IMPACT OF IMPROVED SORGHUM VARIETY (*MELKAM*) A DOPTION ON SMALLHOLDER FARMERS FOOD SECURITY IN BABILE DISTRICT, EASTERN ETHIOPIA

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ABSTRACT

Extreme drought condition is a serious challenge for agricultural production and threating food security in sub-Saharan country including Ethiopia. Adoption of improved crop varieties like sorghum is very important to improve household food security. However, adoption of improved sorghum in our country is very limited due to several factors. The aim of this study was to examined adoption of improved sorghum variety (melkam) and its impact on smallhol der farmers' food security in Babile district Eastern Harerghe zone, Oromia regional state, Ethiopia. A combined research approach (a mix of quantitative and qualitative methods of data collection and analysis) was employed. A multistage sampling procedure was used to select five (5) kebeles and 320 sample household heads. Primary data was collected through an interview schedule assisted survey questionnaire, focus group discussion, key informant interview and secondary data was collected through document review. Descriptive, Household calorie acquisition and econometric were applied for data analyses. The descriptive statistics revealed that age of household head, years of schooling, land size, farm income, market distance, access to extension service, access to credit service, and farmer cooperative were found to significantly differentiate adopter and non- adopter households at various levels. Moreover, the result of binary logistic regression revealed that years of schooling, farm size, annual farm income, access to credit service, access to extension service, farmer cooperative, age of households and market distance were significant factors determining improved (melkam) sorghum variety adoption in the study area. The results of propensity score matching also showed that the adoption of melkam sorghum variety had a positive and significant impact on household food security. Those who adopted improved (melkam) sorghum variety were found to have about 528.67 Kcal/Adult/Day than non-adopter households. Therefore, this result implies that improving educational level, creating a special line for credit access, enhancing farmer cooperative in the area needed government attention to enhance improved sorghum variety adoption. Furthermore, to enhance and sustain the positive impact of improved (melkam) sorghum variety adoption local leaders should work on the dissemination of improved (melkam) sorghum variety in the area.

KEYWORDS

adoption, food security, impact, improved (melkam), sorghum Babile

1. INTRODUCTION

1.1. Background

Climate change results in significant losses of agricultural production and threatens food security across the globe (Lesk *et al.,* 2016). In the last decade, for instance, the agriculture sector shares about 25% of climate-associated disasters, and subsequently lost around 25 billion USD (Karki, 2020). The development and use of well-adapted and resilient crop varieties are the keys to a more sustainable solution for mitigating climate change effects (Makate *et al*., 2019). A drought-tolerant crop, sorghum (*Sorghum bicolor L. Moench*) is the sixth (6) most planted crop in the world (Wagaw *et al*., 2020). It is one of the most vital cereal crops utilized for food and supports in different parts of the world (Mekonnen *et al*., 2021). For those living in dry and semiarid regions, of Africa, sorghum is the most important cereal, which around 300 million individuals depend for their daily consumption (Zhao *et al.,* 2019; Adebo *et al.,* 2020).

The commercial value of sorghum has increased considerably since it is processed into food product (Mundia *et al*., 2019*;* Sissoko *et al*., 2019). Sorghum consumption and utilization has increased in the developing world, and sorghum production has increased at an annual average rate of 2.5 % (Sultan *et al*., 2019).Sorghum crop grown in almost all regions of Ethiopia and used as a staple food crop on which the lives of millions of Ethiopians farmers depend on it (Semahegn and Teressa, 2021). Other authors estimate that sorghum is used in a variety of methods, including traditional meals such as Injera, local bread, porridge, and beverages (Yali and Begna, 2022).

In 2020, out of the total grain crop area covered by cereals; i.e., 10.2 million hectares, 14.97% (1.88 million hectares) covered with sorghum, ranking third next to teff and maize (Teressa *et al.,* 2021). Similarly, out of the total national grain production, cereals contribute to 87% (253 million quintals) with sorghum shares amounting to up to 16% (47 million quintals) (CSA, 2018).

Sorghum contribution to food security where provides more than one-third of the cereal daily diet consumption and it is almost entirely grown by subsistence farmers to meet the needs for food, income, feed, traditional brewing, and construction purposes (Chifra, 2020). Sorghum was measured as a main food security crop in Ethiopia, which is contributing 18% of the total grain production (CSA, 2018). Adoption of improved sorghum varieties to the extreme drought area better than any other crop makes it one of the best crops for improving food security (CSA, 2018). Due to these and other reasons, sorghum cannot simply be excluded in national policy, agricultural research, and development initiatives.

The ability of improved sorghum varieties to withstand drought stress with early maturing and give reasonable yields under adverse environmental conditions has secured its importance as a food security crop in arid and semi-arid lowlands of the East Harerge zone (Markos *et al*., 2020). Sorghum and maize in the Eastern Harerge zone contributed 28.11%, 26.55 % of the grain crop area, and 31.18 %, and 29.67% of the production of the zone, respectively (Markos *et al*., 2020). Despite its huge economic benefits, sorghum production and productivity are limited by a variety of environmental, socio-demographic, institutional, and market-related factors.

