IMPACT OF ROUND POTATO PRODUCTION ON WELL-BEING OF SMALLHOLDER FARMERS: A CASE OF CHIPS PROJECT IN MERU DISTRICT, TANZANIA

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EXTENDED ABSTRACT

Round potato is among the potential food and cash crop cultivated in Tanzania's Northern highlands particularly Meru District in the Arusha Region. Despite of potentiality of potatoes to contribute to smallholder farmers' income and food security, there is scarce empirical evidence on the impact of round potato production on smallholder farmers' well-being. The main objective of the study was to determine the impact of round potato production on the well-being of smallholder farmers in terms of income and food security. The first specific objective was to analyse the socio-economic factors influencing round potato production and the second objective aimed to assess the impact of round potato production on smallholder farmers' food security in terms of dietary diversity. The third specific objective aimed to assess the impact of round potato production on smallholder farmers' income. The study adopted a cross-sectional study design and a multi-stage random sampling approach using purposive sampling and simple random sampling to select 341 potato farmers (122 project participants of the potato project and 219 non-project participants). A multi-stage random sampling approach was used whereby purposive and systematic sampling was applied to select a representative sample of smallholder farmers growing round potato varieties from Meru District. Quantitative information was analysed using Statistical Package for Social Science (SPSS) and STATA while qualitative information was analysed using content analysis. Data were collected using mixed methods and tools namely key informant interviews, focus group discussions and a survey using structured questionnaires. Findings showed that the use of quality potato seeds, loan application, availability of other inputs, access to extension services and area cultivated had a significant impact to round potatoes production ($p<0.05$). There was a positive and significant ($p<0.05$) association between income and production (yield), income and area cultivated, income and cost of fertilizers and income and cost of seeds.

Project participants had a positive and significant impact on the smallholder farmers' income (Gross Margin) and food security in terms of HDDS and HFIAS using NNM and MDM principles. NNM findings show project participants had an average income of TZS TZS 348 603.42 compared to an average of TZS 214 854.55 for non-project participants. MDM findings show project participants had an average income of TZS TZS 418 120.63 compared to an average of TZS 251 270.49 for non-project participants. Finding on food security show NMM results revealed an average HFIAS of 1.211 for project participants compared to an average HFIAS of 1.833 for non-project participants. MDM results revealed an average HFIAS of 1.352 for project participants compared to an average HFIAS of 2.213 for non-project participants. Moreover, both NMM and MDM results revealed an average HDDS of 8.123 for project participants compared to an average HDDS of 7.265 for non-project participants. Therefore, potato production had a positive significant impact on smallholder farmers' income and food security in the study area. It recommended that the Tanzania Ministry of Agriculture should build constructive conditions through the improvement of agricultural policy and formulation of a potatoes forum with rules and regulations that could be the roadmap along the potato value chain. The local government authority (LGA) through extension officers should insist on and encourage farmers' groups and associations to ensure the spreading and adoption of the improved technologies, strategies for marketing potato produce, access to soft loans, and subsides. Research institutions should ensure the production and availability of quality seeds, certified pesticides and insecticides for potato production. Other actors along the potatoes value chain should ensure the supply of proper agro-inputs in a required period at a favourable price in the study area. This will contribute to improving potato production which enhances the well-being of the smallholder farmers in Meru District.

DECLARATION

I, **Thomas M. Lyatuu**, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my original work, done within the period of registration and that it has neither been submitted nor been concurrently submitted for a higher degree award in any other Institution.

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DEDICATION

To the almighty God my creator who must get honor for giving me the ability and strength to complete this work. This valuable work is dedicated to my beloved wife Mrs. Faraja Emanuel Kitundu for her sweetheart and prayers during the study. My brothers Mr. Joseph and Emanuel Lyatuu and my parents Mr. and Mrs. Menyiansumba Lyatuu laid the foundation of my education which made me what I am today.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATT	Average Treatment Effects on the Treated
CHIPS	Calories and Household Income for Potato Sub-Sector
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
GAPs	Good Agricultural Practices
GDP	Gross Domestic Product
GM	Gross Margin
HDDS	Household Dietary Diversity Scale
HFIAS	Household Food Insecurity and Access Scale
IBM	International Business Machines
IFPRI	International Food Policy and Research Institute
KIIs	Key Informant Interviews
LGAs	Local Government Authorities
MDC	Meru District Council
MDM	Mahalanobis Distance Matching
NNM	Nearest Neighbour Matching
PSM	Propensity Score Matching
RECODA	Research Community and Organizational Development Associates
RIPAT	Rural Initiatives for Participatory Agricultural Transformation
SDGs	Sustainable Development Goals
SHF	Smallholder Farmers
SPSS	Statistical Package for Social Sciences
TR	Total Revenue

TVC	Total Variable Costs
URT	United Republic of Tanzania
USAIDs	United States Agency for International Development
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

The round potato *(Solanum tuberosum)* is the world's most important root and tuber crop (Hoekstra, 2008). Round potato is an important crop for improving the well-being of people. The round potato crop is grown in more than 125 countries, being the top fifth important crop worldwide after sugar cane, maize, wheat and paddy (FAOSTAT, 2018). Round potato is one of the crops that are grown by smallholder farmers (SHFs) as a food and cash crop in most developing countries such as Egypt and South Africa (FAO, 2008b). Round potato is a source of income and employment opportunities in developing countries, a good source of dietary energy and some micronutrients (FAO, 2008a). According to Mayona 1992, cited by Mende (2015), the importance of round potatoes is increasing as a food and cash crop.

Agriculture is the backbone of Tanzania's economy, which employs about 70% of its population who are engaged in agriculture as their main source of income (Salami *et al*., 2013). Tanzania's economy depends much on the agricultural sector which contributes about 24% to the Gross Domestic Product (GDP) whereby more than 90% of available food consumed in Tanzania is produced by smallholder farmers in rural areas (URT, 2017). Smallholder farmers consider round potato, which is grown for 2 to 3 seasons per year, as the main source of income and food than other crops grown in Southern Highlands and Northern Zones. Round potato production is considered a reliable source of income and food security to smallholder farmers which showed a positive significant impact on dietary energy consumed to the household level (Mende, 2015: RECODA, 2020). The leading Regions in Tanzania which produce round potatoes are Mbeya, Iringa and Njombe which produced 70% to 80% of all potatoes in the country in 2017 whereby the average yields

were 5 to 7 tons per hectare (Tuinbouw, 2017). According to Lipton (2012), farmers' food security and incomes are directly related to the yield increase which in turn improved the well-being of potato farmers. SHFs in the Southern part depend on round potato as it contributes to cash, employment creation, food, and household income (Mende *et al.*, 2014). According to May (2007), farmers' well-being cannot be attained without the basic material needs of people being met, thus income is an important attribute of well-being because it is a means to purchase necessities. Higher levels of income are associated with higher levels of well-being through greater consumption levels (Heintzelman and Diener, 2019), with the benefits outlined by this study helped to examine the impact of round potatoes on well-being SHFs.

Due to the importance of round potato production different projects have been undertaken in the potato growing areas in Tanzania, and interventions have contributed to improving the socio-economic status of the farmers. One of such projects is the Calories and Household Incomes from Potatoes Sub-sector (CHIPS) Project in Meru District in Northern Zone which has been working in collaboration with the Meru District council and other stakeholders to improve round potato production. The collaboration aimed at increasing round potato production to enhance food security and poverty reduction in the district. The project applied the Rural Initiatives for Participatory Agricultural Transformation (RIPAT) extension approach in facilitating the uptake of agricultural technologies for increased crop yield (Vesterager *et al.,* 2013). According to the CHIPS project progress report; there has been an average increase in yield from 9.9 tons to 16.6 tons per hectare as a result of the project's interventions (RECODA, 2020). However, there is a need to establish how the increase in yield has improved the well-being of the beneficiaries in terms of the household's ability to improve income and food security.

1.2 Problem Statement

The problems facing the round potato producers in the Meru District and other areas in the Northern Zone of Tanzania include inadequate availability of clean potato seeds, knowledge of potato production, harvesting, marketing and losses of more than 30% of harvest (Omary, 2015). Round potato producers in the Meru District are facing problems of low yields which are on average 7 tons per hectare, compared to a potential yield of 30 tons per hectare (Pocketbook, 2018). To improve round potato production, increase income and enhance food security along the potato value chain, different interventions have been undertaken. The interventions have included the introduction of improved varieties of round potatoes, preparation, and acquisition of potato seeds, formation of farmers' field schools, training on good agronomic practices, and post-harvest handling technologies. CHIPS project have been implemented by different stakeholders in collaboration with Meru District Council as part of the Northern zone of Tanzania, aimed at increasing production and hence improving food security and reducing poverty (RECODA, 2020). It has been reported (Namwata *et al.*, 2010) that the adoption of good agricultural technologies for round potatoes increases production and has the potential to enhance food security and increase income for smallholder farmers. However, despite being a good agro-ecological zone for round potato production, and the Kilimo Trust Project supporting potato farmers, there is limited empirical evidence on the contribution of round potato production to the well-being of potato SHFs in the Meru District. This study seeks to establish the contribution of round potato production to the well-being of potato SHFs in the Meru District in terms of income and food security.

1.3 Study Justification

The study produced empirical evidence on the adoption of round potato production using good agricultural practices (GAP) and the status of food security and income. According to

May (2007), well-being cannot be attained without the basic needs of human being met. Round potato production contributed to food security and increased income as a result the well-being of the potato SHFs improved. Understanding round potato production and its impact on the SHFs well-being is important for project implementers and policymakers as well. This information contributes to the understanding or attainment of Sustainable Development Goals (SDGs) especially goals 1 and 2, which is about "to end poverty in all its forms, everywhere" and end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (SDGs, 2016). The findings from this study are useful to donors, policymakers, researchers, and other development actors in understanding the impact of round potatoes on SHFs well-being. Findings are expedient in designing, planning, and implementing other projects related CHIPS along the potato value chain. Extension officers and other development practitioners can utilize the findings to create suitable extension agendas and improve farmer knowledge of potato production and its significance in food security, employment, and income-generating. Also, the study helps to provide valuable information about the contribution of round potatoes to the well-being of SHFs in the Northern part of Tanzania.

1.4 Research Objectives

1.4.1 Overall objective

The overall objective of this study was to determine the impact of round potato production on the well-being of smallholder farmers in terms of income and food security.

