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Development of Improved Groundnut Varieties for Dietary Upliftment among Households in Homa Bay County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author WOO designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors HKB and KWS reviewed the study design and the first manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Low dietary diversity is one of the major causes of malnutrition in Kenya. As a result, the government of Kenya and its partners have promoted the uptake of plant based legumes such as Improved Groundnut Varieties to offer solution to the rising cases of poor nutrition. Understanding the impact of Improved Groundnut Varieties on dietary diversity is critical but evidence shows that it's not yet explored. This study sought to estimate the impact of Improved Groundnut Varieties (IGVs) on dietary diversity among smallholder farmers in Homa Bay County, Kenya. The study used multi-stage sampling procedure where the sub-counties and wards were purposively selected. The villages and respondents were selected using simple random sampling. Cross-sectional data was collected through interview schedules on a random sampling of 384 households. Both descriptive statistics and econometric methods, Propensity Score Matching method were used. The results pointed out that Improved Groundnut Varieties had a positive and significant impact on the diets of the farmers. Households cultivating IGVs had better dietary

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diversity non-adopters. Overally, this study recommends sensitization of farmers to adopt IGVs and the need for the government to facilitate extension service provision, trainings and access to credit to increase yields and incomes. Again, the study recommends formation of farmers groups that are business hubs as opposed to social welfare to enhance bargaining power and access to inputs and outputs market. Additionally, there is need for intersectoral collaboration between agriculture and health sector to sensitize farmers on the importance of diversifying diets and consuming the crops grown in the farms.

Keywords: Improved groundnut varieties; dietary diversity; propensity score matching.

1. INTRODUCTION

Malnutrition is global issue that derails the development of every country in the world and it is the interest of global community and national stakeholders to reduce malnutrition especially among children and women. The progress towards eradication of malnutrition in the world is positive but it is slow and not uniform across all countries. At global level, stunting among children under five years of age has reduced from 32 percent to 22 percent in 2000 and 2017 but it is noted that numbers are increasing in Africa. The progress in addressing anaemia and underweight among women is reported to be very low while the problem of obesity and overweight among men and women is increasing. With the triple burden of malnutrition, the findings of the indicate that the focus towards ending malnutrition in all its forms should be geared towards improving diets at both global and national levels [1].

Kenya is one of the African countries facing high levels of malnutrition. Over ten million suffer from chronic food insecurity and poor nutrition, while almost 30 percent of children in Kenya are considered undernourished [2]. In Homa Bay County, it is estimated that about 82 percent of the households do not have enough food to meet the needs of their households [3]. The occurrence of malnutrition among children is still high with a stunting rate at 26 percent, underweight at 15 percent and wasting at 4.2 percent prevalence [4,5]. Additionally, the minimum dietary diversity at the county level is estimated to be 32.6 percent which is considered quite low. Grains, roots, and tubers are the most frequently consumed food groups at 78.9 percent, Vitamin A rich fruits and vegetables at 45.2 percent while eggs, legumes and nuts are relatively low at 11.4 percent and 23 percent respectively [4].

Low dietary diversity is the leading cause of persistent malnutrition in most countries. Majority of those who are malnourished are found in the rural areas and they depend on agriculture as their major source of food and income. Therefore, programs aimed at improving agricultural production has the potential to improve the production and incomes of the rural farmers leading to improved diets which eventually would enhance nutrition among people [6]. Agricultural interventions should not only focus on the production of foods like rice and maize which are the staple foods in most countries but also production of other foods like legumes (groundnuts, beans, lentils), fruits and vegetables which carry the necessary micronutrients and fibers. Boosting legumes production like groundnuts has the potential to improve diets among smallholder farmers because compared to maize which the major staple foods, legumes are better sources of high quality proteins and contains a large variety of micronutrients [7].

Groundnut (*Arachis hypogea L.*) is ranked 13th among the most important food crops in the world. It is very nutritious and an excellent plant-based source of protein, fats, carbohydrates, vitamins, minerals and has high energy value. Groundnut provides higher satiety than other snacks and very beneficial for weight loss and reduction of cardiovascular diseases, again, it is useful for human consumption and some parts of the crop are also used for livestock feed [8]. Groundnut originated from South America. Currently, the largest producers of the crop in the world are United States of America, China, Nigeria and India [8]. The crop is a very important oil crop in the world that if produced sustainably, can contribute significantly to food security and reduce malnutrition in the already growing population [9].

