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The economic viability analysis on the Adopted Climate Change Adaptation Strategies among Maize Farmers in semi-arid of central Tanzania

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Abstract

An investigation of the economic viability of climate change adaptation strategies facilitates proper identification of strategies with low risk. However, there has been limited investigation of economic viability of the adopted strategies. This study aimed to examine the benefit-cost ratio of climate change adaptation strategies practiced by farmers of maize in Kongwa District, Dodoma Region. The study used a cross-sectional design to collect data. A total of 206 farmers and nine (9) key informants were involved during processes of collecting primary data. As the study adopted cross-sectional design, a questionnaire survey, key informant interview and focus group discussion were used to collect socioeconomic data, climate change adaptation strategies and cost of adaptation strategies. Qualitative data were analysed by using thematic analysis technique. Quantitative data were analyzed using descriptive statistics and econometric analysis by using benefit cost ratio. The study revealed that majority of farmers adopted several climate change adaptation strategies in order to cope with a myriad of climatic risks during maize cropping season. The most adopted strategies were intercropping (81.6%), improved seeds (63.6%), varying planting date (53.4%), tilling by tractor/power tiller (52.5%). A combination of tractor ploughing, inter-cropping, and varying plant date is the mostly (15%) adopted. All combinations of the adopted strategies were found economically viable as they revealed an average BCR of 2.1. However, the combination of tractor ploughing, intercropping, and improved seed varieties had higher BCR=2.9 when compared to other strategies. This study concludes that farmers should be advised to adopt the adaptation strategies which is economic viable with low risk, however, the strategies should be practical based on socioeconomic level of the farmers and environmental conditions.

Keywords: *Climate change adaptation strategies, Benefit Cost Ratio (BCR), Economic viability, Maize farmers*

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Introduction

The most recent Intergovernmental Panel on Climate Change (IPCC) indicates that climate change has affected agriculture (Pörtner*et al.*, 2022). The effects are mostly observed in developing countries particularly in Africa, where most of the farmers practiced rein fed agriculture (Malhi *et al.*, 2021; Yegbemey, 2014). Irregularity of rainfall and long dry span has contributed to a decrease of yields to some of the crops including maize (Mongi *et al.*, 2010; Msongaleli *et al.*, 2015). Such climate changes have a serious problem of food security, since crop productivity has decreased and it is expected to continue to decrease (Pörtner*et al.*, 2022).

In response to climate change, stakeholders such as policy makers, development partners and environmentalists have taken initiatives of creating resilient communities and enabling vulnerable communities to adapt with climate change (Bawakyillenuo *et al.,* 2016). In the context of agricultural sector, farmers have been adjusting their farming practices to cope with the climate change to maintain crop productivity (Azumah *et al.,* 2020; Dang *et al.,* 2019). Most of the farmers have taken initiatives either independently without public reaction or by adhering to a deliberate policy decision to respond to climate change impacts (Bawakyillenuo *et al.,* 2016; McCarl *et al.,* 2016).

The IPCC has been emphasising the importance of adopting climate change adaptation strategies (CCASs) to reduce vulnerability, improve resilient and maintain crop productivity (Ryan and Stewart, 2017). However, adoption of relevant and profitable adaptation strategies have been a problem to some individual farmers since adoption may require some resources (Azumah*et al.,* 2020). In sub-Saharan Africa where agriculture mostly depend on rein fed agriculture, small scale farmers have been adopting various adaptation strategies (Akinnagbe and Irohibe, 2014). Among the most adopted CCASs are based on change of farming practices and these include planting of drought tolerant seeds, mixed cropping, changing planting dates and others (Mburu *et al.,* 2015; Ojo and Baiyegunhi, 2020). Very often, individual farmers select adaptation strategies which are relatively least cost and viable in the environment (Ojo and Baiyegunhi, 2020).