In Ethiopia food insecurity are multifaceted and complex. It is attributed to different factors like land degradation, climate change, low income, low level of farm technology utilization, high level of illiteracy, and high population growth and intra state military conflicts and wars (Hailemariam, 2016; Sileshi *et al.,* 2019;Sisha,2020). Furthermore, the utilization of improved agricultural technologies has paramount importance in ensuring food security at both the household level and national level.

Some studies have looked the impact of improved sorghum varieties adoption on farm families (Assima and Smale, 2016; Firew *et al.*, 2016; Smale *et al.*, 2018; Pawlak and Kołodziejczak, 2020) using Randomized Controlled Trial (RCT) model looked at the food security situation of the household. However, there is an embark to use propensity score matching is evitable that economists mainly recommended for the analyses of impact intervention or evaluation of the program on food security (Wordofa *et al*., 2021). Therefore, this study used the recommended impact evaluation model, which is propensity score matching model to evaluate the impact of improved (*melkam*) sorghum variety adoption on the food security of smallholder farmers.

Yet, information concerning adoption of the technologies and its impact evaluation on food security in the *Babilel* district was not empirically documented and often poorly understood. Therefore, this study was conducted to evaluate the impacts improved sorghum variety (*melkam*) adoption on food security of smallholder farmers in Babile district East Harerghe zone, Oromia regional state, Ethiopia.

1.2. Objectives of the Study

1.2.1. General objective

The general objective of this study is to analyze adoption of improved sorghum variety (*melkam*) and its impact on the food security of smallholder farmers in Babile district.

1.2.2. Specific objective

- To describe the status of improved *(melkam*) sorghum variety adoption in the study area.
- To identify the determinants of improved (*melkam*) sorghum variety adoption in the study area.
- To evaluate the impact of the adoption of sorghum (*melkam) variety* on food security of farm households in the study area.

1.3. Research Question

This study strived to answer the following questions:

- What is the status of melkam sorghum improved variety adoption in the study area?
- What are the determinants of sorghum (melkam) improved variety adoption in the study area?
- What is the impact of sorghum (melkam) improved variety adoption on the food security of smallholder farmers?

2. RESEARCH METHODOLOGY

In this chapter, a description of the study area, sampling method and sample size, data type, data sources and method of data collection, method of data analysis, and description of variables and hypothesis was presented detail.

2.1. Description of the Study Area

Babile district in the eastern lowlands of Ethiopia is situated at the semi-arid transboundary of Oromia and Harari Regions, located about 560 km southeast of Addis Ababa. The capital town of the zone is Harer, which is 15 km from Babile district. Baabile bordered on the South and East by the Somali Regional state and on the North West by Harari Regional state and on the West by Fedis, and the north by Gursum district. Geographical, it is located at 08 9,90'N latitude, 42021'E longitude, and the district has an altitude that ranges from 950 to 2000 m above sea level. The mean annual minimum and maximum temperature range from18-28oC while the mean annual rainfall and humidity ranges from700 900mm and 33 38%, respectively (Amentie, *et al*., 2019). According to the current administrative division, the woreda is subdivided into 22 kebeles (20 rural kebeles and 2 urban kebeles) administrations.

The total population of Babile district was estimated to be 118,537 (DANR, 2020) of the district. Out of this, males were for 59,298 (%) while females were 59,139(%). The woreda also has around 10,874 households. In sex ratio 8,985(82.6%) are male-headed households and 1,889(17.4%) are female-headed households (Gudeta, 2017).

Mixed agriculture is the predominant economic activity of the study area, crop producing as a primary activity and stock rearing as a secondary activity. Cereals, pulses, oil crops and horticultural crops specially sorghum, are the major crops produced by farmers.

Agricultural production is the main means of livelihood for the district. Crop production is dependent on rainfall and the major crops produced in the area according to their importance are maize (29%), sorghum (30%), groundnut (25%), sweet potatoes (17%) of the total area cultivated(DANR,220).Most families also rear livestock. Oxen provide traction power for the cultivation of agricultural lands. On the other hand, livestock was kept as a source of income through milk.

