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Interactions between Farmers' Adaptation Strategies to Climate Change and Sustainable Development Goals in Tanzania, East Africa

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Abstract: This study investigated the potential adaptation measures for farmers in the Mwanga and Same Districts of Tanzania and then assessed their positive and negative interactions towards potential contributions to the selected sustainable development goal (SDG) indicators of no poverty and zero hunger. A total of 200 household surveys were conducted, and 36 participants were interviewed as key informants. Moreover, four focus group discussions were conducted to identify potential adaptation strategies in the studied areas. The literature and expert judgement approaches were used to understand and assess the positive and negative interactions between adaptation strategies and the selected indicators of SDGs. A seven-point scale of SDG interactions was used to determine the interactions between identified adaptation strategies and selected SDG indicators. Qualitative data were subjected to content analysis, whereas quantitative data were analyzed through descriptive statistics. The finding revealed that some of the adaptation strategies (i.e., stream bank crop cultivation, valley bottom crop cultivation, and cultivating crops near water sources) considered potential at the household levels and had strong negative interactions on achieving SDG 2.4.1. Further, most farmers hardly employed strategies (i.e., use of extension officers, concrete irrigation channels, crop insurance schemes, and credit schemes) that had strong positive interactions on the selected SDG indicators. Moreover, most of the identified strategies (i.e., early maturity crops, planting drought-resistant crops, use of improved varieties, mixing improved and local varieties, mixing short and long duration varieties, and crop diversification) are enabling strategies (+1), which, despite their importance, may constrain (−1) the income of small-scale farmers, food security, and poverty reduction. The importance of other strategies (i.e., irrigation infrastructures) must be addressed for better yields and positive impacts. Hence, achieving SDGs 1 and 2 in the studied areas will require the integration of different adaptation strategies that complement each other, and not by promoting only some strategies as used or suggested before. For example, the emphasis on using improved varieties and crop diversification should be complemented by access to credit schemes, irrigation infrastructures, crop insurance, and extension services at the village level.

Keywords: climate change; SDGs interactions; adaptation strategies; farmers; semi-arid; Africa; sustainable development

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1. Introduction

Since adopting the sustainable development goals agenda in 2015, the number of studies focusing on SDG interactions has been proliferating to help decisions and policymakers on how best and successfully to support the implementations of SDGs [1]. There has been an agreement in scientific communities that each SDG should not be treated in isolation from others, as actions to meet one goal impede or accelerate progress on others [2]. The 2030 United Nations sustainable development goals are also referred to as an integrated agenda that stresses the importance of interlinkages within all pillars of sustainable development (social, economic, and environmental dimensions) [3]. It further emphasizes the importance of interactions and partnerships while implementing policies and measures. Understanding interactions among various actions and policies undertaken to achieve SDGs is increasingly important [4].

Several studies have developed frameworks for assessing and understanding interactions among SDGs. For example, a study by [5] used network analysis techniques to show the linkages and interactions among SDGs and their targets. The study further indicates how linkages exist through marks that refer to their contributions toward achieving multiple goals. Further, a study by [6] showed the existing connections and interactions between energy and other SDGs by their context dependencies. Additionally, Ref. [3] also added that the nature of interaction could only sometimes be universally defined since interactions and linkages are context-dependent and highly needed for policy implementation. Place-specific case studies are required due to differences in geographical location, resource base, institutions, cultures, income, and education levels, which define the nature of interactions.

Furthermore, Ref. [4] added that it is essential to ease better representation of heterogeneity by looking at differences in geographical location and socio-political context using different models. In due regard, implementing the SDGs will look very different due to societal and national circumstances [7,8]. Moreover, Ref. [3] further showed a need for case studies that identify interactions using a forward looking model-based analysis.

Despite a seven-point scale framework being widely used and recommended for understanding and assessing SDG interactions, more must be done to understand interactions at local levels [7]. Further, there are scant empirical studies on interactions between adaptation strategies recommended for farmers and their contributions toward achieving SDGs (1: no poverty and 2: zero hunger) in Africa, particularly in Tanzania. SDGs 1 and 2 are the most critical goals in Africa as the region is the poorest and most food insecure globally [9]. Agriculture is the primary economic activity, which employs many people on the continent, and is considered an important sector in alleviating poverty, ending hunger, and achieving food security [9]. With due regard, it is essential to investigate potential adaptation strategies to help farmers achieve SDGs (1: no poverty and 2: zero hunger). Previous studies, including [7,10], assessed the existing linkages and interactions between energy and other SDGs. A study by [4] analyzed the links and interactions between the undertaken practices and planned model developments with SDGs using integrated assessment models. In light of the above situations, this paper tries to fill this knowledge gap by investigating potential adaptation measures for farmers in the selected villages in the Mwanga and Same Districts of Tanzania and then assesses their positive and negative interactions towards potential contribution to the United Nations' sustainable development goals of SDGs (1: no poverty and 2: zero hunger).

