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Economics of On-Farm Climate Smart Agricultural Practices in Crop-Based Farming Systems in Morogoro Rural District

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Abstract: *Crop-based systems across Sub-Saharan African countries, including Tanzania is hampered by climate change. Government and private sectors introduced twenty climate-smart agricultural practices in the country. This study aimed to examine the profitability of using climate-smart agricultural practice in Morogoro Rural District. About 300 respondents were selected using a random sampling technique for interviews. A survey was conducted to collect data from the respondents using semi-structured questionnaires. A cost-benefit analysis was done to analyse the net returns of climate change mitigation interventions. The results showed that each mitigation intervention used by the smallholder farmers was financially feasible because the net returns were positive (revenues exceeded the costs). The varieties tolerant to drought (such as soybeans, maize and rice), row planting, and strip cropping were most financially viable. Less profitable practices included land rotation, tractor ploughing, and contour farming. Climate-smart practices with high profitability are recommended for enhancing farmers' income.*

Keywords: Economic analysis, livelihoods, on-farm, interventions, technology adoption

JEL classification: C35, D63, I37

1.0 Introduction

The Intergovernmental Panel on Climate Change-IPCC (2001) defines climate change as any change in climate over a period caused by natural variability or as a result of human activities. It is at the forefront of debates and discourses on environmental change (Sain et al., 2017). There is a need for collective action regarding the causes and consequences of climate change to ensure efficient and equitable policy response (Kangalawe, 2012). Reducing Green House Gases (GHGs) and enhancing carbon sinks are the two policies identified to address climate change (United Nations Framework Convention on Climate Change-UNFCCC, 2003). McEvoy et al. (2009) pointed out that the success of these mitigation initiatives is questionable.

Tanzania is vulnerable to environmental change, particularly climate change (Kangalawe, 2012). In the next decades, billions of people in the least developing countries will face changes in rainfall patterns that will contribute to rising temperatures, floods, and water shortages that will cause shifts in crop growing seasons (IPCC, 2001). Smallholder farmers in the Eastern Zone of Tanzania face increased climate variability (Swai et al., 2020). According to the United Republic of Tanzania-URT (2009), there are efforts to curb climate change and enhance agriculture production in collaboration with governmental institutions and non-government organisations such as CARE Tanzania.

In Morogoro District, Tanzania, about 20 climate-smart practices have been introduced for farmers against climate variability. These practices include contour farming, zero tillage, planting date, repeated cropping, re-sowing, row-planting, use of varieties which are drought-tolerant, ploughing using a tractor, inter-cropping, use of early maturing varieties, mixed cropping, crop rotation, vegetation cover, manuring, using cover crop, land rotation, organic farming, bunding, ploughing using animals, and strip cropping. These interventions enhance adaptation (Lipper et al., 2014). However, there is a trade-off associated with these interventions (Mutenje et al., 2019). Therefore, studies focusing on the economic implications of on-farm climate-smart agricultural practices is crucial at the farm level because cost constraints limit farmers to adopt the introduced practices. According to Sain et al. (2017), there are limited studies on the economics of farm climate-smart agricultural practices in Tanzania. For example, a study by Ozor et al. (2010) in Southern Nigeria identified constraints that limit the adoption of climate-smart interventions, such as high cost of implementation and low income to smallholder farmers. A study by Mutenje et al. (2019) in Malawi, Mozambique, and Zambia found that climate agricultural interventions are financially feasible. This study examined the profitability of climate mitigation interventions in Tanzania, with evidence from Morogoro Rural District.

2.0 Theoretical Review

The rational choice theory was adopted to guide this study. According to Burns (2016), this theory states that smallholder farmers can make prudent and logical decisions from available alternatives. Based on this theory, smallholder farmers can differentiate the costs and revenues of the available alternatives. The central assumption of this theory is that smallholder farmers maximise revenues and minimises the costs accrued from the implementation of the new interventions. Burns (2016) revealed that smallholder farmers select options with the highest net benefits. Factors such as rational preferences, scarcity of resources, opportunity costs, and institutional information determine farmers' decisions and actions on the available options (Friedman & Hechter, 1988). According to Bichieri (2004), when resources are scarce, farmers are derived to make choices consistent with their preferences. Opportunity costs affect farmers' decisions when making specific choices of interventions (Rahelizatoovo, 2002). Under rational preferences, farmers rank preferences over the possible outcomes of options available. The decision-makers conduct rational calculations and subsequently choose the alternative associated with the highest benefits. This theory is relevant to this study because smallholder farmers choose a technology or a mixture of technologies by weighing costs and benefits based on their experiences.

