Factors Affecting Sustainability of Agricultural Technologies in Tanzania: A Case of *Bustani ya Tushikamane* (ByT) Project in Morogoro Region

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Abstract

Sustainability of agricultural technologies is crucial for improving farmers' livelihoods, food security and poverty reduction. Most agricultural projects tend to be ultimately inactive as they end leaving their beneficiaries poor and food insecure due to unsustainability of the projects. The study on which this paper is based assessed sustainability of agricultural technologies and factors affecting it. The study employed cross-sectional research design. Data were collected from 90 respondents using a questionnaire. Descriptive and ordinal logistic regression analyses were done. Factors like market availability (p=0.000), training (p=0.021), and cost of the agricultural technologies (p=0.000) significantly predicted the likelihood of sustainability of agricultural technologies at 5% level of significance. It is concluded that training, market availability, and cost of introduced agriculture technologies are crucial factors influencing sustainability of agricultural technologies. For increased sustainability of agricultural technologies, it is recommended that introduction of agricultural technologies should utilizing locally available resources to minimize cost of the technologies.

Keywords: Agricultural technologies, Sustainability, Small-scale farmers.

Introduction

Human population growth has exerted pressure on the environment and food requirement to feed the population. Human population causes environmental degradation, soil erosion, shortage of agricultural land, and water scarcity leading to demand for sustainable agricultural technologies to reduce the effects (Nazu *et al.,* 2021). Agriculture, as the world's main source of food, requires sustainable agricultural technologies to protect the environment while increasing production (Santiteerakul *et al.,* 2020). Improved agricultural technologies have received attention as a way to address low production, climate challenges, and increasing population challenges in both developed and developing countries (Ochieng *et al.,* 2021). Farmers need to increase production of food and income while optimizing practices, inputs and conserving the environment. To sustain food production, farmers need to adopt and sustain agricultural technologies that are viable and reduce cost to the farmers through maximizing uses of locally available resources (Ochieng *et al.,* 2021, and Yusuf *et al.,* 2021). Sustainability of agricultural technologies helps to reduce poverty and increase income by providing employment opportunities. However, the adoption and sustainability of various agricultural technologies in Sub-Saharan African countries, including Tanzania, are still low (Muhonja, 2017). This stimulated governments and non-governmental organizations to introduce agricultural technologies with lower impact on the environment and biodiversity, and with minimum inputs with higher yield.

Agricultural technology is defined as the knowledge or information that allows different agricultural activities to be done more easily (Muhonja, 2017). These are mainly done in terms of physical activities or methods of organization to simplify work. Therefore, in this study agricultural technology is defined as the application of different techniques to control the growth and harvesting of vegetables (Yusuf *et al.,* 2021). The technology should have a direct benefit to the farmers in terms of production, and conserving the soil so that it can be sustainable. Sustainability is the ability of fulfilling the needs of the current generations without compromising the needs of future generation while ensuring a balance between economic growth, environmental care and social well-being (Setsoafia *et al.,* 2022). Sustainability is simply the ability to maintain or support a process over time. It consists of three pillars economy, society and the environment. Agricultural technologies will be sustainable if the farmer has the right training, information, clear goals from government policies and profitability of the technologies (OECD, 2001). Where benefits of agricultural technologies do not accrue to farmers their sustainability will be low. Agricultural technologies' characteristics like complexity, observability and compatibility, and divisibility affect their sustainability. Farmers are encouraged to sustain agricultural technologies with sufficient information for technology dissemination, technologies that lower cost of production, availability of extension services to explain the merits of the technologies to the famers, technologies that are participatory to farmers (OECD, 2001, Nazu *et al.,* 2021, Afrous and Abdollahzadeh, 2011a). An agricultural technology is most likely to be sustainable when its benefits (socially, economically and environmentally) are quickly realized by small-scale farmers.

