The sub Saharan Journal of Social Sciences and Humanities (SJSSH)
ISSN: 2619-8894 (Online), 2619- 8851 (Print)

Contribution of Round Potato Production on Smallholder Farmers' Food Security in Meru District, Tanzania

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Received: August 10, 2022; **Accepted:** February 7, 2023; **Published:** June 28, 2023

Abstract: *Round potatoes are cultivated as food and cash crops and have the potential to improve the food security status. This paper analyses factors associated with round potato production to food security in Meru District, Tanzania. The study adopted a cross-sectional research design; multi-stage and simple random sampling techniques were used to select 341 respondents (122 project participants and 219 non-project participants). Mixed methods were used in data collection including structured questionnaires, key informant interviews and focus group discussions. Food security status was estimated using HFIAS, a multiple linear regression model was used to estimate the predictors of food security and the comparison for food security among project and non-project participants was estimated using propensity score matching. Findings showed that the use of quality potato seeds, loan application, availability of other inputs, access to extension services, and area cultivated were important predictors of round potato production ($p<0.05$). Project participants were more food secure than non-project participants in terms of HFIAS and HDDS, using NNM and MDM principles. Therefore, in the study area potato production contributes to the attainment of food security. It recommended that actors engaged in the promotion of round potato production including the LGA, NGOs and development partners should capitalize on factors identified for improved production and productivity such as more use of technologies, access to extension services, marketing strategies for potato produce, availability of quality seeds and other proper agro-inputs as well as provision of soft loans.*

Keywords: *Round potatoes, food security, potato production, Meru district, smallholder farmers*

1. Background Information

World Food Summit defined food security as when *"all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life"* (FAO, 1996 cited by Mushi, 2019). Food security has three main components namely food access, availability, and utilization Swindale *et al.* (2006). Potato (Solanum tuberosum) is one of the food crops cultivated around the world led by the Asia region whereby potatoes are recognized as a potential crop due to high productivity which helps to ensure food security (Su & Wang, 2019; Husain, 2020; FAOSTAT 2020). The Food and Agriculture Organization (FAO) has argued that round potatoes have the potential to contribute to food security, but this potential has not been fully exploited by smallholder farmers (SHFs) especially in Africa to enhance food security. According to Raigond *et al.* (2020); and Kharumnuid *et al.* (2021), round potatoes have shown a significant impact on both food and nutritional security in the world due to their high protein-calorie ratio in a short period and small area than many other crops. In Sub-Saharan African countries, potatoes are important as a staple food, production has increased from 655,447 per hectare year 1998 to 1.47 million per hectare year 2018, helping to reduce the challenge of chronic food insecurity facing SHFs (Krijger & Waals, 2020). Egypt is the main producer of potatoes in Africa followed by Malawi (World Bank Report, 2009 cited by Ugonna *et al.*, 2013). Potato is a major food crop cultivated by smallholder farmers in East Africa at highland elevations contributing to food security (Danial *et al.*, 2016). Mbeya, Iringa, and Njombe are the leading regions in Tanzania which produced 70% to 80% of all potatoes in the country in the year 2017 whereby the average yields were 5 to 7 tons per hectare (Tuinbouw, 2017).

According to Mugisha *et al.* (2017), during critical food shortage periods, potato yields can be used by smallholder farmers as a source of income and spend money to buy other foodstuffs. In Tanzania, round potatoes are also cultivated by smallholder farmers as a food crop in the Northern and Southern Highlands zones (Mende *et al.*, 2015). In the Northern zone, round potatoes are cultivated in Arusha, Manyara, and Kilimanjaro (Lumililo, 2018; Danial *et al.*, 2016). The problem of inadequate availability of clean potato seeds, knowledge of potato production, harvesting, marketing, and post-harvest losses are among the key

challenges to potato farmers in Tanzania's Northern zone (Omary, 2015). Due to the challenges and potentiality of potatoes to smallholder farmers of Northern Highland, different interventions have been implemented by various stakeholders including Kilimo Trust Organisation and Research Community and Organizational Development Associates (RECODA) have joined hands to improve the production of Potato in Meru District, Tanzania. The project interventions to improve food production and productivity for food security by RECODA aimed to increase potato production and enhance food security for SHFs (RECODA, 2020). Therefore, the study on which this paper is based was conducted to determine factors influencing the production of round potatoes, to assess and compare the food security status among project participants and non-project participants based on the Household Dietary Diversity Score (HDDS) and The Household Food Insecurity Access Scale (HFIAS) in Meru District. Findings from this study provide useful information to actors engaged in promoting the production of round potatoes for both income and food security such as local government authorities (LGAs), research institutions, policymakers, and other actors along the value chain.