3.0 Methodologies

3.1 Study Location

This research was carried out in Morogoro Rural District. The reason for the district's choice is that the interventions to combat climate change was implemented.

3.2 Research Design

This research used a cross-sectional design. According to Creswell (2007), in this design, the data are collected at a single point in time. This research design is also appropriate for the determination of relationships among variables (Williams, 2006). It is suitable for researchers to efficiently utilise economic resources in terms of time for collecting data (Kothari, 2004).

3.3 Sampling frame and sample size

This study' sample frame constituted smallholder farmers in Morogoro Rural District. Farmers growing maize in Morogoro Rural District formed a sample of this study. Based on the District Agricultural Development Plans (DADPs) (2019) report, about a total of 753 households adopted different climate-smart agricultural practices in Morogoro Rural District. Due to financial and time resource constraints to contact each household growing sweet maize, a sampling approach was used. The sample was calculated using the formula recommended by Bao Thoa (2006), as presented in Equation 1.

$$n = \frac{N}{1 + Ne^2} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (1)$$

Where:

n = sample size,
N = population,
e^2 = probability of error
With N = 753, e = 5% (95 per cent confidence). The sample size was calculated according to the recommendation as follows:

$$\text{n} = \frac{753}{1 + 753 * (0.05)^2} = 300.2991$$

Therefore, the sample size for the study was 300 households.

3.4 Sampling procedures

This study adopted a multi-stage sampling technique. Purposive sampling was used to select the Wards. Then, villages were selected using simple random sampling (Kothari, 2004).

3.5 Data collection

A survey method was adopted in this study for the collection of primary da A structured questionnaire was prepared as a tool to collect data such as costs, prices, and yields from the respondents. A survey method was used to collect data and was achieved using semi-structured questionnaire.

3.6 Data analysis

This study used the Benefit-Cost Ratio (BCR) to analyse the financial feasibility of each climate smart agricultural intervention using Equation 2.

$$BCR_I = \frac{\sum B_t(1+r)^{-t}}{\sum C_t(1+r)^{-t}} \quad \text{(2)}$$

Where:

BCR_t = The Benefit-Cost Ratio of the i^{th} intervention
B_t = Benefits at year *t*,
C_t = Variable cost at year *t*,
r = The discount rates

In this study, the discount rate used was 16.68%, obtained from the Bank of Tanzania in 2020, which was the prevailing lending rate during the study. The BCR greater than 1 and higher, the better the intervention, while the BCR less than 1 and lower, the less financially feasible the intervention.

4.0 Results and Discussion

4.1 Results

Table 1 shows that all adaptation strategies adopted by smallholder farmers are profitable because the benefit-cost ratio (BCR) are above one.

Table 1: Results of the analysis for the interventions in the study area (N = 300)

	Mvuha Division, Morogoro Rural District								
	Kolero Ward (N = 150)			Kasanga Ward (N= 150)			Total (N= 300)		
Practices	Cost (TZS)	Benefit (TZS)	Benefit Cost Ratio	Cost (TZS)	Benefit (TZS)	Benefit Cost Ratio	Cost (TZS)	Benefit (TZS)	Benefit Cost Ratio
1	82.5	161.82	2.4	124.3	304.1	3.1	103.4	232.7	2.8
2	87.9	176.6	2.2	94.2	190	2.8	91.1	183.6	2.5
3	86.9	208.3	2.7	82.3	218.6	3.4	84.4	214	3.1
4	76.7	150.8	2.8	95.6	234.1	2.8	94.5	229.2	2.8
5	96.7	128	1.8	140	217.8	2.2	138.6	215	2.2
6	203	286.7	1.8	171.7	314	2.8	179.6	307.1	2.5
7	105.1	263	2.8	70.3	189.12	3.9	86.6	223.67	3.4
8	117.9	221.5	2.2	76.6	194.8	3.7	86.1	200.92	3.4
9	63.4	177.7	3.2	64.4	158.4	3.7	64	166.3	3.5
10	89.7	217.9	2.9	64.5	186	4.2	67.4	189.67	4
11	57.5	191.3	3.4	59.4	175.8	4.4	59.4	176.1	4.4
12	84.4	182.6	2.8	69.1	176.7	4.1	75.7	179.3	3.5
13	221.2	294.5	1.6	160.8	275.5	2.9	174.9	280	2.7
14	193.7	220.3	1.6	141.5	250.1	3	145.3	247.9	2.9
15	98.5	125.6	1.4	145.1	246.1	2.9	142.8	240.1	2.8
16	76	183.3	2.5	144.1	250.7	2.8	132.4	239.1	2.8