There are cost implications associated with CCASs. Thus, analysing costs and benefits of adopted strategies has been found imperative to understand economic viability the strategies. Several studies have reported evaluation of CCASs in several sectors including agriculture (Azumah *et al.,* 2020; Narain *et al.,* 2011; Fankhauser, 2010; Parry, 2009). Benefit Cost Ratio (CBR) is one of the most used econometric techniques to calculate costs and benefits, since it allows quantification of costs and use of discount rate to indicate economic viability of a particular adaptation strategy (Ryan and Stewart, 2017). However, most of the conducted empirical studies have analysed economic viability of individual adaptation strategy used by a farmer (Azumah *et al.,* 2020; Ojo and Baiyegunhi, 2018). Meanwhile, farming is a process from farm preparation to harvesting time. Therefore, farmers apply a combination of CCASs in the process of farming in a season. The conducted study, however, does not provide a comprehensive analysis of the financial capital invested for CCASs adopted and the revenue obtained. Therefore, this study analysed economic viability of CCASs comprehensively used among maize farmers. This study is guided by the following research questions: What are the combinations of CCASs employed by maize farmers in Kongwa? Which CCASs are mostly adopted by farmers? Are the CCASs adopted economically viable? The study focused on farmers of maize in semi-arid ecological region of Dodoma, Tanzania as maize is one of the most staple food and most cultivated crops in that region. The findings of this study contribute to the discussion of the economic viability of CCASs among maize smallholder farmers. Furthermore, this study contributes to the existing body of knowledge about economic viability of adopted CCASs among maize farmers in improving maize crop production at the household level. In addition, the study is useful to agricultural planners and other stakeholders on agriculture and climate change to make interventions for the adoption of CCASs to improve maize crop production among maize farmers. The findings are aligned to Sustainable Development Goals (SDGs), thus the current findings add substantially to our understanding of adoption of CCASs, and its economic viability. This knowledge helps to improve agricultural practices, ensure food security at the household level hence contributes to achieving the 1st SDG (End poverty in all its forms everywhere), 2nd (End hunger, achieve food security and improved nutrition and promote sustainable agriculture) and 3rd (Take urgent action to combat climate change and its impacts). It also gives insights to other researchers for further research.

Theoretical background

This paper employed Prospect Theory of Kahneman and Tversky (2013) to explain how farmers make decision under risk of climate change to minimise loss of maize productivity. Climate change has been causing uncertainty of agricultural production in many developing countries (Hirpha *et al.,* 2020). Farmers' decisions to cope with climate change impacts often consider climate risks, since they adopt adaptation strategies with possibility of known risks, though the selected strategy might have low return (Levy, 1992).

The Prospect theory explain that individuals estimate outcomes concerning deviations from a reference point rather than concerning net asset levels, and losses have given more weight comparable gains (Levy, 1992). Accordingly, people are usually risk-averse about gains and risk-acceptant with regard to losses. Therefore, farmers tend to evaluate the production of the crops and give more attention to what are they going to lose after adopting a certain climate change adaptation strategy. For instance, farmers of maize crops would consider much on what they will lose after adopting improved seed varieties rather than concerning level of maize production under the risk of climate change. Farmers have a propensity to reject the strategy with a higher risk of low production outcomes or losing their capital. Therefore, farmers of maize tend to choose the CCASs with low-risk compared to the suggested available strategies.

Materials and methods

Description of Study area

The study was conducted in Kongwa District. The district is located between latitude 5°30' to 6°00' South and longitude 36°15' to 36°00' East (Figure 1) (Chitimbe and Liwenga, 2015; Mkonda and He, 2017a; URT, 2016). Kongwa is found in the drought-prone semi-arid agro-ecological region in the central part of Tanzania. It is one among Dodoma districts leading and famous in maize production (URT, 2020). The district constitutes the international maize market which is located at Kibaigwa ward (URT, 2020). Kongwa, Kibaigwa, and Ugogoni wards were selected purposively, because smallholder farmers of maize crop were found to adopt several CCASs(Gamba *et al.,* 2020; Gwambene and Majule, 2010; Mkonda and He, 2018).