1.4.2 Specific objectives

i. To determine socio-economic factors influencing round potato production among the smallholder farmers.
ii. To analyse the impact of round potato production on smallholder farmers' food security in terms of dietary diversity.

iii. To assess the impact of round potato production on smallholder farmers' income.

1.5 Null Hypotheses

i. Socio-economic factors of SHF do not determine the level of production of round potatoes.

ii. Round potato production does not influence the food security of SHFs in terms of household dietary diversity.

iii. Round potato production does not influence the income of SHFs in terms of gross margin.

1.6 Theoretical Framework

The study was guided by Rational Theory which has three assumptions whereby individuals; have selfish preferences, maximize his/her utility and act independently based on full information. Some of the critics have been associated with the assumptions of the theory such as factors related to scant information, the complexity of human interaction, social action, norms and habits (Ogu, 2013). It may be challenging to make thoughtful decisions as a result individual farmers may depend on other means of making decisions. In this study, it is also contended that an increase in crop production and productivity helps to ensure well-being outcomes at the household level in terms of food security, income increase as well as ability to access basic services. According to Tinkler and Hicks (2011), well-being is used to measure the human standard of living through income, access to health services and food security status. All SHFs engage in agricultural activities to enhance food security and increase income to attain well-being (URT, 2017). According to the rational theory, farmers are guided by various uncertain socio-economic factors which are members of the association, access to extension services, land owned, market price, and access to agricultural inputs (Ankarloo, 2002; Woldemeskel, 1990). Nicholson and Snyder

(2008) explained that SHFs decide what to produce to ensure food security and increase income with the logic of increasing production and profit cost-effectively. SHFs often produce for both food and selling. Therefore, the assumption was that farmers always make reasonable, careful, and logical judgments about one technology over another because they feel it will provide a greater return. Profit accrued from income and food security play a major role in rational decision-making on what to produce based on suitable technologies. The study aimed to prove the theory by examining how round potato production contributes to round potato farmers' well-being in terms of income and food security in the study area.

1.7 Well-being of Smallholder Farmers

There is no agreement on the factors which define well-being, but according to Fujiwara (2011), the key determinants of well-being include income, food security, and health status. The term well-being encompasses the situation of people being socially and economically satisfied due to outcomes or impacts from the activities such as agricultural marketing, and other socio-economic activities (Heintzelman and Diener, 2019). Well-being includes human satisfaction in terms of basic needs and personal development such as health and education (May, 2007). Round potatoes help to improve the well-being of SHFs through income earned as it grows in a short period and sometimes is planted twice a year. It helps also to ensure access to nutritious food hence reducing the problem of food insecurity (Hussain, 2016). Producers of round potatoes have multiple benefits because the crop has high yields and contains much protein and energy which are essential for the improvement of well-being Dersseh *et al.* (2016). Potatoes are a dependable source of food and revenue since they may be consumed as a staple and sold to generate income for acquiring other commodities which help to improve SHFs well-being (Mende, 2015). According to Lutaladio *et al*. (2009), round potato production increased from 350 000

tonnes in 2000 to 650 000 tonnes in 2008 this contributed to the improvement of the standards of living of SHFs and their well-being. Due to the provision of good yield per unit area, early maturity, and being grown twice a year where climate conditions are good, round potato farmers are in a good position to earn more profit from round potatoes compared to other crops (Namwata *et al*., 2010). Therefore, this study focused on income and food security as the main indicators of the SHFs' well-being as explained by Fujiwara (2011). An increase in SHFs' income, as well as food security, are the major indicators of well-being as they influence other aspects such as access to basic needs like education services, and medical services (Garai *et al*., 2017).

1.8 Food Security to Smallholder Farmers

Food security is defined by different actors from different perspectives. According to FAO (1996), food security at the household level is the ability of the family or an individual to meet their physical and economic needs including food preference, safety, dietary needs, and health needs. Food security can be used to determine human well-being by using pillars of food security including availability, accessibility, utilization, and stability. Food availability refers to the ability of the household to produce, access, utilization, and consumption of energy and nutrient from diversified food. Round potato is mostly produced by a majority of SHFs in the Southern Highlands and Northern Zone as the cash and food crop, whereby more than 70% of the potato crop is produced in the Southern Highlands followed by Northern Zone (Namwata *et al*., 2010). It is expected increase in round potato production increases food security and contributes to the increase in income in a household (Mende, 2015). The crop grows fast in a short period in an area of favourable condition with a high yield under GAP compared to other crops, it provides nutrients and energy at the household level which are essential for food security (FAO, 2014). Household Dietary Diversity Scale (HDDS) represent the various type of food eaten

by members of HH within a given period normally 24 hours without counting the frequency of its consumed (FAO, 2014). According to the International Food Policy and Research Institute (IFPRI) (2006), as cited by Jones *et al.* (2013), the HDDS of below 4.5 indicates low dietary diversity; 4.5-6 indicates medium dietary diversity while above 6 indicates good dietary diversity. Household Food Insecurity and Access Scale (HFIAS) was used to estimate mean nutritional adequacy at the household level measured using an algorithmic classification process (1 food secure, 2 mildly food insecure, 3 moderately food insecure and 4 severely food insecure) (Maxwell *et al.*, 2014). HFIAS was used to ask questions on conditions that happened in the past four weeks. In this study food security was measured in terms of food access whereby households have satisfactory incomes or resources to purchase and obtain levels of appropriate food needed to maintain consumption of an adequate diet/nutrition level.

Income of Smallholder Farmers

The gross margin was used to compute income as a proxy attributable to the project and non-project participants. According to Hosea *et al.* (2012) and Muhammad-Lawal *et al.*, (2012) gross margin helps to show the financial direction of the enterprise. The gross margin is given by equation 1

$$GM_i = \sum_{i=1}^{n}(TR - TVC) = \sum P_y Y - \sum P_x X_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where

GM = the Gross Margin (a proxy for potatoes profit)

TR = the Total Revenue of selling potatoes,

TVC = The Total Variable Costs of producing potatoes and are prices of potatoes and inputs while and are quantities of potatoes sold and inputs used respectively.

1.9 Conceptual Framework

The conceptual framework for understanding the contribution of round potato production and its linkage with the improvement of farmers' well-being is presented below.

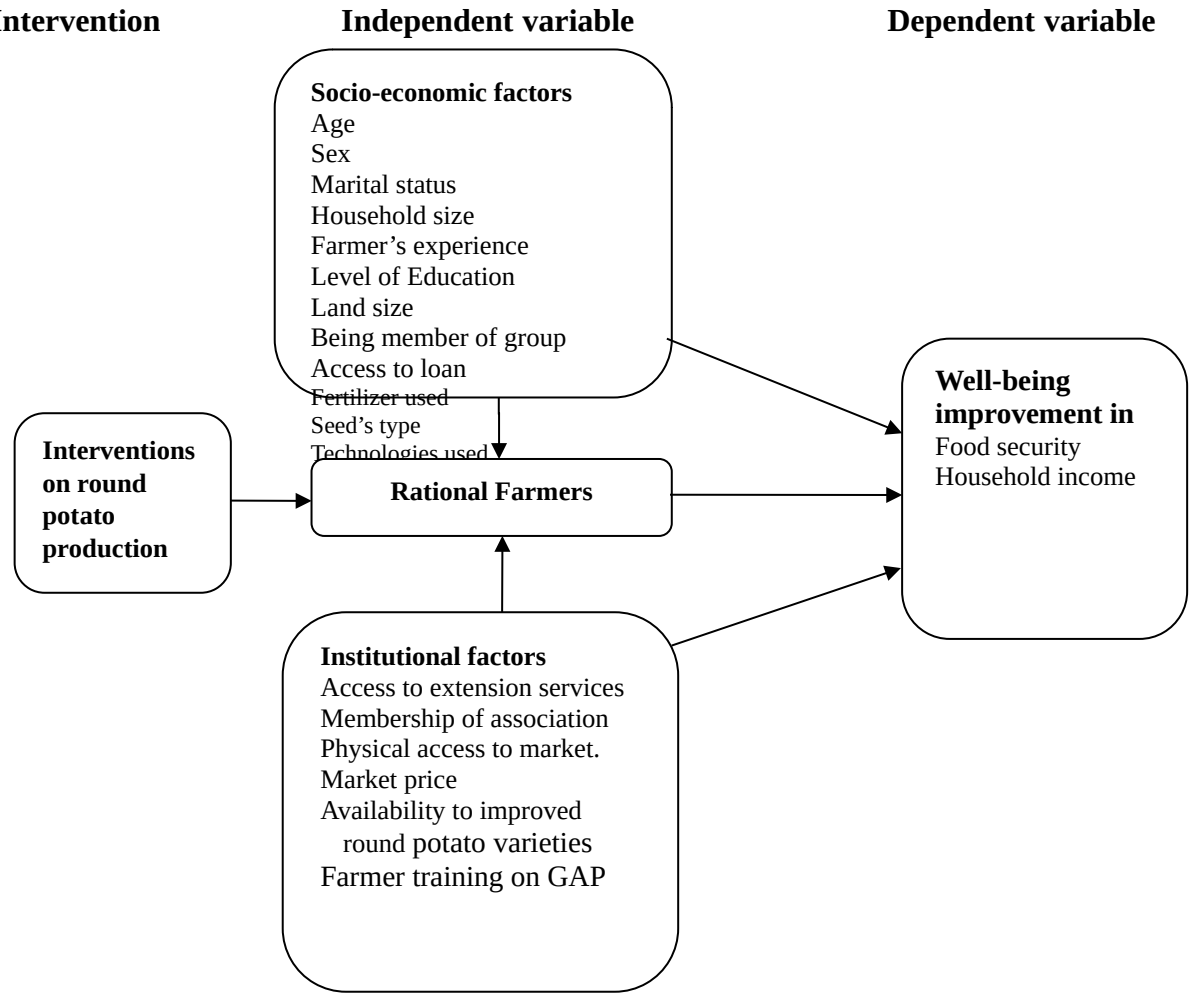

Figure 1.1: Conceptual framework showing the contribution of round potato production and its linkage to improving farmers' well-being, adopted from Rogers (2010)

Socio-economic factors, institutional factors and farmers' perception of that technology may influence the well-being of the potato farmers. The well-being of SHFs in this study depends on the impact or effect of round potato project interventions. In Figure 1.1 above, the well-being (income and food security) of the SHFs depends on round potato production is hypothesized.

This study is guided by this conceptual framework which helped to assess how each variable of round potato production contributes to the well-being of the farmers. Smallholder farmers have a positive perception of the implementation of recommended good agricultural practices (GAPs) to attain an optimal level of round potato productivity and hence improve their well-being.