17	219	295.1	2.1	142.9	240.2	2.7	145.9	242.3	2.7
18	114.1	130.3	2	141.2	240	2.7	140.1	235.4	2.7
19	148	229.3	2.3	135.9	235.5	2.8	136.8	235	2.8
20	78.6	126.7	1.8	111.9	209.7	3.3	107.8	199.5	3.1
Mean ($\bar{\bar{X}}$)			**2.3**			**3.2**			**3**

Source: Field data, 2020

Key: $\bar{X} \geq 2.3$ is critical at Kolero Ward, $\bar{X} \geq 3.2$ is critical at Kisanga Ward, $\bar{X} \geq 3.0$ is critical at both Kolero and Kisanga Wards.1 = Change planting date, 2 = Early maturing variety, 3 = Drought tolerant variety, 4 = Crop rotation, 5 = Land rotation, 6 = Mixed farming, 7 = Row planting, 8 = Intercropping, 9 = Re-filling, 10 = Repeated sowing, 11= Strip cropping, 12 = Zero tillage, 13 = Tractor ploughing, 14 = Animal ploughing, 15 = Cover cropping, 16 = Mulching, 17 = Budding, 18 = Contour farming, 19 = Organic farming, 20 = Green manuring.

For Kolero Ward in Morogoro Rural District, the interventions which recorded the highest BCR values are strip cropping (3.4), refilling (3.2), repeated sowing (2.9), row planting (2.8), and zero tillage (2.8). Interventions with the lowest BCR were cover cropping (1.4), animal ploughing (1.6), tractor ploughing (1.6), mixed farming (1.8), and land rotation (1.8). In Kisanga Ward, the interventions with the high BCR were found to be the strip cropping (4.4), repeated sowing (4.2), zero tillage (4.1), row planting (3.9), and intercropping (3.7). In the same ward, practices with the lowest BCR were rotation (2.2), contour ploughing (2.7), bunding (2.7), mixed farming (2.8), and crop rotation (2.8). The interventions such as strip cropping (4.4), repeated sowing (4.1), zero tillage (3.5) refilling (3.5), and row planting (3.4) recorded the highest BCR in both wards and should be promoted for adoption to smallholder farmers. Interventions such as land rotation (2.2), mixed farming (2.5), early planting (2.5), tractor ploughing (2.6), and contour farming (2.7) were found to have low BCR in both wards. The results of this study conform to the study by Ng'ang'a et al. (2017) in Southern Nigeria.

4.2 Discussion

In both wards, strip cropping was found to have a high Benefit Cost Ratio (BCR). This intervention involved the cultivation of different crops in alternative strips on the same piece of land. Farmers in the study integrated maize production with leguminous crops. This intervention has the advantage of preventing soil erosion. Also, farmers who were interviewed reported that this intervention improved soil fertility and increased farm yields. The second intervention, which was found to have a high BCR is repeated cropping (continuous cropping) in each cropping season. However, this intervention is ineffective in controlling crop pests and diseases on their farms. Zero tillage which recorded the third highest BCR, involved no tillage of the land before planting of the crops. This intervention was common to smallholder maize farmers, but rice farmers claimed their land was tilled each year. This practice improved soil moisture and allowed the microorganisms in the soil to function at a maximum level. This intervention was practised more in Kolero Ward despite financial feasibility being highest in Kasanga Ward. It was revealed that the soil in Kasanga Ward was hardening very fast, so it was not possible to cultivate the crop without tilling the land.

Re-sowing, also known as re-filling, ensure the right crop population and, thus improvement in crop yields. This intervention was found to record high BCR and was the fourth. During interviews, respondents in the study area explained that re-sowing is done because some seeds may not germinate. This can be caused by many factors, such as environmental conditions, poor seed quality, and pest attacks. The fifth intervention, which recorded high BCR in the study areas, was row planting. Smallholder farmers implemented this practice to ensure optimal crop population and the recommended crop spacing. Farmers who used this intervention in the study area realized high crop yields and improved their income.

5.0 Conclusion and policy implications

The objective of this study was to analyze the financial feasibility of using intervention to combat climate change through an on-farm experiment in Morogoro Rural District. Benefit-Cost Ratio was used as an indicator to examine the profitability of each intervention. The use of each intervention was financially feasible because the revenues exceeded the costs accrued during implementation. Zero tillage, row planting, re-sowing, re-filling, and strips cropping were financially feasible interventions to combat climate change, while the less profitable interventions were early planting, contour farming, land rotation, mixed farming, and tractor ploughing. To enhance the adoption of the interventions, the government and private sectors should consider establishing demonstration farms to enable farmers to understand the various interventions against climate change, such as re-sowing, zero tillage, and strips cropping which have been found to have the highest revenues than costs.

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