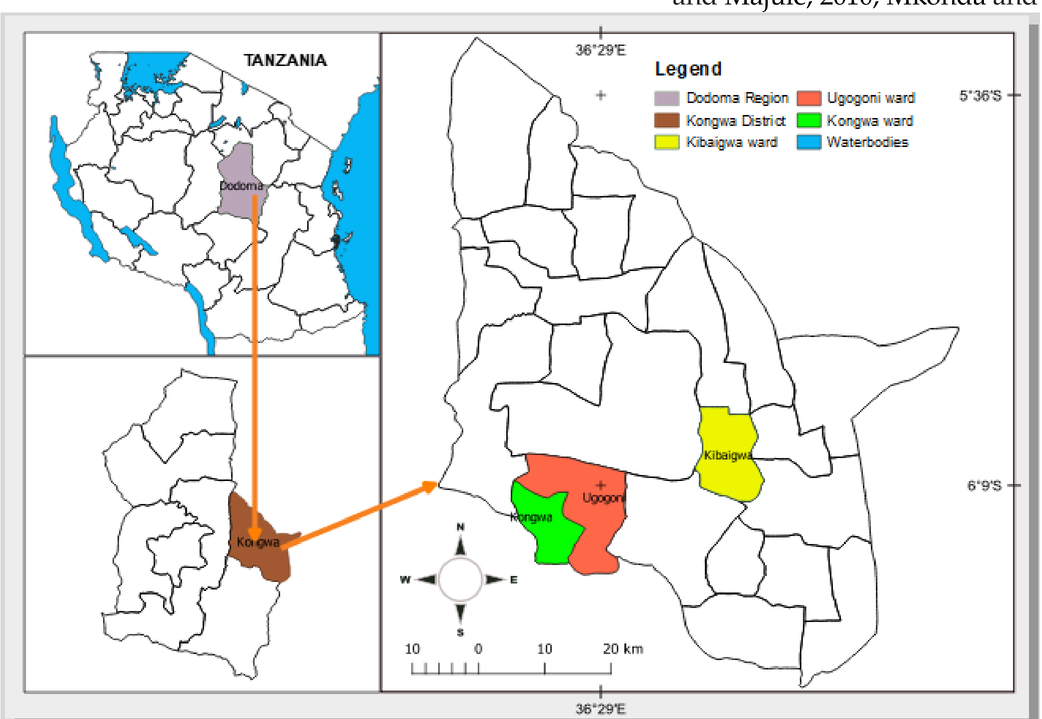

Figure 1. The Location of Selected Study Wards in Kongwa district

The number of farming households is 45,271, which is almost equal to 90% of the total households in which the labour force engaged as farmers and livestock keepers are 85% and are 5

% respectively (Mkonda and He, 2017a). According to Mkonda and He (2017a) Kongwa district has a total annual precipitation range from 400 to 600 mm in the northern part, while in the southern part ranges from 600 to 800 mm, with the maximum rain between December and April. The mean annual temperature varies from a mean minimum of 18°C to a maximum of 34°C.

Data collection and analysis

This study used a cross-sectional research design to collect and analyse data. Both secondary and primary data were collected. The sources of primary data were farmers of maize, government officials, and institutional representatives. Secondary data were collected from documents such as books, journal articles, and dissertations from internet sources and library of the University of Dodoma. Primary quantitative data were collected by using household questionnaire interviews. The questionnaire consisted closed ended questions to collect information such socio-demographic and economic information of the respondents, adopted CCASs, costs of CCASs and revenue gained from maize harvest for the farming season of 2021/2022. Qualitative primary data were collected by using in-depth interviews of key informants, and focus group discussions (FGDs). Interview guides which consisted open ended questions of climate change impacts on maize, CCASs, were used to ask questions KIs and participants of FGDs.

A total of 206 farmers from household were randomly selected and involved in the study (Table 1). Such sample size was determined through Charan and Biswas (2013) formula (Equation 1).

$$n = \frac{Z_{1-\propto\frac{1}{2}}^{2}(p)(q)}{d^2}$$ ....*Equation 1.*

Where:

n = Desired sample size,

d = Absolute error or precision =5%,

$Z_{1-\propto/2}$= Standard normal deviation = (1.96 on using the 95% CI),

p =proportion of farmers' households engaged in cultivation estimated to be 85% (Mkonda and He, 2017b), and q= (1-p).

Then, $n = \frac{1.96^2 .85(1-.85)}{0.05^2}$ n=196

The formula (Equation 2) was used to draw a sample from the three selected sub-villages.

$$N = \frac{(n*t_i)}{\sum t_i}$$ ....Equation 2.

Where, n = estimated sample size

$\sum t_i$ = the sum of Total house hold of selected villages

t_i= Total household of a particular village

N= desired sample from selected village

Table 1

Household and Sample Size for Questionnaire Survey

Types of respondents	Wards	Village	sub-village	Total house hold	Proportionate sample
Smallholder farmers (head of household)	Kongwa	Kongwa	Mnase	327	95
	Kibaigwa	Kibaigwa	Nyerere	235	69
	Ugogoni	Ugogoni	Ugogoni	143	42
TOTAL				705	206

We used purposive sampling to select three (3) wards out of 22 in the Kongwa district. Purposive sampling was also used to select three (3) villages, one (1) village from each ward, and then one (1) sub village was randomly selected from each selected village to get three sub villages. Furthermore, purposive sampling was used to get nine (9) key informants, consisting of three (3) village executive officers (VEOs), three (3) agricultural extension officers (AEOs), three (3) ward executive officers (WEOs), and 21 FGD participants (7 from each village).

