

Impact of level of Enset (*Ensete ventricosum*, Musaceae) Production on Food and Nutrition Security: Empirical Evidences from Wolaita and Kembata Tambaro Zones of Southern Ethiopia

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Impact of level of Enset (*Ensete ventricosum*, Musaceae) Production on Food and Nutrition Security: Empirical Evidences from Wolaita and Kembata Tambaro Zones of Southern Ethiopia

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Abstract

Enset is the only crop that can define food and nutrition security literally. Enset crop is closely related to food availability, access, use, stability, and nutrient balancing of densely populated communities in Wolaita and Kembata Tembaro zones. The climate smart, adaptive, productive, economical, and socially important Enset crop is the optimal way for ensuring food and nutrition security of communities. Hence, this study aims to estimate the causal effect of the level of Enset Production on farmers' food and nutritional security in Southern Ethiopia. The survey applied structured and semi structured questionnaires for the collection of cross-sectional data from 374 sampled households in *Wolaita* and *Kembata Tambaro Zones*. Generalized Propensity Score (GPS) with multilevel treatment option was applied to deal with the impact evaluation of Production on food and nutrition security. Food and nutrition status of farming communities defined by calorie intake of households. The proxy measure of the level of Enset production was the number of Enset harvested across households in the last twelve months. The GPS method applied followed three estimation procedures such as modelling the conditional distribution of the treatment given the covariates, estimating the conditional expectation of the outcome given the treatment and GPS, and defining the dose response function. The results show that the small holder farmers that actively involved in harvesting Enset for food are significantly associated with increased level of daily energy intake. The implication of the study revealed that through the promotion level of Enset production, it is possible to have increased and balanced the energy intake of households in Southern Ethiopia. The empirical evidences illustrate that higher level of Enset harvesting is an optimal way for sustainable and better level of food and nutritious security for farming communities in southern Ethiopia.

Key words: Enset, food and nutrition security, impact, harvesting, and GPS.

1. Introduction

Enset is a special food crop that has been cultivated by more than 20 million farmers in Ethiopia. More than 395 thousand hectares of land was under *Enset* cultivation in the country (CSA.2021). It is an underexploited but resilient staple starch crop with significant potential in Ethiopia and beyond (Borrell *et al.*, 2019). The average dry matter production per plant is 20 kg, placing the total production at 4.13 billion metric tons. The poor extension service delivery, lack of genetic conservation, and lack of information on its benefits and its impact on food security are some of the causes to lose the resource. While the food security sustaining capacity of the plant at family level and the household food shortage protecting capacity of the crop is more than any other crop (Abrham *et al.*, 2012; Awol *et al.*, 2014; Alemayehu, 2017).

The total crop coverage of all crops is 16.51million ha and out of which 3.53% land held by *Enset* crop. The area coverage of *Enset* is 532751ha, which is significantly high and ranked sixth next to Teff, Maize, Wheat, Sorghum, and Barley. *Enset* is the only the single crop cultivated by the largest number of small holder farmers at the country level. The rank of *Enset* is the first for being cultivated by more than 6.5 million small holder farmers and in the holder of indigenous seeds that demand development, research tasks and linkage to science (CSA, 2021). This implies that the majority of Ethiopian farmers prefer *Enset* cultivation, but there are little policy supports for the production system and development.

Enset is a major food security crop and cultivated mainly for human food. It contributes to food security in the catchment and needs to improve its production. Its production demands improvement to satisfy the current supply-demand gap. The increased demand of farmers to ensure food availability, access, use, and stability with population growth highlighted *Enset* cultivation among communities (Robert *et al.*, 2015; Ibsa *et al.*, 2019; Blomme *et.al.* , 2023).

Enset is the best source of carbohydrates, ash, and fibre contents but has less content of protein and fats. *Enset* corms contained 17 of 20 amino acids and had similar or higher concentrations than potatoes of 12 of these. The main food product of the commodity is the starch-rich kocho that prepared from processed and fermented product of the pseudo stem and corm. The pseudo stem is rich in soluble carbohydrates (80%) and starch (65%), but has low protein content (4%). Foods from *Enset* contain mineral content, such as calcium, potassium, and zinc. Foods of *Enset* products are also the best source of essential amino acids

such as lysine and leucine. Enset contains major minerals such as calcium and potassium that are abundant in the crop (Mohammed *et al.*, 2013; Abraham *et al.*, 2016 ;Solomon and Satheesh, 2019).

Enset is a major food crop that has high in carbohydrates, but low in vitamin and protein content. The cultivation of adequate *Enset* plants on the field of small holder farmers makes the households not to go hungry. *Enset*-based households are one step before than the other none producers for food security and a balanced diet with low cost (Jacobsen *et al*, 2018).

