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Smallholder Farmers' Characteristics and their Influence on Adoption of Radical Terraces and Food Security

Emmanuel MURWANASHYAKA[1]*, Preston Orieko CHITERE[2], James Gichuru KARIUKI[3]

[1,2,3]University of Nairobi, Department of Sociology and Social Work, KENYA

[1]https://orcid.org//0000-0003-1113-9254
[2]https://orcid.org/0000-0002-1918-149
[3]https://orcid.org/ 0000-0002-9061-422X
*Corresponding author: emmamurwa@gmail.com

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ABSTRACT

The study assessed the influence of farmers characteristics on their adoption of radical terraces in ensuring food security in Nyamagabe District, Rwanda. The adopted research design was descriptive-correlational. Radical terracing is an innovative agricultural practice encouraged among farmers for increased farming production. Nevertheless, radical terracing has not been fully exploited and this has a great effect on Rwanda's agrarian yield and food security and therefore to a great extent, food security is still a major problem. Perspectives of Adoption-diffusion of farm innovations and food security directed the research. Cluster and purposive sampling techniques were used to sample 192 farmers and 19 key informants. Both quantitative and qualitative data were mainly collected using interviews, questionnaire schemes, and direct observations. Quantitative data were analyzed using descriptive statistics such as frequencies, percentages and inferential statistics of Pearson correlation coefficient and chi-square while thematic content analysis was used for qualitative data. Findings revealed that the level of farmers' adoption of radical terraces by a majority of farmers was medium and contributed to the farmers' level of food security. It also found that farmer characteristics like age, education, marital status, family size, reported seasonal income and land size owned were positively and significantly related to adoption of radical terraces and their food security. It was recommended that local leaders should mobilize farmers who had not exploited radical terraces to effectively use them for improving agricultural production. Finally, farmers needed to be encouraged and supported to exploit radical terraces for food production rather than grazing spaces.

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INTRODUCTION

The current research assessed the influence of farmer characteristics in the adoption of radical terraces for food security in Nyamagabe district, Rwanda. Like other Less Developed Countries, the Rwandan economy is fundamentally farming with smallholder sustenance agrarians generating most of the farm outputs (Republic of

Rwanda, 2014). About 80% of Rwanda's people depend on cultivation. Besides, the majority of agrarians are involved in survival agriculture and as stated by World Bank (2014) the agriculture of Rwanda is characterized by small units of production at an average of 0.33 ha per household. However, inappropriate farming practices have impacted negatively on food production (Republic of Rwanda, 2004). For tackling these challenges, in 2004, the Rwandan government developed the National Agricultural Policy (NAP) which emphasized radical terraces as one of the measures for transforming agriculture from traditional to modernized one (Bizimana, 2011). Radical terraces refer to a farming technique restructuring a section of muddy land into a series of ebbing flat surfaces that resemble steps for more efficient farming (Republic of Rwanda, 2012; Murwanashyaka et al., 2021). For Mupenzi et al. (2014), radical terracing is likely to increase the farm output of farmers living in the highlands. In this regard, the radical terraces project has been introduced in Nyamagabe district for improving food crop yield. Hence, the goal of the terracing project was to address hunger and food shortage that was endemic among the rural poor. Farmers were assisted to adopt radical terraces projects (Bonye et al., 2013). However, smallholder farmers have not been fully involved in exploiting radical terraces. Consequently, food production and security is still a big issue in Nyamagabe District. This is caused by many reasons: their failure to adopt radical terraces as expected thus leading to land degradation by soil erosion (Nyamagabe district, 2012). Similarly, Republic of Rwanda (2015) reported that in Nyamagabe district there was the biggest area of unexploited radical terraces or abandoned by farmers.

RATIONALE

Food is considered a fundamental human need. It's essential in human existing has motivated individuals to participate in farming activities of producing the food through the exploitation of the natural environment (Ndagi, 2017). Furthermore, it has been discovered that radical terraces have a great influence to increase farm production for ensuring food security sustainably (Mupenzi, 2014). NISR in 2016 noted that "in Rwanda, 979,045 a number of the households be situated at high risk to become food unsecured households whereas 473,847 of these food-insecure households being considered to be food insecure. About 63,696 among them are also being considered as severely food insecure households" (Murwanashyaka et al., 2021). In this regard, the radical terraces project is amongst the strategies adopted for protecting land and increasing the farming yield of the people who live in the

uplands (Mupenzi, 2014). Furthermore, in Nyamagabe district, from the 2008 to 2018 period, radical terraces of 7,236 ha were constructed as new farming practices with an estimated cost of $7,236,000 in total (Nyamagabe district, 2018). Regardless of this exertion of terracing, some of the constructed radical terraces are in an alarming condition due to the absence of effective exploitation, maintenance, and rehabilitation of the damaged terraces. The terraced land is not well being completely used. So that this has a consistent negative influence on Rwanda's farm production and household's food secure situation and to some extent, food satisfaction and security remain a great challenge (Murwanashyaka et al., 2021). Therefore, Nyamagbe district has 42% of its households which are experienced with a serious problem of food insecure. Due to this percentage, Nyamagabe district has been ranked at the highest level of foodstuff shortage and insecurity at the Rwandan national level (NISR, 2017).

THEORETICAL FRAMEWORK

Smallholder Farmer characteristics

Several factors like farmer characteristics have been found to affect the adoption of new farming technology (Kinyangi et al., 2014). Therefore, the farmer characteristics examined were age, gender, education, marital status, family size, occupation, source of income, income per season, and land size owned.

Age: The age of individual moderates technology adoption, where young individuals tend to adopt technology more and better than the old people (Wairiuko, 2018). However, older farmers are thought to have gained more knowledge and experience over time and to be better equipped to analyze technical information than farmers who are younger (Mwangi and Kariuki, 2015). In this line, Chitere (1980) found that younger farmers do not manage their crops better than older farmers.

