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Climate Risk Management in Agro-Pastoral Systems of Central and Northern Tanzania: Costs and Benefits of Local Adaptation

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

In Tanzania, agro-pastoral practices have been adapted to climate change for several years. However, the economic benefits and costs of adaptation techniques for agro-pastoralists have not been well documented. Therefore, this paper analyses the economic benefits and costs of adaptation strategies to climate change and variability. The analysis used primary data collected from 411 agro-pastoral households randomly selected from 22 villages in five districts in northern and central Tanzania. Net present value, benefit-cost ratio and internal rate of return were calculated to determine the benefit-cost analysis of adaptation strategies. The planned adaptation strategies were found to be financially viable compared to business-as-usual practices. Sensitivity analysis also showed that maize-sunflower intercropping was viable, while maize-bean intercropping was more sensitive to a 10% change in yield. In addition, drip irrigation and micro-catchment rainwater harvesting have the potential to contribute to climate risk management in these dryland areas by minimising water use and maximising output per hectare; the main

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challenge is the high initial capital cost. There is therefore a need for extension agents to continue to promote crop and livestock diversification among agro-pastoralists in managing climate risks to reduce their vulnerability to climate change and variability. In addition, research and development (R&D) practitioners need to promote and capacitate agro-pastoralists in drip irrigation and micro-catchment rainwater harvesting adaptation strategies.

Keywords: Sensitivity analysis; net present value; internal rate of returns; economic viability.

1. INTRODUCTION

Smallholder agro-pastoralists in semi-arid regions face difficulties in achieving high agricultural production due to a number of factors, including the impacts of climate change [1]. Climate change projections suggest that the frequency and severity of extreme weather events will increase significantly, potentially exceeding current levels of adversity (Bouwer, [2], Eckstein et al., [3]. This calls for the strengthening of climate information and early warning systems to improve the ability of agro-pastoral communities to adapt to different types of climate extremes. Temperature and rainfall play a central role in the weather and climate conditions that affect crop and livestock production in semi-arid regions. In the northern and central regions of Tanzania, rising temperatures have increased evaporation rates, reduced soil moisture, and negatively affected crop growth. In addition, there has been a downward trend in rainfall in these areas. This reduction in rainfall due to climate change has had a profound impact on the adaptation strategies of agro-pastoralists in semi-arid regions.

Adaptation to climate change is essential to improve society's ability to cope with and respond to the challenges of climate change. It is a critical aspect of climate change risk management [4], particularly in the African context. Efforts to promote the use of drought-resistant crops to improve food security and implement other adaptation strategies to enhance agro-pastoral livelihoods have been met with resistance in certain regions where maize production is favoured (Ires, [5], USAID, [6]. Shemsanga et al., [7]. Nevertheless, a minority of farmers have adopted alternative livelihood strategies in response to climate change and variability. These strategies include selling livestock, practicing mixed cropping, adopting new crop and livestock varieties, implementing rainwater harvesting techniques, and growing irrigated vegetables (Bongole et al., [8], Aniah et al., [9], Shongwe et al., [10]. These strategies can vary in duration, being either short-term or long-term, and can be driven by private or public initiatives [11]. The persistence of poverty and food insecurity is a major contributing factor, as many people continue to rely on food aid during droughts. As a result, agro-pastoralists in the semi-arid regions of northern and central Tanzania remain highly vulnerable to the impacts of climate change. In addition, an assessment of diversification portfolios has shown that farmers can mitigate climate change risks by diversifying their crop and livestock enterprises as part of their adaptation strategies Sewando, [12], Nicol et al., [13].

However, the economic viability of these adaptation strategies remains uncertain. Consequently, there is an urgent need to assess the effectiveness of some of these strategies and to gather data that can be used by policymakers and development practitioners to provide guidance to agro-pastoralists. Against this background, this paper aims to assess the viability of adaptation strategies and ultimately identify the most economically viable and practical approaches being adopted by farmers in northern and central Tanzania.