In Sub-Saharan Africa (SSA), groundnut is ranked as the 5th most grown crop after maize, sorghum, millet and cassava and is mostly grown by small-scale farmers with Nigeria as the largest producer in both Sub-Saharan Africa and West Africa [8]. Production of groundnut in Kenya is reported to have increased from 21,115 Metric

Tonnes to 21,817 Metric Tonnes in 2015 and 2016, respectively, [10]. This translates to an increase in value from KES 1.8 Billion to KES 2.0 Billion. Homa Bay County is the largest groundnut producing region in Kenya with the production level rising from 5,211 Metric Tonnes to 6,426 Metric Tonnes and the value increasing from KES 424.7 Million to KES 628 Million between the year 2015 and 2016, respectively [10]. This increase in production is partly attributed to the introduction of modern varieties of groundnut in the country. These new varieties include ICGV-9991, ICGV-12991, CG7, CG2, and CG3 [11]. In western Kenya, groundnut plays a major source of smallholders' incomes and food security [12]. Past research has focused on improved groundnut varieties and its effect on income and poverty reduction [13], capita consumption expenditure [14], food security [15] and welfare; [16,13] but its role on dietary diversity has not yet been explored. In addition to this, the pathways to this effect is not clearly indicated. Therefore, this study contributed to the literature by determining the effect of the improved groundnut varieties on dietary diversity among households in Homa Bay County particularly focusing on Ndhiwa and Rangwe Sub-Counties. The objective of the study was to estimate the impact of Improved Groundnut Varieties on dietary diversity among households in Homa Bay County. To achieve this objective, the study sought to use Propensity Score Matching Method.

1.1 Literature Review

1.1.1 Effects of agricultural technologies on households' dietary diversity among households

Agriculture being a basis for food production shows clearly that it makes a significant contribution to diet of the people [17]. The production and consumption of diverse foods has the potential to increase the dietary diversity of households hence improving the nutrient adequacy in households. Adoption of hybrid maize was reported to have a significant impact on the dietary diversity of the smallholder maize growers [18]. This study established that smallholder farmers who took up the hybrid maize had a more diverse diet than those who did not adopt the new varieties of maize. The study adopted two-stage, instrumental variables, Poisson and ordered logit regression models to estimate the impact of hybrid maize use and four indicators of dietary diversity (food group diversity (24 hours), vitamin A diversity (7 day), food frequency (7 day), and frequency of consuming foods fortified with vitamin A (7 day)). The models were adopted because the study opted to use four indicators of diet diversity and focused on Vitamin A sources. On the other hand, this study was not limited to only one nutrient but all the nutrients necessary for a healthy diet.

A study conducted by [7] indicates that the cultivation of legumes improves children's dietary diversity. The study focused on soy-bean production in Kenya and Ghana and it used structural equation method in the analysis. Although this study addressed dietary diversity, the focus was mainly on Children. Children maybe the best target for evaluating effect of agricultural interventions on nutrition but owing to the challenges of malnutrition in the households, studies ought to cover a household as a whole because nutrient inadequacy affects both Children and adults especially women. This is the reason why this study looks at a household as a whole. Furthermore, the study shows that own consumption and income are the pathways through which Soybean improved dietary diversity but the factors affecting these pathways are not clear. This is because there is a possibility that the income earned from the sale of the crop may be used for other purposes like paying school fees other than purchasing other foods for the household.

1.1.2 Measurement of dietary diversity

According to a study by [19], various indicators that are currently used to measure the impacts of agriculture nutrition interventions aimed at improving nutritional outcomes. The study showed that most indicators used were those that are aimed at measuring diet/food consumption and child anthropometric. The indicators for measuring diet quality were household dietary diversity, women's dietary diversity, young child dietary diversity and Minimum Adequate Diet indicator and that for measuring child nutrition is anthropometric indicators. The studies mostly hypothesize improving diets and child feeding as pathway to improving nutrition. In addition, many agriculture-nutrition projects measure both individual and household dietary diversity for both women and children so as determine food access at household level and micronutrient adequacy of the diets of vulnerable household members [19].

This study intends to use Household Dietary Diversity Score [20] which uses recall method of food groups that the households have consumed in the past 24 hours. Household Dietary Diversity Score is a common indicator used for measuring dietary diversity at household level [21]. It also the best measure that is well-understood and commonly used to assess the quality of diets in a household. Literature further indicates that it has a strong association to micro and macro-nutrient adequacy [20,22]. Therefore, this study adopted Household Dietary Diversity Score to measure how diverse the diets are for smallholder farmers who grow improved groundnut varieties.

There is an extensive study on effect of improved groundnut varieties on household welfare in different countries but there is scarce research on its role on household dietary diversity. The study carried out a detailed study on the potential impact of improved groundnut varieties on dietary diversity.