10.0 Research Methodology

10.1 Study Area Description

This study was conducted in Meru District in Arusha Region, Tanzania. The district was purposefully selected because the CHIPS project was implemented in the district from 2019 to 2020. The district had chosen to implement the project due to good climatic conditions, geographic location, and soil that are suitable for potato production and hence could offer a good development project on the potato value chain and its contribution to household income and food security (RECODA, 2020).

10.2 Study Design

The study employed a cross-sectional research design. The cross-sectional design was used because it is recommended and appropriate for description purposes as well as for the determination of relationships between variables, is cost-effective and saves time over longitudinal and panel data (Omair, 2015).

10.3 Sampling Procedures

A multi-stage random sampling approach was used to select a representative sample of smallholder farmers growing round potato varieties from the Meru District. The first stage involved a purposive sampling method to select groups of potato farmers from the project area. The second stage involved the development of a list of round potato farmers who

participated in the project from its inception. The sample size was determined by using a formula. The participant from both treatment and control were proportionally calculated. Finally, from the list of round potato growers developed in the second stage, a required sample size of respondents was proportionally selected from each group using systematic sampling. Non-participants were selected using simple random sampling from a list of round potato farmers in the study area. This stage involved collaboration with project staff and Ward Extension Officers.

10.4 Sample Size Determination

The study population consists 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 1991 were under the control group (N_C). This study adopted the formula proposed by Krejcie and 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.

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

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.

Proportionate Stratified Random Sampling Formular:

For control $n_c = (N_c / N) * s$ 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).

10.5 Data Collection

The study involved primary data which were collected using a structured questionnaire and an interview checklist. The questionnaire was designed specifically for farmers who are producing round potato varieties. Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) were conducted to provide in-depth information on factors that contribute to the improvement of SHFs well-being. Three FGDs were conducted in the study area each group comprised 8 - 12 participants (observing gender) who were purposively selected round potato producers in the project based on knowledge and experience of potato production. This information was used to validate some information obtained using questionnaires. Eight Key Informant Interviews (KIIs) were used to collect in-depth information and were selected based on their involvement and participation in project implementation activities. Key informants included district and ward extension officers and lead farmers in the study area to obtain their opinions on round potato production's contribution to well-being, and challenges as well as validate some information gathered during FGDs and the questionnaire-based survey.

10.6 Data Analysis

Qualitative data from the key informant interviews and focus group discussions were analysed using content analysis and presented in short narratives to describe quantifiable information gathered during the study as a means of making inferences from primary data. Quantitative data from the questionnaires were coded and analysed using Statistical Package for Social Science (IBM SPSS 20) and STATA. The study's unit of analysis was the individual round potato farmers (participants and non-participants). Descriptive statistics were used to compute mean, maximum, minimum, standard deviation, frequency, and percentages.

Multiple linear regression analysis using SPSS was used to analyse the first objective while Propensity Score Matching (PSM) analysis using STATA was used to analyse objectives two and three. According to Makate *et al.* (2017), PSM is a better way to measure impact by comparing the Average Treatment Effects (on well-being outcomes/indicators) on the Treated (ATT). Therefore, this helped to construct a control group of non-participants using the propensity scores and estimating differences in food security status in terms of dietary diversity and income between participants and non-participants that are attributable to interventions of round potato production.

i. Estimating Propensity Scores

These are conditional probabilities of each potato farmer who participated in the round potato project given their observed characteristics to create a counterfactual group while assuming that a farmer belongs to either participants or non-participants are shown in equation 2 below.

$$p(x)=p(Z=1/X) \quad \ldots\ldots(2)$$

Where:

p(x) = Propensity Score,

Z = Binary dependent variable for adoption decision (1 if participant and 0 if non-participant),

X = Observable socio-economic characteristics of farmers that may influence participation decisions.

Equation 3 below the binary logit model was used to estimate the propensity scores of observable characteristics influencing participation.

$$p(X)=Z=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\ldots\beta_nX_n+\varepsilon_i \quad (3)$$

$$Participation=\beta_0+\beta_1Sex+\beta_2Age+\beta_3Educ+\ldots\beta_nX_n+\varepsilon_i \quad (4)$$

X = independent variables (such as head of household sex, years in school, main occupation, household size, application for a loan, education level, access to extension services, other crop cultivated, years of experience, access to inputs, seed availability, the area cultivated, and access to market information)

ii. Checking Overlap/Balance

According to Montalbano *et al.* (2015), the balancing property states that the conditional distribution of observable characteristics (X), given the propensity score p(X) is the same to both members of participants and non-participant groups. Therefore, to avoid comparing the incomparable, the groups' balance was checked using the histograms approach implemented in STATA.

iii. Choosing the Matching Algorithm

Strengthens were checked using two matching algorithms: Kernel Matching (KM) and Nearest Neighbour Matching (NNM). The difference between the two is that NNM is based on the nearest propensity scores between participants and non-participants group, while the KM matches by subtracting from each propensity score in the participants' group a weighted average of propensity scores in the non-participant's group (Baser, 2006).

iv. Estimating the Average Treatment Effects on the Treated (ATT)

a) Income effect

The gross margin was used as a proxy for income attributable to participation in round potato production. The gross margin is given by equation 5 below.

$$GM_i = \sum_{i=1}^{n}(TR - TVC) = \sum P_y Y - \sum P_x X_i \quad \text{..... (5)}$$

Where**:**

GM = Gross Margin,

TR = Total Revenue of selling round potatoes,

TVC = the Total Variable Costs of producing round potatoes,

Y and X_i = quantities of the round potato sold and inputs used respectively and

P_y and P_x = price of round potato and inputs

Therefore, ATT on profit was given by equations 6 and 7 below

$$ATT=(E((P_1 Y_1/Z)=1)- P_x X))- E((P_0 Y_0/Z=1)-P_x X))) \quad \text{.....(6)}$$

$$ATT=E(GM_1)-E(GM_0) \quad \text{.....(7)}$$

Whereby; GM_1 and GM_0 = Gross Margins for participants and non-participants.

b) Food security

ATT also was used to capture food security attributable to round potato production. The measurement of HDDS indicated the food security status in terms of dietary diversity while HFIAS indicated the food status in terms of nutritional adequacy at the household level among participated and non-participated SHFs in the study area. ATT is given by equations 8 and 9 below

$$ATT=(E(HDD/Z=1)-E(HDDS/Z=0) \quad \text{.....(8)}$$

$$ATT=(E(HFAS/Z=1)-E(HFIAS/Z=0) \quad \text{.....(9)}$$

10.7 Organization of the Dissertation

The dissertation is organized into four chapters by adopting SUA's publishable manuscript format. Chapter one contains the introduction includes; the background information, problem statement and justification, objectives and research questions, and theoretical and conceptual framework. Chapters two and three comprise the publishable manuscripts emanating from the study. Manuscript one, which is the Impact of round potatoes production on smallholder farmers' well-being in Meru District, Tanzania, is presented in chapter two. Manuscript two, which is Round potatoes production and impact on smallholder farmers' food security in Meru District, Tanzania, is presented in chapter three. Chapter four summarizes the major findings from the study as well as the overall conclusions and recommendations revealed from the dissertation.

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CHAPTER TWO

MANUSCRIPT ONE

Round Potato Production and Impact on Smallholder Farmers' Food Security in Meru District, Tanzania[1]

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Abstract

Round potatoes are among the potential food crop cultivated in Tanzania's Northern highlands particularly Meru District in the Arusha Region. Potato has the latent to increase food security for smallholder farmers. However, empirical evidence on the contribution of round potatoes to food security in the area is scarce. This study evaluated the factors associated with round potato production to food security status among project participants and non-project participants. Cross-sectional research was adopted and a multi-stage random sampling approach using purposive sampling and simple random sampling was used to select the 341 total samples (122 project participants and 219 non-project participants). Mixed methods were used in data collection which are structured questionnaires, key informant interviews and focus group discussions. Findings showed that the use of quality potato seeds, loan application, availability of other inputs, access to extension services and area cultivated had a significant influence to round potatoes

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production (p=0.05). Project participants have a positive and significant impact on the smallholder farmers' food security in terms of HFIAS and HDDS, by using NNM and MDM principles. Therefore, potato production had a positive significant impact on smallholder farmers' food security in the study area. It recommended that the Tanzania Ministry of Agriculture should formulate a good policy and potatoes forum that could improve potato production. The local government through extension officers should ensure the spreading of the improved technologies to increase adoption, strategies for marketing potato produce and provision of soft loans. Also, research institutions and other actors along the value chain should ensure the availability of quality seeds and other proper agro-inputs at a favourable price in the study area. This will help to enhance food security for smallholder farmers in Meru District.

Keywords*: potatoes, food security, farmer, production*

1.0 Introduction

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 and Wang, 2019; Husain, 2020). The Food and Agriculture Organization (FAO) insisted on the potentiality of round potatoes that should be fully exploited by smallholder farmers' (SHFs) in Africa to enhance food security. According to Raigond *et al.* (2020); Kharumnuid *et al.* (2021), round potatoes had 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 is important as a staple food, production has increased from 655 447 per hectares year 1998 to 1.47 million per hectares 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 highlands 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 zone (Mende *et al.,* 2015). In the Northern zone, round potatoes are cultivated in Arusha and 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 the 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 had been implemented by various stakeholders including Kilimo Trust Organisation and Research Community and Organizational Development Associates (RECODA) implemented the Potato Project in Meru District Tanzania. The project interventions aimed to increase potato production and enhance food security for SHFs (RECODA, 2020). However, no empirical evidence of the effect of potato production on smallholder farmers' food security in the study area. Therefore, this study enabled the researcher to determine factors influencing the production of round potatoes and to assess

and compare the food security status of 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 the Tanzania government, research institutes, policymakers and other actors along the value chain on what should be done to improve potato production as well as ensure food security as a proxy indicator of well-being to SHFs.

2.0 Methodology

The study on which this paper is based was conducted in Meru District Council in the Arusha Region, of Tanzania. The district was purposefully selected because it is among the higher potatoes producer in the Highlands zone and project interventions to improve food security in the area by improving the production of round potatoes were implemented from the year 2019 to 2020. Hence a good study area to compare the contribution of potatoes to SHFs food security. The district has good climatic conditions, geographic location, and soil that are suitable for potato production (RECODA, 2020). A cross-sectional research design was adopted in this study because it's less expensive, and appropriate for description purposes and determining the relationships between variables (Omair, 2015). Purposive sampling was used to select active groups of potato farmers from the project area which meet every week.