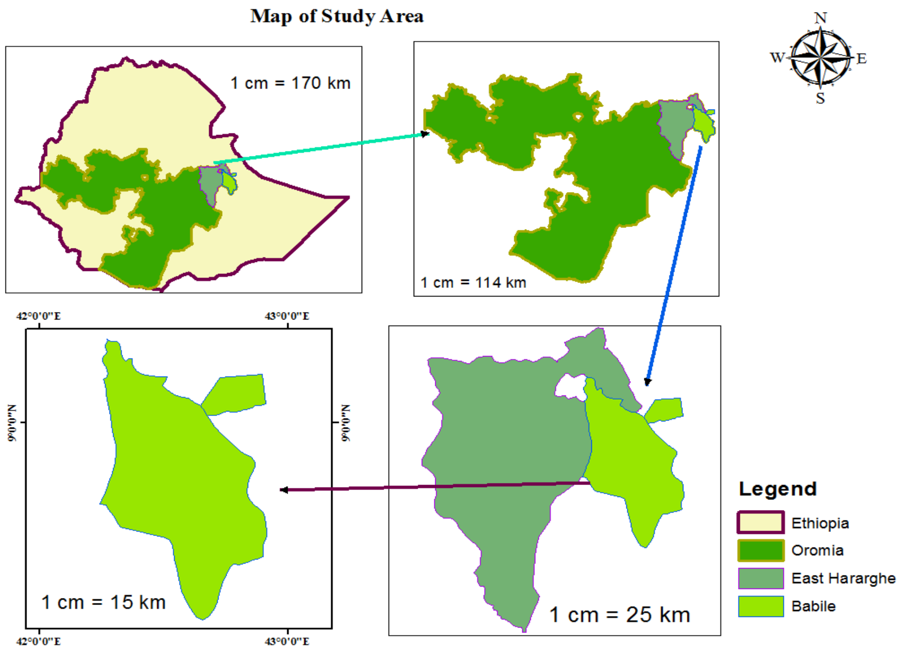

Figure 1: Map of the Study Area Source: Ethio-Arc GIS, 2021

2.2. Research Design

A cross-sectional survey research design with both quantitative and qualitative approach was used in order to capture the data required for the determinants of *melkam* sorghum variety adoption and its impact on food security of smallholder farmer. According to Mann (2003), this type of research design used in descriptive research and the determination of the relationship of variables.

2.3. Sampling procedure and sample size determination

Multi-stage sampling procedures used. At the first stage, out of 18 rural districts of the Eastern Hararhge zone, *Babile* district was purposively selected based on the potential of sorghum production and *melkam* sorghum variety is promoted to the area and crop technology pilot testing was there in the district from the zone. In the second stage of the sampling process, out of 20 sorghum producer *kebeles* of the district, in which improved (*melkam*) sorghum variety was distributed and adopted by some farmer households, five (5) *kebeles* were randomly selected. At the third stage, the household heads in five the (5) *kebeles* were stratified as *melkam* sorghum variety producers and non-producers using stratified sampling. Finally, 320 household heads were selected using a simple random sampling technique by lottery method and probability proportional to the size of the total population of the five (5) *kebeles* (Table 1). The sample size for this study was computed based on Kothari' (2004), sample size determination formula.

$$n = \frac{Z^2 pqN}{e^2(N-1)+Z^2 pq}$$

$$n = \frac{(1.96)^2 0.5 * 0.5 * 1925}{(0.05)^2(1925-1)+(1.96)^2 * 0.5 * 0.5} = 320$$

2.4. Methods of Data Collection

A. Primary data collection methods

Household survey interview schedule

To generate quantitative information at the household level, the survey was undertaken by using an interview schedule. The structured interview schedule has particularly consisted of the issues related to the demographic, socio-economic, market and institutional variables relevant to the study were collected from the respondents. To capture the Household caloric acquisition (daily calorie intake) by each of the sampled households, sort of questions were also included to investigate, the amount of grain purchased, types of grain purchased for food-for-work, and amount of item consumed by sample respondents or households in the last seven days were collected. The surveys were carried out with the help of development agents (DAs) in each of the target *kebele*s.

Focused Group Discussion (FGDs)

To have detailed information and to complement the information obtained from the household survey; qualitative primary data was gathered by holding discussions with purposively selected participants. This technique emerged as a qualitative data collection approach and a bridging strategy for scientific research and local knowledge (Nyumba *et al*., 2018). The topic treated includes, does local farmer grow Melkam Sorghum variety? What makes *melka*m sorghum most preferable crops in the area? In addition, how *melkam* sorghum variety and food security situation in the area interact were captured by FGDs.

Members of the focus group were selected purposively based on similarity in the adoption of *melkam* sorghum variety. In total ten FGDs ,two (2) FGDs at each selected five (5) *kebeles*, by considering their socio-economic background or stratified in two groups adopter (3-4 male and 3-4 female-headed households at one time) and non-adopters(male and female headed household) were organized to generate detailed information related to the research question. Using the necessary checklists developed to guide the discussion was made in the local language (Afan Oromo), the time for discussion was one hour (1) in each group discussion and directed by the researcher.

Key Informant Interviews (KII)

The primary data collected from sample household heads need to be further enriched by additional information gathered through key informants. Thus, the intensive interview was conducted with key informants selected from the district agricultural and rural development office, development agents from target *kebeles,* and community members (men and women) from each five (5) *kebeles* were included as a key informant interview. Topics treated include what is the trends of *melkam* sorghum variety adoption in the past five years, why farmers prefer *melkam* sorghum variety, how *melkam* sorghum contributes to the food security of smallholder farmers in the study area, and how sorghum reduce food shortage in the study area.

B. Secondary data source

Secondary data was gathered by document analyses from published and unpublished documents and literature related to the research objectives was reviewed. Documents and reports maintained at Farmer Training Center (FTC) by Development Agents (DAs) and district agricultural offices were referred to as major sources of secondary data. Document review was the main technique for the secondary data collection.

2.5. Methods of Data Analysis

Binary logistic regression and propensity score matching were employed to analyze the factors influencing the adoption of improved (*melkam)* sorghum variety and its impact on food security respectively.

Measurement of household food security

Household Caloric acquisition approach was used to measure household food security which is measured daily calorie intake measured by Kcal/AE/day at household level. Using 2200 calories per person per day as cut off point, which was used as a measure of minimum calories required per adult equivalent per day to enable an adult to live a healthy and moderately active life FDRE (2002).

2.6. Econometric Model Specification

Following Kothari (2014), this particular study was used a binary logistic regression model, where the dependent variable was Y and the independent one was X was employed. To explain the model, the following logistic distribution function was used (Gujarati, 1995).