Qualitative information from Key informants and FGDs were analysed by using content analysis (Drisko and Maschi, 2016). Themes from transcripts were created and given codes for easy presentation. Verbatim transcriptions have been presented in the boxes. Meanwhile, quantitative data from the questionnaire were descriptively analysed using IBM Statistical Product and Service Solutions (SPSS) version 20 software and Microsoft excel (Ms-Excel 2016) software. Data have been presented in percentages in the text and frequency tables. Also, the economic viability of climate change adaptation strategies was analysed using BCR. Adopted strategies were calculated using the formula (Equation 3) below.

$$\sum BCR_i = \frac{\sum B_t/(1+r)^t}{\sum C_t/(1+r)^t} \text{......................................}$$

Equation 3

Where:

$\sum BCR_i$= Benefit Cost Ratio of the i^{th} strategies

B_t = Total benefits at year t, C_t = Total costs at year t, r = Discount rate, and

$(1+ r)^t$= Discount factor at year t.

Climate change adaptation strategies that farmers practised in the farming season of 2020/2021 were recorded with instant benefits and costs. t in this evaluation was 1 year where r is 5% (BoT, 2017). The strategy seems worth if BCR is greater than 1(Zerbe and Bellas, 2015), the higher the BCR the more economic viability of the strategy.

Results

Socio-demographic and economic characteristics of the respondents

Table 2 shows that the respondents' age categories ranged from 20 to 60+ years. Majority (49.5%) of the interviewed smallholder farmers were in the age group of 40-59 years. Only few smallholder farmers (20%) were in the age group of 60 years and above. These findings are similar to Mtwanga *et al.*, (2022) who also found majority (55.5%) of the farmers in Iringa were at the age group between 40 and 59 years. The findings of this study suggest that majority of farmers were in active working age group important to perform various farming activities.

Table 2

Socioeconomic Characteristics of the maize Small-holder farmers

Variable	Frequency	Percent (%)
Age		
20-39	53	26.0
40-59	111	54.0
60+	42	20.0
Marital status		
Single	12	6.0
Married	160	77.6
Divorced	14	6.7
Widowed	20	9.7
Education Level		
Informal education	41	20.0
Primary education	145	70.3
Secondary education	17	8.3
College education	3	1.4

Farming ownership		
Purchased	20	9.7
Rented	89	43.2
Inherited	97	47.1
Access to Extension Services		
Yes	63	30.6
No	143	69.4

Furthermore, 77.6% of the respondents were married, (9.7) were widowed, (6.7%) were divorced and (6%) were single. Similarly, these findings correspond to Mtwanga *et al.,*(2022) who found that about 70.8% of the respondents were married. Majority (70) of the respondents had attained primary education, (20%) had attained informal education, (8.3%) had attained secondary education while only 1.4% had attained college/tertiary education. Such findings may imply that many of the smallholder farmers of maize have low level of formal education. A similar study of climate change was conducted by Sawe (2022) in Manyoni, Singida and it was found that 65% of the farmers had attained primary education.

Furthermore, Table 2 shows that majority (47.1) of the farmers acquired farms through inheritance from their parents. About 43.2% rented while 9.7% purchased. The findings of this study could be interpreted that farmlands are acquired through inheritance, renting and purchasing. As in many African communities, farmers have attendance of inherit farms from their relatives particularly their parents. However, the findings indicate that there some farmers who rent farms and some farmers purchase land to invest in maize farming. The findings of this study also show that majority (69.4) of the respondents accessed agricultural extension services while 30.6% did not access the extension services. Ojo and Baiyegunhi (2018) also found that some farmers had an access to agricultural extension services that were provided to capacitate them to respond to climate change. During key informant interviews the participants had various perceptions on farmers' access to extension services (Box 1).