The study population consists 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 1991 were under the control group (N_C). This study adopted the formula proposed by Krejcie and 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.

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

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.

Proportionate Stratified Random Sampling Formular:

For control $n_c = (N_c / N) * s$ 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; 3 focus group discussions of 8 to 12 members and 4 key informant interviews were analysed using content analysis. Descriptive statistics analysis by using Statistical Package for Social Sciences (SPSS) was used to find frequencies, percentages, means, minimum and maximum of quantitative data. 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 and 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 had recognized and developed different indicators for measuring food security (Hussein *et al.,* 2018). Food access is 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

hours 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 hours 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 another model established for comparably measuring 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 Developments (USAIDs) 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 lead 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:

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

Where;

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

β_0= the value of Y when all of 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; 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.

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

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

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 FINDINGS 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 the majority of the respondents (60.4%) ranges between 0 to 1 acres. The average land size was 1.35 acres with a minimum of 0 and a maximum size of 6 acres. Findings showed that 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. The majority 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: 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 (potatoes 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 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, area cultivated, and the area cultivated had positive and statistically influencing round potatoes 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 imply 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 and 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 peasants 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 contribute 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 is true. 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 depend on money earned from potato production to buy other sources of foodstuffs. The majority of participants 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 help farmers to plant within a cropping calendar and management of crops from fungus, 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); 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.

Application 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 to improve 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 direct to the market to the processors because they had accessed 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 is 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); 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, Chi2 = 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 has nothing to lose which leads them to be less dependent on project participation. These results are comparable with the finding of Musa and Hiwot (2017); Abebaw and Haile (2013), who studied the impact of agricultural cooperatives 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 are 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 and 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 supports (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 had 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 potatoes 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

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 revealed that project participants were more food secure than non-project participants because of the involvement in potato interventions including farm layout, use of the quality seed, spacing, proper application of agro-inputs, pests and disease management, and post-harvesting

techniques. This led to the round potatoes production having a positive significant impact on smallholder farmers' food security in the study area.

Table 2.7: 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 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 the 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 and Sidique (2014); Ali and 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

4.1 Conclusions

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 study shows that 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.

Likewise, the study shows that the project interventions such as availability of inputs (improved seeds, fertilizers, pesticides and insecticides), application of loans, and access to extension services which enabled the adoption of good agricultural practices have influenced the food security of smallholder farmers. Therefore, it enabled project participants to have more food security than their non-project participants' counterparts as indicated by the difference in the cut-off points of HFIAS and HDDS in measuring food security. It also revealed that potato smallholder farmers in Meru District had food security indicating that farmers had been involved effectively in production activities.

4.2 Recommendations

Supporting round potato show a positive contribution to productivity and food security, the study recommends that the government should formulate a policy and reinforce it for governing the improvement of potato production. There should be guidelines for local government authorities (LGAs) in managing extension services to ensure accessibility and availability to farmers on time and in a cost-effective manner. Furthermore, Ther should be clear in collaboration between research institutions, LGAs, policymakers and other stakeholders should ensure the availability of certified or quality potato seeds and other input by farmers are managed and regulated.

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CHAPTER THREE

MANUSCRIPT TWO

Impact of Round Potatoes Production on Smallholder Farmers' Income in Meru District, Tanzania[2]

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Abstract

Round potato is an important cash crop for increasing smallholder farmers' well-being in Meru District. The potential of the crop has contributed to smallholder farmers' income. Despite different potato interventions being implemented in the district, there is limited empirical evidence on the impact of round potato production on smallholder farmers' income as a proxy indicator of well-being. The objectives of the study on which this paper is based were to evaluate factors associated with potato farmers' income and to assess the impact of round potatoes production on smallholder farmers' income in Meru District, Tanzania. The study involved 341 potato farmers (122 project participants of the potato project and 219 non-project participants). The results showed a positive and significant correlation ($p<0.01$) between income and production (yield), income and area cultivated, income and cost of fertilizers, and income and cost of seeds. The project participants have

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reported a positive impact (income) than their non-participants' counterparts by using Nearest Neighbour Matching and Mahalanobis Distance Matching. The study discovered that the potatoes project indicators had a positive and significant influence on increasing the smallholder farmers' income who participated in the project. It is recommended that the Tanzania government through research institutions and policymakers should ensure favourable conditions for the production and supply of improved and quality agricultural inputs and spread the extension services using extension officers at the local government level. Also, various actors along the potato value chain should ensure; the availability of certified potato seeds and other proper agro-inputs (fertilizers and pesticides) in a required period at a low cost. All of these will help to increase smallholder farmers' income to improve their well-being.

Keywords: *potatoes, income, well-being, farmers, production*

1.0 Introduction

Round potato is one of the horticultural crops which are alternative sources of income and food for a large population in different countries in the world (Juliawati *et al.,* 2021). Potatoes are used as a cash crop and a source of starch for industrial uses in many countries in the world (Wijesinha & Mouille, 2019). Currently, about one-third of the global potato production is produced in Asian countries as a cash crop, especially for raw materials in agro-processing industries (FAOSTAT, 2020). Potatoes production in Indonesia has made a very large contribution to economic development (Juliawati *et al.,* 2021). Round potatoes are grown by smallholder farmers as a cash crop for income generation and employment opportunities in most developing countries such as Egypt and South Africa (FAO, 2008a; FAO, 2008b). In Sub-Saharan African countries, the area cultivated for potatoes doubled from 655,447 hectares in the year 1998 to 1.47 million hectares in the year 2018 (Krijger and Waals, 2020). In Eastern Africa, the demand for round potatoes and their products is

increasing, and the crop has a high potential in doubling smallholder farmers' income as it is used for foodstuff and raw materials for agro-industrial production (Namwata *et al.,* 2010; Korir, 2018).

In Tanzania's Southern highlands and Northern zones, round potatoes are grown for more than one season per year as the main source of income compared to other crops grown. Mpogole *et al.* (2012) found that potato production was more profitable than other cereal crops grown in Njombe, Mbeya, and Nkasi Districts. Also, in the Southern highlands of Tanzania round potatoes showed a positive significant impact on income for smallholder farmers and are the most profitable cash crop (Mende *et al.,* 2014). Moreover, the potato crop is among the main cash crops produced in large quantities in the Northern Highlands of Kilimanjaro and Arusha Regions (Nyunza and Mwakaje, 2012). The majority of smallholder farmers in the Meru district cultivating potatoes as the main cash crop as a source of income still faced challenges of low income from round potatoes (MDC, 2017; FAO, 2018). By recognizing that, different stakeholders including Kilimo Trust and Research Community and Organizational Development Associates (RECODA) were among the Arusha consortium partners implementing a round potatoes project called CHIPS. The project aimed at enhancing smallholder farmers' incomes and sustaining potato productivity for smallholder farmers. Despite the efforts and area being a good agroecological zone in the Northern part of Tanzania for round potatoes production, there is limited empirical evidence on the impact of round potatoes production on smallholder farmers' income as a proxy indicator of well-being. Therefore, this study fills the gap by determining factors associated with potato farmers' income and compares the incomes of potato farmers who are project participants with that of non-project participants in the Meru District. This study adopted rational theory: that farmers always make reasonable and logical judgments on the adoption and implementation of one technology over another one

if they recognize it will provide a greater return (income). The study produced useful information for government, research institutions, policymakers and other stakeholders along the potatoes value chain.

2.0 Methodology

The study was conducted in Meru District Council in Arusha Region, Tanzania. The district was purposefully selected because the potato project was implemented in the area due to its good soil and favourable climatic conditions for potato production. The wards involved in the study were Songoro, Nkwarisambo, Seela-Singisi, and Ngwandua. The study involved a total of 341 potato farmers (122 project participants of the potato project and 219 non-project participants). A cross-sectional research design was adopted because it is recommended and appropriate for description purposes as well as for the determination of relationships between variables. Also, it is cost-effective and saves time over longitudinal design as recommended by Omair (2015). Multi-stage random sampling approach was used to select a representative sample of potato smallholder farmers in the Meru District. Purposive sampling was used to select active groups of potato farmers from the project area which meet every week. The second stage involved the development of a list of round potato farmers who had been participating in the project from the beginning. The study population consists 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 1991 were under 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.

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

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.

Proportionate Stratified Random Sampling Formular:

For control $n_c = (N_c / N) * s$ 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). A representative sample size of respondents was selected from each group using a proportionate stratified random sampling Formular. Project and non-project participants were selected using simple random sampling from a list of round potato farmers in the study area. These stages of sampling involved collaboration with project staff and Ward Extension Officers. Quantitative and qualitative data were collected using a structured questionnaire and an interview checklist respectively which are useful to provide triangulation of information (Creswell, 2013).

Individual variables' frequencies, percentages, statistical means, and standard deviations were analysed by computing descriptive statistics of quantitative data using the Statistical Package for Social Sciences (SPSS) software and STATA. Content analysis was used to analyze the qualitative information collected from 3 FGD of 8-12 members and 8 Key Informant Interviews (KIIs). Correlation analysis was used to determine factors associated with potato farmers' income. Pearson correlation was used to determine the levels of correlation and significance between the dependent variable (income/gross margin) and independent variables (head of household sex, years in school, main occupation, household size, application for loan, education level, access to extension services, other crop cultivated, years of experience, access to inputs, seed availability, the area cultivated, and access to market information) measured at dummy or continuous scale. Results were interpreted according to Cohen and Holliday (1982), cited by Bryman & Cramer (1992) that, regardless of positive or negative signs, correlation coefficients are interpreted as follows: below 0.19 is very low, 0.20 to 0.39 is low, 0.40 to 0.69 is modest, 0.70 to 0.89 is high and 0.90 to 1.00 is very high.

Propensity Score Matching (PSM) was used to measure the impact of round potatoes production on smallholders farmers' income by comparing the Average Treatment Effects (income outcomes/indicators) on the Treated (ATT) which helped to construct the propensity scores of a control group and treatment group by using estimate differences in income between the treatment group (project participants) and control (non-project participants) (Pan & Bai, 2015). The propensity score is defined as an analytical method that can be used in impact evaluation research by comparing a treatment and a control group in a project, given pre-tested characteristics (Pan & Bai, 2015). It consists of four steps: propensity score estimation, evaluating the quality of matching, selecting a matching algorithm, and outcome analysis.