The Kotcho product of *Enset* gives much higher than the yields of any other crop cultivated in Ethiopia in time and space. In terms of edible dry weight and energy. The cultivation of *Enset* and root and tuber crops is highly advantageous and enables the community to get energy at low cost in densely populated areas under low input conditions that can be used sustainably by the population (Admasu and Struik, 2001).

The food and nutritional potential of Enset crop in Ethiopia is promising. Enset was cultivated by larger smaller holder farmer than any staple crop in the country. It is a major carbohydrate and food security crop for the country. Enset can be regarded as a recommended crop to achieve Sustainable Development Goals of the UN to end hunger, achieve food security, and improve nutrition by 2030. Hence, it has to be promoted to all areas to ensure food and nutrition security to poor and marginalized populations (Teshome *et al.*, 2022). It is the only crop that cultivated and domesticated in Ethiopia that known as a symbol for cultural, food, and nutritious security values (Selamawit *et al.*, 2021).

Enset is the first crop in the natural holder and the indigenous seed holder of any crop in the country. The top five crops in terms of natural and indigenous holders are Enset, coffee, Ethiopian cabbage, and banana. The number of natural national holders of Enset, coffee, maize, Ethiopian cabbage, and banana was 6541584, 4531699, 3617251, 3322163, and 2,798,063 respectively. The number of indigenous seed holders of Enset, coffee, maize, banana, and Ethiopian cabbage were 8463403, 7662896, 4718979, and 4452, 789. There are about 4058424 Enset cultivators in Southern Ethiopia that cover 245567ha of land in the region. The indigenous seed holders of Enset in the southern region are 4037151, for which the area coverage is 244361ha. The Irrigation holder of Enset for Southern people is 21,273 and that for which the Enset area coverage is 1006ha. The implication of the figure is the

majority of the farmers used to produce Enset and the crop is preferable to other crops for food and nutrition, climate adaptability, and multiple benefits (CSA, 2021).

Enset farming is reported to result in a difference in calorie intake of farmers at the country level. The level of per capita calorie intake varies across regions and is highest in SNNPR while lowest in Addis Ababa at 3,155.09 and 2,156.95 calories per day respectively. Calorie intake shows variation across the agro-ecological areas, with the humid *Enset* producing highlands recording the highest level of calorie intake per day at 3,197.54. The pastoralist areas have the lowest level of calorie intake, totalling 2,632.07 calories per day (Berhane *et al.*, 2011).

Enset is the first ranked climate-smart and superior hunger solution because of its apparent ability to endure long periods of drought, highest yield, energy, food supply, and cost advantages. But the development policy attention given to the commodity is weak that limits its optimal use. The listed constraints posing Enset cultivation to be underutilized and confined to the southwest part of the country were cultural perceptions, politics, historical reasons, and less research and policy support (Gezahagn *et al.*, 2022).

Table 1. Major staple food crops and their cost of energy intake

<i>Major Staple Food Crops</i>	<i>Yield Per Ha</i>	<i>Price Per Quintal</i>	<i>Energy Obtained (Kcalorie) Per Kg</i>	<i>Total Energy Yield Per Ha</i>
<i>Enset</i>	750	3300	2110	1582500
<i>Taro</i>	251.62	1000	3620	910864.4
<i>Sweet Potato</i>	257.39	1400	3510	903438.9
<i>Potato</i>	132.79	132.79	3160	419616.4
<i>Maize</i>	41.79	2000	3560	148772.4
<i>Wheat</i>	30.46	3700	3550	108133
<i>Barley</i>	25.26	4000	3723	95308.8
<i>Teff</i>	18.82	4500	3580	67375.6

Source: own calculation from CSA, 2021

The table above illustrates that root and tuber crops are the cheapest source of energy for the farming community and needs policy support for further development and utilization. In particular, *Enset* is the cheapest source of any commodity consumed in the country and needs strong policy support. Admasu *and* Struik (2001) indicated that Enset ranked 1st in the country by Kotcho yield per unit space and time in edible dry weight and energy. Enset products provide high yields of dry matter and energy than other major food crops. The cultivation of Enset and root and tuber crops in densely populated areas under low input conditions owns food sustainability and ecological advantages.

Expanding the range of cultivation of currently underutilised root and tuber crops and *Enset* in particular can support the diversification and resilience of global agricultural systems under climate change. *Enset* cultivation is a beneficial and climate resilient asset to address food and nutritional insecurity outside its current cultivation area (Koch *et al.*, 2021).