Gender: Gender moderates the adoption of technology (Wairiuko, 2018). Moreover, Some research has concluded that gender influences new technology adoption, whereas others have not, according to Masinde (2009). Men and women farmers embrace farming technology differently because women farmers are less likely to have the resources (such as land, credit, or information) to fully utilize the technology (CIMMYT,1993). Mwangi and Kariuki (2015) stated that in Ghana, there was no significant link between gender and the likelihood of adopting enhanced

maize. Chitere (1980) similarly observed that gender had no impact on the use of IPM technology in agriculture (Masinde, 2009).

Education: The existing study found that educational level has a function in the adoption of farming technologies and innovations for producing food (Gathaara et al., 2011). Therefore, more educated individuals are considered to have better adoption of new technology as compared to the less educated (Wairiuko et al., 2018). In this regard, farmers who had attended school for more years adopt innovations faster than illiterate farmers (Chitere, 1980).

Marital status: Single (never married), married monogamous, married polygamous, and divorced were the marital statuses of the household heads. Besides, married people are likely to have a wide range of needs from childrearing to agricultural development projects (Kariuki, 2016). This means that small-scale farming is dominated by families, with the majority of families being monogamous. But husband knows technologies more than a wife (Sigei, 2014).

Family size: The adoption process is influenced by the size of the family, as a larger household can relax the labour constraints imposed during the introduction of new farming technology (Mwangi and Kariuki, 2015). Supportively, Muya et al. (2016) found that farmers with large family sizes opt for the adoption of new technologies faster as compared to those with small families. In so doing, families with more members also tended to participate better than those with fewer members (Sseguya, 2009).

Occupation: Occupation was defined as farming and any other income-generating activity. Masinde (2009) discovered that the occupation of the household head has an impact on the adoption of new farming practices. However, Mango et al. (2018) discovered that sub-categories of the nature of employment, formal employment, and small-scale business had a significant negative impact on small-scale irrigation farming adoption. As a result, household heads will be more focused on their work and small companies, making the adoption of small-scale irrigation farming more difficult.

Main source of income: Agricultural technology adoption has a favourable and significant influence on farm revenue, according to Shita et al. (2018), with adopters outperforming non-adopters. Farmers with a greater commercial orientation, who

sold a considerable share of their product, were also the ones that embraced certain agricultural technologies, according to CIMMYT (1993).

Income: Farmers' income may have influenced agricultural technology adoption (Masinde 2009). The concept of income can be beneficial in explaining the adoption of new farming technologies (CIMMYT, 1993). Farmers with more money may be the first to experiment with new agricultural technologies, especially if it requires purchasing inputs. They may be able to take more risks or have better access to extension knowledge or credit, or they may be able to experiment with new techniques using their cash resources. However, the major option for increased adoption of new technology was to overcome the income constraint (Kinyangi et al., 2014).

Farm size: In agriculture, the land is the most basic production unit and an indicator of wealth status in rural communities. The land was hypothesized to positively influence new farming technology adoption (Masinde, 2009). Much empirical adoption literature focuses on farm size as the most important determinant of adopting new farming techniques (Kinyangi et al., 2014). Moreover, In adoption studies, farm size is a common variable. Farmers on vast farms are frequently assumed to be more willing to adopt innovative farming practices (CIMMYT, 1993). Furthermore, for Uaiene et al. (2009) as cited by Mwangi and Kariuki (2015), farmers with larger farms are more likely to accept new farming technology because they can afford to dedicate a portion of their land to experimenting with new technology, as opposed to those with smaller farms.

Adoption-diffusion of farm innovations theoretical perspectives

First, the adoption-diffusion of innovations theoretical perspective was emphasized by Rogers (1983). Adoption was defined as the incorporation of innovations interested in a farmer's continuing operations concluded in repetitive and incessant use as stated by Peshin et al. (2014) whereas diffusion is considered as a procedure by which the adoption of an innovation spreads out from its early adopters to subsequent ones. Masinde cites Rogers (1983) as an example of the dissemination of innovation through time among members of a social system (2009). According to Rogers (1995), some determinants affect the adoption and diffusion of innovation among society members. In so doing, Turner et al. (2017), stressed that farmers

enthusiastically accept innovative thoughts which are alleged to be easier to understand more than inventions that necessitate gaining new skills and deeper understanding. Ogunleye-Adetona and Oladeinde (2013) reviewed "adoption and diffusion theory" and stated that there was a strong influence of the awareness of ideas and innovation by a community member which helped in its spread to all other members of a given society. Adoption-diffusion theory was used in the current research for assuming that it would help toward explanations of farmers' adoption, difficulties they had encountered with radical terraces and permit figuring out of a system of optimum advantages derived from the use of radical terraces project.

The food security perspective

Food security refers to a scenario in which all people have physical and economic access to enough, safe, and nutritious food that fits their needs and preferences for an active and healthy life at all times (Sneyd, 2014). It also refers to food accessibility, availability, and consumption (NISR, 2016). The terminology of food security was introduced in the 1970s during a period of global food calamity. Initially, definitions of food security emphasized mainly on food supply matters related to availability (FAO, 2006). Furthermore, as many authors expressed, food security can be studied under three core areas which are availability, accessibility and utilization of food (Muthoka, 2010; Kithu, 2012; Bashir et al., 2014; Karplus, 2014; Sneyd, 2014). However, the main challenge of food security as it has been found by Karplus (2014) was precisely the use of out-of-date agricultural practices. In this study, the food security theoretical perspective helps to investigate the level of household food needs in terms of yield obtained the number of months the harvest lasts, selling the surplus milk, utilization of household crop production, and meals taken per day before and after the adoption of radical terraces.