Climate adaptation strategies can be categorised as either 'autonomous' or 'planned'. Autonomous adaptation occurs organically, without deliberate intervention by a well-informed decision-maker. In contrast, planned adaptation involves deliberate, strategic actions driven by the recognition that the climate is changing and requires proactive responses [14]. Furthermore, IPCC [15] and Stern [16] highlight that adaptation can be either 'reactive' or 'proactive', depending on the timing, objective, and motive of its implementation. Reactive adaptation takes place after the impacts of climate change have occurred, while proactive adaptation takes place before the impacts become apparent. Therefore, autonomous adaptation is reactive, while planned adaptation can be both reactive and proactive. In the process of implementing a strategy, whether autonomous or planned, farmers are confronted with three different types of costs related to the effects of climate change: direct costs, indirect costs, and adaptation costs [13].

1.1 Theoretical Framework

The expected utility theory provides guidance on how rational people ought to make decisions, not how they are made today [17]. Descriptive theory, a theory on how people actually behave, can give insights into decision makers' behaviour and limitations, but such a theory does not replace the normative theory. It provides little tangible guidance for attacking new and specific decision problems of some complexity [17]. Hence, a method, a prescriptive tool, which provides a consistent procedure to process the elements of the decision problem and aids in making a decision, is required. Such tools are often identified with the normative theory.

The expected utility (EU) theory can be seen as such a tool and is recognized by many as a good framework for making decisions, as its assumptions and coherency are hard to disagree with in principle. The theory not only applies to individual choices but also to ethical decisions, for instance, in cost-benefit analysis of climate change policy measures that affect future generations [18]. The Theory still provides the standard theoretical tool for cost-benefit analysis under conditions of risk which, in the context of exclusively environmental economics to climate change, is used to assess whether or not adaptation strategies to climate change are economically beneficial [19].

In this paper the EU theory is extended to cost-benefit analysis to guide decision making under risky situations, because normally farmers who are risk averse attach a high discount rate on expected future returns under risky situations. Cost-benefit analysis weighs harms and benefits that come at different times. Most such analyses, as practiced by economists, adopt a rate of discount. Using a discount rate is a way of counting future harms and benefits for less than similar harms and benefits in the present [20.].

A big challenge in this analysis is the selection of discount rate. Hence, important difference must be marked between private investments (which are for profit above the prevailing market interest rate) and investments in public goods such as dams, roads, canal construction or emergency services. Indeed, public adaptation investments are typically meant to maximise not just economic but also the social and environmental benefits and therefore cannot be compared to private investments [19].

Therefore, a social discount rate (SDR) may be appropriate for public investments which are concerned with adaptation to climate change. Social discount rates are typically lower than financial discount rates as the purpose of these investments is not to compete with stock-market or other market based rates of return. Social discount rates for climate change have been suggested in the range of 1 to 6% (ADB 2013) for a detailed discussion on different approaches of calculating the SDR). For instance, the "Stern Report" proposes a SDR of 1.4% for assessing the costs of climate change for present and future generations. Other economists such as Nordhaus [21] recommend for the use of SDR of 5.5%.

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in five semi-arid districts in the northern and central zones of Tanzania. The districts were Arusha, Mwanga, Babati (northern zone), Kongwa, and Ikungi (central zone). These districts were selected as semi-arid agro-pastoral areas highly affected by climate change. The study used primary data collected from a random sample of 411 agro-pastoralists in northern and central Tanzania. A multistage sampling technique was used. The first stage involved purposive sampling of five regions, namely Kilimanjaro, Arusha, Manyara, Dodoma, and Singida in the northern, and central zones of Tanzania. To obtain a representative sample, the selection of the sample regions was influenced by the density of the livestock population and the semi-arid nature of the regions where agro-pastoralism (crop and livestock farming) is practiced. In the second stage, one district was selected from each region using the same criteria. The districts were Mwanga (Kilimanjaro), Arusha (Arusha), Babati (Manyara), Kongwa (Dodoma) and Ikungi (Singida). The third stage of sampling involved the selection of 22 villages based on the same criteria. The number of villages selected from each district. Thus, a sample of 411 agro-pastoralists was interviewed from the central and northern zones.