The eradication of poverty in Ethiopia and assuring food security is the dominant strategy, a major livelihood activity, and an overriding objective of Ethiopian government. Food insecurity becomes a key policy challenge and a growing concern in Ethiopia by now. Food production and its security status of farming communities in Wolaita and Kembata Tembaro zones highly depends on the level of *Enset* production. The climate smart, productive and adaptive *Enset* highly support food system for the rural households in the district. Even if *Enset* is known for a number of economic, social, and environmental benefits, little policy support was given. The major reason for the weak support to the sector were the information gap on the causal impact of *Enset* on food and nutrition security. One of the most important benefits of *Enset* production is assuring food and nutrition security assurance. Hence, the production of the specific crop helps all human beings better energy intake for improved food and nutrition security. The food support of the *Enset* crop is highly supposed to explain the food security of the households and optimizing their nutrition level. For information generation and filling the related knowledge gap, it is timely and indispensable to undertake a study on the causal impact of the level of *Enset* production on energy intake. Hence, the study aimed to investigate the causal impact of *Enset* production on food and nutrition security in densely populated districts of Wolaita and Kembata Tembaro Zones in Southern Ethiopia.

2. Methodologies

2.1 Description of the study area

The study was carried out in Wolaita and Kembata Tembaro Zones. The four potential districts selected purposely for the survey were Damot Sore and Damot Gale in Wolaita zone and Doyogena and Katcha Bira in Kembata Tembaro zone, respectively.

The Enset area coverage of Wolaita zone is 2, 1621.5ha. The number of Enset cultivating farmers of the Zone was 172,972, out of which 129,729 are male headed and 43,243 are female headed. The Enset trees harvested in Wolaita zone was 3,062,429. The extent of products harvested in quintal was 98,309.81 Amicho, 18,806.62 Kotcho and 6,850.16 Bulla (CSA, 2021).

2.1.1, The study districts of Wolaita Zone

Damot Gale Woreda

Damot Gale District is one of the twenty Woreda and towns administrative of Wolaita Zone. The total population of the Woreda is 224,356, of which 109,402 are male and 114,954 are female. Damot Gale is bordered on the southwest by Sodo Zuria, on the northwest by Boloso Sore and Damot Pulasa, on the north by the Hadiya Zone, on the east by Duguna Fango, and on the southeast by Damot Weyde. The Enset area coverage of the district is 2,049ha. The number of Enset growing farmers in the Woreda is 16,344 and out of which 13,716 are male headed households and 2,618 are female headed households (CSA, 2021).

Damot Sore Woreda

Damot Sore is one of the twenty Woreda and towns administrative of Wolaita Zone. It is bordered on the southeast by Sodo Zuria, on the west by *Kindo Koiysha*, on the northwest by *Boloso Bombe*, and on the north by Sore. The Woreda is located at 318 km through Hosanna road from Addis Ababa, the capital of Ethiopia. The district has 17 rural and 3 urban kebeles. The total population of the Woreda are 136,647, out of which 66,563 are male and 70,084 are female. The Major crops grown in the Woreda are common beans, *Enset*, sweat, potato, potato, maize, cassava, *teff*, barley, banana, and field pea. The number of Enset cultivators in the Woreda are 9,776 of which 7,332 are male and 2,444 are female headed households. The Enset land holding of district 1,212ha (Abate *et al.*, 2017; CSA, 2021).

2.1.2, The study districts of Kembata Tembaro Zone

The land coverage of Enset in Kembata Tembaro zone is 22,617ha. The natural Enset holder of the zone is 209,047 with land holding of 7,347ha. The Indigenous Enset Seed holder of the zone is 219,661 with an area holding of ha. The number of Enset harvested annually is estimated to be 1,960,834. The production of *kotcho*, *Amicho*, and *Bulla* production in the 2021 fiscal year is 535,718.11 quintal *amicho* 594,629.25 quintal *kotcho* and 8,866.4 quintal *Bulla* (CSA, 2021).

Kachabira Woreda

Katcha Bira Woreda is one of eight Woredas of Kembata Tembaro zone. Total population of the Woreda is 165,859, out of which 80,837 are male and 85,022 are female. The Katcha Bira Woreda is divided into 21 Kebels. The area coverage of Enset for the Woreda was 3,056.5ha. The number of Enset cultivators in the Woreda is 9,395 households, out of which 8,604 are male headed and 791 are female headed (Alemu *et al.*, 2016)

Doyogena Woreda

Dyogena district is one of the eight Woredas in Kembata Tembaro Zone. It is one of the eight Woredas of Kembata Tembaro zone. Total population of the Woreda is 109,251, out of which 53,379 are male and 55,872 are female. The district is classified in to 14 peasant associations. The total Enset area coverage of fourteen kebeles in Doyogena district is reported as 4535ha. Doyogena is bordered on the south by Kacha Bira, on the west and north by the Lemu woreda of Hadiya Zone, and on the east by Angacha. The number of Enset cultivator farmers in the Woreda is 15,660 and out of which 13,434 are male headed and 2,526 are female headed. The major crops grown in the Woreda are Enset, wheat, Irish potato, common bean, fababean, Teff, cabbage, head cabbage, barley, field pea, beetroot, tomato, onion, carrot and garlic (Teketel *et al.*, 2021)..