Pi=∈ (Y=1/Xi) = 1/ (1+e^ (-(β1+β2xi)…... (1)

When Zi replaces β 1+ β2Xi in Equation 1, Equation 2 is obtained:

Pi=1/ (1+e^ (-Zi)…………………………….……………….…..……….….... (2)

Z i is between - ∞ and + ∞, and P i is between 1 and 0. When Pi shows the possibility of the household being participant, the possibility of being a non-participant is 1- Pi. Then, the possibility of non-participants can be explained as in Equation 3 as follows:

1−Pi=1/ (1+e^Zi)……………………………………………………….…………..…..(3)

Equation 4 is obtained by dividing the participants by non-participants:

Pi/ (1-Pi)=(1+e^Zi)/(1+e^(-Zi))=e^Zi……………………………….....……..….. (4)

When the natural logarithm of both sides of the equation is written, Equation 1 is obtained

Li=ln(Pi/(1-Pi))=Zi=$\beta 1$+$\beta 2Xi$…………………………….………………..……..…. (5)

Pi=∈(Y=1/(Xi)=1/(1+e-(β1+β2X1+β3X2+⋯+βk Xk))……………..…..…………..…(6)

Odds are defined as the ratio of the number of events that occurred to the number of events that did not occur.

Zi=βo+$\varepsilon\beta iX$+Ui………………………………………………………………..... (7)

Propensity Scores Matching (PSM)

The propensity score matching method was used in this particular study to analyze the impact of sorghum *(melkam)* variety adoption on the food security of smallholder farmers. The main challenge in undertaking a reliable impact evaluation is the construction of the counterfactual outcome.

According to Caliendo and Kopeinig, (2008), some steps apply in PSM. These steps are predicted propensity scores, choosing matching algorism, restricting common support areas, testing matching quality or balancing tests, and sensitivity analysis. These are described as follows:
Step 1: Propensity scores- A Logit model is used to estimate Propensity Scores for each observation. The advantage of this model is that the probabilities are bounded between zero and one. The dependent variable is dichotomous, taking two values, 1 if an individual participates in sorghum (*melkam*) adoption and 0 otherwise. The covariates used to predict treatment assignment using logistic regression, specified as:-

$$L_i = l_n\left(\frac{p_i}{1-p_i}\right) = \ln\left(e^{\beta_\circ} + \sum_{j=1}^{n}\beta_j X_{Ji}\right) = Z_i = \beta_\circ + \sum_{j=1}^{n}\beta_j X_{Ji}$$

Average Treatment on Treated (ATT): It was used to evaluate the impact of *melkam* sorghum (adoption on the participant group. It is the difference between the outcome of treated and the outcome of untreated observations if they had not been treated (counterfactual) computed as:

$$ATT = E\left(Yi^T - Yi^c|D=1\right) - E\left(Yi^T\,|D=1\right) - E(Yi^c|D=1).$$

3. RESULTS AND DISCUSSION

3.1. Impact of *melkam* Sorghum variety adoption on Food Security of Smallholder Farmers.

As indicated in Table 7 below, the mean daily household calorie consumption of the whole sample respondents is 2180.86 Kcal/AE/day. The mean daily household calorie intake of the sample adopter's households is 2440.95 Kcal/AE/day while that of the non-adopter household was 1960.789 Kcal/AE/day. The mean difference in calorie intake per adult equivalent between the adopter and the non-adopter households was found to be 480.170 Kcal/AE/day. The statistical test shows a significant association between improved *(melkam)* sorghum variety adoption and caloric intake at a p<1% significance level (t=7.674, P<1%).

Table 1: Table Descriptive statics of survey outcome variable

Outcome Variable	Minimum	Maximum	Adopter	Non-Adopter	Overall mean	Mean Differen	T-value
Calorie intake/AE/day	990.2	3568	2440.95	1960.78	2180.8	480.17	7.67***

Source: Own survey result, 2021
Note: *** Significant at 1% probability level of significance

As indicated in Table 2 below, about 68.16% of *melkam* sorghum variety adopters and 31.84% of non-adopter were food secured while 78.72% of non-adopter and 21.28% adopters were food insecurity. This indicated that most non-adopter were food insecure. The Chi2-test indicated that there was a significant association between adopters and non-adopters in terms of food security status at a 1% significant level. However, this result cannot tell us whether the observed difference was exclusive because of the adoption or not. It is not possible to attribute the difference in calorie intake/adult equivalent of the two groups exclusively to the program, as comparisons were not yet restricted to households who have similar characteristics. Therefore, further analysis was performed using propensity score matching techniques to address this issue.