2.1 Computing Propensity Score Matching

The first step involved estimating propensity scores for probabilities of each potato farmer (project participants and non-project participants) given their observed characteristics (independent variables) to create a counterfactual group. The independent variables were (head of household sex, years in school, main occupation, household size, application for loan, education level, access to extension services, other crop cultivated, years of experience, access to inputs, seed availability, the area cultivated, and access to market information) measured at dummy or continuous scale. Another step 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 comparing comparable groups. The third stage involved choosing the matching algorithm; the robustness of findings was checked by using two matching algorithms namely Nearest Neighbour Matching (NNM) and Mahalanobis Distance Matching (MDM). Nearest Neighbour Matching is based on the nearest propensity scores between project participants and non-project participants group, while the Mahalanobis Distance Matching is 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 last step was to compute outcome (income) analysis (Estimating the Average Treatment Effects on the Treated). The Gross Margin (GM) was used as a proxy for income attributable to round potatoes production. The Gross Margin is given by equation 1.

$$GM_i = \sum_{i=1}^{n}(TR - TVC) = \sum P_y Y - \sum P_x X_i \quad \text{...} (1)$$

Where:

GM = Gross Margin,

TR = Total Revenue of selling round potatoes,

TVC = Total Variable Costs of producing round potatoes,

Y and X_i = Quantities of the round potatoes sold and inputs used respectively and

P_y and P_x = Price of round potatoes and inputs

Therefore, ATT on profit was given by equations 2 and 3

$$ATT = (E((P_1 Y_1/Z)=1) - P_x X)) - E((P_0 Y_0/Z=1) - P_x X))) \quad (2)$$

$$ATT = E(GM_1) - E(GM_0) \quad (3)$$

Where:

GM_1 and GM_0 = Gross Margins for project participants and non-project participants respectively.

3.0 FINDINGS AND DISCUSSION

3.1 Socio-economic Characteristics of Potatoes Farmers in Meru District

A total of 341 potato farmers (122 project participants and 219 non-project participants in the potato project) were interviewed in the survey. Out of them, 169 (49.6%) were male and 172 (50.4%) were female. Among the respondents, 68.6% were aged from 36 to 65, indicating the energetic and active engagement of farmers in different agricultural activities. Also, the findings showed that 79.8% of the farmers interviewed had attended primary school up to standard seven, indicating that there had good literacy. Most of the respondents (82.4%) were married. The land owned by the majority of the respondents (60.4%) ranged between 0 to 1 acre. The average land size was 1.35 acres with minimum and maximum sizes of 0 and 6 acres respectively. The majority of the farmers (88.3%) depended on crop production as their main occupation, and 91.8% depended on crop production as their main source of income in the household. The average household size was 4.5 people with a minimum of 1 person and a maximum of 10 persons, this average

household size is well comparable with the national average household size of 4.8 in Tanzania (URT, 2013; MDC, 2017) and indicates that the farmers interviewed had reasonable labour for farm activities.

Table 3. 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
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
Education level	No formal education	5	1.5
	Adult education	3	.9
	Class four	23	6.7
	Standard seven	272	79.8
	Form two	2	.6
	Form four	33	9.7
	Form six	2	.6
	Diploma	1	.3
Size of land (acres)	0-1	206	60.4
	2-3	123	36.1
	4-6	12	3.5

3.2 Production and Income of Round Potatoes Farmers in Meru District

The findings as presented in Table 3.2 show that the average potato production in Meru District was 23 bags (each with 100kgs) per acre, a minimum of 7 bags, and a maximum of 105 bags per acre with a standard deviation of 0.93. These results agreed with the finding

from key informant interviews and focus group discussions which declared that potato yields had increased since the year 2019 per acre after the project interventions. The majority of the participants elaborate more by acknowledging that, production increased after project implementation compared to before project implementation. They said that, the findings which show very low production and low income were due to the very poor quality seeds supplied and distributed in the field year 2021 which was quite different (very poor quality) compared to the previous years. Due to those findings, researchers take into consideration the increase in potato production from 55 to 70 bags per acre in the study area. Findings also revealed the average income of potato farmers was TZS 264 321.29 per acre, with a minimum of TZS -616 000 and a maximum of TZS 3 966 000 per acre. The findings are different from Mende *et al.* (2014) who found an average potato farmer's gross income of TZS 722 250 with a minimum and maximum of TZS 8 000 and 12 000 000 respectively in the Mbeya and Makete Districts. Similarly, the decline in potato production leads to a decrease in income for SHFs because of low sales. Therefore, the study revealed that the income of SHFs in the study area could be twice than calculated income taking into account the production increase of 55-70 bags elaborated by the majority of participants and key informants.

Variable	Average	Minimum	Maximum
Production (Bags)	23.05	7.00	105.00
Farmers' income (TZS)	264 321.29	-616 000	3 966 000.00

Table 3.2: Descriptive analysis of amounts of potatoes produced and income from them

3.3 Factors associated with Potatoes Farmers' Income

The correlation results in Table 3.3 show that four out of ten independent variables (production (bags), area cultivated, cost of fertilizer and cost of seeds) were positively

correlated significantly with the dependent variable (income). Other independent variables were not correlated significantly as shown in Table 3.3.

Table 3.3: Determine factors associated with potatoes farmers' income (n=341)

Correlation between potatoes farmers' income and explanatory variables	Correlation coefficient (r)	p-value (two-tailed)
Age of respondent (years)	-.096^{ns}	.077
Years in school	.028^{ns}	.606
Household size (household member)	-.060^{ns}	.272
Number of visits made by the extension officer	.049^{ns}	.386
Production (bags)	.657**	.000
Farmers' experience (years)	.082^{ns}	.130
Area cultivated	.212**	.000
Cost of fertilizers	.217**	.000
Cost of pesticides	.014^{ns}	.789
Cost of seeds	.242**	.000

Levels of statistical significance *P<0.1, **P<0.05, ***P<0.01 and **ns** means not significant.

Area cultivated

Area cultivated (acres) had a positive relationship with income (r = 0.212) at the significant level of (p<0.01). This implies that an increase in the cultivated unit of land was associated with an increase in farmers' income from potatoes. The findings also showed that the majority of the households owned an average land of 1.35 acres with a minimum of 0 and a maximum of 6 acres. Due to a lack of land for crop production farmers were forced to depend on the same piece of land to replace other crops in the next season. Participants of focus group discussants agreed as follows: *"due to shortage of land we cannot leave our produce on the farm when waiting for the price to rise because we depend on the same farm to plant other crops, noting that other farms are rented for a short period for the owner to replace other crops next season"*. Despite being a major factor of production as stipulated by the majority of participants in focus group discussions, land scarcity led to low production as well as low income. The finding is in line with a finding by Juliawati *et al.* (2021); Mersha *et al.* (2017) who found that farm size had a significant effect on potato farmers' income.

Cost of fertilizers

The findings in Table 3.3 show that the cost of fertilizer had a low positive association ($r=0.217$) with potato farmers' income at a significant level of ($p<0.01$). The positive correlation indicates that an increase in the use of fertilizers was associated with an increase in smallholder farmers' income. The majority of participants from the focus group discussion also explained the importance of fertilizers as a major input for potato production which contributes much to increase yield. They added by saying that fertilizer costs were constantly sold at high prices which led to underutilization of fertilizer, hence low yields. The findings are similar to the results by Mersha *et al.* (2017) and Juliawati *et al.* (2021) who found that the input costs for fertilizer were a positive correlation but were not significant with household income from potatoes.

Age of respondent

The age of the potato farmer was a negative association with income ($r=-0.049$) and was not significant ($p>0.05$). This indicates that an increase in farmers' age led to a decrease in farmers' income from potato production. In the study area, the activities related to potato cultivation are related to young and active workers for income-generating activities. Since activities associated with potato production are very tough and therefore require young and energetic people. The finding is compared with Juliawati *et al*. (2021) found age of farmers had no significant association with the potato farmers' income in the Ijen district Indonesia. The finding also is different from Kabungo, (2008) who states age has a significant relationship with potato productivity in the Mbeya District.

Household size

Despite that in smallholder farming (or peasants farming) the household is the primary source of labour for income-generating activities, the study discovered that family size had a negative association (r=-0.60) with farmers' income but was not significant (p>0.05). This indicates that the higher the number of household members the lower the smallholder farmers' income from potatoes, because a high number of household members may influence the household to engage in the production of different crops to raise income than sticking to one crop (round potatoes) as a source of income. However, the finding is different from the findings by Mwatawala *et al.* (2020) and Achike *et al.* (2012) who looked into profitability factors of potatoes and cocoa in Tanzania's Mbeya District and Nigeria's Ondo state respectively. They reported that the number of household members has a positive correlation with the smallholder farmers' income from potatoes. This difference might be due to different production activities and communities involved within a particular area.

Farmers' experience

Farmer's experience had a positive association with potato farmers' income (r=0.003) but not a significant level (p>0.05). This indicates that experienced farmers were in a better position of earning more income compared to inexperienced farmers because they have received some extension services and exposure and overcome many field challenges related to pests and diseases. Therefore, farmers' experience was associated with a rise or fall in the income of smallholder farmers. The finding is different from a finding by Mwatawala *et al.* (2020) who found that farming experience had a significant association with potatoes profitability.

Years in school

Years in the school of farmers had a positive association (r=0.025) with potatoes' income and was not significant (p>0.05). Farmers who had spent more years in school had the possibility of increasing potatoes' income compared to farmers who had fewer years in school. It's expected that, the more years of schooling the more the likelihood of acquisition of relevant knowledge and skills which help farmers to make planning and proper decisions on their agricultural activities. Also, more years in school give farmers the ability to read different extension materials, comprehend and adopt new technologies. This finding is compared with the findings of Mwatawala *et al.* (2020) who found the level of the household head had a significant association with the productivity of round potatoes.

Number of visits made by extension services

The findings from the study revealed access to extension services had a positive association (r=0.49) with round potatoes income but not significant (p>0.05). The positive correlation indicates farmers' access to extension services is capable of applying the good agricultural practices attributable to increased production as well as their income. Access to extension services using lead farmers through RIPAT (Rural Initiatives for Participatory Agricultural Transformation) approach introduced by the project was revealed by the majority of participants as a good approach enabled to reach many farmers within a short time in the study area. The majority of participants explained that the adoption of the new improved technologies leads to an increase in production hence higher farmers' income. The finding is compared with Mersha *et al.* (2017), who showed extension services had a significant association with households' potatoes income.