2.2 Data Collection and Processing Analysis

Data were collected using a structured questionnaire and key informant interview guide (checklist). The tool was used to collect information on the respondents' socio-economic and institutional characteristics, adaptation strategies used, perception, and costs and revenue attached to these strategies. In addition, a key informant interview guide was used to collect information from key informants including the livestock extension staff, village leaders, and progressive agro-pastoralists who adopted modern technologies in adapting to climate change and kept records on the fixed and operational costs and revenue collected from their enterprises. Such technologies included drip irrigation and rainwater harvesting.

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The data collected were coded, entered, cleaned, and analysed using Statistical Package for Social Sciences software. Information on adaptation strategies was identified or loaded by factor analysis and adopted as the main adaptation strategies. These strategies included crop diversification, rainwater harvesting, irrigation, livestock diversification, and off-farm activities. The information on these adaptation strategies was entered into Microsoft Excel for CBA calculations of climate change adaptation strategies as planned adaptations. The planned adaptation strategies were compared with the business-as-usual (autonomous) adaptation strategies.

Working capital and sales were projected for 10 years. The depreciation of fixed assets was estimated using the sum of the year's digits (SYD) method, discounting the values by 15% for the adaptation strategies, while a discount rate of 20% was used for small irrigation schemes in estimating the BCR, NPV, and IRR as specified in the analytical framework. The study then created a set of scenarios to determine how changes in one variable would affect the target variable. Such scenarios were "What if the cost of production increased by 5 to 20%" and "What if the yield of crops and livestock decreased by 5 to 20%" for sensitivity analysis [22].

2.3 Analytical Framework

Adaptation to climate change, and in particular the valuation of adaptation strategies, has received increasing attention in scientific and policy debates over time [23]. Various economic methodologies have been developed to identify and value options. Niang-Diop and Bosch [24] suggest three main techniques to be used in the economic assessment of climate change adaptation options: cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), and multi-criteria analysis (MCA).

From a purely economic perspective, CBA is preferred whenever possible for the assessment of climate change adaptation options [25]. The technique is also widely used for this purpose (Hallegatte et al., [26], Chambwera and Stage [27]. A CBA is essentially a comparison of the costs and benefits of an intervention over time [28]. However, the main limitation of a CBA is that all costs and benefits must be measurable in monetary terms [23].

CBA focuses on the quantitative assessment of climate change impacts on crops, allows estimation of the net benefits of different adaptation options, and is used to evaluate adaptation options when efficiency is the only decision criterion (Shongwe et al., 2013). The approach identifies and ranks the most economic adaptation strategies on the basis of economic efficiency. NPVs are preferred because they determine whether an adaptation strategy will result in a net gain or loss, while IRRs are used to evaluate the most economically viable adaptation strategy. The economic viability indicators of adaptation strategies are BCR, NPV, and IRR. The BCR is a numerical ratio that expresses the total discounted benefits relative to the total discounted costs. A BCR equal to or greater than 1 indicates that the benefits of the adaptation measure are equal to or greater than its costs. The Benefit-Cost Ratio was estimated as:

$$BCR = \frac{\sum_{t=1}^{n} R_t \frac{1}{(1+r)^t}}{\sum_{t=1}^{n} C_t \frac{1}{(1+r)^t}} \quad \text{......... (1)}$$

On the other hand, the net present value is the difference between the discounted total benefits and the discounted total costs. This has also been used to estimate the benefits of climate change adaptation strategies. A positive NPV indicates that the adaptation measure is cost-effective and will pay for itself over time. A high NPV indicates the most efficient and cost-effective adaptation strategy. Its formula is:

$$NPV = \sum_{t=1}^{n} R_t \left(\frac{1}{(1+r)^t} \right) - \sum_{t=1}^{n} C_t \left(\frac{1}{(1+r)^t} \right) \ldots \quad (2)$$

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$$IRR = \sum_{t=1}^{n} R_t \left(\frac{1}{(1+r)^t} \right) - \sum_{t=1}^{n} C_t \left(\frac{1}{(1+r)^t} \right) = 0 \cdot\cdot \quad (3)$$

where:

NPVs = Net Present Value of an adaptation practice (Tanzanian Shillings)

BCR = Discounted BCR of the practice

R_t = revenue in year t (Tanzanian Shillings)

C_t = costs in year t (maintenance plus production costs) (Tanzanian Shillings)

r = discount rate

$t \ldots n$ = year t to n^{th} of the adaptation strategy time horizon.