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in the Mwanga and Same Districts of the Kilimanjaro regions in Tanzania (see Figure 1). The districts were selected as study sites because of being located in the semi-arid region. Other factors considered include the repeated problems of chronic food shortages experienced in both Districts caused by frequent droughts due to prolonged dry spells and unreliable rainfall [11]. The lowland zones in both Districts have been more affected than the highland zones, leading to crop failures [12]. Further, in 2013, the Tanzanian Emergency Appeal Final Report on Drought and Food Insecurity indicated that Mwanga and Same were among the seven Districts that were severely affected by food insecurity and droughts, a situation that necessitated immediate food assistance [11]. The fact that agricultural activities in the districts are largely subsistence, rain-fed, and in semi-arid areas increases their vulnerability to climate change impacts [11]. Agriculture is the predominant economic activity in both districts [13]. The Mwanga District is located between latitude 3° 25″ and 3° 55″ south of the equator and between longitudes 37° 25″ and 37° 58″ east of the Greenwich meridian [11]. The District receives a total annual rainfall ranging from 800 to 1250 mm in the highlands and 500 to 600 mm in the lowlands. On the contrary, the Same District lies between latitudes 4° 00′ to 4° 45′ to the south of the equator and longitudes 37° 30′ to 38° 15′ to the east. The District receives a total annual rainfall ranging from 500 mm to 800 mm [12].

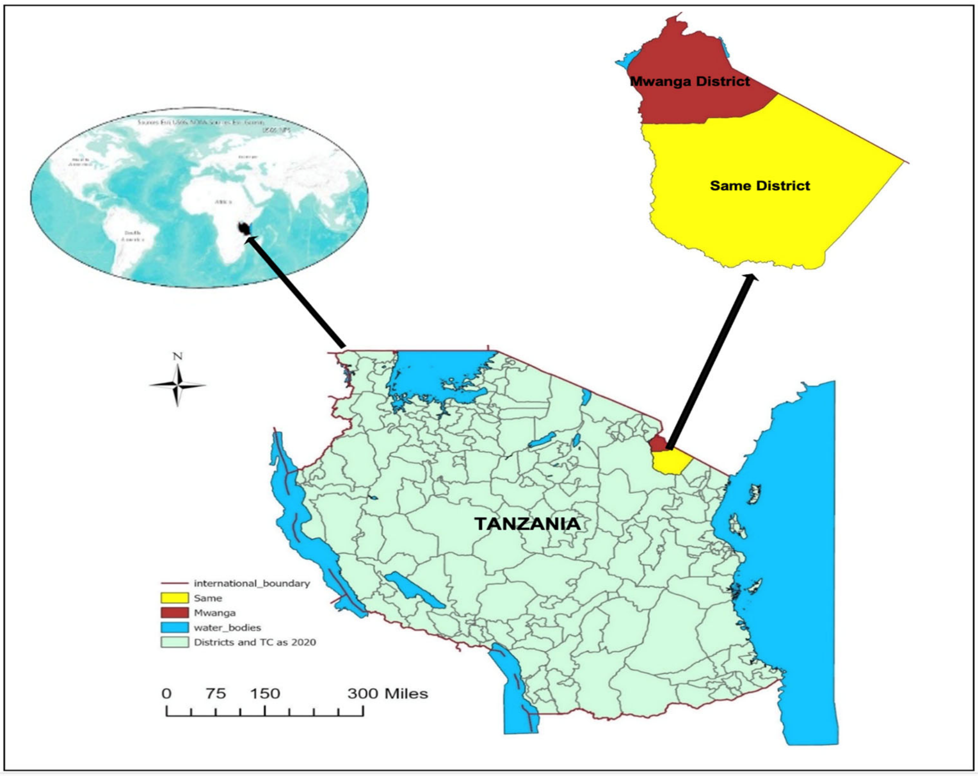

Figure 1. Tanzanian map showing Mwanga and Same Districts.

2.2. Sampling Procedures, Design and Size

Simple and purposive sampling procedures were used to obtain a sample for the study. A purposive sampling procedure was used to obtain key informants for face-to-face interviews and discussants for focus group discussions (FGDs). During the process, the Village Executive Officers were requested to help identify people with long experiences regarding village history; only those who had lived in the village for at least 15 years and above were considered for the face-to-face interviews and FGDs. In addition, factors such as being experienced and knowledgeable about farming activities and climate change adaptation strategies were considered. Furthermore, a purposive sampling procedure was used to select the study sites.

Four villages were selected, two from Mwanga and two from the Same District. In the Mwanga District, Kwakoa and Kigonigoni villages were selected, whereas, in the Same District, Ruvu and Mwembe villages were selected. Further, a simple random sampling technique was used to determine households for household surveys. The sampling procedure and process began by obtaining a comprehensive list of households in each selected village from the village households' book register to make up the sampling frame. After obtaining a list of households and identifying the population of each village, a sample size of about 50 households in each village was selected and identified from the population using a simple sampling technique (Table 1). In total, 200 households were selected for the household survey in this study. The determination of sample size (50 households in each village) was guided by the Tanzanian Local Government Act, 1982, which defines a village as an area with no less than 250 households and a population not exceeding 10,000 people. Additionally, a study by Boyd et al. (1981) suggested that a sample size of 5% is satisfactory under certain conditions, such as resource limitations and time. Moreover, village leaders were requested to help identify each village's sampled households.

Table 1. Sample size and design.

