showed that they have important contributions in increasing dairy technology adoption. Therefore, government and other stakeholders in the sector need to consider the importance of farmers' cooperatives in the development of the dairy sector.

Finally, managing the family size of rural households in the study area could reduce the financial burden of dairy farmers due to large family size. This would boost the adoption dairy technologies. Accordingly, developing access and practice of family planning tools for dairy farmers in the study area is useful for farmers to fully benefit from the adoption of dairy technologies.

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**Conflict of Interest**

The author declares he has no competing interests.

**Authors' Contribution**

The author contributed solely to the article.

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# Appendix

## Likelihood Ratio Test of Dependence

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 47.8823 Prob > chi2 = 0.0000

The likelihood ratio test of dependence test rejected the null hypothesis that there is no significant correlation among the error terms of the bivariate probit regressions suggesting that the bivariate equations are dependent to each other and need to be accounted using multivariate probit regression thereby dictating the use of multivariate probit regression instead of separate bivariate probit regressions.

**Table A: Description of categorical variables (N= 252)**

| No. | Variable Description | Response Categories | Frequency (Percent) |
|---|---|---|---|
| 1 | Sex of household head | Female<br>Male | 66 (26.19%)<br>186 (73.81%) |
| 2 | Marital status | Married<br>Divorced<br>Widowed<br>Single | 222 (88.10%)<br>9 (3.57%)<br>16 (6.35%)<br>5 (1.98%) |
| 3 | Education of the head | Illiterate<br>Informal education<br>Formal Education | 91 (36.11%)<br>49 (19.44%)<br>112 (44.44%) |
| 4 | Participation on off-farm activities | Yes<br>No | 73 (29.08%)<br>178 (70.92%) |
| 5 | Participation on non-farm activities | Yes<br>No | 34 (13.55%)<br>217 (86.45%) |
| 6 | Participation in irrigation farming | Yes<br>No | 104 (41.27%)<br>148 (58.73%) |
| 7 | Access to credit over the last 2 years | Yes<br>No | 26 (10.32%)<br>226 (89.68%) |
| 8 | Access to remittances | Yes<br>No | 30 (12.00%)<br>220 (88.00%) |

| | | | |
|---|---|---|---|
| 9 | Membership to farmers cooperatives | Yes<br>No | 55 (21.83%)<br>197 (78.17%) |

Source: computed from Survey Data (2023)

Table B: Multicollinearity test using *collin* command in Stata

| Descriptions of variables | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| Sex of household head | 1.10 | | | | |
| Age of household head | 1.36 | | | | |
| Informal education | 1.39 | | | | |
| Formal education | 1.52 | | | | |
| Experience in dairy farming | 1.17 | | | | |
| Equb Participation | 1.17 | | | | |
| Access to Credit | 1.07 | | | | |
| Cooperative membership | 1.09 | | | | |
| Training on dairy technology | 1.53 | | | | |
| Awareness on dairy technology | 1.51 | | | | |
| Household size | 1.43 | | | | |
| Dependency Ratio | 1.23 | | | | |
| Livestock Asset (TLU) | 1.37 | | | | |
| Mean VIF | 1.30 | | | | |

Source: computed from Survey Data (2023)