Table2: Food security status of sampled respondents

		Food secured	Food insecure	
		Frequency %	Frequency %	Chi^2-test
Adoption of *melkam* sorghum variety	Adopter	122 (68.16)	30 (21.28)	69.5***
	Non-adopter	57 (31.84)	111 (78.72)	
	Total	179(55.94)	141(44.06)	

Source: Own survey result, (2021)
*** Refers to significant at 1% level

3.2. Propensity score matching

As stated in the methodology part, further analysis was performed using propensity score matching techniques to evaluate the impact of *melkam* sorghum variety adoption or intervention program on food security of smallholder farmers. Therefore, to generate statistically acceptable matched pairs between adopter and non-adopter, the propensity score matching (PSM) probability model was performed. The logic behind propensity score methods is that balance on observed covariates through careful matching on a single score. This study used propensity score matching techniques to build a matching pair for an adopter that has similar observable characteristics between improved (*melkam*) sorghum variety adopter and non-adopter households based on p-score in absence of baseline data**.**

3.2.1. Estimation of Propensity Score

Propensity scores can be constructed using a logit or probit regression to estimate the probability of a unit's exposure or assignment to the program. The probability of participating in (*melkam*) sorghum variety adoption, conditional on a set of observable characteristics that may affect probability in *melkam* sorghum variety adoption, in this study the propensity scores were constructed using the logit regression because it is the most common model for propensity score estimation as stated in Staurt (2010). Therefore, in this study, a logit model was used to match adopter and non-adopter households to provide information on household's probability of adopting *melkam* sorghum variety on household food security. The results of the estimated propensity score distribution by logit model was depicted (Appendix table III.

3.2.2. Identifying common support region

As depicted in Table 3 below, the propensity scores vary between .334 and .9755 for adopters of improved *(melkam*) sorghum with a mean of .6915, whereas the score varies between .0055 and .9562 for non-adopter households with a mean score of .2746. Then the common support region lies between .334 and .9562. This means that households whose propensity score is less than the minimum (.334) and larger than the maximum (.9562) are not considered for matching purposes. Based on this procedure, some of the sample respondents were discarded from the impact assessment. Thus, in the analysis, 2960 sampled households that have common support regions were included for analysis.

Table 3: Distribution of estimated propensity score of smallholder farmer household

Variable	Observation	Mean	STD	Min	Max
All sample respondent	320	.4726	.3242	.0055	.9755
Adopter	152	.691	.2311	.0334	.9755
Non-adopter	168	.2746	.2636	.0055	.9562

Source: Own survey result (2021)

3.2.3. Choosing Matching Algorithm

Matching estimators were tried in matching the treatment and control households in the common support region. The final choice of a matching estimator was guided by different criteria such as equal mean test (balancing test), pseudo $R^{2,}$ and size of the matched sample. A balancing test is performed to know whether there is a statistically significant difference in the mean values of covariates for adopters and non-adopters and preferred when there is no significant mean difference. Matched estimators like the nearest neighbor, caliper, kernel, and radius with different bandwidths and the nearest neighbor were selected.

A matching estimator that balances all explanatory variables contains low Pseudo-R^2 value, and has a large matched sample size is the best estimator for impact. Thus, Nearest Neighbor (2) was selected for the matching analysis as the best estimator since it resulted in a relatively low pseudo R^2 after matching, best balancing test all covariates, the p-value was insignificant after matching, and it contains high matched sample size as compared to other matching estimators.

As depicted in Table (4) below, Nearest Neighbor (2) was founded to be the best estimators for this study, and the impact analysis procedure was followed and discussed by using this matching algorism.

Table 4: Performance of matching estimators

Matching Algorisms	**Performance criteria**		
	Balancing test*	**Pseudo-R2 after matching**	**Matched sample size**
Nearest Neighbor (NN)			
Neighbor(1)	14	0.391	296
Neighbor(2)	**15**	**0.026**	**296**
Neighbor(3)	14	0.028	290
Neighbor(4)	15	0.029	292
Neighbor(5)	14	0.028	290
Caliper Matching(CM)			
0.01	12	0.46	296
0.1	13	0.393	296
0.25	13	0.052	296
0.5	13	0.039	296
Kernel Matching (KM)			
With band width of (0.01)	12	0.039	296
With band width of (0.1)	14	0.031	302
With band width of (0.25)	12	0.336	296
With band width of (0.5)	12	0.341	296
Radius Matching(RM)			
With band width of (0.01)	11	0.302	296
With band width of (0.1)	12	0.302	286
With band width of (0.25)	12	0.326	289
With band width of (0.5)	11	0.302	302

Source: Own survey result, 2021.

3.2.4. Verifying the common support condition

As depicted in Table 5 below the total treated observation 6 (3.947 %) households are off support, while 146 (96.05%) households are in the support region. Each treated unit is matched only with the control units whose propensity scores fall into a predefined common support region of the propensity score matching. Households that lie outside this region are discarded from analysis and because of this restriction, 6 treated and 18 untreated households were excluded from the analysis.

Table 5**:** Psmatch2 Common Support

Psmatch² Treatment assignment	**Common support**		
	Off support	On support	Total
Untreated (non- adopter)	18	150	168
Treated(adopter)	6	146	152
Total	24	296	320

Source: own survey results in 2021

A visual inspection of the density distributions of the estimated propensity scores for the two groups indicates that the common support condition is satisfied: there is substantial overlap in the distribution of the propensity scores of both adopters and non-adopter groups. The bottom half of the graph shows the propensity scores distribution for the non-adopters and the upper half refers to the adopters. The densities of the scores are on the y-axis (Figure 1).