2.0 Methodology

The study on which this paper is based was conducted in the Meru District Council in the Arusha Region, of Tanzania. The district was purposefully selected because it is among the higher potato producers in the Highlands zone; in the study area, there is a project intervention (RECODA) to improve food security through round potato production implemented during the 2019 to 2020 production season. Hence a good study area to compare the contribution of potatoes to SHF's food security. A cross-sectional research design was adopted in this study, the design was appropriate given the nature of the objectives for the study as it allowed data collection from multiple sources to enable comparison and to determine the relationships between variables at a single round of data collection (Omair, 2015). Purposive sampling was used to select active groups of potato farmers from the project area which meet every week.

The study population consisted of 3100 round potato farmers in the study area. These consist of target farmers under the project and non-participants. The project participants were 1109 taken as the treatment group (N_t) and non-participants in 1991 were used as the control group (N_C). This study adopted the formula proposed by Krejcie & Morgan (1970) in determining the sample size of the study from treatment and control groups from farmers in the Meru District Council as shown below.

$$\mathbf{S} = \frac{X^2NP\,(1-P)}{d^2\,(N-1) + X^2P\,(1-P)}$$

Where: S = required sample size, X =z value (assumed to be 1.96 for 95% confidence level), N = Population size, P = Population proportion (assumed to be 0.5 since this would provide the maximum sample size), d = degree of accuracy (5%), expressed as a proportion (0.05).

$$S = \frac{1.96^2 x 3100 x 0.5 x 0.5}{0.05^2 x (3100-1) + (1.96^2 x 0.5 x 0.5)} = 341$$

The Proportionate Stratified Random techniques were used to get a representative of the population.

For control $n_c = (Nc / N) * s$ and for treatment $n_t = (N_t / N) * s$ Also, Propensity Score Matching (PSM) is effective when the sample size is higher with a minimum of 200 samples (Howarter *et al*, 2015). Also, the main condition in the PSM is the matching of the treated group and control group, whereby a high sample of the control group was selected to comply with the condition of matching. This study used 122 participants from the treatment group (n_t) and 219 non-participants from the control group (n_c). Systematic sampling was applied to select representative samples from the active groups in the project which meet every week area namely, Songoro, Nkwarisambo, Seela-Singisi, and Ngwandua wards. Non-project participants were selected using simple random sampling from a list of round potato farmers from the villages not included in the project implementation namely, Urisho, Ushili and Nkwanekoli villages. This was selected to match the observable characteristics between the project participants (treatment) and non-project participants (control group) during analysis. The study involved both quantitative and qualitative primary data which were collected using a structured questionnaire and an interview checklist which are useful to provide triangulation of information (Creswell, 2013).

Qualitative data were collected from the checklist guide questions; three focus group discussions of between 8-12 members and four key informant interviews were conducted. The data analysis for the qualitative data was undertaken using content analysis techniques with a constant comparison. Quantitative data was analysed with the aid of Statistical Package for Social Sciences (SPSS); descriptive statistical analysis including frequencies, percentages, means, minimum and maximum was computed to establish the characteristics of the sample. Multiple linear regression analysis was used to determine factors associated with round potato production. All variables reported at the ratio level that was to be included in the regression model were tested for normality using a histogram and normal distribution curve to see whether any were skewed. All variables which were found to be skewed were transformed into normal distributions using log10 transformation. Tolerances and variance inflation factors (VIF) were computed to check for multi-collinearity. According to Landau & Everitt (2003),

tolerance levels of more than 0.1 and VIF values of not more than 10 show that there is no multi-collinearity. Propensity Score Matching (PSM) using STATA was used to measure impact by comparing the Average Treatment Effects (food security) on the Treated (ATT) which helped to construct a treatment group (project participants) and control group (non-project participants) by using the propensity scores and estimate differences in income between project participants and non-project project participants.