The cost-benefit analysis does not capture potential changes in the factors that alter the profitability of firms (does not take into account risks and uncertainties). NPV, IRR and BCR are subject to change with changes in market prices of inputs and outputs [22]. In order to test whether our results would remain stable or be subject to shocks resulting from price changes, sensitivity analysis was recommended. Sensitivity analysis is a systematic method of examining how the outcome of the benefit-cost analysis changes with variations in input prices, assumptions or the way the analysis is set up. Sensitivity analysis identifies the 'critical' variables of the adaptation strategy. Such variables are those whose variations, either positive or negative, have the greatest impact on the financial and/or economic performance of the adaptation strategy [29].

Therefore, financial indicators such as benefit-cost ratio (BCR), net present value (NPV), internal rate of return (IRR), and sensitivity analysis were estimated to assess the economic benefits of these methods. Adaptation strategies with high BCR and NPV are considered efficient. The adaptation strategy with the highest IRR is the most economic approach. The sensitivity analysis identified the most resilient adaptation strategy to shocks such as policy changes and severe climate events. The following considerations were explicitly taken into account in the benefit-cost analysis: -

First, the choice of evaluation criteria: for small projects, the NPV, BCR, and IRR of such adaptation strategies (i.e., crop diversification, water harvesting, irrigation, and livestock diversity) among smallholder agro-pastoralists were calculated as measures of the value of adaptation strategies.

Second, the discount rate: The issue of discount rate is highly debated (Senkondo et al., [22], Patel and Daykin, [30]. For the purpose of analysing farm-level adaptation strategies, market/private interest rates have typically been used. In general, interest rates between 8% and 15% are considered in many investment calculations (ADB, 2013). In this study, a discount rate of 15% was used. This is considered to be the opportunity cost of capital in Tanzania and is suggested by the World Bank and the Bank of Tanzania (BOT, 2014). However, since under climate change, agro-pastoralists who are risk averse usually apply high discount rates to expected future returns, a discount rate of 15 and 18% was also used in the sensitivity analysis [22].

Third, time horizon: This study used a time of 10 years, after which the Rain water harvesting and drip irrigation structures will need to be reconstructed or undergo major rehabilitation [31], Senkondo et al., [22]. The time horizon (10 years) also coincides with the end year of the Tanzania Development Vision 2025 (TDV).

3. RESULTS AND DISCUSSION

The distribution of sampled population on the adaptation strategies in the northern and central semi-arid agro-ecological zones where the study was conducted indicates that there was a low percentage of agro-pastoralists who had adopted the widespread adaptation technologies. Table 1 shows that only 18.7% and 5.8% of agro-pastoralists from the northern and central zones, respectively, had adopted livestock diversification as an adaptation option to climate change. Crop diversification was practised by 29.2% from the central zone and 10.2% from the northern zone. Agro-pastoralists in the northern zone are better at diversifying livestock than those in the central zone. However, agro-pastoralists in the central zone were better at crop diversification than those in the northern zone.

3.1 Financial Viability of Agro-Pastoralists Adaptation Strategies

The decision on when to adapt depends on the costs of adaptation in different time periods, the short-term benefits of adaptation, and the long-term effects of early adaptation (OECD, 2008). Costs are likely to be higher in the short term and decrease over time, while benefits may only accrue in the medium to long term. A CBA was conducted for each of the selected adaptation strategies for agro-pastoralists in northern and central Tanzania.