Study Site (District)	No. of Villages	Total Number of Households	No. of Sampled Households		FGDs		Participants in KII
			No.	%	Discussants	No. of FGDs	
Mwanga	Kwakoa	286	50	17.5	8	1	8
	Kigonigoni	253	50	19.8	7	1	9
Same	Mwembe	866	50	5.8	10	1	10
	Ruvu	924	50	5.4	14	1	9
Total			200		39	4	36

2.3. Data Collection

Data for this study were collected in two phases: in the first phase, data were collected through a questionnaire survey. Questionnaires were prepared and administered to 200 household heads (Table 1). The second phase of data collection involved FGDs and key informant interviews. Village leaders were requested to help to identify discussants for FGDs and participants for key informant interviews (KII) in each village. Topics discussed during the FGDs included the potential adaptation strategies that can help to increase food security and reduce poverty in the studied areas. Other issues addressed include each identified adaptation strategy's positive and negative aspects. Moreover, 36 participants were interviewed to understand potential adaptation strategies that can be used in the studied areas (Table 1). Additionally, participants were asked about the positive and negative aspects of each identified adaptation strategy.

2.4. Assessment of the Positive and Negative Interactions between Identified Adaptation Strategies and SDGs Indicators

The literature and expert judgement approaches were used to understand and assess the positive and negative interactions between the identified potential adaptation strategies and the selected indicators of SDGs (1: no poverty and 2: zero hunger). In an expert judgement approach, experts determine the interlinkages based on group discussions with the other experts or respondents [14]. If no agreement is reached, the interlinkages can be backed by scientific publications [14]. Further, [3] used the same approaches (literature and expert judgement) in assessing the nature of interactions between the energy SDG targets and non-energy-focused SDGs. In due regard, during the data collection (household survey, FGDs, and KII), the positive and negative aspects of each identified or perceived potential adaptation strategy toward achieving selected indicators (no poverty and zero hunger) were discussed (Figures 2 and 3). The process started by identifying the possible adaptation strategies perceived as necessary and undertaken at the household level. The next step was the identification of potential adaptation strategies through focus group discussions and key informant interviews. After gathering information on each adaptation strategy's positive and negative aspects, a seven-point scale of SDG interactions (Figure 4 and Table 2) presented in [3,7] was used to assess the linkages and interactions between identified adaptation strategies and selected SDG indicators. This framework was used because it emphasizes the role of critical contextual determinants such as governance, technologies, geographical contexts, time horizon, and policies in assessing interactions. The interactions may be either negative (constraining, counteracting, or cancelling) or positive (indivisible, reinforcing, or enabling) (see Table 2). Additionally, the interactions may be entirely consistent, indicating no significant positive or negative interactions [7].

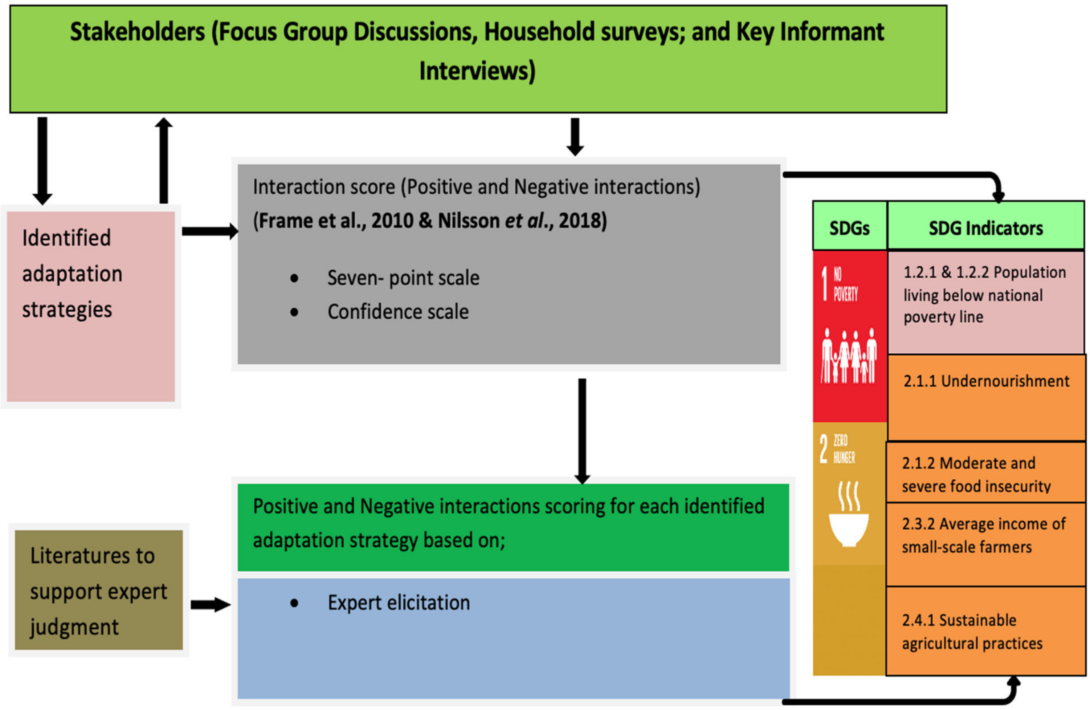

Figure 2. Scoring framework of the interactions. Source: Authors' developed research framework. Source: [3,15].