2. METHODOLOGY

2.1 Sample Size Determination

The sample was drawn from a population of groundnut farmers from Ndhiwa and Rangwe Sub-counties. The required sample size was determined using Fischer formula.

$$n = \frac{pqZ^2}{d^2}$$

where; sample size, Z-1.96, P-proportion of target population (use p= 0.5 if p is not known), q=1-p, d=α=0.05,

$$n = \frac{0.5 \times 0.5 \times 1.96^2}{(0.05^2)} = 384$$

2.2 Sampling Procedure

The study used multistage sampling. Ndhiwa and Rangwe sub-counties were purposively selected because Ndhiwa is one of the largest groundnut-producing zones in Kenya particularly in Homa Bay County where farmers received interventions while Rangwe was also purposively selected because it is an area where groundnut is grown but never received interventions. The wards were purposively sampled. In Ndhiwa Sub-County, Kanyamwa, Kosewe, Kwabwai and Kanyidoto wards were selected while in Rangwe Sub-county, Kochia and Kagan wards were selected. The villages in the selected wards were randomly selected. Through the assistance of the officer of the Ministry of Agriculture, the chiefs and the contact farmers, the location of the framers in the villages were identified. Respondents were drawn from the villages using a simple random procedure. The sample size was divided in proportion to the population size of the two Sub-counties. According to Census Survey 2019, the estimated population for the Ndhiwa Sub-County was 217,549 while Rangwe Sub-County was 117,128.

Sub-counties	Population	Percentage	Sample Size Proportion
Ndhiwa	217,549	65	250
Rangwe	117,128	35	134
Total	**334,677**	**100**	**384**

2.3 Data Collection Method

The study employed primary data which was collected from a sample of groundnut farmers. The data was collected using Interview Schedule through observation and face to face interview. Information from the respondents was collected by trained enumerators. A household was considered an adopter if improved groundnut varieties were planted during the season under consideration. The respondents for dietary diversity in the interview was the person responsible for the planning and cooking of meals in the households. A pilot study was done using a sample of 38 respondents.

2.4 Methods of Data Analysis

Data collected from the field was coded, cleaned and analyzed using two methods; descriptive and econometric analysis. The data was analyzed using STATA. The model specification and analysis are as shown below.

Diversity was measured using Household Dietary Diversity Score (HDDS). Household Dietary Diversity Score is based on the number of food groups a household consumes and this accurately reflects the diversity of macro and micronutrient intake. HDDS has 1-12 scores for 12 food groups consumed by household based on 24-hour recall. This means that HDDS has a range of one as the minimum and 12 as the maximum. A higher HDDS indicate a diverse diet while a low HDDS indicates that the diet is not diverse. To estimate the causal impact of improved groundnut varieties on household dietary diversity, the study adopted propensity score matching. Previous studies for instance [12] have used Propensity Score Matching (PSM) to establish causal impacts of agricultural technologies. Other studies have adopted two-stage, instrumental variables, Poisson and ordered logit regression models to estimate the impact of hybrid maize use on the dietary diversity of the smallholder maize growers [18]. The study used four indicators of dietary diversity (food group diversity (24-hours), vitamin A diversity (7days), food frequency (7 days), and frequency of consuming foods fortified with vitamin A (7 days). This was the basis of the adoption of poison model. In the case of the current study, Propensity Score matching was appropriate because only one indicator was used.

2.5 Model Specification

Below is the equation for PSM.

If a household has adopted IGVs ($G=1$), the expected average income is $E(Y_1 \mid \mathrm{G}=1)$,and the counterfactual situation when the household has not adopted IGVs is $E(Y_0 \mid \mathrm{G}=1)$. However, the counterfactual is unobservable but we can observe the outcome of non-adopter represented as

$(G=0), E(Y_0 \mid \mathrm{G}=0)$. Therefore, in estimating the ATT, we use the following estimation:

$$ATT = E(Y_1 - Y_0 \mid \mathrm{G}=1) = \mathrm{E}(\mathrm{Y}_1 \mid G=1) - E(Y_0 \mid \mathrm{G}=1) \quad (1)$$

Since $E(Y_0 \mid \mathrm{G}=1)$ is not observed, PSM uses observed mean of the outcome of non-adopters that are similar to the adopter households in the observed characteristics, that is;

$$E(Y_0 \mid \mathrm{G}=1) - E(Y_0 \mid \mathrm{G}=0) \quad (2)$$

Equation (14) confirms that there is no bias from self-selection in the ATT. Equation (14) is fulfilled under two conditions: conditional dependence, equation (17) and common support, equation (15). The first condition requires that the outcome variable is independent of the treatment variable with observed covariates. This is expressed as:

$$Y_1, Y_0 \perp \mathrm{G} \mid \mathrm{X} \quad (3)$$

The second condition of common support ensures that individual household has a positive probability of being IGVs adopters or not. This is expressed as:

$$0 < pr(G=1 \mid X) < 1 \quad (4)$$

With both conditions in place, the ATT is estimated as follows:

$$ATT = E(Y_1 - Y_0 \mid G=1) = E[E - (Y_1 - Y_0 \mid G=1, P(X))] \quad (5)$$

$$= E[E(Y_1 \mid G=1, P(X)) - E[E(Y_0 \mid G=1, P(X))G=1]]$$

$$= E[E(Y_1 \mid G=1, P(X)) - E[E(Y_0 \mid G=0, P(X))G=1]]$$

Table 1. Description of variables used in poisson model for dietary diversity

Variables	Description of variables	Measurement	Expected sign
Dependent Variables			
Household dietary diversity status	Diverse in diets=1, 0-not diverse in diets	Binary	
Independent Variables			
Agehh	Age of the household Head	Continuous	+/-
Hhsze(AE)	The number of people in the household	Discrete	+/-
Market Distance	Distance to the nearest market in Minutes	Continuous	+/-
Wealth	Value of household assets in Shillings	Continuous	+
Off-farm Occ	Off-farm income in Shillings	Continuous	+
GrndPrice	Price paid for groundnuts in Shillings	Continuous	+/-
Yield	Output from last season in tonnes/ha	Continuous	+/-
Hhhead	Gender of the household, Male=1, Female=0.	Binary	+/-
HhEduc	Number of years of education	Continuous	+/-
Marital status	Marital status of HH head. Married=1, Not Married=0	Categorical	+/-
Nuteduc	If the farmer had received nutrition education. YES=1, NO=0	Binary	+/-
Incogrdnt	Income from the sale of IGVs in Shillings	Continuous	+/-

3. RESULTS AND DISCUSSION

This section discusses the empirical results of the Propensity Score Matching Model on the effect of improved groundnut variety on household dietary diversity in Homa Bay County.

3.1 Summary Statistics of Household Dietary Diversity (Outcome) and Food Groups

Table 2 shows descriptive statistics of household dietary diversity scores (outcome variable), and food groups among smallholder groundnut households in Homa Bay County. The results revealed that there was a statistically significant difference in household dietary diversity score between the two groups, IGV adopters and non-adopters (local groundnut farmers) (p = 0.000). The average household dietary diversity score for the overall sample is 10 food groups with IGV households on average having approximately 11 food groups while local groundnut households having a dietary diversity of approximately 9 food groups. On average, improved groundnut households recorded higher dietary diversity scores than local groundnut households in the study area. T-test results show that the household dietary diversity score was statistically significantly higher among improved groundnut households (p =0.000) compared to local groundnut households in Homa Bay County. This implies that on average improved groundnut farmers have better access to greater and quality diet diversity compared to local groundnut farmers. This is attributed to the multiplier effect and direct consumption resulting from IGV production. Chi-square results also revealed that there is a significant relationship between the type of groundnut variety grown and food groups consumed in the last 24 hours, between IGV households and local groundnut households, except for Pulses/ legumes/ nuts and oil/fat food groups (Table 2).

3.2 Variables Selection and Determination of Propensity Scores Using a Probit Model

Based on the conditional independence assumption, measuring the causal effect of IGV uptake on dietary diversity requires that only covariates that are significant determinants of dietary diversity, as well as IGV adoption, are selected and tested for the presence of multicollinearity, heteroscedasticity, and omitted variables test. First, the estimated results of the Variance Inflation Factor (VIF) are presented in Table 3. The results revealed the model was free of multicollinearity as indicated by Variance Inflation Factor mean value of 1.16. The VIF for each independent variable range from 1.07 to 1.29, and were all less than the recommended critical value of 3.3, indicating the non-existence of multicollinearity [23]. Secondly, Breusch-Pagan and white test for heteroscedasticity revealed that the model was free from heteroscedasticity problems, as the null hypothesis for homoscedasticity (constant variance) was not rejected (*p*= 0.4210). Lastly, Ramsey RESET test for omitted variables (F (3, 373) = 0.90; Prob > F = 0.4395) showed that there were no omitted variables in the model.

The resulting estimates of the probit model for factors influencing farmers' decisions to uptake IGVs are shown in Table 4. The explained variable takes the value of one (1) if the farmer adopted IGV, and zero (0) if the farmer completely never adopted or still using local varieties. The log-likelihood ratio of -162.312 indicates that the model quickly converged. Besides, the likelihood ratio chi-square statistic (LR chi2 (9) = 209.23, p = 0.000) and Pseudo R^2 of 0.3919 show that the model wholly and significantly fits the data well. It implies that the decision to uptake IGVs was attributed to the regressors considered in the probit model. Apart from age, education, household size, group membership, and credit access that were not significant, the rest of the regressors (number of extension visits, gender, total land size owned, and availability of IGV seeds) were all significant.