Cost of pesticides

The cost of pesticides showed a positive correlation (r=0.014) with potato farmers' income but was not significant (p>0.05). This entails that an increase in the use of pesticides

contributed to an increase in potato farmers' income. It was explained by the majority of participants that potatoes are one of the crops which need intensive supervision with the application of pesticides due to the climatic condition of potatoes production. The results differ from that of Juliawati *et al*. (2021) who found that cost of seeds had a negative correlation and was not significant in increasing potato farmers' income, this is probably due to the type and amount of pesticides used during diseases and pest management.

Cost of seeds

Seeds cost showed a positive association ($r=0.242$) with potato farmers' income at significant ($p<0.01$). This indicates that an increase in the use of improved seeds was associated with an increase in farmers' income from potatoes. This was another major input explained by the majority of participants saying that seeds determine the amount of yield expected from the farm. The findings differ from Juliawati *et al*. (2021) who found a negative association and not significant on potato farmers' income because farmers did not spend a lot of money to buy quality seeds for production instead they used seeds from the last cropping season.

3.4 Impact of Round Potatoes Production on the Well-Being of Smallholder Farmers

The impact of potato production on smallholder farmers' well-being was analysed using Propensity Score Matching (PSM). The propensity score was calculated by regressing smallholder farmers' on the predictors (independent variables) to find the probability of farmers participating in the project. Individual socio-economic characteristics of project participants and non-project participants were used to form matched pairs of observation whereby similar individual characteristics were used to obtain a propensity score matching estimator using the logit regression model. Table 4 shows the logit model was found to be

a good predictor of participation as demonstrated by the results of $R^2 = 0.8257$ ($p > 0.5$) meaning that the model was a good fit. Secondly, the model had a chi-square static of 367.5 which was statistically significant at the 1 % confidence level. This implies that all the predictors that were included in the model were capable of predicting the probability of farmers' participation in the potatoes project.

Table 3.4: Probability of farmers for participation in the potatoes project (n=341)

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

Chi-square = 367.25, Pseudo-R^2= 0.8257 Log likelihood= -38.751474 *,**, *** = 10%, 5% and 1% respectively.

The findings in Table 3.4 show that project indicators; market information, application for loans, and access to extension services had a positive association and statistically significantly influenced farmers' participation in the potatoes project. Also, the area cultivated, availability of quality seed, availability of other agro-inputs, other crops cultivated, household size, main occupation, years in school, head of household sex, and age showed positive association but not statistically significant influenced farmer's participation in the potatoes project. This implies that the predictor variables included in the model are capable of predicting the probability of farmers' participation in the potatoes project with $R^2 = 0.8257$ ($p > 0.05$). A common support graph was drawn in Figure 1 to

test quality match for balance. The test helps to show the overlap of propensity scores between the treated and control group. According to Dehejia and Wahba (2002), a good match of treated and control groups concern a larger proportion of overlap of propensity scores. Figure 3.1 shows that the match was good and balanced due to the overlap of propensity scores between the treated and control cases.

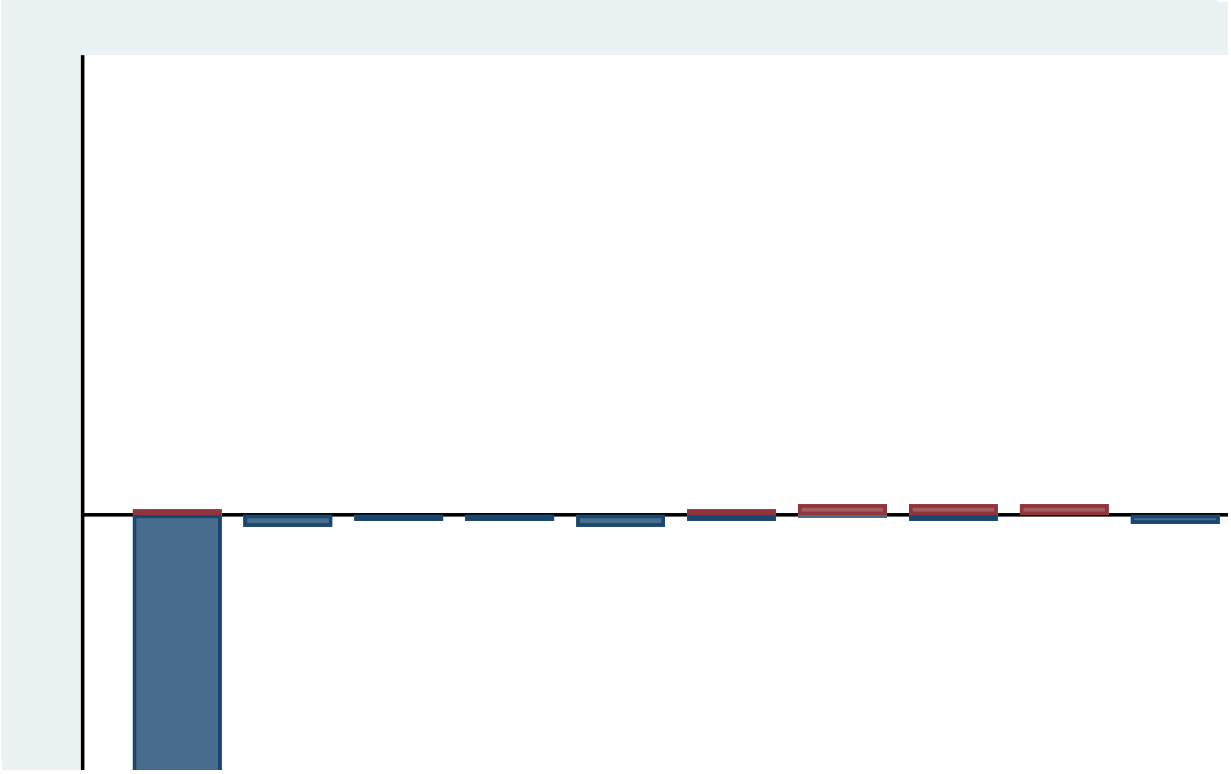

Figure 3.1: Common support graph

Findings from Figure 3.1 show the propensity scores for farmers' participation that were computed from the logit regression model. The smallholder farmers (counterfactual farmers) whose propensity scores for participation were different from the range of scores of common support were dropped from the analysis to avoid the comparison of the un-compared group. Thereafter, the differences in income outcomes were then computed to compare project participants' and non-project participants' farmers attributed to the project interventions.

Nearest Neighbor Matching (NNM) and Mahalanobis Distance Matching (MDM) are used to find a subset of control units similar to treated units to arrive at a balanced sample where the distribution of covariates is the same in both treatment and control groups (Baser, 2006). In this study as presented in Table 3.5, ATT used were NNM and MDM.

The NNM results revealed in Table 3.5 indicate that the smallholder farmers who participated in the project intervention had an average gross margin (income) of TZS 348 603.42 compared to the non-project participants who had an average of TZS 214 854.55, a positive significant difference income of TZS 133 748.87. Similarly, ATT in terms of income had a positive difference income of TZS 239 477.52 to that of the unmatched groups, whereby project participants and non-project participants had an average income of TZS 418 120.63 and TZS 178 643.11 respectively. MDM results presented in Table 5 show an average income of TZS 418 120.63 for project participants compared to an average income of TZS 251 270.49 for non-project participants a positive significant difference in income of TZS 166 854.13. Likewise, income for unmatched groups of project participants was TZS 418 120.63 and TZS 178 643.11 for non-project participants a positive difference in income of TZS 239 477.57. Based on the findings, it is statistically proved that project participants had higher incomes than non-project participants. The project participants showed to have good opportunities by adopting good agro-practices including; spacing, intensive supervision, proper management and application of inputs such as proper application of fertilizers, pesticides for diseases, and pest control which finally lead to higher production than non-project participants. All of these were attributed to the increase in smallholder farmers (project participants) income as discussed above.

The findings are compared with Juliawati *et al*. (2021) findings which showed that there is a difference in average income between partner and non-partner potato producers.

Table 3.5: NNM and MDM the effect of smallholder farmers' income for project participants (treated) and non-project participants (control)

Matching and Variable	Sample	Treated	Control	Difference	**t-stat**
Neighbour Matching Income Variable	Unmatched	418 120.631	178 643.114	239 477.517	3.66
	ATT	348 603.418	214 854.545	133 748.873	0.46
Mahalanobis Matching Income Variable	Unmatched	418 120.631	178 643.114	239 477.517	3.66
	ATT	418 120.631	251 270.492	166 850.139	0.54

The results of the ATT estimation show that the potatoes project had a positive impact on the potato farmers' income in Meru District. These findings are similar to the findings by Rifa'I & Samir (2019) in their study on the impact of seed varieties programme on the welfare of rice farmers; they used different matching approaches and obtained similar results. Also, their study showed that the new seed varieties programme had a positive and significant impact on the welfare of farmers.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

Round potato production affects the well-being of smallholder farmers positively. It shows that the round potato is the main cash crop and a major source of income for the majority of smallholder farmers. The adoption of improved technologies contributed to the increase of farmers' income hence improving livelihood. Also, the positive outcomes contributed by project interventions using RIPAT approach which was friendly used by farmers. Application of fertilizers and good agricultural practices improve yields of the round potato. Furthermore, the availability and accessibility of services as well as loan, and market information had a positive impact on the smallholder farmers' income.

Furthermore, the findings showed that potato project indicators which are the availability of inputs (improved seeds, fertilizers, pesticides and insecticides), application to loan, access to extension services, and market information had a positive and significant impact on the smallholder farmers' income. These helped project participants to have a higher income than non-project participants due to their access to the project opportunities.

4.2 Recommendation

Through the findings of this research, it's recommended that the local government continues to build good conditions to improve potato production in Arusha Region, particularly Meru district so that potatoes smallholder farmers can improve their well-being. Strategies should focus on local government to ensure on spreading of good agro-practices to other wards and villages to enable the adoption of improved technologies and agricultural inputs which contribute to increasing production.

Also, the Tanzania government through policymakers and research institutions should focus to ensure favourable conditions for the production and supply of proper agro-inputs (improved seeds, fertilizers, pesticides and insecticides) at a low price by providing subsidies and soft loans to potatoes smallholder farmers. Moreover, other stakeholders or actors along the potato value chain should encourage farmers to produce more potatoes crop by the focus on the timely availability of proper agro-inputs such as quality or certified seeds, fertilizers, and pesticides. This will help improve the well-being of potatoes smallholder farmers' particularly in Meru district, Tanzania.