3.1.1 Crop diversification strategy

The crop diversification adaptation and specialised system analyses were carried out for maize production and the results are presented in Table 2. The net present value (NPV) for crop diversification maize intercropped with legumes (beans) and specialised maize was positive. This indicates that the present value of the benefits exceeds the discounted present value of the costs. The benefit-cost ratios are all greater than an IRR and greater than the opportunity cost of capital, which is 15%. However, the BCR, NPV, and IRR for crop diversification are higher than those for the specialised system, indicating that among the two scenarios, the crop diversification adaptation strategy is more viable than the specialised system.

3.1.2 Drought tolerant versus conventional crops

The cultivation of drought-resistant crops (sorghum and finger millet) is one of the climate change adaptation technologies being disseminated to farmers in the study areas. However, the technology was found to be more widely practiced in Kongwa and Ikungi (Central Tanzania) than in Northern Tanzania. The adaptation strategy of planting drought-tolerant crops was more viable than the business as usual (BAU) practice (planting conventional maize and finger millet).

Nevertheless, the sorghum and finger millet enterprises were found to be economically viable compared to growing conventional maize because their NPVs were positive and higher than growing conventional maize. Table 3 shows that the NPV of the sorghum enterprise was TZS 48 754.90 while that of the finger millet enterprise was TZS 214 414.80. The IRRs for sorghum and finger millet were 20% and 42% respectively.

3.1.3 Micro catchment rainwater harvesting versus rainfed system

The cost differential suggested high investment in irrigation and RWH systems as opposed to the rain-fed system. The micro-catchment rainwater harvesting (MCRWH) system is commonly used in the study area. Other typologies commonly used by agro-pastoralists in the study area are in situ and macro catchment RWH. The MCRWH system consists of a catchment area that collects runoff water from roofs or ground surfaces and a cultivated area that receives and concentrates runoff from the catchment area for crop water supply Nicol et al., 2015; Hatibu and Mahoo, [32].

Table 1. Distribution of agro-pastoralists in the adaptation strategies by zones

Strategy	Central	Northern
Livestock diversification	24 (5.8%)	77 (18.7%)
Diversifying from farm to non-farm activity	35 (8.5%)	51 (12.4%)
Increased use of irrigation/groundwater / watering	32 (7.8%)	35 (8.7%)
Water harvesting schemes	65 (15.8%)	22 (5.4%)
Planting drought-resistant crops/ intercrop	120 (29.2%)	42 (10.2%)

Table 2. Production (kg/ha), Cost, and benefits (TZS/ha) of the crop diversification versus specialized system

Measures	Crop diversification (Maize and beans)	Crop diversification (Maize and sunflower)	Specialized system (maize)
Maize in kg	495	495	455
Beans in kg	139	N/A	N/A
Sunflower	N/A	400	N/A
TC for year 1	813 714	885 714	480 599
TR for year 1	1 035 750	1 166 140	563 063
Marginal Profit in *TZS*	222 036	280 426	82 464
BCR	1.2	1.24	1.09
NPV	342 922	400 979.47	17 136
IRR	39%	48%	17%

TZS = Tanzanian Shillings

Table 3. Production (kg/ha), Costs, and benefits (TZS/ha) of planting drought tolerant vs conventional crops

	Planting drought-tolerant crops		Planting conventional crops
Measures	Sorghum	Finger millets	Maize
Sorghum in kg	381	N/A	N/A
Finger millet in kg	N/A	306	N/A
Maize in kg	N/A	N/A	455
Total Cost (TC) for year 1	408 869	453 455	480 599
Total Revenue (TR) for year 1	464 620	612 000	563 063
Marginal Profit	55 751	158 545	82 464
BCR	1.15	1.21	1.09
NPV	48 754.90	214 414.80	17 138.65
IRR	20%	42%	17%

The roof water collected by the MCRWH was used for domestic purposes, and the surface water collected in boreholes, reservoirs and ponds was used for livestock and irrigation of maize, rice, beans, and horticultural crops. Fixed costs included water tank, installation, gutters, first flush devices and downpipes, and maintenance costs. Direct costs included land rent and agronomic practices (land preparation, planting, weeding, harvesting, and post-harvesting), seeds and farmyard manure.