2.1 Measuring Food Security in terms of food accessibility

Given the multidimensional nature of food security, practitioners and policymakers have developed different indicators for measuring food security (Hussein *et al.*, 2018). Food access has been defined as the ability to obtain sufficient quality and quantity of food to meet the nutritional needs of all family members measured using the HDDS model given a 24-hour recall Swindale *et al.* (2006). The study adopted the 15 food groups suggested by the Food and Nutrition Technical Assistance (FANTA) and World Health Organization (WHO) during the 24-hour recall at the household level. According to the International Food Policy and Research Institute (IFPRI) (2006), as cited by Jones *et al.* (2013), the HDDS below 4.5 implies low dietary diversity, 4.5 – 6 medium dietary diversity, while 6 and above implies good dietary diversity. The HFIAS is among the commonly used models to establish and compare food accessibility during the previous 30 days (Ballard *et al.*, 2011). The study also adopted HFIAS to measure food accessibility suggested by FANTA and the United States Agency for International Development (USAID) comprises nine occurrence questions and nine frequencies of occurrence questions during the past 4 weeks or 1 month. The model was designed to reflect three features: feeling of anxiety about household food supply, perception of insufficient quality (variety, preferences, and social acceptability), and perception of insufficient food supply and consumption. During the analysis, the following steps were conducted; the first step was a recording of new variables, a frequency response of "rarely" and "sometimes" (originally coded as 1 and 2 respectively) was coded as "1" and a frequency response of "often" (originally coded as 3) was coded as "2". In the second step, a new code of "0" was added for households that replied "no" to each binary question, hence leading to the value of 0-2 per household per nine variables. Finally, three categories were used to measure the household hunger level namely, 0-1 little to no hunger, 2-3 moderate hunger and 4-6 severe hunger in the household (Ballard *et al.*, 2011).

2.1.1 Specification of the multiple linear regression model used

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\ldots\ldots\ldots\ldots\ldots\ldots\beta_nX_n+\varepsilon_i$$

Where,

Y = the predicted or expected value of the dependent variable (yields).

β_0= the value of Y when all the independent variables (X_1 through X_n) are equal to zero.

$\beta_1 - \beta_n$= estimated regression coefficients, i.e. change in the outcome variable caused by a unit change in the predictor variable, holding all factors constant.

$X_1 - X_n$ = predictor variables entered in the linear regression model; the age of respondent (years), years in school, household size, access to extension services (0=no;1=yes), application to loan1 (0=no;1=yes), farmers' experience, use of quality seeds (0=no;1=yes), area cultivated, availability of other inputs (0=no;1=yes) and where sales produce (1= to the market or processors; 0=otherwise).

ε_i= An error term (due to inherent errors in the model and other variables which were not entered in the model).

2.1.2 Computing Propensity Score Matching (PSM)

Propensity Score Matching is defined as the estimated probability obtained from the regression model assigned to the treatment and control group given the observable characteristics which are satisfactory to reduce bias in the study (Rosenbaum & Rubin, 1983). Two matching principles were used; Nearest Neighbour Matching (NNM) based on the nearest propensity scores between project participants and non-project participants group. Mahalanobis Distance Matching (MDM) is based on an effective multivariate distance metric that measures the distance between a point and a distribution from propensity score between project participants and non-project participants, the two matching algorithms were used to find the robustness of the findings (Baser, 2006). PSM consists of four steps: propensity score estimation, checking overlap, selecting a matching algorithm, and estimating ATT or sensitivity analysis. The first step involved estimating propensity scores (using the logit model) for probabilities of each potato farmer who participated in the round potatoes project given their observed characteristics (independent variables) to create a counterfactual group. The independent variables used were the age of the respondent (years), years in school, household size, access to extension services, application to loan, farmers' experience, use of quality seeds, area cultivated, availability of other inputs and where sales produce is measured at dummy or continuous variable. The second stage involved checking overlap/balance, the distribution of the observable characteristics in the propensity score should be the same for both project and non-project participants to ensure the comparing of the comparable groups. Another step involved choosing the matching algorithm; strength was checked by using two matching algorithms namely Nearest Neighbour Matching (NNM) and Mahalanobis Distance Matching (MDM). The last step is to compute outcome (food

security) analysis (Estimating the Average Treatment Effects on the Treated). Food security was given by equation 1.

$$ATT=(E(HDDS/Z=1)-E(HDDS/Z=0) \quad (1)$$

$$ATT=(E(HFIAS/Z=1)-E(HFIAS/Z=0) \quad (2)$$

Where:
ATT = Average Treatment Effects on the Treated
HDDS = Household Dietary Diversity Score
HFIAS = Household Food Insecurity Access Score
The measurement of HDDS indicates the food security status in terms of dietary diversity among project participants and non-project participants in the study area.