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CHAPTER FOUR

4.0 Summary of the Major Findings, Reflection on the Results of the Rational Theory, Conclusions and Recommendations

4.1 Summary of the Major Findings

The first objective of this study was to determine socio-economic factors associated with round potato production among smallholder farmers. The findings are presented in the first paper of the thesis; years in school, farmer's experience, use of quality seeds, and area cultivated had a positive and significantly influence to round potato production. Other factors such as household size, extension services, loan application, and availability of other inputs also had a positive but not significant influence to round potatoes production. The age of farmers and where products are sold had a negative impact and were not significant to round potatoes production in the Meru District.

The second specific objective of this study was to analyse the impact of round potato production on smallholder farmers' food security in terms of dietary diversity in the study area. The results for this objective also are presented in the first paper of this thesis. PSM using two algorithms (NNM and MDM) was applied to analyse food security using food accessibility which was measured based on HDDS recall of 24 hours and HFIAS recall of 30 days adopted as suggested by FANTA, WHO, and USAIDS. Findings showed that, although both project participants and non-project participants were found to be food secured, project participants had shown statistically significant food security than non-project participants using cut-off points of HDDS and HFIAS. This implies that project participants had opportunities to increase food security using project interventions

including the application of good agricultural practices, access to and use of quality inputs, access to loans, and access to extension services.

The third specific objective of this study was to assess the impact of round potato production on smallholder farmers' income presented in the second paper. Before impact analysis, the study was done to determine factors associated with smallholder farmers' income. Potatoes production was found to associate with smallholder farmers' income which was gradually found to improve the well-being of their life. The quality of inputs, cost of potatoes seed, the costs of fertilizer, amount produced (yields) and area cultivated had positive and significantly correlated to smallholder farmers' income. Other factors such as access to extension services, farmers' experience, years in school and the cost of pesticides also had positive and not significantly associated with the enhancement of smallholder farmers' income in the Meru District. Household size and the size of land had a negative correlation and were not significant with smallholder farmers' income.

The impact was analysed using PSM to compare the income (gross margin) between the project participants and non-project participants. The two matching algorithms namely NNM and MDM were used to find the effects of smallholder farmers' income. Both matching algorithms found that the potatoes project had a positive impact on the potato farmers' income in Meru District, whereby statistically project participants were found to have significantly more income compared to non-project participants. This indicated that project participants had a good position of increasing income compared to non-project participants because they had access to and use quality agricultural inputs, access to extension services, access to loans, area cultivated and access market information during project implementation.

4.2 Reflection on the Results of the Rational Theory

This study adopted rational theory: that farmers always make reasonable and logical judgments on the adoption and implementation of one technology over another one if they recognize it will provide a greater return (income). The findings from this study indicated that farmers that willingly participated in the project their well-being in terms of food security, and increased income have improved after adopting various improved technologies. The findings show that not only adoption and implementation that provide greater returns but also the availability and accessibility of the improved technologies contribute a lot.

4.3 Conclusions

The main objective of this study was to determine the impact of round potato production on the well-being of smallholder farmers in terms of income and food security in Meru District in Arusha Region. The findings show that through the support of the project using RIPAT approach, the production of round potatoes for project participants increased significantly compared to those who not participated in the project. These changes are contributed by the support provided in the availability and accessibility of extension services, inputs and use of improved technologies and practices. Findings revealed that the accessibility of quality round potato seed enables farmers to earn high yields in the area.

Also, the findings revealed that the use of improved technologies and practices increased the potato yields per acre which result in the production of a surplus that farmers sell and contribute to household income. The farmers used the addition income for domestic expenditure, investments and social contribution which hence improve their livelihoods. Again the findings show that food security improved among the project beneficiaries due to production increase which ensures food availability, accessibility, utilization and

stability at household levels and community as well. Furthermore, the findings revealed the difference between farmers that participated and those not participated in the project in terms of various factors like yield, income, food security as well as the power to access loans for investments. Ultimately, the findings indicated that the farmers who participated in the round potatoes project their well-being improved significantly as compared to those who did not participate.

4.4 Recommendations

Based on the empirical findings reported in this research, the following recommendations were made: the government should formulate a policy for governing the round potato sub-sector, including guidelines for local government authorities (LGAs) in managing extension services to ensure accessibility and availability to farmers on time and in a cost-effective manner. To increase productivity, there should be a clear collaboration between research institutions, LGAs, policymakers and other stakeholders to ensure the availability of certified or quality potato seeds and other input by farmers are managed and regulated.

The Ministry of Agriculture should support more research on round potatoes which will produce improved varieties which will contribute to increasing productivity and improve the income of the SHFs. Also, the governance agricultural marketing board should support the round potato markets. Given the significant contribution of improved round potato varieties on food security, economically viable and improvement of well-being among smallholder farmers who adopted improved technologies in the study area, farmers should be encouraged to also adopt improved potato varieties and other production technologies to increase potato yield and improve their well-being.

APPENDICES

Appendix 1: A Questionnaire for Farmers

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF POLICY, PLANNING AND MANAGEMENT

P. O. BOX 3024, MOROGORO.

Research title: Impact of round potato production on the well-being of smallholder farmers in Meru District, Arusha-Tanzania

Dear Citizen(s),

My name is Lyatuu, Thomas M a student of Master of Project Management and Evaluation at Sokoine University of Agriculture (SUA) 2020/2021. Kindly, a request is extended to you that you participate in this research study by filling out the questionnaire attached herewith. You are assured of the confidentiality of any information you will share. However, the information shared is only for research. I have got permission from SUA, the district office and from RECODA to conduct interviews with you for my research.

The general objective is to determine the impact of round potato production on the well-being of smallholder farmers in Meru District. I'm going to use a maximum of one hour. You have all the freedom to accept or decline to participate in this research study. Are you willing to participate in the research by responding to the questions I will ask you?

1=Yes ( ) 0=No ( )

A. RESPONDENT'S IDENTIFICATION DETAILS

	Questionnaire No.	
	Date of interview:	
	Ward	
	Village	
	Name of respondent	
	Age (years)	
	Sex 1=Male 0=Female	

B: Social economic characteristics of the Respondents

B1	Are you the household head	1)Yes, 0)No	
B2	Marital Status	1) Single 2) Married 3) Divorced 4) Separation 5) Widow 6) Widower	
B3	Education level	1) No formal education 2) Adult education 3) Standard Seven 4) Form Four 5) Form Six 6) Vocational training 7) Certificate 8) Diploma 9) Degree 10) Other Specify	
B4	What is your mainstay? *(Single response)*	1) Farming 2) Casual labour 3) Employed Specify 4) Business 5) Other Specify	
B5	Household size (number of people in the household)		
B6	Number of people aged >15ages		
B7	What size of land does your household own? (in acres)		
B8	What is the main source of income in your household? *(Single response)*	1) Farming (crop cultivation) 2) Animal husbandry 3) Employed (salary) 4) Causal labour 5) Business 6) Other (Specify) ……	
B9	What is the main source of food in your household? *(Single response)*	1) Farming (crop cultivation) 2) Animal husbandry	

		3) Employed (salary) 4) Small business 5) Other (Specify) …….	
B10	Are you a member of any producer group of round potatoes?	1=Yes 0= No	
B11 a	If yes the name of the group		

C; Training and Extension services on round potato production

C1	Have you received any training on potato production?	1= Yes 0= No	
C2	If yes, From whom did you get training? *(Multiple responses)*	1) Extension Officer 2) NGOs (…….) 3) Group member of the project 4) Neighbour 5) Relative 6) Lead farmer 7) Others specify……	
C3	What types of training did you receive? *(Multiple responses)*	1) Seed selection/use of quality seeds 2) Land preparation practices 3) Planting/spacing 4) Diseases and pest management 5) Application of fertilizer 6) Harvesting techniques 7) Grading and sorting 8) Storage techniques 9) Marketing skills 10) Others ……	
C4	If not, What did you learn on your own from project members without being taught?	1) Land preparation practices 2) Planting/spacing 3) Diseases and pest management 4) Application of fertilizer 5) Harvesting techniques 6) Grading and sorting	

		7) Others	
C5	Did you apply good agricultural practices last season?	1=Yes 0= No	
C6	If not, why?	1) Very expensive 2) Time-consuming 3) Difficult to prepare 4) Others …….	
C7	If yes, which type of technologies did you use? (Multiple responses)	1) Ridges using manure 2) Ridges using fertilizer 3) Ridges without fertilizer or manure 4) Sesa using manure 5) Sesa using fertilizer 6) Sesa without fertilizer or manure 7) Other …….	
C8	Do you have access to extension services?	1=Yes 0= No	
C9	If yes, where do you get extension services	1) Village extension Officer 2) NGOs 3) Research 4) Lead farmers 5) Others Specify……	
C10	On average how many times (during the last production season) were you visited by the extension officer		
C11	What advice do you get from extension services?	1) Crop management 2) Land preparation practices 3) Diseases and insect pest problems 4) Others Specify……	
C12	Do you have access to a loan?	1=Yes 0= No	

C13	If yes, Did you apply for a loan during the past 12 months		
C14	If yes C14, Where did you get the loan?	1) Personal savings 2) Membership group 3) From friends/relative 4) Others ……	
C15	How did you use the loan?	1) Buying agro-inputs 2) Paying fees 3) Household consumption 4) Agricultural activities 5) Others ……	

D; Household Farming Activities

D1	What are the three main cash crops grown in your household? (*Write by priority*)	(i) (ii) (iii)	
D2	What are the three main food crops grown in your household? (*Write by priority*)	(i) (ii) (iii)	
D3	For how long have you been growing potatoes? Years		
D4	How many seasons do you grow round potatoes in a year?		
D5	How many acres of land do you grow round potatoes last season this year?		
D6	What other crops do you grow apart from a potato?	1) Maize 2) Carrot 3) Banana 4) Beans 5) Other (Specify) ……	
D6	Are agro inputs for potato production available in the village?	1=Yes; 0=No	
D8	Did you use an improved seed last season?	1=Yes; 0=No	
D9	If not using improved varieties, what are the reasons?	1) Not available 2) Too expensive 3) Not easily accessible 4) Others (Specify…….	
D10	Source of improved varieties;	1) Association	

	(Multiple responses)	2) Group 3) Neighbours 4) Traders 5) NGO's (……) 6) Others (specify) ……	
D11	Did you plant local varieties last season?	1=Yes; 0=No	
D12	If yes, mention those local varieties planted.	(i) (ii) (iii)	
D13	Source of local varieties; *(Multiple responses)*	1) Own farm 2) Group 3) Neighbours 4) Traders 5) Others (specify) …….	
D14	Do you keep farm record	1) Yes 2) No	