2.2 Sampling Techniques and Sample Size Determination

Sampling Techniques

The Sampling Techniques applied were both random and non-random sampling techniques. The study zones, districts, and Kebeles were selected purposely based on Enset production, population density, and geographical settings. Two districts selected from Wolaita zone were Damot Gale and Damot Sore. Two Woredas selected from Kembata Tembaro zone were

Doyogena and Kacha Bira districts. From both districts were selected purposively based on their production potential. Two kebeles from each Woreda were selected purposively based on the production potential. Then, an updated list of households were obtained from each kebele administration. Representative households were selected based on systematic random sampling techniques. Finally, a proportional sampling procedure based on the total number of households in each kebele was applied.

Sample Size Determination

Following Cochran (1977), the sample size is determined by the formula for two zones:

$$n = \frac{Z^2 \cdot pq}{e^2} = \frac{(1.96^2) \cdot (0.85 \cdot 0.15)}{0.05^2} = 196 \quad (1)$$

Where n is the minimum number of sample size, Z is the confidence level (t_{value}) of 1.96; p is the estimated proportion population that could be able to sense and estimate genetic and other related attributes of Enset, and q is $1 - p$; and e is margin of error (i.e. the desired level of precision). Assuming a 95% confidence level, the margin of error to be 5% and assuming that 85% of the local communities at least understand the genetic erosion of the resources and economic attributes (food, biodiversity, feed, fibre, and wrapping) in the Kembata Temabaro Zone. Based on this formula above, our estimated sample size was 196, but the survey considered 199 households in *Kembata, Tambaro* from the districts of *Katcha Bira* and *Doyogena*. The sample size of Wolaita zone was estimated with the formula bellows:

$$n = \frac{Z^2 \cdot pq}{e^2} = \frac{(1.96^2) \cdot (0.9 \cdot 0.1)}{0.05^2} = 139 \quad (2)$$

As calculated in the equation above, the number of households interviewed in Wolaita zone was 139, but we considered in the impact evaluation was 188 Enset harvested households. The sample size determination in Wolaita zone was done assuming at least 90% of the local communities in the district understand the genetic erosion, biodiversity loss, and economic attributes (food, biodiversity, feed, fibre, and wrapping) of Enset production. The sample size considered the existence of better knowledge on biodiversity, genetic loss, and attributes of Enset for Wolaita than Kembata Tembaro communities. Therefore, the extent of sample size planned to be included in the survey in Wolaita and Kembata Tembaro zones was 338, but the survey interviewed 386 sampled households. From these samples, the analysis used 374 households that consumed Enset from their own production through harvesting.

2.3. Data Collection Methods and Data Types

In the data collection procedure, activities done include key informant interview, focus group discussion, and household interviews. The survey instrument used was both structured and unstructured questionnaires. The key informant interview included 6 experts from two zones, 4 researchers from Areka Agricultural Research Centre, 12 experts from four Woredas, and 8 development agents from four kebeles. Focus group discussion was done with producers from a by categorizing them into women, men, and youth groups at kebele level. The size of participants in the focus group discussion were 30 men and women farmers and 10 youths. After a key informant interview and focus group discussion, the survey instrument was tested across two kebeles of two zones in 10 households and finalized for the household survey.

The survey applied the level of Enset harvested as the best proxy measure of Enset production annually for the commodity perennial crop and cross-sectional data. The consumption of Enset products can be explained concisely by harvesting area coverage. The Major data gathered include *Enset* area coverage, productivity, losses due to diseases and pests, currently available and lost varieties of *Enset*, major products produced from *Enset*, market participation and level, Tropical Livestock Unit, total land and *Enset* land in ha, role of gender in input preparation, planting, weeding, harvesting, product transportation, marketing and consumption) and the time devoted for Enset production.

The amount of dietary energy available for a household per day was calculated by converting food items into their kilocalorie values, adding up the total and dividing that figure by the number of days under consideration. This estimate was divided by the number of adult members of the household for evaluation of the adequacy of dietary energy available per individual (Napoli *et al.*, 2011; Smith and Subandoro, 2007).

2.4. Review on Application of Generalized Propensity Score Matching

The generalized propensity score is used for estimating continuous treatment. GPS allows estimating a continuous dose response function that relates each value of the number of treatments given and response to the treatment. In this approach, the dose-response function is estimated after adjusting for covariate imbalance under continuous treatment regimes. The GPS approach preferred to improve its robustness and suitability to estimate the full dose response function rather than the average treatment effect. It can generalize propensity scores

in the direction of the propensity function that aim to improve its robustness. (Michael and Alessandra, 2007; Jochen *et al.*, 2012; Peter, 2019; Shandong *et al.*, 2020).