The coefficient for the gender of the household head is positive and significant at the 5% level. The implication here is that male farmers are more likely to uptake IGVs compared to their female counterparts. Male farmers tend to have more access to necessary farm resources such as land, labor, capital, and information that increases their chances of adopting new agricultural technologies i.e. IGVs than female farmers [24]. The size of land owned by the household also positively and significantly influences the probability of IGV adoption at 1% level. Larger farm size decreases plot competition as it provides more space for testing, experimentation, and commercialization of new agricultural production techniques such as IGVs for increased yield as well as profit maximization. This finding is consistent with that of [25], who found a positive and significant influence of land size on the adoption of improved maize varieties in the northern region of Ghana.

The influence of the number of extension visits on IGV adoption was positive and significant at 1% level. The implication here is that the probability to adopt IGVs increases with an increase in the number of extension visits/contacts. More extension visits equip farmers with more agricultural information as well as resources concerning production and marketing to adopt new technologies like IGVs [26,23]. Lastly, the availability of IGV seeds had a positive and significant influence on IGV adoption. The availability of IGVs seeds increases the probability of adopting IGVs. Seed availability and exposure increase accessibility and affordability through enhanced farmers' knowledge to try them.

3.3 Determination of Region of Common Support and Balancing Test

To measure the effect of IGV uptake on dietary diversity, it is paramount to consider the fact that IGV adopters might also realize a higher level of diet diversity, even if they had not adopted the technology. Consequently, this study adopted the propensity score matching method to account for all observable variables to differentiate the intrinsic effect of IGV adoption on household dietary diversity. Therefore, balancing of relevant covariate distribution between IGV adopters and local groundnut farmers, before and after matching was performed using "the balance test". A line and bar graph were then used to check the region of common support or the overlap which ranges from 0 to 0.999 (Fig. 1). The graph uses the propensity scores distribution (x-axis) between IGV adopters (treated) and local groundnut farmers (untreated). Common support condition ensures that all observed variables or regressors both in the treatment and control group are matched. From Fig. 1, it is evident that most of the propensity scores between the IGV adopters' category and non-IGV adopters' category lie within the region of common support, as shown by the overlaps between the treated and untreated groups, with only a few observations being excluded from the analysis. This shows that good and balanced matches were obtained.