Table 4 shows that MCRWH (as an adaptation strategy) and rainfed (in-situ) were viable for the production of maize, beans and lablab. However, the BCR, NPV and IRR of MCRWH were higher than those of rainfed. These results are similar to those of Pina and Kassaye [33], who found that RWH in Zimbabwe was the adaptive water management system that led to diversification with better yields that increased incomes, thereby reducing poverty, promoting sustainable forms of agriculture, mitigating climate change, and spreading year-round vegetative cover to prevent erosion. These results imply that investment in RWH adaptation strategies for crop production to climate change and variability is profitable in the long run, as agro-pastoralists can pay for investment and operational costs and still make profits compared to business as usual (rainfed) [34].

3.1.4 Drip irrigation versus rainfed

The drip irrigation adaptation strategy included purchase costs (tanks, pump, PVC pipe), installation costs, borehole costs, and drip system equipment costs. Indirect costs included electricity bills and casual labour. Furthermore, irrigation as an adaptation strategy (through drip irrigation system) was the most viable system as it had a higher net present value per hectare at a discount rate of 15% for papaya, vegetable, and banana (intercropped) than rain-fed for the same intercropped crops (Table 5). The BCR and IRR for drip irrigation were also higher than for rainfed, suggesting that drip irrigation for intercropping is a viable and profitable adaptation practice.

Table 4. Production (kg/ha), cost and benefits (TZS/ha) of the MCRWH versus rainfed crops in TZS per hectare

Measures	RWH (maize, beans and lablab)	Rainfed (maize, beans and lablab)
Maize	800	610
Beans	630	510
Lablab	500	500
TC for year 1	2 579 735	2 254 735
TR for year 1	6 085 000	5 307 500
Marginal Profit	3 505 562	3 052 765
BCR	1.44	1.35
NPV	2 844 838.12	1 355 211.16
IRR	29%	22%

Table 5. Cost and benefits of drip irrigation versus rainfed TZS/hectare

Measures	Drip irrigation system per two-season	Rainfed system per two-seasons
Pawpaw in fruit counts	30 000	15 000
Banana in Bunches	800	500
Vegtable in kg	3 000	1 500
TC for year 1	15 612 694	8 231 347
TR for year 1	23 100 000	10 500 000
Marginal Profit	7 487 306	2 268 653
BCR	1.42	1.22
NPV	14 724 297.41	2 606 687.60
IRR	51%	27%

3.1.5 Livestock diversification versus single specie system

Livestock diversification, which involved keeping different types of livestock such as cattle (0.7 Livestock Unit (LU)), goats (0.1 LU), sheep (0.1 LU), and chickens (0.01 LU), was compared with a single species system that included a cow of 0.7 LU. In the production process, agro-pastoralists incurred costs that were classified as variable and fixed costs of livestock diversification. The variable costs (which vary with the level of production) included: veterinary medicines, vaccinations, fodder and feed supplements, artificial insemination, and cattle dipping fees, while the fixed costs were those such as maintenance costs and paddock (cattle shed) and did not vary with the level of production.

Total revenue was calculated as the price of output (stock in LU) and stock per LU. The enterprise as a strategy had a net present value of TZS 300 000, while the IRR was 51% (Table 6). The estimate for single species was lower than that for livestock diversification. The results suggest that livestock diversification was financially viable.