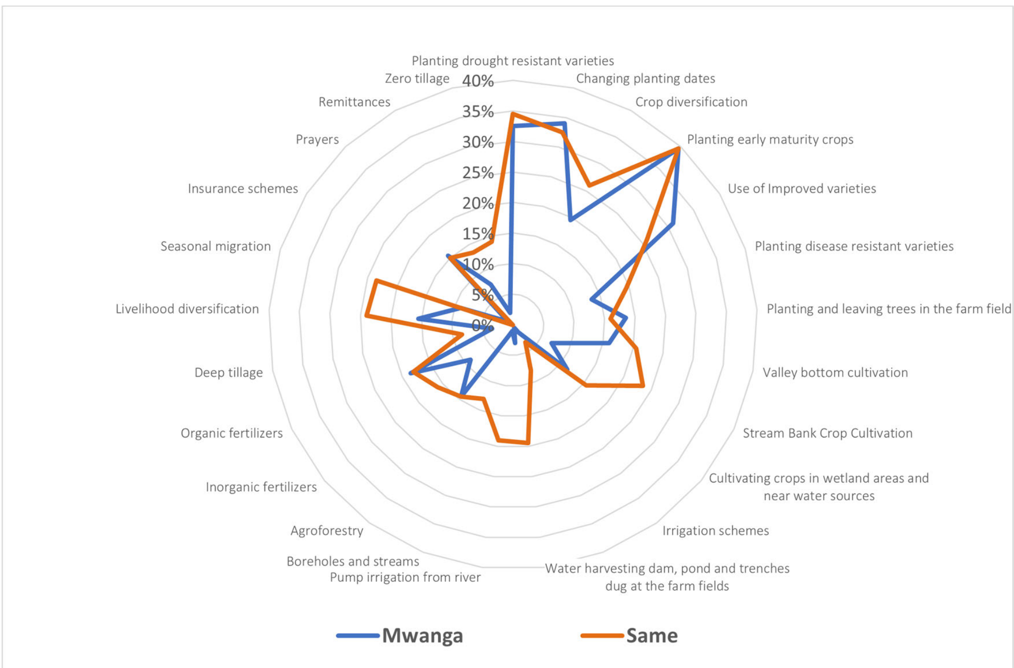

Figure 3. Identified potential adaptation strategies from the household survey. Source: Household survey, March to April 2022.

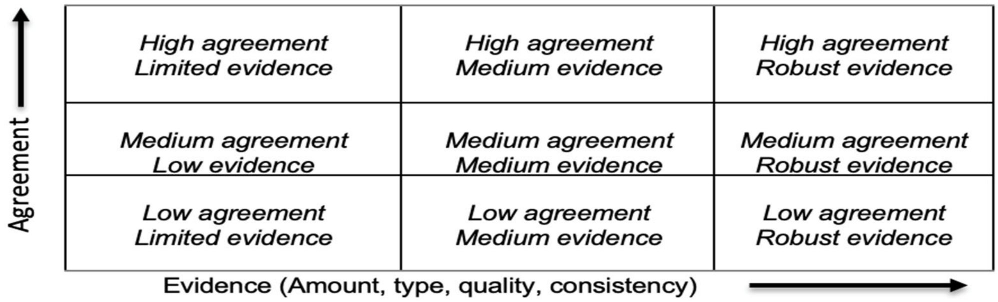

Figure 4. Confidence level of findings. Source: [3,15].

Table 2. A seven-point scale of SDG scoring assessment of the interactions. Source: Modified from [3].

Scoring Assessment	Meaning
+3: Indivisible	The strongest form of positive interaction in which progress on one goal delivers progress on another
+2: Reinforcing	Progress on one goal aids the achievement of another goal
+1: Enabling	Progress on one goal creates conditions that enable the achievement of another goal
0: Consistent	No significant positive or negative interactions
−1: Constraining	Progress on one goal constrains or limits options for the achievement of another goal
−2: Counteracting	Progress on one goal makes it more difficult to achieve another goal
−3: Cancelling	Progress in one goal makes it impossible to reach another goal and leads to negative impacts or a deteriorating state of another goal

The value of the interaction scores was determined based on expert elicitation (researcher judgement) using the information collected from focus group discussions, household surveys, and key informant interviews conducted in the studied villages (see Figure 2). Additionally, the interactions scoring exercise considered the level of robustness of evidence and the degree of agreement of the evidence from FGDs, KII, and household surveys. This was guided by an established approach provided by the 5th IPCC Assessment Report to assist all lead authors in consistently treating uncertainties across working groups [3,15] (see Figures 2 and 4). The guideline allowed researchers to make expert judgements in developing key findings by describing evidence quality, amount, consistency, and degree of agreement [15]. According to this guideline, the validity of results can be evaluated based on the evidence's amount, quality, type, and consistency (limited, medium, or robust) and the degree of agreement (low, medium, or high). The evidence is strong when there are consistent and multiple independent lines of high-quality evidence [3]. The interaction scoring was also supported by literature, allowing us to arrive at a measure of confidence in the scores. The study describes the validity of findings from the household survey, FGDs, KIIs, and literature by assessing the quality, amount, type, and consistency of the evidence supporting the results.

The SDG indicators assessed were 1.2.1 and 1.2.2, which are about reducing poverty below the national poverty line (no poverty). These indicators are intended to achieve target 1.2, "reducing at least by half the proportion of women, men and children of all ages living in poverty in all its dimensions according to national definitions by 2030". For SDG 2 (zero hunger), four indicators were selected; these include undernourishment (2.1.1), moderate and severe food insecurity (2.1.2), the average income of small-scale farmers (2.3.2), and sustainable agricultural practices (2.4.1). SDG indicators 2.1.1 and 2.1.2 are geared towards achieving target 2.1 (Ending hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious, and sufficient food all year round by 2030), indicators 2.3.2 (target 2.3) (double the incomes of small-scale food producers and agricultural productivity, in particular women, indigenous peoples, pastoralists, family farmers, and fishers including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment by 2030), and 2.4.1 (target 2.4) (To ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality by 2030).