In so doing, none of the above research endeavours applied focused on farmer characteristics, food production and security through the adoption of radical terraces projects. There was no emphasis on the exploitation of radical terraces projects and farmers' participation. In Rwanda, there was not much-documented knowledge on adopting radical terraces for producing food and ensuring its security. No study had looked at the influence of farmers characteristics on food production projects as well as the impact of radical terraces on food production. This study was therefore necessary as it strived to analyse sociologically the farmer characteristics and their influence on the level of adopting terraces for ensuring food Safety in the Rwandan

community. For the current research, the crucial goal was: "To examine the influence of farmer characteristics in the adoption of radical terraces and food security in Nyamagabe district". Therefore, it also intends to investigate "How do farmer characteristics influence the adoption of radical terraces and food security in Nyamagabe district, Rwanda?"

MATERIALS and METHODS

The study adopted a descriptive and correlational study design using both quantitative and qualitative approaches. According to Orodho (2004), a descriptive survey design is a method of gathering empirical data by administering a questionnaire to or interviewing the sampled individuals. The descriptive survey methodology was chosen because it was a quick and easy way to acquire descriptive information about feelings, opinions, habits and perceptions about farmers' adoption of radical terraces. Besides, correlational design was chosen because the researchers wanted to establish a link between the study's independent and dependent variables.

Data presented in this paper was gathered in the district of Nyamagabe, Rwanda. Rwanda is divided into 30 districts. Nyamagabe District was selected because it is a highland district with unproductive topsoil with an explosion to great soil erosion. Besides, during the 1980s and 1990s and aftermath of the 1994 genocide in Rwanda, some people suffered and died from starvation whereas many others journeyed to other regions for searching for food and productive lands (Murwanashyaka, 2013). In this regard, radical terracing projects were introduced as a strategy to increase food production. Also, in 2016, approximately, 42% of the district's households were in food insecurity condition as highlighted by NISR (2017). This district had 17 sectors out of which 4 had constructed radical terraces and were chosen for the current research namely: Nkomane, Kibilizi, Buruhukiro and Gatare sectors. Sectors also are divided into different cells. In this study, two cells and three villages were chosen from the aforementioned and carefully chosen sectors.

The purposive sampling was used to select eight farmers' households at the village level. The sampled households of farmers had possessed land for farming and constructed radical terraces in their plots respectively. Hence, this gave a sample size of 192 heads of households/farmers. The study also purposively interviewed 19 Key Informants. These were involved in the projects of radical terracing either directly or indirectly and own needed information related to radical terraces. This

category comprised the both Mayor and Vice Mayor of Finance and Economic Development of the district, Agronomist of the district (1), Planner of the district (1); Representative of Rwanda Agriculture Board in Nyamagabe (1); Representatives of Non-Governmental Organizations intervening in farming sector (2); Sectors Agronomists (4); Representatives of Farmer field school for cells (4), and Agricultural cooperative representatives (4).

Both qualitative and quantitative data were collected. Quantitative data were collected using opened and closed-ended questionnaire survey. Qualitative data were collected using an interview guide and observation checklist. All interviews were conducted in the Kinyarwanda language with the key informants in person, then translated into English. The information was recorded using tablets, smartphones and recorders. Furthermore, the researcher visited and observed different sites of exploited and non-exploited radical terraces in the various sub-sites.

Quantitative data were analysed using descriptive statistics such as frequency and percentages distributions for determining the indicators of farmer' characteristics, the levels of farmer's adoption and food security; and inferential statistics of chi-square analysis for assessing the association of the study variables. Pearson correlation was also used to determine the relationships between farmer characteristics, adoption of radical terraces and food security. Further, multiple regression analysis was utilized to investigate the various associations between the predictor factors as well as the potential contribution of each farmer's attributes to the variation in radical terraces adoption and food security. At the 0.05 level of significance, the chi-square, Pearson correlation, and multiple regression analysis were performed. The responses to the questionnaires were numerically coded before being analyzed and cleaned in a Microsoft Excel spreadsheet version 2016. Data were tabulated in cross-tabulation tables after quantitative data was uploaded into the statistical Package for Social Science (SPSS) version 23.0 software, which assisted in data analysis. Qualitative data were coded and organized in a manner that made it easy for content analysis. In this case, the purpose we looked out for concepts and themes and interpreted various aspects related to smallholder farmer participation in radical terracing. The Express Scribe Transcription Software and Express Scribe Dictation Software were used in transcribing and helped in content analysis.

Operationally, farmer characteristics like age, gender, education, marital status, family size, occupation, source of income, seasonal income, and land size owned were categorized. The adoption of radical terraces was examined in terms of square

meters of the terraces constructed, levels of maintenance of the terraces and types and acreage of fodder planted in the terraces. While food security was assessed by households' yield obtained for the next harvest; several months the harvest lasted; selling the surplus of milk, utilization of household crop production and meals are taken per day before and after the adoption of radical terraces. For the response variables like the food security and adoption of radical terraces, we gave a range of 0 scores to a maximum of three (3) scores depending on the importance of the factors in the study to each of their indicators Adoption of radical terraces was scored with 41 total points, divided into three categories: 0-20 low adoption, 21-27 medium adoption, and 28-41 high adoption. And Scoring Food security had 18.0 total scores with scores categories of variables 0-5 insecure, 6-9 secure, and 10-18 very secure. Hence, these categories directed analysis of empirical data.

Characteristics of the Farmers' Households

The first research question of this study was: What were the characteristics of the smallholder farmers sampled? The characteristics of households investigated were age, gender, education, marital status, family size, occupation, source of income, income per season, land size owned (Table 1). **Age:** Table 1 shows that 7.3 percent of the farmers were young (aged below 29 years); 49.0% of farmers were middle-aged (aged between 30-49 years), and about 43.8% of farmers were old (aged 50 years old and above). **Gender:** About 74% of the respondents were males while 26% were females.