3.0 Results and Discussion

3.1 Social-demographic Characteristics of the Potatoes Smallholder Farmers'

The findings as presented in Table 2.1 reveal that a total of 341 sample potato smallholder farmers' (project participants and non-project participants) in Meru District were interviewed. Out of that 169 (49.6%) were male and 172 (50.4%) were female, most of the respondents (82.4%) were married. Among the respondents, 68.6% were aged between 36 and 65 years indicating an energetic and active commitment to farmers in different agricultural activities. The land owned by many of the respondents (60.4%) ranges between 0 to 1 acre. The average land size was 1.35 acres with a minimum of 0 and a maximum size of 6 acres. About three-quarters of respondents (79.8%) had attended primary school training up to standard seven indicating that there was a good literacy level. The average household size was 4.5 with the minimum and maximum sizes of 1 and 10 respectively indicating that they had reasonable labour for farm activities. Many of the farmers (88.3%) depended on crop cultivation as their main occupation and 91.8% depended on crop cultivation as their main source of income in the household (Table 2.1).

Table 2.1: Descriptive analysis of socio-economic characteristics of respondents (n=341)

Characteristics	Category	Frequency	Per cent
Sex of respondent	Male	169	49.6
	Female	172	50.4
Age of respondent (years)	18-35	80	23.5
	36-65	234	68.6
	65 above	27	7.9
Size of land (acres)	0-1	206	60.4
	2-3	123	36.1
	4-6	12	3.5
Marital status	Divorced	2	.6
	Married	281	82.4
	Separated	6	1.8
	Single	23	6.7
	Widow	20	5.9
	Widower	9	2.6

3.2 Factors Influencing Round Potatoes Production

Potatoes yield (dependent variable) was regressed with ten independent variables which were thought to account for more variation in potato production (Table 2.2). Based on the R-square value. 54.8% variation in the dependent variable (potato yield) was due to the ten independent variables entered in the model. The coefficient value β-values show the influence (positive or negative) of independent variables on the dependent variable while the P-value shows the statistical significance of the independent variables.

Table 2.2: Social-economic factors influencing round potatoes production

Characteristics	Coefficients	Standard error	P value
(Constant)		.123	.000
Age of respondent (years)	-.085	.001	.042
Years in school	.106	.106	.009
Household size	.079	.008	.038
Access to extension services	.017	.029	.697
Application to loan	.078	.029	.062
Farmers experience	.118	.043	.004
Use of quality seeds	.392	.040	.000
Area cultivated	.400	.049	.000
Availability of other inputs	.036	.029	.412
Where farmers sell produce	-.021	.061	.582

Dependent Variable: quantity of potatoes harvested (bags of 100kg/acre)
R^2 = 0.548, Adjusted R^2 = 0.534, Durbin-Watson = 1.694

Findings presented in Table 2.2 reveal that farmers' experience, use of quality seeds, the area cultivated, and the area cultivated had positive and statistical influences round potato production ($p<0.05$). Years in school, household size, access to extension services, application to loans, and availability of other inputs had positively but not statistically influenced potato production ($p>0.05$). The age of respondents and where farmers sell produce had negative but not statistically influenced round potatoes production.

Age of respondent: Findings revealed that the age of the potato farmer had a negative impact on potato yields (β = -0.085) and was significant ($p<0.05$). This indicates that with all other predictor factors maintained constant, an increase in the age of the farmer resulted in a decrease in potato yield. In this study, 70% of the total samples were aged between 36 and 65 years which implies that potatoes were most cultivated by adults. This implies that older farmers are less productive compared to young farmers who are active in productive activities. The finding was comparable with Kafle & Shah (2012), who found aged farmers above 55 years less adopted the improved potato varieties which aimed to increase productivity. Therefore, since potato production activities require high energy the more energetic farmers are more engaged.