The network theory was further used to analyze and provide quantitative insight into the degree of interactions (positive and negative) of an individual adaptation strategy with the selected indicators of SDG 1 and 2 (1: no poverty and 2: zero hunger) [16,17]. A network is a collection of nodes or vertices joined by edges (links) [17]. After scoring each identified adaptation strategy, networks indicating the positive and negative interactions between adaptation strategies and selected SDG indicators were generated using Gephi software (see Figure 2). Networks were weighted and directed to show the estimated interactions between potential adaptation strategies (direction) and SDGs with different strengths (weight) (Figures 5 and 6). Edges with different weights (strengths) were used in this study to show the interactions between adaptation strategies and selected SDG indicators. The higher the weight of the edge, the stronger the interaction. For example, in Figure 5, the higher weight means more positive interactions of a specific adaptation strategy with SDG indicators. Further, in Figure 6, the higher weight indicates more negative interactions of a specific adaptation strategy with the selected SDG indicators.

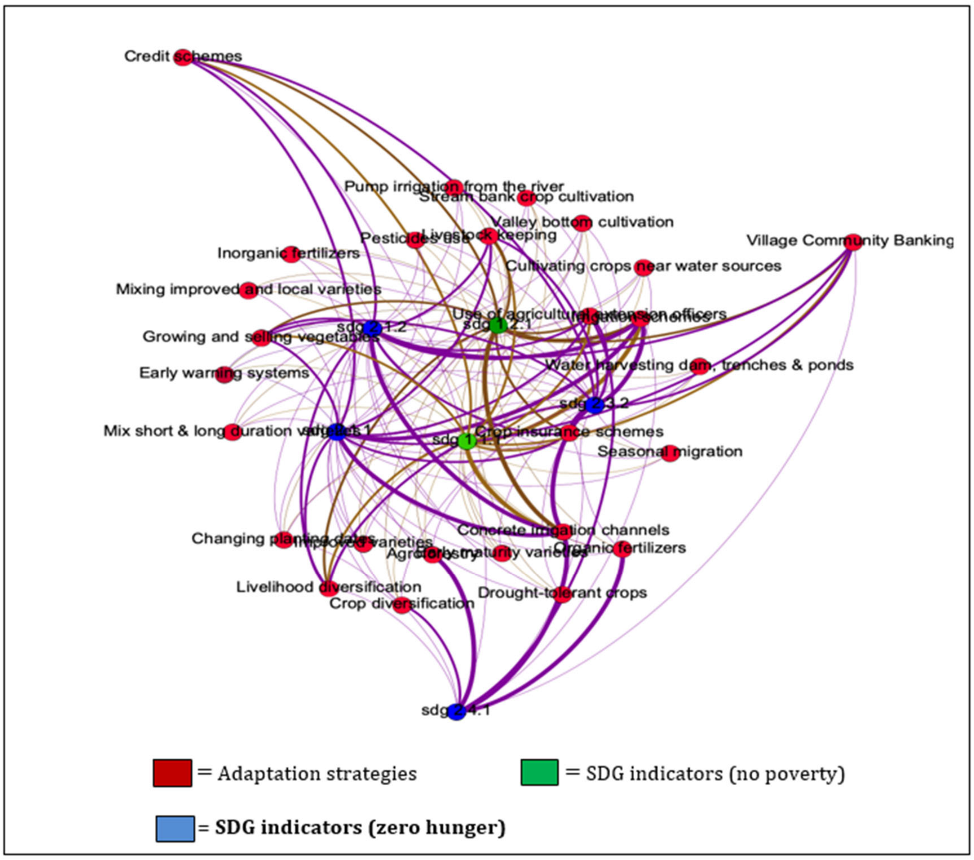

Figure 5. Positive interactions between identified potential adaptation strategies and selected SDG indicators of no poverty and zero hunger. Note: Edge weights; (Enabling, +1), (Reinforcing, +2), and (Indivisible, +3).