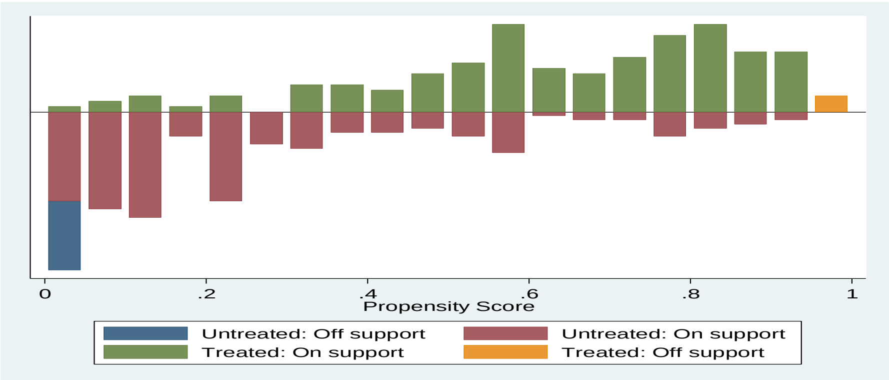

Figure 1: Propensity score distribution and common support for propensity score estimation.

Note: ‘‘Treated/untreated: on support’’ indicates the observations in the adopter group that have a suitable comparison and off support indicates the observations in the adopter group that have no suitable comparison.

3.2.5. Testing the balance of the score and covariates

Checking the balancing of propensity score and covariate is the next step that is performed using different procedures by applying the selected matching algorithm, after choosing the best performing matching algorithm and common support condition. According to Dehejia (2005), the main purpose of the propensity score estimation is not to obtain a precise prediction of selection into treatment, but rather to balance the distributions of relevant variables in both groups. Different test methods, such as the reduction in mean standardized bias between matched and unmatched households, equality of means using t-test, and chi-square test for joint significance for the variables used, are used to determine the estimations' balancing powers. After selecting the best performing matching algorism, which satisfies prior identified performance criteria, the balance of propensity score and explanatory variables was checked by the selected matching algorism (Neighbor (2) in this study).

The results from show that the standard bias difference between explanatory variables before matching was in the range of 25.5% and 83.6% in absolute value. But after matching, the remaining standardized error differences between explanatory variables lay between 0.7 % and 11.6% in absolute value which is below the critical level of 20% suggested by Rosenbaum and Rubin(1983). The main intention of estimating propensity scores is not to get a precise prediction of selection into treatment. Rather, to balance the distributions of relevant variables in both groups (Caliendo and Kopeinig, 2008). Therefore, the selected matching algorism, Neighbor (2) has created a covariate balance between *melkam* sorghum variety adopters and non-adopter households, which is important to conduct impact analysis.

As indicated in Table 6 below, the standardized mean difference for overall covariates used in the propensity score (around 62.0% before matching) reduced to about 7.4% after matching. The pseudo- R2 also dropped significantly from 35.2% before matching to about 2.6% after matching. After matching, the adopter and non-adopter households had the same distribution in the covariates, based on the low pseudo-R2, low mean standardized bias, high total bias reduction, and insignificant p-values of the likelihood ratio test. The results indicate that the matching procedure can balance the characteristics in treated and matched comparison groups. Hence, these results can be used to assess the impact of adoption of improved *(melkam)* sorghum variety among groups of households having similar observed characteristics. This enables to compare observed outcomes for adopters (participants) with those of a non-adopter group sharing common support in the study area.

Table 6: Propensity score matching quality test

Sample	Ps R2	LR chi2	p>chi2	Mean Bias	Med Bias	B	R	%Var
Unmatched	0.352	155.6	0.000	62.0	53.4	165.1*	0.65	33
Matched	0.026	10.72	0.826	7.4	5.8	38.3*	1.35	22

Source: Own survey result, 2021.

3.2.6. Estimating Average Treatment Effect on Treated (ATT)

As already mentioned, the following impact indicators of the treatment effect have been performed using the PSM model to attain the stated objective. Table (7) presents the estimation result that provides supportive evidence of the statistically significant effect of the adoption of improved *(melkam)* sorghum variety households' food security. A positive value of the average treatment effect on the treated (ATT) indicates that the farmer households' food security status in Kcal/AE/day has been improved as a result of the adoption of improved *(melkam)* sorghum variety in the study area. This means that as compared to similar/matched farmer households that improved (*melkam*) sorghum variety adopters had an average consumption of food of 528.67 kcal/AE/day than non-adopter, which is accepted at a 1% level of significance. That means the contribution of the adoption of improved *(melkam)* sorghum variety has increased the calorie intake of the participant households by more than about 21.81 % from what they would have consumed in the absence of adopting improved *(melkam)* sorghum variety.

As clearly depicted in Table 7 below, the kcal/AE/day of adopters of improved *(melkam)* sorghum variety were higher than those of non-adopter farmer households in all propensity score matching methods. Therefore, the current research hypothesis that said, "Adoption of improved *(melkam)* sorghum variety increases food security status of adopters" is accepted at a 1% level of significance. This indicates that the adoption of improved (*melkam*) sorghum varieties has brought a significant impact on adopters' household food security status. This study is in line with other studies undertaken on other crops' impact of adoption on food security. For instance, Wabwile (2016), revealed the positive impact of the adoption of improved sweet potato varieties led to a higher probability or more likelihood of being food secure when compared to non-adopters in Kenya.