Household size: Household members in smallholder farming (or peasant farming) are the primary source of labour in developing countries. The study discovered that family size had a positive impact (β=0.079) on potato production at a significant level of 5% (p<0.05). This indicates labour is an important factor in potato production in the study area. The findings are comparable with Ebrahim, (2019) who also found that a large number of household members influenced crop production due to their ability to involve in different farming activities at the household level.

Farmers' experience: The farmer experience had a positive influence (β=0.118) at a significant level of 1%, indicating the more experienced farmers are more likely to produce more yields because of the adoption of different technologies which can help to increase yields. Similar findings have been reported by Tadesse *et al.* (2017); Bukul, (2018) who reported a positive impact of farmers' experience on agricultural technology adoption which leads to high production.

Area cultivated: Area cultivated (acres) had a strong influence on yields (β=0.392) at a significant level of 0.1%, directing that an increase of 1 unit of land cultivated resulted in a 0.048 increase in potato yield while other predictor factors maintained constant. Since land is another major factor of agricultural production enables farmers to cultivate large areas with different varieties preferred, hence increasing production. The findings are comparable with Mende *et al.* (2014) found that potatoes had high yields per unit of land and time compared with other crops cultivated in Southern highlands in Tanzania. Ephraim, (2019) also showed large farmers who owned larger plot sizes were allowed to grow diversified crop varieties which contributed to increased production.

Use quality seed: Also, the study (Table 2.2) revealed that the use of quality seed (β=041) at a significant level of 0.1%, shows a positive impact on potato yield. Findings revealed that the quality seed enables farmers to earn high yields and vice versa. During the focus group discussion (FGD) the majority of them reported that they buy seeds from middlemen whereby are not sure of which generation of seed, how much they can produce, and how many times they can replicate. This contributed to food insecurity because farmers depended on money earned from potato production to buy other sources of foodstuffs. Farmer portrayed the problem by saying that "*quality seeds brought by stakeholders are sold at high cost and when comes to marketing the required to sell them at a very low price which leads most of the farmers to use inequality seeds due to unaffordable price of quality seed.* Another participant adds that "*they could get profit (gross margin) even by selling at a low price if they could get high-quality seed because they will be able to produce at large quantity*".

Availability of other agro-inputs: The findings from Table 2.2 show availability of other agro-inputs had a positive effect (β=0.036) on potato production but was not significant (p>0.05). Farmers who had access to agricultural inputs (fertilizer, pesticides, and insecticides) in a required period produced more yields compared to farmers who had no access to agricultural inputs. According to the FGD findings, participants elaborated that the availability of agro-inputs helps farmers to plant within a cropping calendar and management of crops from fungi, insects, and pests which are commonly found in potato production. Another farmer clarified by saying that, *"potatoes need very close supervision due to the environmental planting condition in winter's season, failure in close supervision and management leads to a very low yield".* Mende (2015); and Bukul (2018), also discovered the majority of farmers from group participants reported the high cost of agro-inputs had an impact on round potatoes production in the Mbeya District of Tanzania.

Access to loan: Loan application (Table 2.2) showed a positive impact (β=0.078) on round potatoes production but was not significant. It indicates that farmers who had access to and applied for a loan produced more yields compared to farmers who did not apply for a loan. During FGD, participants reported the challenge of access to inputs cost due to low access to credit, this showed access to soft loans to SHFs has a significant impact on improving potato production. The finding was comparable with Mwatawala *et, al.,* (2020); Bukul (2018), who found that access to credit was statistically significant to potato production with a positive coefficient. Moreover, the findings from the study discovered that there is a strong significant association between being a member of a farmers' group and access to loans (Table 3).

Table 2.3: Cross-tabulation between membership and application to loan (n=341)

Application for a loan during the past 12 months	No (Non-group member) %	Yes (Group member) %
No	77	23
Yes	35.8	64.2

Chi-square = 53.893 (df = 1, p = 0.000) Phi = 0.398 (p = 0.000)

Where farmers sell potatoes: The majority of participants had reported selling their crops on the farm or at home. Marketing of potato produce was found to have a negative influence (β=0.021) but not significant. This indicates that farmers who sold the produce on the farm or at home produced less compared to farmers who sold their produce directly to the market to the processors because they had access to the market and were assured of a good price.