"Bustani ya tushikamae (ByT)" is a grassroots programme which later led to formation of Sustainable Agriculture Tanzania (SAT), which is based in Morogoro Region. ByT aimed to introduce organic agricultural technologies to small scale farmers (SAT, 2017). SAT introduced agricultural technologies which encourage production of organic vegetables such as cabbage, pea leaves, Chinese leaf, tomatoes and amaranth. The mission of SAT is to provide networking, promotion, advocating, undertaking and facilitating sustainable agricultural technologies through research, dissemination and application in Tanzania. The main aim of SAT is to improve food security, reduce poverty by offering agricultural technologies packages, and guide small-scale farmers to increase production through employing sustainable agricultural technologies to improve livelihoods. ByT programme is a Sustainable Agriculture Tanzania project implemented in Mvomero District, Morogoro Rural District, and Morogoro Municipality. The ByT programme was started as a grassroots project to help small scale farmers from Mvomero, Morogoro District and Morogoro Municipality to reduce poverty and improve food security.

Small-scale farmers' livelihoods are improved through agricultural technologies that help to improve production and protect natural resources, increase profit, increase soil fertility, and improve food quality and small-scale farmers' income. It is important to concentrate on sustainability of introduced agricultural technologies for land improvement and small-scale farmers' livelihoods (Afrous and Abdollahzadeh, 2011a). Sustainability of the agricultural production technologies is crucial for improving farmers' livelihood and poverty reduction. This paper therefore assesses the extent to which the introduced agricultural technologies in the study area are sustainable, and the factors influencing the sustainability a time after the completion of the project.

Methodology

Study Area

Mvomero District, Morogoro Rural District, and Morogoro Municipality were purposively selected because ByT project had been being implemented in the districts since 2009. The districts lie within longitudes 37˚25'00"E, 37068'12"E and 37˚40'14"E and within latitudes 6˚19'59"S, 6078'00'S and 6˚49'49"S in that order (URT, 2015). The project covers 14 villages and 15 vegetables farmer groups each with 6-40 members. Two (2) of the groups are in Mvomero District; 5 groups are in Morogoro Rural District; and 8 groups are in Morogoro Municipality. A large part of the area is warm and semi-tropical, characterized by an average annual rainfall range of 487-1951 mm. The study area was chosen since it is a potential area for agriculture as the main source of income (URT, 2017).

Study Design

In this study, a cross-sectional research design was used. The design allows a researcher to compare many different variables at the same time (Levin, 2014) which is pertinent to this study which aimed to compare different variables and was a population based study. The design allows to make inferences about the population of interest at one point in time (Lavrakas, 2008).

Population, Sample Size and Sampling Procedures

The study population consisted of all group members involved in the ByT programme. The programme consisted of 15 groups with at least 6-40 group members, from three districts and 14 villages in Mvomero District, Morogoro Municipality, and Morogoro Rural District. Seven farmer groups were purposively selected based on their having been in the programme since its inception. In this study, proportionate stratified sampling was used to select respondents involved in the *Bustani ya Tushikamane* programme.

Where: n = sample size, N = Population size, e = Error term and cv = coefficient of variation, where: N = 825 e = 0.05 and cv = 0.5. Therefore,

$$n = \frac{825\,(0.5)^2}{(0.5)^2 + (825-1)0.05^2}$$

n = 90

The following formula was used to determine number of respondents from each group in order to ensure equal representation of respondents:

$$n_i = n_{\left(\frac{N_i}{N}\right)} \qquad \text{……………….(1)}$$

Where:
ni = Sample selected from the group,
n = Total sample size,
Ni = Total group members, and
N = Total population from all the groups.

Then, a list of farmers involved in the ByT programme was obtained from the implementing organization (SAT). After obtaining the sub-samples indicated in Table 1, the "=Rand ()" command in Microsoft Excel was used to generate random numbers for each of the seven (7) groups. Group members whose serial numbers corresponded with some of the random numbers that were generated were selected and requested to be interviewed for data collection for the research.