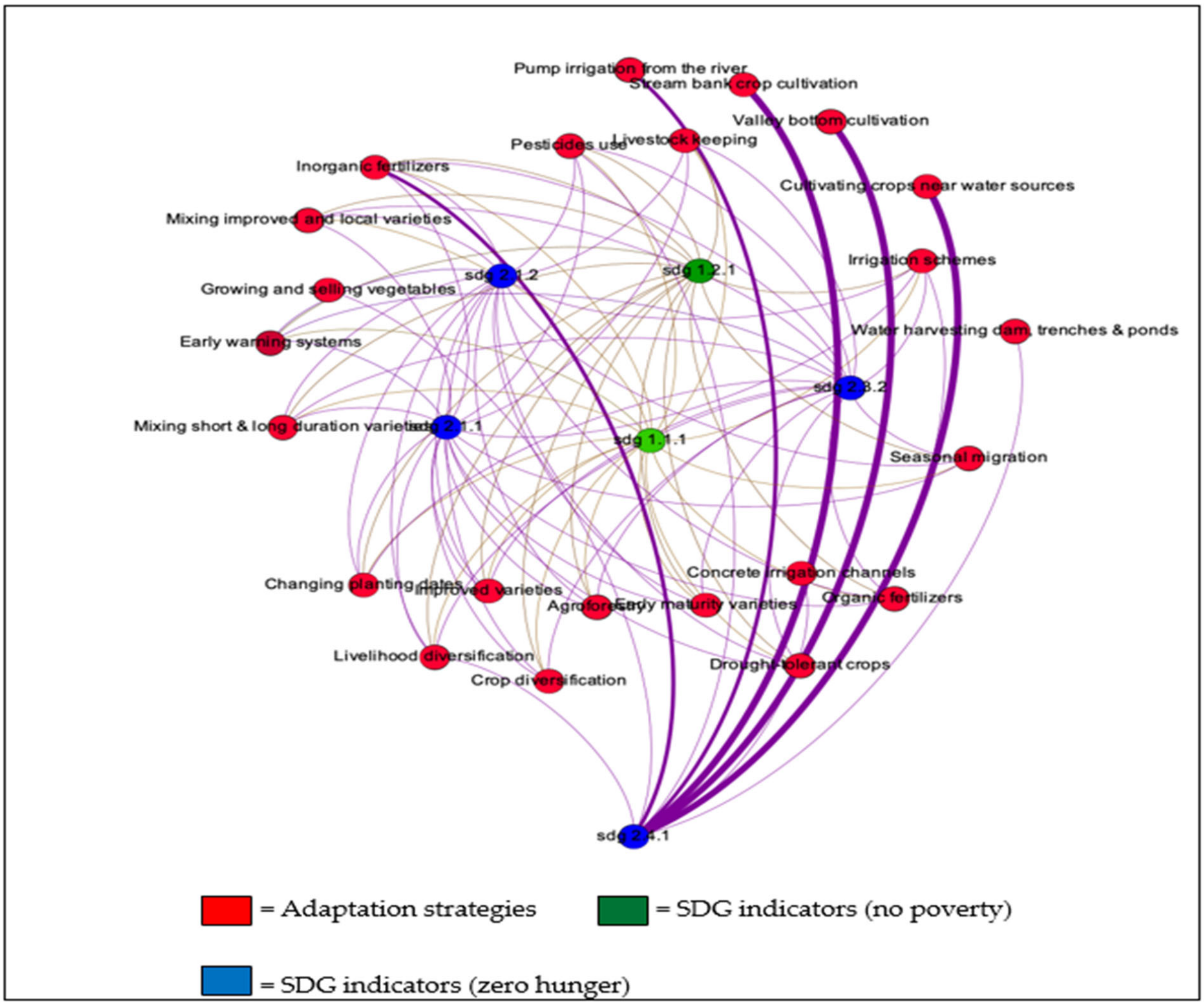

Figure 6. Negative interactions between identified potential adaptation strategies and selected SDG indicators of no poverty and zero hunger. Note: Edge weights; (Constraining, −1), Counteracting (−2), and Cancelling (−3).

3. Results

Identified Potential Adaptation Strategies for Farmers in the Study Areas

The results (see Figure 3) show adaptation strategies perceived as necessary and undertaken at the household level. Results further indicate that about 79% of the surveyed households employed early maturity crops as potential adaptation strategies to climate change impacts, followed by planting drought-tolerant varieties (67%) and changing planting dates (67%). Other strategies include the use of improved varieties (57%), crop diversification (46%), livelihood diversification (40%), valley bottom crops cultivation (37%), organic fertilizers (37%), stream bank crop cultivation (31%), and planting and leaving trees in the farm fields (35%). Some adaptation strategies were related to water and soil management practices; these include practices such as irrigation schemes (5%), water harvesting dams, ponds and trenches (23%), pump irrigation from the river (20%), boreholes and streams (15%), agroforestry (29%), and inorganic fertilizers (25%). Additionally, results in Table 3 indicate adaptation strategies perceived as necessary for farmers from focus group discussions and key informant interviews. More adaptation strategies (i.e., joining village community banking groups, mixing both improved and local varieties, livestock keeping, and mixing both short and long-duration crop varieties), which should have been revealed during the household survey, are provided in Table 3.

Table 3. Identified possible adaptation strategies from FGDs and KII in the studied areas.

Potential Adaptation Strategies	Mwanga				Same			
	Kwakoa		Kigonigoni		Mwembe		Ruvu	
	FGD	KII	FGD	KII	FGD	KII	FGD	KII
• Joining Village Community Banking groups (VICOBA)		√			√	√	√	√
• Use of agricultural extension officers	√	√	√	√		√	√	
• Early warning systems	√	√	√					
• Pesticides use	√	√	√	√	√	√	√	√
• Irrigation schemes	√	√	√		√	√	√	√
• Construction of concrete irrigation channels	√	√	√		√		√	√
• Inorganic fertilizer use	√	√	√	√	√	√	√	√
• Organic fertilizer use	√		√	√	√	√		
• Livestock keeping	√		√		√	√	√	√
• Growing and selling vegetables					√	√	√	√
• Mixing both short- and long-duration crop varieties	√	√	√		√		√	
• Mixing both improved and local varieties	√	√	√	√	√	√	√	√
• Planting drought-tolerant crops	√	√	√	√	√	√	√	√
• Planting early maturity varieties	√	√	√	√	√	√	√	√
• Use of improved varieties	√	√	√	√	√	√	√	√
• Crop diversification	√	√	√	√	√	√	√	√
• Changing planting dates	√		√	√	√	√	√	√
• Livelihood diversification	√	√	√	√	√	√	√	√
• Crop insurance schemes		√		√	√	√	√	√
• Agroforestry	√	√	√	√		√	√	√
• Water harvesting dam, pond, and trenches in the farm field	√	√					√	√
• Pump irrigation from the river		√					√	√
• Credit schemes	√	√	√	√	√	√	√	√
• Seasonal migration					√	√	√	√