GPS approach confirmed its applicability to analyse the welfare impact of smallholder farmers' participation in *Moringa* market, the effect of producing improved sheep breed on household income, effects of nutrients on stream invertebrates, to evaluate the impact of *Prosopis* invasion on pastoralist and agro-pastoralist households' annual per capita consumption expenditure and effect of Enset value chain participation on the food security and income of rural farmers using cross sectional survey data (Solomon *et al.*, 2015; Ketema *et al.*, 2018; Ouyang *et al.*, 2018; Tezera *et al.*, 2020; Toyiba *et al.* (2023).

Parametric models are problematic for the violation of distributional assumptions to lead to incorrect estimates due to misspecification errors. This would make the inferences drawn from such models potentially incorrect and misleading for policy recommendation. When estimating the causal effects of continuous dependant variable that measured in level, quantity or currency in observational studies, the generalized propensity score procedure preferable to adjust confounding bias (Xiao *et al.*, 2018).

The study result by Christian *et al.* (2018) confirmed that the semi-parametric covariate balancing propensity score approach is known for increasing the robustness to model misspecification by directly optimizing the sample covariate balance between the treatment and control groups. This approach also can be applied to estimate the causal effects relationship of variables from observational data.

The study result by Rodrigo (2009) reported the empirical applications of GPS estimator for the case of multiple treatments. For cases of important data limitations faced by the empirical application, the potential advantages of GPS approach are suggested to apply its results as a useful tool for policy purposes.

2.5 Econometric Model Specification

GPS method is the preferred and advanced extension of PSM for multiple treatments implemented in three procedures. In the first step, GPS estimate was defined as a conditional density of *Enset* production given the covariates assuming a normal distribution of levels. Giving $r(t, x) = (fT/x(t/x))$ The conditional density of treatments given the covariates,

GPS was defined as:
$$PS = R = r(T, X) \quad (3)$$

Within strata with similar values of $(r(t, X))$ the probability that $T = t$ does not depends on values of X , that is GPS has the property that $X \in 1\{T = t\}/r(t, X)$.

GPS is applied to remove bias that is associated with differences in covariates in three stages. First, modelling and stating GPS; in the second step, estimating the conditional expectation of the outcome as a function of two scalar variables that are the treatment T and the $GPS R$, i.e.

$$\beta(t, r) = E[Y/T = t, R = r] \quad (4)$$

For equation (2) the study assumed some functional form of relation between calorie intake for food security status Y , the level of Enset production T and the GPS R . The third step was to estimate the level of production:

$$\mu(t) = E[\beta\{t, r(t, X)\}] \quad (5)$$

The procedure undertake averages over the $GPS = R = r(T, X)$ that is the score evaluated for the treatment of interest $r(t, X)$. As the main goal of estimating the GPS was to certify the balancing of covariates across different levels of production, for sufficient covariate balancing properties of the estimated GPS was conducted before proceeding to the next step.

The other procedure used in the modelling of the conditional expectation of energy intake for food security status (Y_i) as a quadratic function of observed treatment (T_i), estimation of GPS (R_i), and analysis of the interaction between the two. Since the study normal distribution of the level of production collected, covariates

$$T_i/X_i \sim N(\beta_0 + \beta_1 X_i, \sigma^2) \quad (6)$$

This was estimated by ordinary least squares regression; here the study assured the balance of the covariates. The GPS can be estimated as:

$$R_i = \frac{1}{\sqrt{2\pi\sigma^2}} \left\{ -\frac{1}{2\sigma^2} (T_i - \beta_0 - \beta_1 - \beta_1 X_i)^2 \right\} \quad (7)$$

In the following step, the study can estimate the conditional expectation function of the probability of employment Y_i given T_i and R_i as a flexible function. Our experimental approach used the following polynomial approximation:

$$E[Y_i/T_i, R_i] = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 T_i^3 + \alpha_4 R_i + \dots + \alpha_n T_i R_i^n \quad (8)$$

For each individual, the observed number of Enset harvested for extent of production T_i and estimate $GPS R_i$ are used and the equation was estimated by OLS. Given the estimated

parameters in the in the second stage, the study estimates the average potential outcome at production level $\underline{t}$ defined as

$$E[Y(t)] = \frac{1}{N} \sum_{i=1}^n \{\alpha_0 + \alpha_1 t + \alpha_2 t^2 + \dots + \alpha_n tr(t, x_i)^2\} \quad (9)$$

The entire cause effect function was defined by estimating the average potential outcome for each level of treatment. In the study, bootstrap methods were used to obtain standard errors that take into account estimation of the GPS and the α parameters, i.e. the study bootstrap the entire estimation process. Plots of the cause-effect function and marginal treatment impact function were demonstrated graphically. The mean cause-effect function implied the magnitude and the nature of the causal relationship between the level of harvesting on production and energy intake. The cross-sectional survey data analysed in STATA version 17, SPSS version 20, and excel 2007 package (Kluve *et al.*, 2012).