Table 1: Number of respondents selected from each village/ group

District	Ward	Village/Street	Group name	Number of group members	Number of respondents
Mvomero		Mgeta	Tughetse	33	17
Morogoro Municipality		Towelo	Maendeleo	18	9
		Mwanzo Mgumu	Twawosa	19	10
		Mangala	Lamka	28	15
Morogoro Rural		Kibuko	Muungano	23	12
		Mkuyuni B	Twiyame	11	6
		Luholole	Jitegemee	40	21
Total				**172**	**90**

The sample size was first obtained by the Neuman formula (2000) which is:

$$n = \frac{Ncv^2}{cv^2 + (N-1)e^2}$$

Data Collection

Data were collected through a questionnaire. Questionnaires were assigned to the farmers who participated in ByT program to collect quantitative data on socio-economic characteristics, sustainability and factors affecting sustainability.

Data Analysis

The data collected using the questionnaire were coded and analysed using Statistical Package for Social Sciences (SPSS) Version 20. Data cleaning was first done to ensure quality. Sustainability was measured by a sustainability assessment tool according to the procedures of measuring sustainability provided by OECD (2001). The dependent variable, sustainability index, was captured as a categorical variable. According to Munyaneza (2018), the sustainability index was generated using normalized indicators for environmental indicators, social indicators, and economic indicators. Sustainability was obtained by first selection of relevant indicators(social, environmental and economic) which were obtained from literature, brainstorming and discussions with project implementers. Then indicators were measured, normalized and lastly aggregation of indicators in to sustainability indices. According to Afrous and Abdollahzadeh (2011), the generated sustainability indices were categorized into low sustainability (<0.33), medium sustainability(0.33 ≤ and < 0.66), and high sustainability(≥0.66). Frequencies and percentages were used to describe the level of sustainability of agricultural technologies.

Factors affecting sustainability were analysed by ordinal logistic regression since our dependent variable has more than two categorical data. Where different factors obtained from literatures, brainstorming and consulting project implementers were collected. According to Schreiber-Gregory and Jackson (2017), then multicollinearity was tested to avoid negative impact on the analysis. Equation 2 is presented hereunder, based on Singh *et al.* (2020) who assert that ordinal logistic regression model with more than one predictor variables can be written as:

$$logit\big(P(Y \leq j)\big) = \beta_{j0} + \beta_{j1x_1} + \cdots \ldots \ldots \ldots + \beta_{jpx_p}$$

Where:

($logit(P(Y \leq j))$) is the cumulative probability of the farmer to fall under a certain sustainability level,

B_{j0} are the respective intercept parameters; β_j is a vector of regression coefficients corresponding to sustainability, and X_1, X_2, and X_p are the predictors or independent variables included in the model as shown on Table 2.

Table 2: Variables included in the model

Variables	Types	Description of the variable
Sustainability	Categorical	1 = Lower sustainability
		2 = Medium sustainability
		3 = High sustainability
Sex	Dummy	Gender of household head
Market	Dummy	The availability of reliable market for organic products
Training	Dummy	Household received training on organic farming
Technology availability	Dummy	Availability of technology introduced
Technology cost	Dummy	Cost of using the organic technologies is it cheap or expensive

Results and Discussion

Socio-Economic Characteristics of the Respondents

Table 3 shows the comparison of socio-economic characteristics of respondents and level of sustainability of ByT technologies. The results showed that respondents who were older had higher sustainability compared to younger respondents. This implies that older people had adopted ByT agricultural technologies more compared to younger ones. This is because elder people are mainly involved in agricultural production which makes them regard introduced agricultural technologies as opportunities to them, compared to younger ones who are reluctant to be involved in agriculture but are mainly involved in other income generating activities. These results are similar to results by Usman (1997) who reported that younger generation people are reluctant to do farm work and that they are rather involved in other income generation activities. The results in Table 3 show that women have higher sustainability (64%) on the agriculture technologies in comparison to men. Women in rural areas are the main producers of family food which makes them adopt agricultural technologies for a long time. Introduction of improved agricultural technologies helps women in family food production which makes the technologies more sustainable to women compared to men. These findings are consistent with findings by Setsoafia *et al.* (2022) who reported that women are more likely to adopt and sustain agricultural technologies to increase productivity.

As for the marital status, the results showed that agricultural technologies from ByT adopted by married people were more sustainable (67.3%) (Table 3). This implies that technologies adopted by married people have higher chances of being sustainable than other those adopted by other categories of marital status. Married people have more manpower to help each other in production and require more food to feed their family; hence adoption of agricultural technologies which improve production makes the family to sustain the technologies for food production.