4. Discussion

The findings of this study (see Figures 5 and 6; Table 4) indicate that most of the identified potential adaptation strategies (i.e., planting drought-tolerant crops, early maturity crops, changing planting dates, use of improved varieties, and crop diversification) are enabling (+1) strategies to increase households' food security (SDG 2.1.2) and the average income of small-scale farmers (SDG 2.3.2). They are also helping poverty reduction (SDG 1.1.1 and 1.2.1) and reducing undernourishment (SDG 2.1.1). Additionally, strategies such as crop diversification can improve soil and water quality, enhance carbon sequestration, and reduce loss of biodiversity, the pattern that contributes to sustainable agricultural practices (SDG 2.4.1). Further, these strategies may also constrain (−1) the achievement of households' food security (SDG 2.1.2), the income of small-scale farmers (SDG 2.3.2), poverty reduction (SDG 1.1.1 and 1.2.1), and reducing undernourishment (SDG 2.1.1) (see Figure 6 and Table 4). Despite the importance of these strategies, they may not be effective during the severe decline in rainfall [9]. For example, during the household survey, some farmers complained that they planted early-maturity crops, but they dried up due to a lack of rain. Other studies, including [18,19], showed that adaptation strategies (i.e., improved varieties, early maturity crops, and drought resistance crops) used by farmers in Ghana and Ethiopia, respectively, were not effective during times of extreme climate events, and [18] further showed that farmers could not achieve better yields during droughts despite using fertilizers and pesticides. Additionally, a study by [6] revealed that adaptation strategies (i.e., changing planting dates, crop diversification, early maturity crops, and improved varieties) used by smallholder farmers in the Amathole District in South Africa were insufficient to lessen the impacts of climate change. Even though these adaptation strategies can reduce the impacts of climate change on agricultural productivity, water is still essential to get better yields [18]. These strategies work better in wet soils. During the FGDs, key informant interview participants revealed that improved crop varieties (i.e., maize varieties) were more vulnerable to crop pests and diseases than local varieties. It was further added that the costs of enhanced seeds were reported to be high, which many farmers could not afford.

Additionally, the use of organic and inorganic fertilizers in the study areas is an enabling (+1) strategy to increase crop yields and agricultural productivity, which may enhance households' food security (SDG 2.1.2), poverty reduction (SGD 1.1.1 and 1.2.1), and income (SDG 2.3.2) (see Figure 6 and Table 4). These strategies can also constrain (−1) income of small-scale farmers, households' food security (SDG 2.1.2), poverty reduction (SDG 1.1.1 and 1.2.1), and undernourishment reduction (SDG 2.1.1) as they may still need water to work better. Moreover, the use of inorganic fertilizers can also counteract (−2) achieving sustainable agricultural practices (SDG 2.4.1) (see Figures 4 and 6). Several studies, such as [20–22], have shown that the excessive use of inorganic fertilizers can cause serious environmental problems such as loss of biodiversity, increased greenhouse gas emissions, soil acidification, and eutrophication of water bodies. Inorganic fertilizers can also increase the resistance development of crop pests, weeds, and diseases and change soil pH. The overuse of inorganic fertilizers can lead to the accumulation and absorption of heavy metals by plant tissues, which, in turn, reduces the nutritional and quality of crops [20].

Strategies such as crop insurance schemes (+2), joining community banking groups (+2), livelihood diversification (+2, −1), and credit schemes can reinforce food security (SDG 2.1.2), income (SDG 2.3.2), and agricultural production by securing capital (Figures 4 and 6). Insurance can buffer the financial implications of unintended crop failure due to extreme events such as floods and droughts [23]. Credit schemes can help farmers access farm inputs (e.g., improved varieties and pesticides) and irrigation technology and diversify their livelihood activities [24]. Irrigation schemes (+3, −1) show a strong positive interaction (indivisible) with agricultural productivity, food security (SDG 2.1.2), poverty reduction (SDG 1.1.1 and 1.2.1), and income (SDG 2.3.2) (see Figure 5). An irrigation system can make crop production possible even in areas where rainfall is insufficient, like semi-arid areas. However, it is important to note that if irrigation schemes are not well managed, they can accelerate salinization and soil sodification, which puts environmental sustainability at risk (SDG 2.4.1) [20]. On the other hand, agroforestry (+3, +1, −1) shows a strong positive interaction with the sustainable agricultural practice indicator (SDG 2.4.1). Agroforestry can improve soil fertility, enhance system resilience to climate change, reduce greenhouse gases, and maintain biodiversity on farmland (SDG 2.4.1) and the patterns that increase agricultural productivity and households' income (SDG 2.3.2), food security (SDG 2.1.2), and poverty reduction (SDG 1.1.1 and 1.2.1). Despite the importance of agroforestry, they still need water to provide better yields [9]. Hence, they may still offer limited additional benefits during times of severe decline in rainfall leading to food insecurity (SDG 2.1.1 and 2.1.2), a decrease in households' income (SDG 2.3.2), and an increase in poverty (SDG 1.1.1 and 1.2.1) [25]. Furthermore, adaptation strategies such as valley bottom crop cultivation (+1, −3), stream bank crop cultivation (+1, −3), and cultivating crops in wetlands and near water sources (+1, −3) are cancelling (−3) strategies, which show a strong negative interaction with the sustainable agricultural practices (SDG 2.4.1) (see Figure 6). These strategies can be a source of water pollution and drying up of water resources, exacerbating the vulnerability of the natural and human systems [25,26]. For example, farming activities near water sources in the highland areas in Kwakoa village reportedly reduced water availability for farming activities in the lowland areas. Additionally, farming activities near the river Ruvu in Ruvu village were reportedly accelerating riverbank erosion and sedimentation of the river Ruvu. This situation has been contributing to the river's overflow, leading to floods. Despite their impacts on the environment, they can ensure continued agricultural productivity even during low rainfall seasons leading to increased income (SDG 2.3.2), food security (SDG 2.1.1 and 2.1.2), and poverty reduction (SDG 1.1.1 and 1.2.1).