2.6 Methods of Data analysis

The statistical procedure applied was Generalized Propensity score. The study applied GPS for its advantages of adjusting for confounding based on continuous treatment. The treatment variable used was the number of Enset harvested for food that ranged from two to seventy-five. The estimation procedure of GPS is summarized as modelling the conditional distribution of the treatment given the covariates, estimating the conditional expectation of the outcome given the treatment and GPS, and estimating the dose response function (Bia and Mattei, 2008). In the first step of estimating the conditional distribution of the treatment, given the covariates, the estimates, GPS, and tests, balancing was done. The dose response estimates were defined following the algorithm such as estimating the GPS, verifying the normality of the model used for the GPS, and testing the balancing property.

The study objective was to examine the impact of *Enset* production on food security and the outcome variable was daily calorie intake of individuals. The level of *Enset* production for small holder farmers was estimated using the level of harvesting at a given production period. The food security status of the household was defined based on a survey of producers on the type and level of food items consumed in the last seven days. The small holder farmers may cultivate the crop but not harvest due to the immaturity of *Enset*. If the household did not harvest and use the products in the last 12 months, the study was considered as non-participant.

3. Results and Discussions

3.1 Socioeconomics and demographic features of Enset Producers

Education level of Household head Farmers in Kembata Tembaro Zone

The mean years of schooling of the household head in Doyogena and Kacha Bira districts were 4.8 years. From respondent farmers in Doyogena, 21.9 % were not formally educated, 39.47% educated up to grade six, 11.3% educated grade six and seven, 22.1% educated grade nine up to 12 and 5.2% educated above high school. Of Kacha Bira Woreda farmers, 21.8% were not educated formally, 35.9% educated grades one to six, 14.1% attended grade seven and eight, and 28.2% attended grades nine to twelve.

Education level of farmers in Wolaita zone

The mean years of schooling for farming communities in Damot Sore and Damot Gale district were 4.04 years. From Damot Sore residents, 34% were not educated formally, 37% educated grade one up to six, 19% attended grades seven and eight, three percent attended grades nine to twelve and 7% attended above high school. The education level of Damot Gale district was characterized as 43% not educated formally, 37% attended grades one to six, 9% followed grades seven and eight, 8% attended grade nine up to twelve, and 3% followed territory level.

Age of Kembata, Tambaro, and Wolaita farmers

The mean age of farmers in Doyogena and Katchabira Woreda is 50.41 years old. The average age of farmers in Damot Sore and Damot Gale district is 44.25 years.

Table 2. Family size of the Farmers in Doyogena and Katcha Bira district (N=186)

Descriptive Statistics	Minimum	Maximum	Mean	Std. Deviation
Total family size	3.00	18.00	7.59	2.49
Family size aged below 5 year old	.00	9.00	1.27	.55
Family size aged between 5 to 14 years	.00	7.00	1.65	.34
Family size aged between 15 to 65 years	.00	11.00	4.21	1.24
Family size above 65 year old	.00	6.00	.61	0.15

As it illustrated in the table above, 55.47% of the small holder farmers under active labour force and 44.53% categorized under dependant age category.

Table 3. Education level of farmers in Wolaita Zone

Descriptive Statistics	Mini mum	Maxi mum	Mean	Std. Deviation
Total family size	2.00	12.00	6.41	2.18
Family size aged bellow 5 year old	.00	12.00	.91	.32
Family size aged between 5 to 14 year	.00	5.00	1.46	.13
Family size aged between 15 to 65 years old	.00	11.00	4.04	1.96
Family size above 65 year old	.00	7.00	.23	.15

As indicated in the table above, 63% of small holder farmers are under active labour force and 37% households grouped under dependants.

3.2 Impact of Enset Production on Food and Nutrition Security

Table 4. Common support region

Variable	Dosage of Enset	Treatment proportion	Obs	Mean	Std. dev.	Min	Max
gps_1	<=8	27.81%	374	.1436491	.118502	6.31e-06	.642895
Variable			Obs	Mean	Std. dev.	Min	Max
gps_2	> 8 & <=14	24.33%	374	.4221419	.2573454	.0013142	.7328076
Variable			Obs	Mean	Std. dev.	Min	Max
gps_3	>14 & <=24	25.40%	374	.5112581	.193746	.0140772	.732801
Variable			Obs	Mean	Std. dev.	Min	Max
gps_4	>24	22.46%	374	.3866378	.2520459	.0138443	.7328075

The study results indicated that 27.81 % of the small holder farmers harvest more than two and less than or equal to eight Enset yearly, 24.33% of the farmers harvest nine to fourteen Enset, 25.40% of small holder farmers harvest fifteen to twenty-four Enset and 22.46% harvest more than twenty-four Enset annually for consumption. Based on the minima and maxima criteria, the common support region would then lie between 0.0140772 and 0.642895. In other words, households with estimated propensity scores less than 0.0140772 and greater than 0.642895 were not considered for the matching exercise.