More than three-fifths (61.5%) of the respondents with primary education had higher sustainability, unlike those with secondary education. This implies that most of the people with primary education level had no other options of being employed in other job categories unlike people with higher level of education; the former concentrate on agriculture. People with higher education level see agriculture as an occupation with low status; hence they are reluctant to undertake farming activities, a thing which leads to agricultural technologies introduced being unsustainable.

As for the occupation, the results showed that technologies adopted by respondents who were crop producers had higher sustainability (60.7%) (Table 3), which implies that crop producers regarded introduced agricultural technologies as an opportunity to improve production. Small scale farmers are conscious

Table 3: Socio-economic characteristics of the respondents and sustainability of technologies

Social Characteristics		**Sustainability index group**		
		Low sustainability	**Medium Sustainability**	**High sustainability**
Age groups	18-35	2(13.3)	5(33.3)	8(53.4)
	36-50	3(9.4)	12(37.5)	17(53.1)
	51 and above	6(14)	8(18.6)	29(67.4)
Sex	Male	3(12.0)	6(24.0)	16(58.5)
	Female	8(12.3)	19(29.2)	38(64.0)
Marital status	Single	3(25.0)	4(17.4)	3(5.5)
	Married	4(33.3)	12(52.2)	37(67.3)
	Separated	2(16.7)	3(13.0)	9(16.4)
	Widow/Widower	3(25.0)	4(17.4)	6(10.9)
Level of education	No formal education	1(12.5)	4(50.0)	3(37.5)
	Primary education	11(14.1)	19(24.4)	48(61.5)
	Secondary education	2(33.3)	2(33.3)	2(33.3)
Main occupation of the respondents	Crop production	12(14.3)	21(25)	51(60.7)
	Trade	2(33.3)	2(33.3)	2(33.3)

N.B.: The numbers in brackets are per cents of technologies which improve their production at minimum costs. The ByT programme has introduced vegetable production technologies which are typical organic with higher production and lower cost of production.

Sustainability of Agricultural Technologies

The results in Table 4 show that technologies introduced under the ByT programme were highly sustainable (60%), followed by medium sustainability (27.8%). This implies that farmers in the project area were able to sustain the introduced agricultural technologies by 60%.

Table 4: Level of Sustainability

Sustainability index group	Frequency	Percent
Low sustainability	11	12.2
Medium Sustainability	25	27.8
High sustainability	54	60.0

Farmers in the project area were taught to produce organic vegetables to increase their income. The findings suggest that access to training, participation in demonstration plots, and access to market information improve social networking leading to sustainability of agricultural technologies. Similar results were observed by Ochieng *et al.* (2021) who found that access to training on the demonstration plots, market information and group membership influence sustainability of agricultural technologies. Sustainable Agriculture Tanzania (SAT) under the *Bustani ya Tushikamane* (ByT) programme introduced different agricultural technologies for vegetable production . SAT have been forming farmer groups and training them to use agricultural technologies which are cost-effective so as to reduce cost of production while conserving the environment.

Factors Affecting Sustainability of Agriculture Technologies

Factors affecting sustainability of agricultural technologies introduced by ByT were identified. It was reported that attending training, availability of the agricultural technologies, sex of the farmers, cost of the introduced agricultural technologies, and crop market availability predict sustainability of agricultural technologies adopted by farmers. Sustainability was categorized into three categories (Low sustainability, medium sustainability, and high sustainability) in which case high sustainability was a reference category.