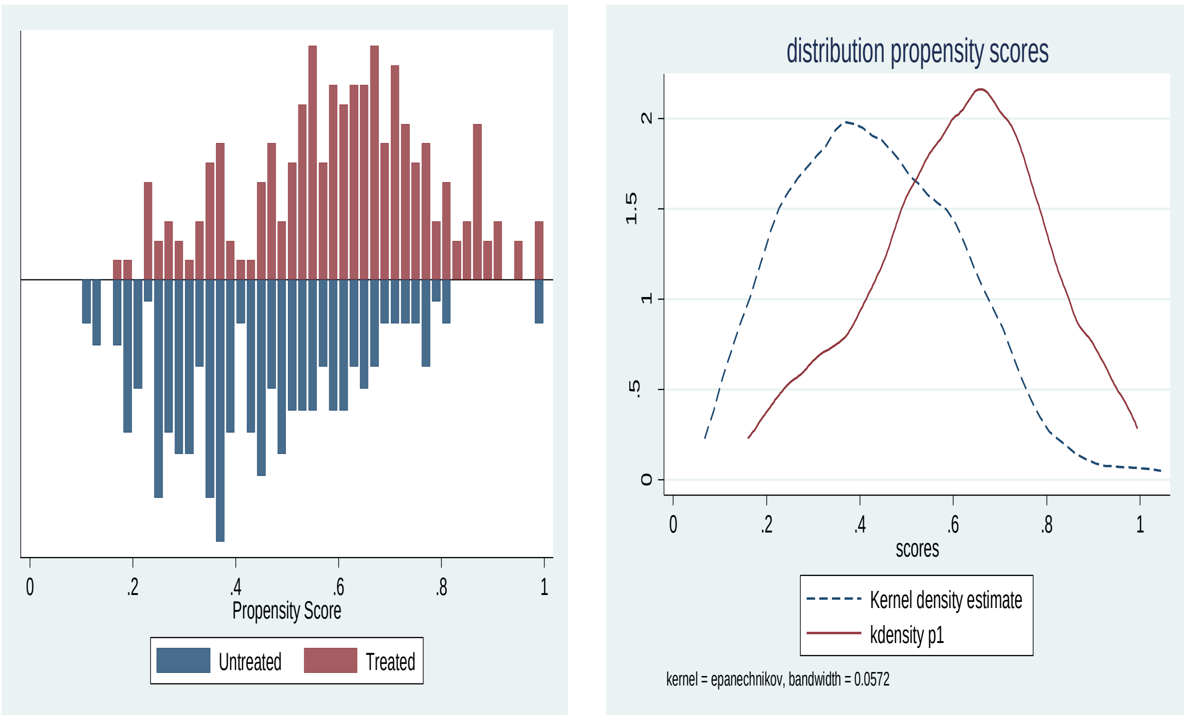

Fig. 1. A bar and line graph showing the region of common support graph and overlap

Table 2. Summary statistics of household dietary diversity and food groups among groundnut farmers in Homa Bay County

		Groundnut production			
Variables	**Description**	**Overall (n=384)**	**Improved Groundnut Farmers (n=204)**	**Local Groundnut Farmers (n=180)**	**Chi-square/ t-value**
		Mean/ Percent	**Mean/ Percent**	**Mean/ Percent**	
Dietary Diversity Score (HDDS)	Number	10	11	9	-8.969***
Food Groups					
Cereals	Yes	91.45	99.51	82.42	35.942***
	No	8.55	0.49	17.58	
Roots and tubers	Yes	73.83	86.76	59.34	37.444***
	No	26.17	13.24	40.66	
Vegetables	Yes	87.31	1.47	74.73	49.178***
	No	12.69	98.53	25.27	
Fruits	Yes	82.38	85.78	78.57	3.448*
	No	17.62	14.22	21.43	
Meat	Yes	58.55	70.10	45.60	23.778***
	No	41.45	29.90	54.40	
Eggs	Yes	67.88	74.51	60.44	8.733***
	No	32.12	25.49	39.56	
Fish and seafood	Yes	90.16	93.14	86.81	4.334**
	No	9.84	6.86	13.19	
Pulses/ legumes/ nuts	Yes	80.69	80.88	79.67	0.089
	No	19.69	19.2	20.23	
Milk and milk Products	Yes	76.42	84.80	67.03	16.860
	No	23.58	15.20	32.97	
Oils/fats	Yes	100.00	100.00	100.00	0
	No	0.00	0.00	0.00	
Sugar/honey	Yes	84.72	99.02	68.68	68.371***
	No	15.28	0.98	31.32	
Miscellaneous/ condiments	Yes	89.12	98.04	79.12	35.502***
	No	10.88	1.96	20.88	

*Note: ** and *** is significant at 5% and 1% level, respectively. Standard errors are in parenthesis*

Table 3. Multicollinearity diagnosis results of the variance inflation factor (VIF)

Variable	VIF	1/VIF
Age of household head	1.15	0.869
Gender of the household head	1.14	0.874
Education level of the household head	1.29	0.777
Household size	1.07	0.936
Total land size owned	1.09	0.918
Group membership	1.25	0.802
Number of extension visit	1.09	0.919
Availability of IGV seeds	1.11	0.899
Access to credit	1.23	0.815
Mean VIF	**1.16**	

Table 4. Factors influencing the uptake of IGV at the household level

Variable	Coefficient	Standard errors	Z-values
Age of household head (Years)	-0.008	0.005	-1.55
Gender of the household head (1=Male, 0=Female)	0.426	0.171	2.49**
Education level of the household head (Years)	-0.002	0.017	0.13
Household size (Number)	0.008	0.032	0.21
Total land size owned (Acres)	0.121	0.037	3.28***
Group membership (1= Yes, 0=No)	-0.120	0.188	-0.64
Number of extension visit (Number)	0.112	0.034	3.34***
Availability of IGV seeds (1=Available, 0= Otherwise)	1.762	0.160	11.00***
Access to credit (1= Yes, 0=No)	-0.167	0.174	-0.96
Constant	-1.040	0.406	-2.56**

*Note: Number of observation = 386; Log likelihood =-162.312; log-likelihood χ^2 (9) = 209.23, Prob > χ^2 = 0.000; Pseudo R^2 = 0.3919; *** and ** denote significant at 1%, and 5% levels, respectively*

3.4 Matching Quality and Test for Selection Bias

Three matching algorithms namely nearest neighbor matching (NNM), caliper matching, and kernel matching (KM) were used to determine the effects of IGV uptake on household dietary diversity. These matching algorithms resulted in different quantitative findings, but with similar qualitative meaning. Based on somewhat different samples, the matching criterions presented a unique common support area, thus resulting in the selection of various observations. Therefore, a balancing test was used to assess the matching quality examining whether the differences in the covariates in the matched sample category have been eliminated. Various indicators were, therefore, utilized to check the quality of the matching process, before and after matching to determine the balance in the distribution of the covariates in all groups. The results on matching quality are shown in Table 5. This includes the mean differences, the percent reduction in bias after completion of the matching algorithm, and the percent bias of the matched and unmatched group based on the observed characteristics used in the probit model of IGV uptake decision. The results revealed a significant percentage reduction in biases. Importantly, after matching, there were no significant differences between IGV and local groundnut households for any of the regressors.