Access to extension services

The findings as reported in Table 2.2 revealed that access to extension services had a positive influence (β=0.017) on

round potatoes production but was not significant (p>0.05). Access to extension services this the main factor that influences farmers to adopt different improved technologies to increase production because it helps farmers with technical support compared. This was also reported by the majority of participants who explained that cascading of technologies was easily done by lead farmers through the Research Initiative for Participatory Agricultural Transformation (RIPAT) approach introduced by project implementation. The finding is comparable to those reported by Dahal & Rijal (2019); and Bukul (2018), who found access to extension services had a positive influence on potato cultivation on a large scale. Other independent variables had a statistical influence on round potato production as shown in Table 2.2.

3.3 Production and Food Security of Round Potatoes Farmers in Meru District

The major importance to note in the matching principle was to compare the project participants with one or more non-project participants who had a similar set of observed characteristics. In this study, the researcher used the logit regression model to predict the probability that farmers who participated in the potatoes project using observed characteristics. Table 4 shows the logit regression model was found to be a good predictor of participation as demonstrated by the results of R^2 = 0.8257 showing that the model is a good fit. Secondly, the model has a chi-square static of 367.5 which is statistically significant at the 0.1% confidence level (Windmeijer, 1995; Hoetker, 2007). Therefore, this indicates the predictors included in the model are capable of predicting the probability of individual participation in the potatoes project.

Table 2.4: Probability of farmers for participation in the potatoes project

Participants	Coefficient.	P-value
Access to extension services	8.525	0.000
Area cultivated	0.401	0.472
Market information	2.357	0.003
Age	0.022	0.443
Other crop cultivated	0.547	0.595
Farmers' experience (years)	-0.031	0.597
Availability of other inputs	3.601	0.000
Where Sales potatoes	-0.102	0.985
Availability of quality seeds	1.464	0.101
Head of household sex	1.636	0.212
Loan application	3.367	0.000
Household size	0.385	0.105
Main occupation	0.140	0.935
Years in school	0.064	0.239

Number of observation= 341, Chi^2 = 367.25, Pseudo-R^2= 0.8257
Log likelihood= -38.751474

Findings presented in Table 2.4 reveal that market information, the area cultivated, availability of quality seed, availability of other agro-inputs, other crops cultivated, application to loan, access to extension service, household size, main occupation, years in school, head of household sex, and age had statistically influenced smallholder farmers participating in the project (p<0.05). Farmers' experience and marketing of potato yields had negatively statistically influenced farmer participation, which justified that experienced farmers have learned a lot and farmers sell their produce in the market have nothing to lose which leads them to be less dependent on project participation. These results are comparable with the findings of Musa & Hiwot (2017); and Abebaw & Haile (2013), who studied the impact of agricultural cooperative membership on the well-being of smallholder farmers and the impact of cooperatives on agricultural technology adoption respectively in Ethiopia.

The region of common support was then checked to ensure matches of observable characteristics were compared for both treatment and comparison groups. This was done to ensure that the mean propensity score was not different between the project participants and the non-project participants. A good match between treated and comparison groups concerns a larger proportion of overlap of propensity scores Dehejia & Wahba (2002).

Table 2.5: Common support table

Variable	Obs	Mean	Std.Dev.	Min	Max
Overall	341	0.358	0.444	0.000	1.000
Project participants	122	0.909	0.178	0.045	1.000
Non-project participants	219	0.051	0.157	0.000	0.989

The results presented in Table 2.5 show that the region of common support (propensity scores) ranges between 0.00 and 1.00. For the project participants lay between 0.055 and 1.00 and for the non-project participants ranged between 0.00 and 0.99. The self-selection bias was eliminated by dropping the counterfactual farmers whose probability of participation was very different. Thereafter, the difference in outcomes variable was then computed to compare the food security status of project participants and non-project participants' farmers.

3.4 Outcome effect (food security) in terms of HHDS and HFIAS for project participants and non-project participants

The findings presented in Table 2.5 and Table 2.6 show the impact of round potato production on smallholder farmers' food security estimated by using Nearest Neighbour Matching (NNM) and Mahalanobis Distance Matching (MDM) in terms of HFIAS and HDDS for both project participants and non-project participants respectively.