The results in Table 5 show that technology cost, market availability, and attended training were significantly influencing sustainability of agricultural technologies introduced to small scale farmers. The results show that the costs of technologies introduced to the farmers were significantly predicting the level of sustainability (p = 0.000). This implies that change in status on the cost of technologies from cheaper to expensive decreased the likelihood that agricultural technologies would be sustainable. This means that changes in status of agricultural

Table 5: Factors affecting sustainability of ByT sustainable agriculture technologies

Parameter	Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound Lower
Lower sustainability	0.648	1.203	0.290	1	.590	-1.709	3.006
Medium sustainability	3.383	1.257	7.243	1	.007	.919	5.847
Sex	-0.486	0.619	0.617	1	.432	-1.699	.727
Market availability	3.000	0.641	21.874	1	.000	1.743	4.257
Attending training	1.324	0.573	5.343	1	.021	.201	2.447
Technology availability	0.321	0.617	0.271	1	.603	-.888	1.530
Technology cost	2.029	0.568	12.757	1	0.000	.916	3.142

technologies from cheaper to expensive agricultural technologies would restrict farmers from adopting the agricultural technologies, leading to lower sustainability. Expensive agricultural technologies involve different levels of technologies, leading to more cost of practising them. Small scale farmers capture and adopt agricultural technologies in order to optimize inputs and maximize outputs using locally available technologies which are also cheaper, depending on their level of production. Expensive agricultural technologies hinder sustainability of agricultural technologies. These findings are supported by Thi *et al.* (2002) who reported that farmers prefer agricultural technologies with lower inputs but bring higher benefits and ensure higher productivity.

The results show that markets were positively predicting sustainability of the agricultural technologies introduced in the study area (p = 0.000). This implies that, change on status of market for the crops produced from market available to non-available the level of agriculture technologies sustainability introduced to the farmers' decreases. This means that market availability for the crops produced using the introduced agricultural technologies were more likely to influence agricultural technologies sustainability among the small-scale farmers. Small-scale farmers produce at a small-scale with intention to generate income from the crops produced. Market availability will influence the farmer to sustain the agricultural technologies used to produce crops which are easily marketable with good prices. These results are consistent with results by Ochieng *et al.* (2021) who reported that market imperfection such as production risk plays an important role in agricultural technology sustainability. Small-scale farmers in the study area were trained and assured for market to the produced organic vegetables which are bought by ByT.

The results show that attending training was positively predicting the likelihood that agricultural technologies adopted by farmers would be sustainable (p = 0.021). This implies that change in status on farmers attending training to not attending training decreased the likelihood that agricultural technologies would be sustainable. This means that, farmers who had attended training for specific agricultural technologies were more likely to use relevant technologies in more su stainable ways compared to those who had not attended training. Training involved facilitating farmers to use the technologies, both agronomic practices and technical know-how, and making farmers knowledgeable on planting techniques, crops rotation, and post-harvest management. These helped farmers to increase yield, improve their income, food security, and protect their crops against hazardous weather conditions and pests. The findings are in conformity with Xie and Huang (2021) and Mutiso (2015) who reported that training farmers on agricultural technologies improves farmers' knowledge, access to information and reduces uncertainty on production. ByT had been training farmers on production of organic vegetables, involving making compost, use of farm yard manure, and raised seed beds for vegetable production. These findings are consistent with arguments of FGD participants who reported that the ByT programme had trained them to use farmyard manure and compost manure which had helped them increase volumes of organic vegetables they produce.

Conclusions and Recommendations

The study aimed to determine levels and factors influencing sustainability of agricultural technologies among small-scale farmers under the ByT programme. Based on the study findings, it is concluded that technologies introduced were highly sustainable. It is further provided insight that market availability, training, and the cost of introduced technologies influence sustainability of agricultural technologies. The ByT programme plays a crucial role in provision of market for the vegetables produced, offering training on good agricultural practices, and provision of cheaper agricultural technologies which ensure greater yield among beneficiary small-scale farmers. It is implied that factors like training, market of the produced crops and the cost of introduced agricultural technologies offer restrictions and incentives necessary for agricultural technologies to be sustainable among small-scale farmers.

Based on the study findings and conclusions, the study recommends to the Ministry of Agriculture and Co-operatives and to non-governmental organization that agricultural technologies introduced to the farmer should be of lower operational costs with relatively high yield to reward small-scale farmers to increase sustainability of the agricultural technologies. Securing market for the crop products produced using the technologies, the technologies will help improve wellbeing and influence the sustainability of the agricultural technologies. In addition, the study recommends that further research should be done in the study area on the role of agricultural technologies in improving livelihoods across the land catena of Uluguru Mountains.

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