Table 6. Production (TLU) Costs and benefits of the livestock diversity versus single species in TZS per LU

Measures	Livestock diversification	Single specie system (cattle)
TR for year 1	413 898	289 729
Marginal Profit	113 898	53 129
BCR	1.17	1.14
NPV	198 840	31 732.64
IRR	27%	21%

TLU = Total Livestock Unit

3.2 Sensitivity Analysis

As insisted by Senkondo et al. [22] that the CBA does not capture the latent changes in factors that alter the profitability of adaptation strategies (i.e., it does not account for risks and uncertainties); the NPV, IRR, and BCR were subjected to changes in market prices for inputs and outputs. A sensitivity analysis is recommended to test whether the results are stable or unstable as a result of the above changes. The main assumption is that one factor is changed while the others are held constant. The sensitivity analysis was carried out using two parameters, namely the decrease in yields, which refers to the forecast decrease in yields, and an increase in production costs to the assumed level of 10%. In addition, different discount rates (interest rates) were considered to assess the sensitivity of climate change adaptation strategies to changes in the cost of capital. These were assumed to be 10%, 15%, and 18% as alternatives representing different opportunity costs of capital. The results of the sensitivity analysis are presented in Tables 7, 8, 9, 10, and 11.

Table 7. Sensitivity analysis for maize-beans and maize-sunflower intercropping

Adaptation strategy	**Performance indicators**				
	NPV (10%)	NPV (15%)	NPV (18%)	BCR	IRR (%)
a) Maize-beans intercropped					
Basic scenario	505 675	342 922.07	268 551	1.20	39
10% decline in yield	93 852	-2 307	-43591	1.08	15
10% increase in operating exp	418 906	267 911	199 212	1.18	33
b) Maize-sunflower intercropped					
Basic scenario	696 695	493 900	400 980	1.24	48
10% decline in yield	231 568	105 211	48 436	1.12	21
10% increase in operating expenses	609 926	418 889	331 641	1.22	41

Table 8. Sensitivity analysis for rainfed adaptation system drought tolerant crops

Adaptation strategy	**Performance indicators**				
	NPV (10%)	NPV (15%)	NPV (18%)	BCR	IRR (%)
a) Planting drought-resistant crops – Sorghum					
Basic scenario	122 371	52 821	22 099.65	1.15	21
10% decline in yield	29 428	-28 507	-48 346.11	1.1	12
10% increase in operating expenses	93 914	28 221	-640.61	1.13	18
b) Planting drought-resistant crops - Finger-millets					
Basic scenario	311 480.12	214 415	170 074	1.21	42
10% decline in yield	189 428.88	112 412	77 567	1.09	28
10% increase in operating expenses	266 735.64	175 746	134 337	1.19	36

Table 9. Sensitivity analysis for livestock diversification

Adaptation strategy	**Performance indicators**				
	NPV (10%)	**NPV (15%)**	**NPV (18%)**	**BCR**	**IRR (%)**
Basic scenario	130 563	74 679	49 595	1.17	27
10% decline in yield	-18 016	-49 483	-63 021	1.05	8
10% increase in input expenses	109 137	56 156	32 473	1.15	24

Table 10. Sensitivity analysis for micro rainwater harvesting

Adaptation strategy	**Performance indicators**				
	NPV (10%)	**NPV (15%)**	**NPV (18%)**	**BCR**	**IRR (%)**
Basic scenario	4 801 746	2 815 161	1 945 137	1.44	29
10% decline in yield	2 280 655	748 035	48 258	1.29	18
10% increase in operating expenses	1 863 940	2 750 967	1 885 729	1.43	28

Table 11. Sensitivity analysis for drip irrigation

Adaptation strategy	Performance indicators				
	NPV (10%)	**NPV (15%)**	**NPV (18%)**	**BCR**	**IRR (%)**
Basic scenario	20 761 439	14 724 297	11 983 929	1.42	51
10% decline in yield	11 547 767	7 024 770	5 000 420	1.28	30
10% increase in operating expenses	20 306 491	14 331 372	11 620 907	1.41	50

3.2.1 Sensitivity analysis for maize-beans and maize-sunflower intercrops

For maize-beans intercropping, with an increase in production costs and a 10% decrease in yields, the adaptation strategy remains viable when the NPV is 10% (Table 7). However, the strategy becomes sensitive when the NPV is set at 15% to 18%, as it becomes unviable, especially when the yield decreases by 10%, as the NPV becomes negative.