E; Production cost (Tsh) for round potato; items contributed last season

(Variety code1=Obama; 2=Asante; 3=Tengeru; 4=Sherekea; 5=Sagita; 6=Meru; 7; others

E1	**E2**	**E3**	**E4**
Seed varieties	**Seed type 1=improved 0=local**	**The total quantity bought in kg**	**Unit Cost**

	For Plot 1,2,3…	**Unit Cost**
E1	Transport cost of seed	
E2	Land preparation	
E3	Fertilizer/manure application (Planting)	
E4	Transport cost of manure	
E5	Planting	
E6	Fertilizer application (Top dressing) booster	
E7	Transport cost of fertilizer	
E8	Insecticide/fungicide spraying	
E9	Weeding 1, 2, 3…	
E10	Harvesting	
E11	Sorting/grading and packaging	
E12	Transportation cost	
E13	Storage cost	
E14	Other Costs specify	

F; Marketing of round potato produce

F1	Where do you sell your potato produce? *(Multiple responses)*	1) Farm 2) Market 3) Association 4) Other ……	
F2	If the market mentions it		
F3	What is the distance from your homestead to market place?	In km	

F4	To whom do you sell your potatoes? *(Multiple responses)*	1) Wholesaler 2) Retailers 3) Vendors 4) Processors 5) Brokers 6) Other specify ……	
F5	Do you get market information on round potato crops easily?		
F6	If yes, Where do you get market information? *(Multiple responses)*	1) Don't get information 2) Radio/Tv 3) Extension officer 4) Neighbours 5) Brokers/Middlemen 6) Others ……	

G: Earnings from round potato to smallholder farmers' last season

***(Varie**ty code 1=Obama; 2=Asante; 3=Tengeru; 4=Sherekea; 5=Sagita; 6=others*

G1	G2	G3	G4			G5			G6		
Varieties		Seed type 1=improved 0=local	Amount of yield from a local variety Grade 1-3 in kg			Amount sold Grade 1-3 in kg			Unit cost Grade 1-3 in kg		
			1	2	3	1	2	3	1	2	3
1											
2											
3											
4											
5											

G7	Mention other categories where produce was used and amount ***Code 1=Giving relatives; 2=Offering, 3=Consumption***

Categories	Amount-kg
1	
2	

3		
4		
G8	Did you do value the addition of round potatoes? 1=Yes, 0=No	
G9	Types of products you make from potato (i) (ii) (iii)	
G10	If yes, Revenue earned from potato value addition last season. (Tsh)	
G11	If yes H8, the amount of potatoes thrown away due to being rotted (kg)	

H: Contribution of round potato to food security in terms of HDDS of smallholder farmers

In the past 7 days (one week), did the member of your household consume any of the following?		
Food Group	**Food Item**	Yes = 1 No = 0
H1	**Cereals, Grains and Cereal Products**: (Maize Grain/Flour; Green Maize; Rice; Finger Millet; Pearl Millet; Sorghum; Wheat Flour; Bread; Other Cereal)	
H2	**Roots, Tubers, and Plantains**: (Cassava Tuber/Flour; Sweet Potato; Irish Potato; Other Tubers)	
H3	**Nuts and Pulses:** (Bean; Pigeon Pea; Groundnut; Ground Bean; Cow Pea; Other Nut/Pulse)	
H4	**Vegetables**: (Onion; Cabbage; Wild Green Leaves; Tomato; Cucumber; Other Vegetables)	
H5	**Meat, Fish and Animal Products:** (Egg; Dried/Fresh Fish (Excluding Fish Sauce/Powder); Beef;	

	Goat Meat; Pork; Poultry; Other Meat)	
H6	**Fruits:** (Mango; Banana; Citrus; Pineapple; Papaya; Guava; Avocado; Apple; Other Fruit)	
H7	**Milk/Milk Products:** (Fresh/Powdered/Soured Milk; Yogurt; Cheese; Other Milk Products -Excluding Margarine/Butter or Small Amounts of Milk for Tea/Coffee)	
H8	**Fats/Oil:** (Cooking Oil; Butter; Margarine; Other Fat/Oil)	
H9	**Sugar/Sugar Products/Honey:** (Sugar; Sugar Cane; Honey; Jam; Jelly; Sweets/Candy/Chocolate; Other Sugar Product)	
H10	**Spices/Condiments:** (Tea; Coffee/Cocoa; Salt; Spices; Yeast/Baking Powder; Tomato/Hot Sauce; Fish Powder/Sauce; Other Condiment - Including Small Amounts of Milk for Tea/Coffee)	

I. Contribution of round potato to food security in terms of Household Food Insecurity Score (HFIS) of smallholder farmers

I1	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip to Q2) 1=Yes	
I1.a	How often did this happen? weeks)	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four	
I2.	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred	0 = No (skip to Q3) 1=Yes	

	because of a lack of resources?		
I2.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
I3.	In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = No (skip to Q4) 1 = Yes	
I3.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
I4.	In the past four weeks, did you or any household member have to eat some foods that you did not want to eat because of a lack of resources to obtain other types of food?	0 = No (skip to Q5) 1 = Yes	
I4.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
I5.	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to Q6) 1 = Yes	
I5.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
I6.	In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to Q7) 1 = Yes	
I6.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
I7.	In the past four weeks, was there	0 = No (skip to Q8)	

	ever no food to eat of any kind in your household because of a lack of resources to get food?	1 = Yes	
I7.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
I8.	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (skip to Q9) 1 = Yes	
I8.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
I9.	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No (the questionnaire is finished) 1 = Yes	

J. Perception of smallholder farmers towards improved seed and GAP compared to local seed and local practices

Concerning round potatoes production, please indicate your level of agreement concerning the following traits (put a tick where appropriate)

5= Strongly agree, 4= Agree, 3=Neutral, 2= Disagree, 1=Strongly Disagree

	Item	**1**	**2**	**3**	**4**	**5**
J1	Improved seeds have higher yields compared to local seeds					
J2	Earnings from improved seeds are more than local seeds					
J3	Improved seeds are preferable compared to local seeds					
J4	Farmers should be encouraged to use more improved seed					

J5	GAP increase the level of yield					
J6	You can easily get technical support because you are using GAP					
J7	Farmers should be encouraged to use GAP					
J8	Round potatoes contribute in large percentage to household food security.					
J9	Improved seeds mature for a long period compared to local seeds					
J10	It's not easy to sell produce from improved seed compared to local seed					
J11	Improved seeds are not tolerant to drought and diseases					
J12	Improved seeds are very expensive for the farmer to afford					
J13	Improved seeds have soft potato shell					
J14	There is a low demand for produce from improved seed					
J15	Improved seeds can be cannot be stored for a long time					
J16	It's not easy to apply GAP					

K: Post-harvest technology and contribution of round potato to socio-economic benefits of smallholder farmers and

K1	Does your household have access to any potato storage facility?	1) No 2) Yes	
K2	If yes, where did you store potato yields after being harvested?	1) Not stored 2) In my house 3) Neighbour DLH 4) Association 5) Other ……	

K3	How did you spend the money earned from selling round potato produce? *(Multiple responses)*	1) Buying agro-inputs 2) Paying fees 3) Buying other sources of food 4) Buying animals/cattle 5) Capital for small business 6) Bills payment 7) Treatment 8) Others (specify)……	
K4	What asset did you buy using the money obtained from selling the round potato produce? *(Multiple responses)*	1) House construction/repair 2) Build/repair toilet 3) Buying a motorcycle 4) Buying Solar 5) Radio 6) Runinga/TV 7) Phone 8) Others…….	
K5	How many meals did you take yesterday?	Select (1/2/3/4/5)	
K6	Please tell me if there were round potatoes in the morning breakfast yesterday.	1) Yes 0) No	
K7	Please tell me if there were round potatoes in the lunch yesterday.	1) Yes 0) No	
K8	Please tell me if there were round potatoes in the dinner yesterday.	1) Yes 0) No	
K9	Can you in summary tell me the importance of potatoes in your life/in your household?		
K10	What are the 3 major constraints related to potato production?		
K11	Suggest 3 intervention measures improve potato production in this village		
K12	Mobile number of the respondent (optional)		

THANK YOU FOR YOUR COOPERATION

Appendix 2: Checklist for Key Informant Interviews

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF POLICY, PLANNING AND MANAGEMENT

P. O. BOX 3024, MOROGORO.

Research title: Impact of round potato production on the well-being of smallholder farmers in Meru District, Arusha-Tanzania

Name of respondent: ……..……... **Sex;** ……

Position of the respondent; ……..……...….

Phone number: …… **Date of the interview;** ……..

1. Describe the situation and level of round potato production in Meru
2. Explain the contribution of round potatoes to the income of food security of smallholder farmers
3. Explain the contribution of round potatoes to the food security of smallholder farmers
4. What are the factors which influence the production of round potatoes in your area?
5. What are the farmers' perceptions of GAP in your area?
6. What are the farmers' perceptions of the use of improved seeds in your area?
7. What are the challenges facing round potato producers in this area?
8. What do you think should be done to improve the round potatoes production in Meru District?

Thank you so much for your cooperation. Do you have any questions you would like to ask me or any comments?

Appendix 3: Focus Group Discussion

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES
DEPARTMENT OF POLICY, PLANNING AND MANAGEMENT
P. O. BOX 3024, MOROGORO.
Research title: Impact of round potato production on the well-being of smallholder farmers in Meru District, Arusha-Tanzania

Group number: …… Date of discussion; ……...

Village name; ……. Ward……

1. What are the three main cash crops and food crops produced in this area?
2. Can you please explain about round potato production in the area
3. What is the contribution of round potatoes to your household food security
4. What facilitation did you receive from CHIPS project?
5. How is the situation of extension service in this area
6. Explain the situation of availability of agro-inputs in this area (including seeds)
7. Explain the contribution of round potato farming in supporting food security at the household level
8. Explain the contribution of round potato farming in raising a family income
9. Explain the market conditions for the round potato crop in Meru District (for example; how sales are made, who set the price, who are the main buyer, where do you get market information etc)

10. Explain if there are any specific challenges you are facing in round potatoes production

11. What should be done to improve the round potatoes production in Meru District?
12. What are the challenges in round potato production?

    Thank you so much for your cooperation. Do you have any questions you would like to ask me or any comments?