Table 7: ATT of outcome Variable

Outcome Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Mean HHFS	Unmatched	2440.95	1960.788	480.17	62.56	7.67
	ATT	2423.80	1895.129	528.67	98.15	5.25***

Source: Own survey result, 2021

In addition, the narrative results from FGDs during survey collection also support the result of the quantitative study analyses. The high production capacity of *melkam* sorghum variety in the area improved the income and food security of smallholder farmers in the area. Because, *melkam* sorghum variety has a good yield in production and can be eaten in different ways like injera, porridge for consumption of household and attractive grain yield than other improved sorghum varieties.

For example, during the FGDs, A 40 years female hh from the *melkam* sorghum variety adopter group of *Ifadin kebele* said that:

"I have produced melkam sorghum variety in the last 5 years in our kebele as well as in other kebele which nearest to our kebele more than 2 hectares per year and I got more than 50 quintal per year, which is more advantaged than local variety before 5 years. We produce enough for home consumption; also, we supply to the market in our area and collect an almost good amount of money to buy clothes and other educational materials for our children, and saved our money in the bank. Bishinga ammayya melkam jedhamu erga omishuu jalqabne wagga shan(5) tane jira .Fayiddaan is gudda kuno!Qarshi ykn birr kissi kenya kessa hin dhabamtu akkasumaas, mana bankii kawacha jirraa jette. She says, I have produced this melkam sorghum variety for the last five (5) years and we saved our money to the bank when melkam sorghum variety was sealed and we have money in our pocket every.

In other FGDs of Erer ibada kebele, 40 years male from the adopter group expressed as;

"I have planted improved (melkam) sorghum variety for seven(7) years. I have used melkam sorghum variety both for selling and home consumption. This variety is food security to my family because it is a drought-tolerant variety, has good yield and quality for consumption. For me, this variety was in Bank in the form of cash and house in the form of grain yield.

As confirmed from FGDs, the adoption of *melkam* sorghum variety serves farmer households through various ways in their livelihood like to feed in the form of injera, porridge for consumption, and animal feed. The adopter groups were started to teach their children served by the outcome obtained from *melkam* sorghum variety in the study area. KIIs also have confirmed the vital importance of *melkam* sorghum variety by smallholder farmers and confirmed its positive impact on their livelihood and food security of smallholder farmers in the study area.

3.2.7. Sensitivity analyses

Sensitivity analysis has a great advantage to reduce this problem of deciding which variables should be included in a statistical model that was probably the most debatable issue in an observational study (Caliendo and Kopeinig, 2008). It is, of course, well known that relevant but omitted variables cause bias in the outcome of the intervention. The standard response to this knowledge has been to include additional control variables under the belief that the inclusion of every additional variable serves to reduce the potential threat from omitted variable bias. However, the reality is more complicated, and the control variable strategy does not protect from omitted variable bias (Cinelli and Hazlett ,2020).

Sensitivity analysis is the final diagnostic that must be performed to check the sensitivity of the evaluated treatment effect to unmeasured characteristics, which affect both assignment in treatment and the outcome variable (Schneeweiss, 2006.). If a given study is not affected by unobserved characteristics, the effect of unobserved variables will be zero. As a result, the participation probability is determined only by observed characteristics. However, if there is unobserved bias, even if the two individuals with similar observed characteristics have a different chance of receiving the treatment. Based on the concept the sensitivity analysis needs to be conducted.

As indicated in Table 8, below, the conclusion for the effect of improved (*melkam* sorghum*)* variety adoption is not changing, though the adopter and non-adopter household has been allowed to differ in their odds of being treated up to gamma =2 (100%) in terms of unobserved covariates**.** That means for outcome variable estimated, at various level of the critical value of gamma, the p-critical values are significant (i.e., there is no hidden bias due to unobserved confounder) which further indicate that important covariates that affected the participation in improved sorghum *(melkam*) variety adoption and outcome variable that is household food security. Thus, it can be concluded, that the impact estimates (ATT) were not sensitive to unobserved selection bias and is a pure effect of sorghum (*melkam*) variety adoption.

Table 8: Result of sensitivity analysis using Rosenbaum bounding approach

Outcome variable	e^{γ} =1	e^{γ} =1.25	e^{γ} =1.5	e^{γ} =1.75	e^{γ} =2
HH Kcal/AE/Day	0.000	0.000	0.000	0.000	0.000

Source: Own survey result, 2021.

4. SUMMARY, CONCLUSION AND RECOMMENDATION

This section is divided into three subsections. The first sub-section summarizes the major findings of the study. The next subsections present the conclusions of the results, while the third subsection forwards the recommendation based on the results of the study.

4.1. Summary

Sorghum is the most important cereal crop in production and area coverage in Ethiopia. Its contribution to households' income and food security is very high. Although nationally the emphasis given to improved sorghum, technology has been high. The study was conducted in *Babile* district; with the objective of the adoption of improved (*melkam*) sorghum variety and its impact on smallholder farmers' food security in *Babile* district Eastern Harerghe Zone. In the study area, sorghum is an important crop that serves as a major source of food for small holder farmers. Considering the contribution of sorghum production in the study area, the local government has introduced different agricultural technologies as a component of institutional support services.