Education: About 16.1% of the respondents did not attend school while 57.8% had only attended primary level, 13.5% completed the vocational training schools' level, w While only 12.5% completed secondary and above level of education. **Marital Status:** About 92.2% of the farmers were married, 4.2% were single while 3.6% were widowed.

Family size: About 90.6% of farmers had between 4-9; 6.3% had 1-3; 3.1% had 10 and above family members. **Occupation**: About 98.4% of the respondents were full-time whereas 1.6% were part-time farmers. **Source of Income:** The respondents' main source of income was farming and livestock at 97.9% of respondents, and farming at 2.1% of respondents.

Income per Season: About 68.2% of the respondents earned medium income (between 100,000 and 1 million Rwf). Whereas 17.7% reported low income (less than 100,000 Rwf), and 14.1% had high income (above 1 million Rwf).

Land size owned: About 54.7% of the farmers owned above 1 ha and 45.3% owned less than 0.9ha of land.

Table 1. Characteristics of Farmers' Households

		Number	Percent
Farmer's age	Young (<29)	14	7.3
	Middle-aged (30-49)	94	49.0
	Old (50+)	84	43.8
	Total	**192**	**100.0**
Gender	Male	142	74.0
	Female	50	26.0
	Total	**192**	**100.0**
Level of education	None	31	16.1
	Primary	111	57.8
	Secondary and above	24	12.5
	TVET/CERAI	26	13.5
	Total	**192**	**100.0**
Marital status	Single	8	4.2
	Married	177	92.2
	Widowed	7	3.6
	Total	**192**	**100.0**
Size of the family	1-3	12	6.3
	4-9	174	90.6
	10+	6	3.1
	Total	**192**	**100.0**
Occupation of farmer	Full-time farmer	189	98.4
	Part-time farmer	3	1.6
	Total	**192**	**100.0**
Main source of income	Farmer	4	2.1
	Farmer and livestock	188	97.9
	Total	**192**	**100.0**
Reported seasonal income	Low income (<100k)	34	17.7
	Medium income (100k-1M)	131	68.2
	High income (>1M)	27	14.1
	Total	**192**	**100.0**
Land sized ownership	Less than 0.9 ha	87	45.3 .3
	Above 1 ha	105	54.7 .7
	Total	**192**	**100.0 .0**

The level of smallholder farmers' adoption of radical terraces

The second research question we posed was**:** What is the level of farmers' adoption of radical terraces? To answer this question, the researcher referred to the acreage of terraces constructed, level of maintenance of the terraces, and fodder planted in the terraces as indicators. Table 3 shows different levels of farmers' adoption of radical terraces. This level was computed using the above-mentioned indicators. It shows levels of radical terraces adoption examined in terms of low, medium and high adoption categories. About 82.8% of the farmers recorded medium 12.0% high adoption, and only 5.2% of the farmers had low adoption of radical terraces.

Table 3. Levels of farmer's adoption of radical terraces

Level of adoption	Frequency	Percentage
Low adopted	10	5.2
Medium adopted	159	82.8
High adopted	23	12.0
Total	**192**	**100.0**

Concerning the importance of radical terraces, one key informant at the district level (Vice Mayor in Charge of Economic and Development) noted:

"The importance of radical terraces includes preventing soil erosion in the period of heavy rain, keeping good arable land for the next generation and keeping good relationships among farmers. It is better to spread radical terraces to fight against hunger and poverty by increasing food production and income from the sold surplus. Radical terraces keep rainwater that feeds the crops which permit farmers to cultivate during the dry season (months of June, July, August,) because the land is fresh."

Thus, most farmers adopted radical terraces at medium and high levels which were likely to contribute to a certain level of food security.

Farmers' level of Food Security

The third research question we posed was**:** What is the level of farmer's food security situation? The indicators of food security were: household's yield obtained; the number of months the harvest lasted; use of household food crop production; selling of surplus milk, and meals are taken per day after the adoption of radical terraces. Referring to indicators of food security, food security was categorized in different levels such as insecure, secure and very secure. Table 4 indicates the farmer's levels of food security. A majority of the respondents (73.4%) reported being averagely food secure, 25.5% as insecure while 1.0% as very secure.

Table 4. Levels of farmer's food security

Levels of farmer's food secure	Frequency	Percentage
Insecure	49	25.5
Secured	141	73.4
Very secured	2	1.0
Total	**192**	**100.0**

The key informant at the sector level (FFS Buruhukiro) regarded radical terraces as important in increasing food availability in households:

"*If there were no radical terraces in this sector, everybody would have died of hunger caused by soil erosion. Food is available abundantly and people are satisfied with their production of Irish potatoes and other food crops.*"

Regarding the main crops cultivated by farmers, a key informant from Nkomane sector reported:

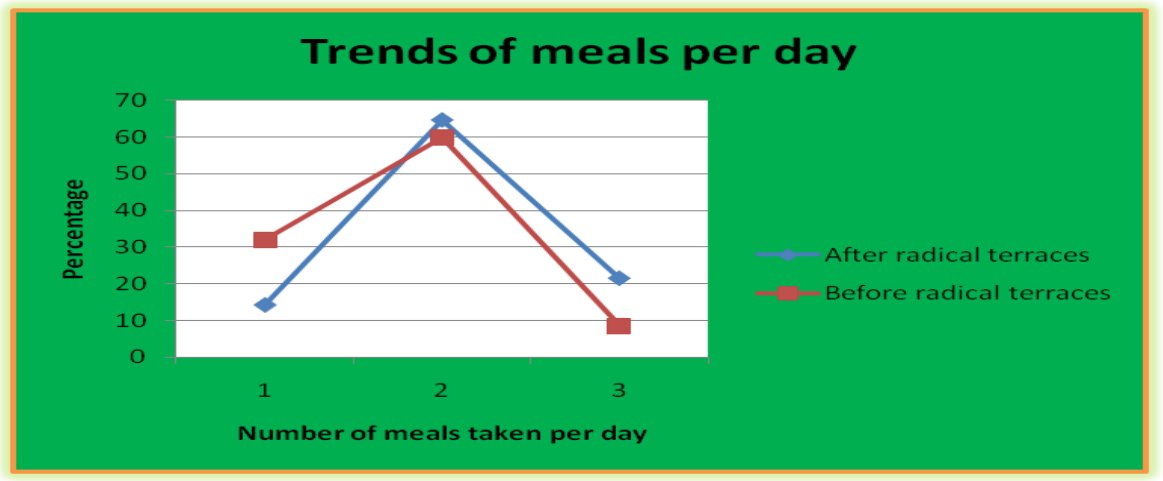
"*This area is among places which are very cold which results in having few crops especially food crops. The main crops cultivated in this sector include Irish potatoes, wheat, maize, beans and peas but some people grow vegetables and some fruits which help to fight against malnutrition.*"

For the utilization of the crop production, a key informant from Gatare (agronomist) sector reported:

"As we practice market-oriented agriculture, people aim at taking the surplus to the market. We have already formed a cooperative that collects Irish potatoes with a vehicle to distribute them in other districts of the country. This activity was previously done by bicycles or by people carrying it on their heads. Beans cultivated are sold at the local market while green peas are sold in Kigali city".

Chart 1 illustrates the pattern of the situation of food security before and after the adoption of radical terraces in the study area. As it appears, Chart 1 shows that the number of respondents who take meals before the adoption of radical terraces once a day reduced from 31.8% to 14.1% and an increase in the number of respondents (from 59.9% to 64.6%) who take meals twice a day after the adoption of radical terraces. Also, there is an increasing number of respondents who take meals three times per day from 8.3% to 21.4%.

Chart 1. Number of meal taking vs Radical terraces



It was obvious that a substantial number of farmers had met their food needs by implementing radical terraces. This showed that there was the possibility of a positive and significant association between the adoption of radical terraces by farmers and the food security of their households.

Relationship between the adoption of radical terraces and food security

The fourth research question we posed was**:** What is the relationship between the level of farmer's adoption and food secured situation? We cross-tabulated food security and the predictor factor of adoption of radical terraces using their above scores and categories.

Food crop production versus adoption of radical terraces

Table 5 shows the relationship between farmers' adoption of crop production versus their adoption of radical terraces. At the P>0.05, we did not find a significant association between the adoption of food crops adoption of radical terraces (**χ^2=9.774, df=6, p=0.134**). This implies that radicle terraces did not significantly influence hectarage planted to food crops. The Pearson Chi-square test (**χ^2=7.696,df=4, p=0.103**) also there was no significant association between crop output (in kgs) and the use of radical terraces, according to the study. This implied that the adoption of radicle terraces did not influence the yield of crops obtained by the farmers.

Table 5. Adoption of radical terraces versus Food crop production

	Adoption of radical terraces							
	Low adopted		Medium adopted		High adopted		Total	
	n	%	n	%	n	%	n	%
Planted food crops								
Beans	1	0.5	36	18.8	3	1.6	40	20.8
Irish potatoes	5	2.6	88	45.8	19	9.9	112	58.3
Maize	3	1.6	21	10.9	1	0.5	25	13.0
Wheat	1	0.5	14	7.3	0	0.0	15	7.8
Total	10	5.2	159	82.8	23	12.0	192	100.0
χ^2=9.774,df=6, p=0.134								
Yield of crop production (in kgs)								
80-200	1	0.5	13	6.8	1	0.5	15	7.8
201 – 400	4	2.1	25	13.0	1	0.5	30	15.6
401+	5	2.6	121	63.0	21	10.9	147	76.6
Total	10	5.2	159	82.8	23	12.0	192	100.0
χ^2=7.696,df=4, p=0.103								

Food crop production versus food security

Referring to Table 6, the results show that the types of food crops planted by the farmers were not significantly associated with their level of food security (**χ^2=7.155,df=6, p=0.198**) implying that the types of food crops did not significantly influence the levels of farmers' food security. In the Pearson Chi-square test (**χ^2=6.802,df=4, p=0.094**), there was no significant association between crop output yield (in kilograms) and farmers' food security, according to the study. This implied that the yield of planted crops did not significantly influence farmers' food security.

Table 6. Food crop production by Food security

	Food Security							
	Low food secured		Medium food secured		High food secured		Total	
	n	%	n	%	n	%	n	%
Planted food crops								
Beans	13	6.8	26	13.5	1	0.5	k40	20.8
Irish potatoes	22	11.5	89	46.4	1	0.5	112	58.3
Maize	10	5.2	15	7.8	0	0.0	25	13.0
Wheat	4	2.1	11	5.7	0	0.0	15	7.8
Total	49	25.5	141	73.4	2	1.0	192	100.0
χ^2=7.155,df=6, p=0.198								
Yield of crop production (in KG)								
80-200	6	3.1	9	4.7	0	0.0	15	7.8
201 – 400	11	5.7	18	9.4	1	0.5	30	15.6
401+	32	16.7	114	59.4	1	0.5	147	76.6
Total	49	25.5	141	73.4	2	1.0	192	100.0
χ^2=6.802,df=4, p=0.094								

When we cross-tabulated food crop production and food security, we found no significant association between the two factors (χ^2=2.206,df=4, p=0.508). This in effect showed that while adoption of recommended farm inputs and practices may take place, it might not be to the standard desired by the Extension Service. A key informant at sector level (Gatare Agronomist) talked about no use of farming inputs:

"Farmers were assisted in agricultural activities such as purchasing fertilizers and improved seeds but some of them did not use agricultural inputs as required, and others sold them. There was also ignorance of farmers towards using farm inputs for food production".