Estimation of Generalized Propensity Score

The Generalized propensity score was estimated at the level of Onset harvested as a continuous dependent variable that takes only positive values. The participant and to none participants of Enset production were categorized based on the source commodity and quantity Enset harvested from own production. Hence, the analysis removed the households that did not harvest from their farmyards. In addition to these, at the first step of estimating the generalized propensity score, the group created based on the level of harvested into four clusters at 30% and 70% (Kluve *et al.*, 2012). Four groups of comparable size were then formed based on the level of harvesting, i.e., group one (two to eight); group two (nine to fourteen), group three (fifteen to twenty-four) and group four (more than twenty-four). The first group represents a relatively low level of *Enset* harvesting and the majority of the small holder belongs to this group (27.81%), while the fourth group referred as higher level of producers and low proportion (22.46%). The proportion of small holders grouped under the second and third group were 24.33% and 25.4%, respectively.

Table 5. Estimate of Generalized Propensity Score

	<i>T</i>	<i>Coefficient</i>	<i>Odds</i> <i>ration</i>	<i>Std.err.</i>	<i>Z</i>	<i>P>z</i>	<i>[95% conf. interval]</i>	
<i>eq1 TLU</i>		.109 ***	1.115	.031	3.55	0.000	.0488237	.1694254
<i>Total land</i>		.025	1.025	.019	1.29	0.196	.0127092	.0621478
<i>Ensetsource</i>		.417***	1.517	.073	5.74	0.000	.2745033	.558852
<i>Total family size</i>		.052***	1.053	.014	3.81	0.000	.0252097	.0786593
<i>Education level</i>		.0005	1.0005	.009	0.06	0.953	.0169818	.0180434
<i>Age</i>		-.0005	0.999	.003	-0.20	0.845	.0056006	.0045853
<i>Zone</i>		.318***	1.374	.074	4.30	0.000	.172873	.4629281
<i>Matured Enset</i>		.003***	1.003	.0007	3.83	0.000	.0012763	.003946
<i>Market distance</i>		.0014**	1.001	.0007	2.02	0.043	.0000436	.0026884
<i>EBW avail</i>		.080	1.083	.063	1.27	0.202	.0431038	.2033945
<i>_cons</i>		-.611 ***	0.543	.180	-3.40	0.001	.9641748	-.258449
<i>eq2 _cons</i>		.542 ***	1.719	.021	25.53	0.000	.5006766	.5839289

Log likelihood = -63.085, *No. of obs* = 374 | *Wald chi2(10)* = 269.10, *Prob > chi2* = 0.000

*** and ** denote Significance at 1% and 5%, respectively.

In the first procedure, the conditional distributions of the level of Enset harvested given the identified demographic, institutional, and socioeconomic covariates were estimated using the maximum likelihood (ML) estimator. The variables included in the estimation of GPS include tropical livestock units, land size, matured Enset, source of Enset for harvesting, education level, age zone, availability of EBW in their farmyard and family size. The assumption of normality is statistically satisfied at 0.01 level. The primary purpose of estimating the GPS is not to interpret the coefficients but to check the balancing of the covariates. Accordingly, the balancing test results also indicate that the GPS has fulfilled quite well the balancing properties.

Table 6. Results of the dose-response function

	Coefficient	Std. err.	T	P>T	[95% conf. interval]
Enset harvested	56.72188	1063.985	0.05	0.958	-2035.512 2148.956
GPS	4639.194	1752.843	2.65	0.008***	1192.378 8086.009
GPS square b	-2251.552	885.0338	-2.54	0.011**	-3991.894 -511.2092
Enset Harvested*GPS	-150.3658	929.2359	-0.16	0.872	-1977.628 1676.896
Cons	2058.454**	1194.138	0.086	1.72*	-289.7144 4406.622
Source	SS	Df	MS	F(4, 369)= 1.88, Adj R-Squared= 0.009	
Model	73939142	4	18484785.5	Prob > F = 0.1131	
Residual	3.6257e+09	370	9825680.67	R-Squared = 0.0200	
Total Kcal Energy for a Day Individually	3.6996e+09	374	9918539.7	Root MSE= 3134.6	

*The statistical significance indicated *** for 1%, ** for 5% and * for 10% significance.*