Table 2.6: Average Treatment Effect on the Treated using NNM and MDM to find HFIAS

Matching algorithm	Outcome variable	Project Participants	Non-project participants	Difference	S.E.	T-stat
NNM	HFIAS Unmatched	1.352	1.648	-0.296	0.085	-3.46
	ATT	1.211	1.833	-0.623	0.35	-1.78
MDM	HFIAS Unmatched	1.352	1.648	-0.296	0.085	-3.46
	ATT	1.352	2.213	-0.861	0.301	-2.86

Table 2.6: Average Treatment Effect on the Treated using NNM and MDM to find HDDS

Matching type	Variable Sample	Project participants	Non-project participants	Difference	S.E.	T-stat
NNM	HDDS Unmatched	8.246	7.571	0.675	0.177	3.82
	ATT	8.123	7.265	0.858	0.574	1.49
MDM	HDDS Unmatched	8.246	7.571	0.675	0.177	3.82
	ATT	8.123	7.265	0.858	0.574	1.49

The NNM results presented in Table 2.6 show the estimated ATT for project participants had an average HFIAS of 1.211 compared to an average HFIAS of 1.833 for non-project participants, a different average of -0.623 points. This indicates that both project participants (1.211; 0-1 cut-off point) had little or no hunger compared to non-project participants (1.833; 2-3 cut-off point) means they had moderate hunger at the household level. Likewise, the MDM results presented in Table 2.6 also revealed the estimated ATT for project participants had an average HFIAS of 1.352 compared to an average HFIAS of 2.213 for non-project participants, a different average HFIAS of -2.86 points. This indicates that project participants had little or no hunger (1.352; cut-off point of 0-1) compared to non-project participants who had moderate hunger (2.213; cut-off point of 2-3) at the household level respectively. Therefore, the findings indicate that project participants were more food secure than non-project participants because of the involvement in potato interventions including farm layout, use of quality seed, spacing, proper application of agro-inputs, pests and disease management, and post-harvesting techniques. This led to the round potato production having a positive significant impact on smallholder farmers' food security in the study area.

The findings as presented in Table 2.7 NNM show that the ATT for project participants had an average HDDS of 8.123 while the non-project participant had an average HDDS of 7.265 a different average HDDS of 0.574 points. This indicates that both project participants and non-project participants (8.123 and 7.265; HDDS >6 cut-off points) respectively had good dietary diversity. Likewise, the MDM estimated ATT show that project participants had the same average HDDS of 8.123 more than an average HDDS of 7.265 for non-project participants a positive difference average of 0.574 points.

The results in Table 2.6 and Table 2.7 proved that findings from the study are fairly robust for two matching algorithms. Similarly, the researcher found the project indicators had a positive and significant impact on smallholder farmers' food security in Meru District. This indicates that the project farmers were more food secure due to the adoption of good agricultural practices, identification and use of quality seed, application to loans in the farmers' group, access and proper use of agricultural inputs and marketing of potato yields. The findings are comparable with Shehu & Sidique (2014); and Ali & Peerlings (2012) who investigated the impact of non-farm entrepreneurial activities on farm household well-being in Nigeria and Ethiopia respectively using a related approach. Also, findings by Gitonga *et al.* (2013) who researched on impact of metal silos on households' maize storage, storage losses and food security obtained similar results. The PSM results revealed that participation in

nonfarm enterprise activities and the use of metal solos had a significant positive impact on household food security.

4.0 Conclusions and Recommendations

Round potato is a food crop and nutrition security for the majority of the smallholder farmers in Meru District. Improved round potato production has the potential to increase smallholder farmers' food and nutrition security which in turn will gradually improve their well-being. The factors affecting round potato production and its contribution to food security in the Meru District of Tanzania are the use of quality potato seeds, loan application, availability of other inputs (fertilizers, insecticides, and pesticides), access to extension services, and area cultivated.

The project interventions for more access to inputs (improved seeds, fertilizers, pesticides and insecticides), access to loans, and access to extension services contribute to the adoption of good agricultural practices and enhance the achievement of food security among smallholder farmers. The project has contributed to food security as indicated by the different food security statuses among project participants as compared to non-project participants' counterparts in terms of HFIAS and HDDS measures of food security.

Supporting round potatoes shows a positive contribution to productivity and food security, the study recommends that actors engaged in the promotion of round potato production including the LGA, NGOs and development partners should capitalize on factors identified for improved production and productivity such as more use of technologies, access to extension services, marketing strategies for potato produce, availability of quality seeds and other proper agro-inputs as well as provision of soft loans.

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