The analysis resulted in a better balance in the matched sample for all the regressors after controlling for bias. The recommended percentage bias after matching all the covariate and the mean absolute bias should be less than 20% for validation [27]. All these criteria after matching were satisfied thus validating the balancing property, that IGV adopters and non-adopters (local groundnut farmers) with similar observable covariates are successfully matched. Kernel, three nearest neighbors, and caliper matching algorithms were considered as the best matching techniques for this study. All these matching algorithms resulted in a significant reduction in bias after the matching process. Importantly, there were no significant differences in the mean distribution (p>t) in matched control and treatment groups. Generally, there were insignificant p-values of the likelihood ratio test, low pseudo R^2, and a greater reduction in total bias after matching for all algorithms as shown in Table 6.

For instance, the mean standardized biases for all variables observed was 46.8 before matching. However, after matching, mean standardized biases significantly reduced to 9.8, 139, and 9.7 for the nearest neighbor, kernel matching, and caliper matching, respectively. The pseudo-R2 value before matching was 0.392, and it was significantly reduced after matching to 0.016, 0.018, and 0.072 for three nearest neighbor, kernel matching, and caliper matching, respectively. Importantly, p-values were all rejected after matching for all the matching algorithms. The implication of this is that there were no differences in the observed covariates between treated and control groups. Greater total percentage reduction biases were obtained and were 79.06%, 70.30%, and 79.27% for the three nearest neighbor, kernel matching, and caliper matching, respectively.

3.5 Testing for Hidden Bias Post Estimation Using Sensitivity Analysis

Interestingly, propensity score matching only caters for the selection bias in the observable variables, but not on the unobservable variables, especially after matching, thus the need to test or check for the hidden bias. Consequently, an unobserved variable may simultaneously determine individual assignment into the treatment group as well as the welfare outcomes, thus resulting in redundant, inaccurate, and non-robust matching estimators such as Average Treatment Effect on the Treated. To eliminate this problem, a bounding approach or sensitivity analysis is used to evaluate how strongly unobserved factors might affect the treatment selection process to alter the matching analysis implications [27].

In the bounding approach, the upper and lower bounds are calculated with a Wilcoxon sign rank test to test the null hypothesis of no treatment effect for different hypothesized values of unobserved selection bias [27]. The absence of a hidden bias means that the treatment process indeed ensured that two parties having the same observed covariates have the same chances of getting the treatment, resulting in the odds ratio of one as shown in Table 7. This also implies that the results on the effect of the adoption of IGV on dietary diversity are robust.

Table 5. Mean differences in covariates before and after matching

		Mean Sample		Bias		t-test	
Variable	**Sample**	**Treated**	**Control**	**Bias (%)**	**Reduction bias (%)**	**T**	**p>t**
Age of household head	Unmatched	49.078	54.198	-32.7		-3.21	0.001
	Matched	50.007	54.109	-26.2	18.9	-2.38	0.118
Gender of the household head	Unmatched	0.751	0.505	45.2		4.44	0.000
	Matched	0.660	0.645	3.2	92.9	0.28	0.780
Education level of the household head	Unmatched	9.569	8.017	33.8		3.36	0.001
	Matched	9.575	9.656	-1.8	94.8	-0.14	0.891
Household size	Unmatched	6.026	5.767	10.1		1.00	0.320
	Matched	5.780	5.641	5.4	46.4	0.51	0.614
Total land size owned	Unmatched	3.863	2.780	42.8		4.14	0.000
	Matched	3.258	3.635	-14.9	65.2	-1.46	0.536
Group membership	Unmatched	0.259	0.368	-23.4		-2.31	0.022
	Matched	0.288	0.320	-7.1	69.8	-0.62	0.536
Number of extension visit	Unmatched	1.549	0.582	43.6		4.29	0.000
	Matched	1.072	1.412	-15.3	64.8	-0.85	0.395
Availability of IGV seeds	Unmatched	0.804	0.165	165.9		16.24	0.000
	Matched	0.745	0.728	4.5	97.3	0.34	0.730
Access to credit	Unmatched	0.422	0.538	-23.5		-2.31	0.022
	Matched	0.471	0.521	-10.1	57.1	-0.87	0.382