Table 7 indicates that food security varied across the level of adoption of radical terraces. The Chi-square test (χ2=19.950,df=4,p=0.003) showed that the adoption of radical terraces significantly influenced the levels of farmers' food security. That is, the farmer's adoption of radical terraces was associated with farmers' food security.

Table 7. Food security versus Adoption of radical terraces

	Food Security							
	Low food secure		Medium food secure		High food secured		Total	
	n	%	n	%	n	%	n	%
Adoption of radical terraces								
Low adoption	3	1.6	7	3.6	0	0.0	10	5.2
Medium adoption	45	23.4	114	59.4	0	0.0	159	82.8
High adoption	1	0.5	20	10.4	2	1.0	23	12.0
Total	49	25.5	141	73.4	2	1.0	192	100.0
χ2=19.950,df=4, p=0.003*								

Livestock ownership versus adoption of radical terraces

The results in table 8 show the relationship between the adoption of livestock versus the adoption of radical terraces. The results show that the number of livestock kept by households was not significantly associated with farmers' adoption of radical terraces (**χ^2=8.833,df=6, p=0.183**). The table also shows that milk production was significantly associated with farmers adoption of radical terraces (**χ^2=87.279,df=6,p<0.001**). This indicated that farmers who realized more milk adopted radical terraces better than those who realized less. Similarly, the sales of farmers' livestock per year influenced their adoption of radical terraces (**χ^2=32.816,df=6, p<0.001**) implying that the farmers who had higher livestock per year had adopted radical terraces better than those who has less or no sales.

Table 8. Livestock keeping production versus Adoption of radical terraces

	Radical terraces adoption							
	Low adopted		Medium adopted		High adopted		Total	
	n	%	n	%	n	%	n	%
Types and number of livestock kept by Households								
None	2	1.0	16	8.3	0	0.0	18	9.4
Cows	8	4.2	111	57.8	21	10.9	140	72.9
Goats	0	0.0	13	6.8	0	0.0	13	6.8
Pigs	0	0.0	19	9.9	2	1.0	21	10.9
Total	10	5.2	159	82.8	23	12.0	192	100.0
χ^2=8.833,df=6, p=0.183								
c. Yield of milk production								
None	10	5.2	142	74.0	3	1.6	155	80.7
1-10L	0	0.0	13	6.8	11	5.7	24	12.5
11-20L	0	0.0	4	2.1	5	2.6	9	4.7
>=21	0	0.0	0	0.0	4	2.1	4	2.1
Total	10	5.2	159	82.8	23	12.0	192	100.0
χ^2=87.279,df=6, p<0.001								
d. Sales of farmer's livestock per year								
< 100000	2	1.7	23	19.2	1	0.8	26	21.7
100000 – 549999	3	2.5	63	52.5	11	9.2	77	64.2
550000 – 999999	0	0.0	6	5.0	7	5.8	13	10.8
1000000+	0	0.0	0	0.0	4	3.3	4	3.3
Total	5	4.2	92	76.7	23	19.2	120	100.0
χ^2=32.816,df=6, p<0.001								

Livestock ownership versus food security situation

The findings in table 9 indicate the relationship between the adoption of livestock and food security. The results show that types and numbers of livestock kept by

households were not significantly correlated with the farmers' food security status (**χ^2=9.708,df=6, p=0.137**). The Chi-square test (**χ^2=10.448,df=6, p=0.070**) also indicated that the yield of milk was not significantly associated with farmers' food security. This indicated that the food security situation of those who had more milk was not different from that of those who had less or no milk. Despite this, farmers' sales of livestock per year influenced their food security (**χ^2=20.838,df=6, p=0.034**). That is the food security situation of those who had livestock sales were much better than that of those who had low or no sales.

Table 9. Livestock keeping production versus Food security

	Food Security							
	Low food secure		Medium food secure		High food secured		Total	
	n	%	n	%	n	%	n	%
Important livestock kept by Household								
None	8	4.2	10	5.2	0	0.0	18	9.4
Cows	28	14.6	110	57.3	2	1.0	140	72.9
Goats	6	3.1	7	3.6	0	0.0	13	6.8
Pigs	7	3.6	14	7.3	0	0.0	21	10.9
Total	49	25.5	141	73.4	2	1.0	192	100.0
χ^2=9.708,df=6, p=0.137								
Yield of milk production								
None	46	24.0	108	56.3	1	0.5	155	80.7
1-10L	3	1.6	20	10.4	1	0.5	24	12.5
11-20L	0	0.0	9	4.7	0	0.0	9	4.7
>=21	0	0.0	4	2.1	0	0.0	4	2.1
Total	49	25.5	141	73.4	2	1.0	192	100.0
χ^2=10.448,df=6, p=0.070								
Sales of farmer's livestock per year								
< 100000	5	4.2	21	17.5	0	0.0	26	21.7
100000 – 549999	13	10.8	64	53.3	0	0.0	77	64.2
550000 – 999999	0	0.0	12	10.0	1	0.8	13	10.8
1000000+	0	0.0	3	2.5	1	0.8	4	3.3
Total	18	15.0	100	83.3	2	1.7	120	100.0
χ^2=20.838,df=6, p=0.034								

When aggregate scores of livestock production (production plus sales) were cross-tabulated with food security, a significant relationship was observed between them (χ^2=21.654,df=4, p=0.001). This in effect implied that the farmers who kept livestock and sold some of them or their products were much more food secure than their counterparts in a reverse situation.