Improved sorghum variety *(melkam)* is one of the newly introduced variety in the last decade. Despite such institutional support services, utilization of improved technologies remained low in *the Babile* district at which crop technology plotting test was there in the district. Hence, this study aimed to identify resource endowments, institutional, infrastructure, and market factors concerning adoption of melkam sorghum variety and its impact on smallholder farmers' food security.

A multi-stage sampling procedure was employed to select kebeles and 320 sample respondent of household heads. Primary data were collected directly through a structured interview. In addition, secondary data were obtained from various relevant sources. Descriptive, econometric model were used to describe the household and farm characteristics. Mean, standard deviation, T-test, and Chi-square test were employed to differentiate between two groups (adopters and non-adopters). Accordingly descriptive analysis, some mean differences were observed between adopters and non-adopters in terms of demographic (age, educational level, and family size of the household), resource endowment (having number of livestock, farm size, annual farm income), and institutional related factors (distance to nearest market). Mean association also deployed, sex, access to credit, social cooperative, off-farm activities, accessibility to improved sorghum varieties, and access to extension service show the strong mean association.

The binary logistic regression model output shows that the adoption of improved *(melkam)* sorghum variety has been significantly influenced by eight variables. Those variables were the education level of the household head, age of the household head, farm size, access to credit service, distance nearest market, farmer cooperative, annual farm income, and access to extension service of the household head are those variables significantly influence adoption *melkam* sorghum variety(technology). Except distance from the main market and age of household head, all other variables were positive and significant influence on melkam sorghum variety.

By using a minimum of 2200 kcal/AE/day as cut point, the result shows that a total of 148 (46.25%) sampled farmer households were found to be food secured who were fulfilled the minimum recommended daily calorie, while 172 (53.7%) were food insecure who fail to supply the minimum daily calorie requirement.

Propensity score matching (PSM) was employed to evaluate the impact of *melkam* sorghum variety on the food security of smallholder farmers. Based on the criteria of selecting a matching algorithm, the ATT was calculated. The impact estimation result shows that the adoption of improved (*melkam*) sorghum variety had a positive impact on household food security in the study area. Adopters of improved (*melkam)* sorghum variety had an average consumption of food 528.67 kcal/AE/day than non-adopters households in the study area.

4.2. Conclusion

The main objective of this study was to analyze adoption improved *(melkam)* sorghum variety and its impact on food security of smallholder farmers in Babile District East Harerghe zone, Oromia region, Ethiopia.

The education level of household was influences *melkam* variety adoption positively; this implies that educated farmers may be more aware of the benefits of modern technologies and may have a greater ability to search up-to-date information. Landholding size of the household was other important factors, which was found to significant and have positive correction with adoption of *melkam* sorghum variety. This likely reflects the importance of a large land area among smallholder farmer for the cultivation of a new generation of crop varieties. Furthermore, the result found that total annual farm income influences improved (*melkam)* sorghum variety adoption positively; this reflect that households with a high annual farm income were likely to purchase improved variety or other essential agricultural inputs. This investigation conclude that resource endowments of the household had played a significant role in the adoption of *melkam* sorghum variety.

Access to extension service, access to credit, and the social cooperative were also positively influenced *melkam* sorghum variety adoption. This is reflect that, access to credit service commands the farmer's financial resources to buy inputs. Smallholder farmers who were more access to extension service were get information on technology utilization and farm advice, this support them to decide to participate in the adoption of improved agricultural technology. Therefore, institutional support is one of the enabling environments for the adoption of *melkam* sorghum variety. On the other hand age and market, distance has negative influence on adoption of improved *(melkam)* sorghum variety. This study reflects that improved *(melkam)* sorghum variety adoption is a function of demographic, socio-economic, institutional and market factors.

The impact estimation from propensity score matching model show that the adoption of improved (*melkam*) sorghum variety had a positive impact on household food security. Adopter of improved *(melkam*) sorghum variety had energy or calorie prepared for consumption at household level, which is kcal/AE/day than non-adopter household in the study area.This concluded that *melkam* sorghum variety had drought tolerance, good yield in production ,because of that adopter household can consume and sell to buy other food item easily than non-adopter households.

4.3. Recommendation

Based on the findings of the study, the following recommendations were forwarded

- Education office incorporated with the agriculture office should make the possible way of delivering adult education for the smallholder farmers (user).
- Access to extension service was among the important variable that positively influenced the adoption of *melkam* sorghum variety. This indicates extension agents facilitate improved *(melkam)* sorghum variety adoption. Therefore, to sustain the positive contribution of the extension service government should improve the knowledge & skills of extension personnel or development agent at the kebele level
- The result of PSM indicated that the adoption of improved *(melkam)* sorghum variety has had a positive and significant impact on the food security of smallholder farmers. Therefore, development and local administration should integrate to sustain the adoption of *melkam* sorghum variety and its dissemination.
- Finally, for further study for all specific improved sorghum technology package (varieties) adoption and extension approaches with their impact evaluation, which is followed, by experts and officials to introduce agricultural technology can be study areas for researchers. Since the current study was limited with only one improved (*melkam)* sorghum variety and its impact s evaluation on food security. Therefore, feature research prospects will be more advantageous if they take adoption of improved sorghum varieties and its impact on income of smallholder farmers to come up with advanced evidence that will help shape the adoption of improved sorghum varieties uptake.

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