Table 6. Propensity score quality indicators

Matching algorithms	**Three nearest neighbors matching NNM (3)**	**Kernel matching (KM)**	**Caliper (0.01)**
Before matching			
Pseudo R^2 before matching	0.392	0.392	0.392
LR chi^2 before matching	209.23	209.23	209.23
Mean standardized bias before matching	46.8	46.8	46.8
Prob > chi^2	0.000	0.000	0.000
After matching			
Pseudo R^2 after matching	0.016	0.018	0.072
LR chi^2 after matching	6.89	7.47	27.86
Mean standardized bias after matching	9.8	13.9	9.7
Prob > chi^2	0.649	0.589	0.891
Total % bias reduction	**79.06**	**70.30**	**79.27**

Table 7. Sensitivity analysis with rosenbaum bounds (this is a sensitivity analysis test for matched and unmatched data)

Gamma	Q_mh+	Q_mh-	p_mh+	p_mh-
1	.	.	.	.
1.05	-0.095346	.	0.53798	.
1.1	-0.095346	-0.095346	0.53798	0.53798
1.15	-0.095346	-0.095346	0.53798	0.53798
1.2	-0.095346	-0.095346	0.53798	0.53798
1.25	-0.095346	-0.095346	0.53798	0.53798
1.3	.	-0.095346	.	0.53798
1.35	-0.095346	-0.095346	0.53798	0.53798
1.4	-0.095346	-0.095346	0.53798	0.53798
1.45	-0.095346	.	0.53798	.
1.5	-0.095346	-0.095346	0.53798	0.53798
1.55	-0.095346	-0.095346	0.53798	0.53798
1.6	-0.095346	-0.095346	0.53798	0.53798
1.65	-0.095346	-0.095346	0.53798	0.53798
1.7	.	-0.095346	.	0.53798
1.75	-0.095346	-0.095346	0.53798	0.53798
1.8	-0.095346	-0.095346	0.53798	0.53798
1.85	.	.	.	.
1.9	-0.095346	-0.095346	0.53798	0.53798
1.95	-0.095346	-0.095346	0.53798	0.53798
2	-0.095346	-0.095346	0.53798	0.53798

Note: Gamma: odds of differential assignment due to unobserved factors, Q_mh+ : Mantel-Haenszel statistic (assumption: overestimation of treatment effect), Q_mh- : Mantel-Haenszel statistic (assumption: underestimation of treatment effect), p_mh+ : significance level (assumption: overestimation of treatment effect), p_mh- : significance level (assumption: underestimation of treatment effect)

Table 8. Effect of improved groundnut variety uptake on household dietary diversity

		Sample size		Mean outcome				
Matching algorithm	**Livelihood outcome**	**Treated**	**Control**	**Treated**	**Control**	**ATT**	**Standard error**	**t-Statistics**
Nearest neighbor matching (3)	Household dietary diversity	51	153	10.732	9.162	1.516	0.380	4.00***
Kernel Matching	Household dietary diversity	51	153	10.73	9.288	1.444	0.352	1.10***
Caliper Matching	Household dietary diversity	65	139	10.690	9.302	1.389	0.421	3.30***

*Note: *** denote significant at 1% level; t-values are calculated using bootstrap with 50 replications. ATT denotes Average Treatment Effect on the Treated*

3.6 Effect of Improved Groundnut Variety Uptake on Household Dietary Diversity

To determine the effect of IGV uptake on household dietary diversity, the average treatment effect on the treated (ATT) was calculated after matching. A common support condition and the best matching algorithms were selected to match the different propensity scores for the treated and control groups. The results of kernel matching (KM), three nearest neighbor matching (NNM), and caliper showing the effect of IGV uptake on household dietary diversity are in Table 8.

4. CONCLUSION

Overall, using 50 times bootstrapping recommended for testing of the statistical significance, all matching algorithms show similar results that, on average, adopting IGVs significantly increases the household nutrition as measured by the household dietary diversity score. In other words, the results of the three matching methods indicate that IGV uptake had a positive significant effect on household dietary diversity score. The implication here is that IGV adopting households had access to approximately 2 more food groups than those households growing local varieties. Therefore, in households growing IGVs, there was better food access and a more diversified and quality diet thus higher nutritional quality compared to those households growing local groundnut varieties. Productivity changes result in better nutritional quality and economic well-being.

Based on this study, there is need for intersectoral collaboration between Ministry of Agriculture and Ministry of Health in Kenya to develop initiatives through which farmers can receive trainings on the importance of consuming various kinds of food groups and the need to consume the crops grow in their households. This will contribute to reduction of malnutrition in Homa Bay County.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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