Regression Analysis between Farmers' food security, adoption, production and their characteristics

The adoption, production, and characteristics of farmers were used to regress their food security. Table 10 summarizes the findings. Farmers' adoption of radical terraces would be influenced by predictor variables, according to the study. To test this theory, researchers used multiple regression analysis to look for links between farmers' food security, adoption, food production, and personal factors. The adoption of radical terraces (r=.618, p.00), food production (r=.252, p.001), family size (r=.160, p.005), reported seasonal income (r=.394, p.001), and land size ownership (r=.387, p.001) were all shown to be significantly connected with food security in the analysis. The remaining predictor variables had no meaningful relationship with the food security of farmers (Table 10).

Table 10. Relationships between farmers' food security, adoption, production and their characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Food security(1)	1											
Adoption(2)	.618**	1										
Food production(3)	.252**	.592**	1									
Age(4)	0.076	.193**	-0.001	1								
Gender(5)	0.045	0.131	.172*	0.12	1							
Education(6)	0.118	0.099	0.091	-0.1	-0.058	1						
Marital status(7)	0.087	0.077	0.072	0.027	-0.027	-0.09	1					
Family size(8)	.160*	0.073	0.03	.256**	-0.022	-0.05	.483**	1				
Occupation(9)	-0.004	0.036	0.046	0.075	0.117	-0.062	-0.035	-0.013	1			
Income source (10)	0.034	0.096	0.091	0.027	-0.087	0.039	-0.04	-0.015	-0.018	1		
Seasonal income(11)	.394**	.546**	.316**	0.032	.154*	.191**	-0.02	-0.034	-0.084	0.115	1	
Land sized ownership(12)	.387**	.524**	.172*	.183*	0.08	-0.067	-0.131	-0.059	-0.03	0.087	.301**	1

** At the 0.01 level (2-tailed), the correlation is significant. *At the 0.05 level, the correlation is significant (2-tailed).

The regression model was significant (R2=.437, F (11, 180) =12.721, p.001) and explained 43.7 percent of overall connections between farmers' food security, adoption, food production, and characteristics. Farmers' food security and adoption were substantially influenced by the predictor variables of radical terrace adoption (=.282, p=.000), food production (=.282, p=0.022), and family size (=-.968, t=2.338, p=.021) (see table 11).

Table 11. Regression of farmers' food security, adoption, production and their characteristics

Model	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	-2.674	3.778		-.708	.480	-10.129	4.780
Adoption	.282	.042	.631	6.776	.000	.200	.364
Food production	-.282	.122	-.167	-2.303	.022	-.524	-.040
Farmer's age	-.299	.188	-.097	-1.590	.114	-.671	.072
Gender	-.112	.505	-.013	-.223	.824	-1.109	.885
Level of education	.131	.126	.061	1.040	.300	-.117	.379
Marital status	-.018	.286	-.004	-.063	.950	-.583	.547
Size of the family	.968	.414	.156	2.338	.021	.151	1.785
Occupation of farmer	.046	.581	.005	.079	.937	-1.101	1.193
Main source of income	-.354	.754	-.027	-.469	.639	-1.841	1.133
Reported seasonal income	.280	.260	.075	1.075	.284	-.234	.793
Land sized ownership	.246	.177	.097	1.391	.166	-.103	.594

Note: Dependent Variable: Food security; R^2 =.437; F (11, 180) =12.721, Number of observations(N) = 191, $p<0.001$

It was revealed that radical terraces have a positive impact to increase farm productivity and that they are pillars in mobilizing farmers to adopt new farming practices to ensure food security sustainably (Mupenzi, 2014). In this regard, farmer characteristics were considered as a means for adopting radical terraces for producing food crops in the highland region and ensuring its security.

DISCUSSIONS

The study examined the influence of smallholder farmers' adoption of radical terraces on food security. The results showed that the level of adopting radical terracing was medium among a majority of the farmers sampled. This contributed to improvement in farm production and livestock keeping. This finding concurs with Masinde (2009) who found that livestock ownership influenced positively the adoption of radical terraces. The finding is also in agreement with those of Mutarutwa (2014) and Mudingu (2018) discovered that livestock was vital for meeting the basic needs of areas of the country that were severely food insecure. The livestock keeping supplemented small scale cropping activities in meeting household food needs. Consequently, the integration of livestock into smallholder farming activities was a key contributor to farmers' food security. This was in line with what (Republic of Rwanda 2015) found that higher crop diversity in radical terraces, vegetable gardens and livestock ownership were factors associated with better

household food security. Moreover, It was also clear that the farmers' adoption of radical terraces contributed to food security. This result concurred with that of Murwanashyaka (2013); Acabado (2010) and Posthumus (2005) who found that agricultural terraces were symbols of humanity's accomplishment to modify the environment to suit their needs for food production. Likewise, Karplus (2014); Mupenzi (2014) and Republic of Rwanda (2014) found that radical terraces have a positive influence on food security for subsistence farmers.

Furthermore, the regression model explained 43.7 percent of the overall correlations between farmers' food security, radical terrace adoption, food output, and their characteristics (R^2=.437, F (11, 180) =12.721, p< .001). This finding concurred with Mupenzi (2014) who found that farmers characteristics are pillars in mobilizing farmers to adopt new farming practices to ensure food security sustainably. In this regard, farmer characteristics were considered as a means for adopting radical terraces for producing food crops in the highland region. In this regard, farmers' age, marital status, size of the family, reported seasonal income and land size owned were factors that influenced their food production, adoption of radical terraces, and food security.