Table 4. Interactions between adaptation strategies and SDGs indicators (1: no poverty and 2: zero hunger).

Potential Adaptation Strategies	SDG Indicators	Score	Evidence	Agreement	Confidence
◦ Planting drought-tolerant crops	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Robust	High	Very high
◦ Planting early maturity varieties	2.1.1, 2.1.2, 2.4.1	(+1, −1)	Robust	High	Very high
◦ Use of improved varieties	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Medium	Medium	High
◦ Crop diversification	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2, +1, −1)	Robust	High	Very high
◦ Changing planting dates	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Medium	High	High
◦ Inorganic fertilizers	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1, −2)	Robust	High	Very high
◦ Organic fertilizers	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+3, +1, −1)	Robust	High	Very high
◦ Livelihood diversification	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2, −1)	Robust	Very high	Very high
◦ Crop insurance schemes	1.1.1, 1.2.1, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2)	Limited	Low-medium	High
◦ Irrigation schemes	1.1.1, 1.2.1, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+3, −1)	Robust	High	High
◦ Agroforestry	1.1.1, 1.2.1, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+3, +1, −1)	Medium	High	high
◦ Cultivating crops in wetland areas and near water sources	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −3)	Robust	High	High
◦ Water harvesting dam, pond, and trenches in the farm field	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Robust	Very high	High
◦ Pump irrigation from the river	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −2)	Limited	Medium	High
◦ Valley bottom cultivation	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −3)	Robust	High	Very high
◦ Stream bank crop cultivation	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −3)	Robust	Very high	Very high
◦ Credit schemes	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2)	Medium	High	High
◦ Seasonal migration	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Medium	High	High
◦ Joining Village Community Banking groups (VICOBA)	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2)	Medium	High	High

Table 4. *Cont.*

Potential Adaptation Strategies	SDG Indicators	Score	Evidence	Agreement	Confidence
○ Use of agricultural extension officers	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2)	Medium	Very high	High
○ Early warning systems	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Limited	Medium	High
○ Pesticides use	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1, −2)	Robust	High	Very high
○ Construction of concrete irrigation channels	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+3, −1)	Robust	High	High
○ Livestock keeping	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2, −1)	Robust	Very high	Very high
○ Growing and selling vegetables	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+2, −1)	Very high	High	High
○ Mixing both short- and long-duration crop varieties	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Medium	Medium	High
○ Mixing both improved and local varieties	1.2.1, 1.2.2, 2.1.1, 2.1.2, 2.3.2, 2.4.1	(+1, −1)	Medium	Medium	High

5. Conclusions

This study investigated the potential adaptation measures for farmers in the Mwanga and Same Districts of Tanzania through a multi-stakeholder participatory approach and then assessed their positive and negative interactions toward potential contributions to the selected SDG indicators of no poverty and zero hunger. The findings of this study indicate that most of the perceived potential adaptation strategies (i.e., early maturity crops, planting drought-resistant crops, changing planting dates, use of improved varieties, mixing improved and local varieties, and mixing short and long duration varieties), which were also reportedly used by many farmers, are both enabling (+1) and constraining (−1) strategies. Even though these adaptation strategies can reduce the impacts of climate change on agricultural productivity, the importance of other adaptation strategies (i.e., concrete irrigation channels, extension officers, irrigation schemes, and credit facilities) must be addressed for better yields and positive impacts. In due regard, climate change adaptation planning and projects in the studied areas should consider all these factors during the implementation.

Based on these findings, it is clear that achieving SDGs (1: no poverty and 2: zero hunger) in the studied areas will require the integration of various adaptation strategies that complement each other, not by promoting only strategies used or suggested before. In due regard, there is a need for policies and measures that strengthen the integration and interactions of different adaptation strategies. For example, the emphasis on using improved varieties and crop diversification should be complemented by access to credit schemes, irrigation infrastructures, crop insurance, and extension services at the village level. Additionally, there is a need for continuous learning, monitoring, and evaluation of the suggested potential adaptation strategies to help make periodic adjustments to the adaptation strategies to accommodate socio-economic and climate conditions.

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