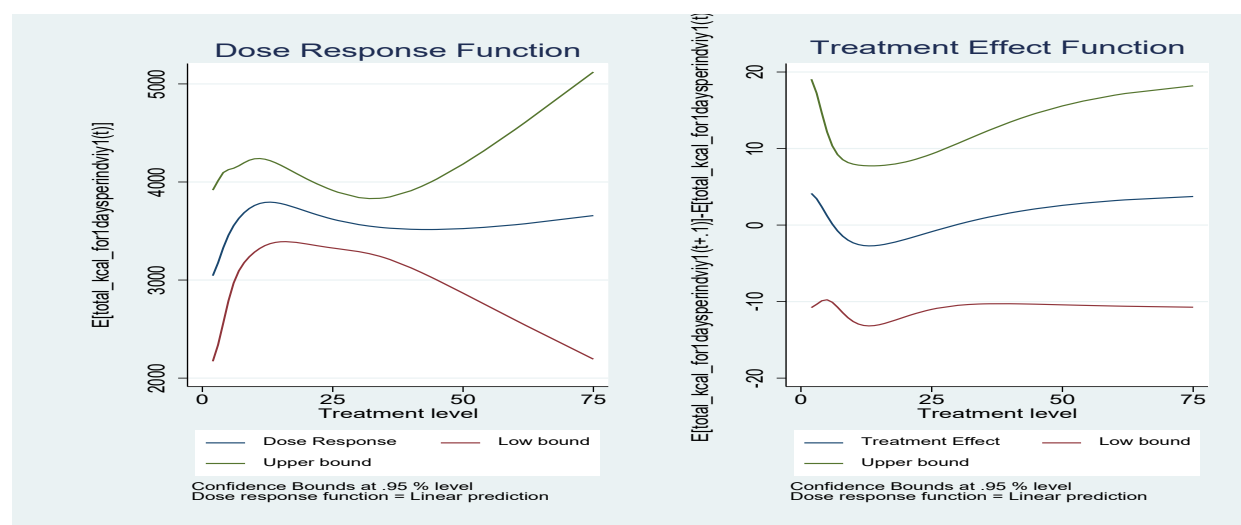


Figure 1 Dose response and Treatment effect function

Impact of level of Enset harvesting on food and Nutrition Security

Estimates of the DRF for the total energy intake in calorie of households are presented in Figure above. The relationship is non-linear and reveals that the levels of energy intake from different sources are virtually similar for the level of participation up to thirteen Enset harvested, but begins to rise after 25 of quantity supply, which indicates that the high level of Enset production has a significant causal effect on household energy intake in calorie. The result implied that after 25 levels of Enset harvesting showed increased level of energy intake. However, as the graphs show above, after this optimum harvesting, household total energy intake varies with the level of Enset harvested and processed for food. The marginal effect functions also show the same as the respective dose-response function. Therefore, only for very high levels of Enset harvesting after twenty-five does have an impact on the total energy intake of farmers. The finding of the results points out that promoting Enset production causes improvement in the level of energy intake that is a proxy measure of household food and nutrition security. At a low level of harvesting, Enset production has a negative causal effect on household energy intake. The optimum level of Enset harvesting for food and nutrition security is 25, and the corresponding yearly household energy intake in kilocalorie is 5592.77. The finding is in line with Morrow *et al.*, (2023) that the reported area of mature *Enset* can explain and improve 75% estimates of food security indicators and it is a food security safeguard and an active adaptation strategy in the face of shock.

Conclusions and policy implications

This study targeted to examine the impact of Enset production on food and nutrition security of households in rural communities. It is to estimate the full dose response causal exposure response function of Enset production on daily energy intake. This is important because both subsistent agricultural activities require those farmers to be food and nutrition secured in densely populated zones of Southern Ethiopia. Enset farming is known for the important contribution in the food and nutrition system of small holder farmers in Wolaita and Kembata Tembaro zones. The study applied cross sectional data from 374 sampled Enset producers. For sustainable food and nutrition security require information on the impact of Enset production on individual calorie intake for policy formulation and effective intervention. As a consequence, the study applied the GPS for causal inference estimation technique to determine the impact of the number of Enset harvested on daily calorie intake. This technique has many good-looking characteristics than standard binary treatment propensity score matching technique and appropriate for continuous treatment. The chosen crop for this analysis is essential because it is a major staple crop in Southern Ethiopia that can fulfil households' demands of carbohydrates in a low cost and sustainable manner. There is empirical evidence justifying that the extent of Enset production has a positive impact on energy intake of individuals for improved food and nutrition security. The relationship between the number of Enset harvested and energy intake is nonlinear, implying that a unit change in Enset harvested does not necessarily cause a proportionate change in carbohydrate intake. The return to the number of Enset harvested in energy intake increases at an increasing rate for maximum treatment categories of 50 to 75 Enset harvested. The maximum level of energy intake for the maximum 75 levels of Enset harvested daily energy was 4800 kilo calories. The minimum level of energy intake for the minimum level of the two Enset harvested annually for an individual was 3900 kilocalories daily. This implies that all levels of Enset harvesting group categorized under food and nutrition secured group with different level of energy intake that optimized by increased level Enset production. Farmers' inability to produce sufficient Enset explains the lower energy intake of households in the study district. In Ethiopia and Enset potential zones of southern and Southwest Ethiopia where governments seek to ensure food security of the household, the cost effective and efficient way is enabling small holder farmers to produce more Enset, supporting the production and technology disseminations system. This result provides a useful insight into rural smallholder Enset cultivation, that is, the optimal way for improved energy intake of households.

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