Age was linked to the farmers' adoption of radical terraces positively and importantly. This finding concurred with what Mwangi and Kariuki (2015) and Chitere (1980) found that the older farmers had land and experience required for adopting new farming technology; whereas younger farmers did not manage their crops better than older farmers. In this study, the older farmers were experienced in using radical terraces. It was also linked to the age of farmers because the majority of the respondents had been aware of the terraces for over 25 years. Contrary to this, Wairiuko (2018) found that young individuals tended to adopt technology more and better than old people.

The level of education significantly influenced farmers' adoption and food security in favour of better-educated farmers. That is, adoption was high among more of the better than less educated respondents. These findings concurred with what Wairiuko (2018) and Gathaara et al. (2011) found that educational level had a function in the adoption of farming innovations for producing food. The finding is in agreement with what Chitere (1980) found that farmers who had been to school for more years tended to do better than those who had attended school for fewer years. To him,

farmers who had attended school for more years adopted radical terracing techniques faster than less literate farmers.

Marital status was significantly associated with the adoption of radical terraces. The adoption was high among more of the married farmers than among the other marital status categories. This finding corroborates what Kariuki (2016) and Sigei (2014) found where people with families dominated small-scale farming and a wide range of needs from childrearing. In this study, married people adopted radical terraces as they had permanent residence which influenced their complementarity in farming households than single and widowed farmers.

F**amily size** influenced the level of adopting radical terraces. This meant that the larger the family size, the more labour was available for farming activities related to radical terraces adoption. This finding matches with what Muya et al. (2016); Mwangi and Kariuki (2015) and Sseguya (2009) found that farmers, having large families easily opted for new technologies with the hope that the new technology adoption would increase their food products that would satisfy the needs of their families. This implies that children are the labour force taken as manpower for radical terraces use.

Reported Seasonal income significantly influenced food production, adoption, and food security. That is, farmers with higher incomes tended to adopt more than those with smaller incomes. This finding is consistent with the findings of CIMMYT (1993), which revealed that wealthier farmers were the first to try new agricultural technology, particularly when it involved purchased farming inputs. In this study, income helped to gain agricultural inputs, improved seeds, and farm labour. It was also used for satisfying food needs in farmers' households.

Land size owned by farmers was significant in influencing their food production, adoption and food security. That is, more of the farmers who owned big sized land adopted more new farming practices. The finding is supported by what Mwangi and Kariuki (2015); Kinyangi et al. (2014) and Masinde (2009) that farmers with big land sizes were more likely to accept new farming technology, according to their research, because they could afford to devote a portion of their property to experimenting with new equipment, as opposed to those with smaller farms. In this study, the more you own a big sized land, the more you release the part of your land for experimentation in adopting radical terraces.

Gender, occupation, and source of income, on the other hand, did not affect the adoption of radical terraces. Masinde (2009), Mwangi and Kariuki (2015) and Chitere (1980) concluded that gender had no impact on the adoption of new agricultural technologies. Male and female farmers had an equal chance in this study to perform their gender roles in terms of implementing radical terraces for food security. Furthermore, Mango et al. (2018) discovered that formal jobs and small-scale businesses had a detrimental impact on small-scale farming adoption. In this study, all respondents were farmers who had radical terraces and their occupation as full-time and part-time did not show differences in their adoption behaviour. However, the finding on the main source of income negates what CIMMYT (1993) and Shita et al. (2018) found that farmers with a more commercial mindset, who sold a substantial share of their produce, were the ones that implemented specific agricultural technologies, according to the study. And that adoption of agricultural technology had a favourable and considerable impact on farm revenue, with adopters outperforming non-adopters. In this study, agricultural activities of farming and livestock were the main source of farmers' income. The results were in agreement with what Bolarinwa et al. (2019) found in their studies on household food safety and its determinants in Rwanda that household socio-demographic characteristics and income diversification were some of the factors that led to a consistent increase or decrease in food security of the households.

CONCLUSIONS and RECOMMENDATIONS

The goal of this study was to see how smallholder farmer characteristics influenced the adoption of radical terraces and food security in Rwanda. The level to which radical terraces have been adopted was medium among the majority of the farmers sampled and this contributed to the improvement of their food security. It was found that farmer characteristics such as their age, level of education, marital status, size of the family, reported seasonal income and land size owned were positively and significantly related to the adoption of radical terraces, which had an impact on their food security. Furthermore, there was a link between the adoption of radical terraces by farmers and food security. However, even with the increased level of food crop production, food security was not as high as had been expected. Furthermore, the regression model described 43.7 percent of the overall correlations between farmers' food production and security, radical terrace adoption, and their characteristics (R^2=.437, $F(11, 180) = 12.721$, p.001). Hence, it was concluded that is older farmers,

married with large families and with higher seasonal income and large land adopted radical terraces more than those in the reverse situation as; while gender, occupation and main sources of income did not.

This study found a positive influence on farmers' characteristics and adoption of radical terraces for ensuring food production and security in the study area of Nyamagabe. In this regard, the following recommendations are made: The agrarian community should mobilize farmers with their capacity and resources to adopt the new farming practice of radical terraces for producing food crops. Besides, local leaders and agricultural extension officers should be engaged in sensitization and mobilization campaigns targeting farmers who have not adopted radical terracing. Moreover, the owners of land with unexploited terraces should be encouraged to either adopt terracing or to lease land to willing farmers for better use including radical terraces and the application of other good farming practices. Furthermore, private investors should be encouraged to set up processing units for food crop products and Milk collection centres (MCC) to add value to the farm produce, create a ready market for local farmers and hence encourage smallholder farmers to increase food and milk production and make them more enterprising. Finally, a comparative study between the adopters and non-adopters of radical terraces should be a concern for further studies.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Contribution Rate Statement Summary of Researchers

The authors contributed equally to the article.

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