The results suggest that the maize-beans intercropping strategy is more sensitive to a decrease in yields than to an increase in input prices. In addition, maize-sunflower intercropping is less sensitive to both scenarios (yield decline and input price increase) and is therefore financially viable.

3.2.2 Sensitivity analysis for planting drought-resistant crops

The sensitivity analysis of planting drought-tolerant crops (sorghum and finger millet) as an adaptation strategy shows that an increase in sorghum production costs and a 10% decrease in yields leads to a negative NPV at a discount rate of 15% and 18% respectively, but the effect was more pronounced as sorghum yields decreased with IRRs of 12% and 18% respectively (Table 8). The results also suggest that sorghum production was more sensitive to changes in yields than in input prices [22]. This is to be expected as the use of variable inputs such as fertiliser and improved seeds were low in the study areas, although finger millet production was viable in all scenarios, but more sensitive to a decrease in yields than to an increase in operating costs.

3.2.3 Sensitivity analysis for livestock diversification

Furthermore, a 10% increase in production costs would not affect the viability of the livestock diversity strategy. Thus, a 10% decrease in livestock yields per LU makes the strategy unprofitable, as the IRR is less than the discount rate (Table 9). The decrease in livestock diversity returns for dryland agro-pastoralists may be the result of climate change and variability. However, an increase in operating costs in livestock diversity (cattle, goats, sheep, and indigenous chickens) becomes less sensitive to climate change and variability. Yields can be strongly affected by climate change and variability. This means that livestock diversification alone cannot reduce the vulnerability of agro-pastoralists to climate change and risks, hence the need for greater integration with crop production to improve food security and income in semi-arid areas (Ng'ang'a, 2018).

3.2.4 Sensitivity analysis for Micro-Catchment Rainwater Harvesting (MCRWH)

For the MCRWH adaptation strategy to climate change and variability, as for maize, bean, and lablab production, the results indicate that the MCRWH is more sensitive to changes in yields of maize, bean, and lablab production; and this was viable in all scenarios of NPV discount rates. Thus, a 10% change (decrease) in crop yields reduced the NPV more than an increase in operating costs (Table 10). Similar results are reported by Senkondo et al. [22], who found that crops grown through RWH were more sensitive to changes in input prices.

3.2.5 Sensitivity analysis for drip irrigation

Furthermore, the IRR of the small-scale irrigation strategy was 18% for both strategies when the yields of the strategies were reduced by 10%, but when the cost of inputs was increased by the same percentage, the IRR became higher than that of a yield reduction. However, all IRRs exceeded the opportunity cost of capital. This indicator shows that both strategies were financially viable and attractive to farmers.

Sensitivity analysis shows that all climate change adaptation strategies, except livestock diversification, remain viable when operating cost and yield prices are changed by 10% at a 10% discount rate (Table 11). However, at discount rates of 15% to 18%, maize-beans intercropping, drought-tolerant finger millet, MCRWH, and drip irrigation remain financially viable. However, the adaptation strategies were very sensitive to changes (declines) in the yields of the crops grown by the agro-pastoralists [35,36].

4. CONCLUSIONS AND PRACTICAL IMPLICATIONS

Based on the results of a cost-benefit analysis of adaptation strategies to climate change and variability, there is sufficient evidence to conclude that BAU practices are no longer viable compared to planned adaptation strategies. The planned adaptation strategies to climate change and variability are still financially viable for household livelihoods. However, it should be noted that livestock diversification is more sensitive to changes in yields, but when combined with a food and cash crop, such as maize-sunflower intercropping, there is a likelihood of improving both food and income security for agro-pastoralists in the drylands of Tanzania. In addition, drip irrigation and MCRWH have the potential to contribute to climate change adaptation in these dryland areas by minimising water use and output per cultivated area; the main challenge is the high initial capital cost. There is therefore a need for extension agents to continue to promote crop and livestock diversification among agro-pastoralists to reduce their vulnerability to climate change and variability. In addition, research and development (R&D) practitioners need to promote and capacitate agro-pastoralists in drip irrigation and micro-catchment rainwater harvesting adaptation strategies.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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