Box 1 Key informants' perceptions on farmers' access to agricultural extension services

Agricultural extension officer, Kongwa, ward. 13th May, 2022.
"One among my responsibilities is to provide knowledge to the farmers. I educate farmers on the impacts of climate change and I provide them with knowledge on how to cope with the changes by adopting different adaptation strategies. However, it is difficult to visit all famers, therefore, some time I prepare meetings to meet famers to educate them, unfortunately not all famers may attend the meetings, and thus some of them have not received the knowledge". (KInf 1, 51 years, male, Kongwa)

Agricultural extension officer, Kibaigwa, ward. 14th May, 2022.
"*I visit farmers in their farms to share with them research knowledge on how they can improve crop productivity to reduce the impacts of climate change. I also have given the famers my mobile number. My mobile number also is available at each village executive offices of this ward and at the ward executive offices. I have provided my mobile number so that farmers can access me when they have got a problem, because it is difficult to visit them all and frequently. However, I just receive few calls from the farmers who search technical advice*". (KInf 2, 38 years, male, Kibaigwa)

Agricultural extension officer, Ugogoni, ward. 25th May, 2022.
"I provide accessibility to agricultural extension services through registering s farmers in farmer's groups and through mobile phones with the aid of the system known as M-kilimo system. M-Kilimo is a mobile phone programme used to inform farmers on issues related to agriculture and climatic condition. However, only few farmers have joined farmers groups. In addition, we only registered insufficient number of farmers in M-Kilimo system. Therefore many farmers have no access to appropriate extension services". (KInf 3, 41 years, male, Ugogoni)

Adoption of Climate change Adaptation Strategies by farmers of Maize crop.

Table 3 presents multiple responses on adoption of CCASs by farmers of maize crop in Kongwa. The most (81.6%) adopted strategy is intercropping, followed with improved seeds (63.6%), varying planting date (53.4%), tilling by tractor/power tiller (52.5%), tilling by an ox-plough (18.9%) and the least is zero tillage (18%). These findings differ from the findings of Azumah *et al.,*(2020) who found that the most adopted adaptation strategy to climate change by farmers in Ghana is changing of planting date. Moreover, Azumah *et al.,*(2020) found that farmers adopted about twenty (20) climate change adaptation strategies in Ghana, meanwhile, in this study only six (6) adaptation strategies were found to be practiced by smallholder farmers. The difference between the findings of this study and those of Azumah *et al.,*(2020) might be contributed as this study focused on adaptation of maize crop only while the study in Ghana focused on crops cultivated by smallholder farmers in general.

Table 3

Multiple responses on Adaptation Strategies Adopted by the maize smallholder farmers in Response to Climate change

S/N	CCAS adopted by Small-holder farmers	Responses		Percent of Cases
		Frequency	Percent (%)	
1	Inter-cropping	168	28.3	81.6
2	Improved seeds	131	22.1	63.6
3	Varying planting date	110	18.5	53.4
4	Tilling by Tractor/power tiller	108	18.2	52.5
5	Tilling by an Ox-plough	39	6.6	18.9
6	Zero tillage	37	6.3	18
	Total	593	100.0%	288

During FGDs, the participants explained that climatic condition of their area limits adoption of some of the adaptation strategies in maize cultivation. For instance, it was found that farmers do not use organic and inorganic fertilizers. Box 2 presents participant's opinions on the adoption of adaptation strategies

Box 2 FDGs participants' perceptions on farmers of maize to adaptation Strategies

Participant focus group discussion 1

Male (58 years), Kongwa village; *"Most of us-the maize cultivators, we grow maize and other crops that can sustain and grow if there will be not enough rainfall simultaneously in the same farm. For instance, maize and sunflowers or maize and groundnuts. If you cultivate only maize you are in a risk of being affected by climate change, since, maize plants are easily affected when there is no reliable rainfall".*

Participant focus group discussion 2

Female (51 years), Kibaigwa; *"During farm preparation time, mostly the soil is very dry thus it is hard to till using a hand hoe. It requires a famer to use tractor/power tillers or ox-plough, but some of us we do not have money to hire tractor/power tiller or ox-plough; we clean our farms and just dig small halls using a hand hoe (zero tillage) to sowing seeds.*

Participant focus group discussion 3

Male participants (45 years) Ugogoni village, *"Maize productivity is not much reliable due to unreliable rainfall. We follow technical advice from AEOs such as planting improved seeds varieties such as ZM401, ZM521, Situka 1 and Situka M1 that take about three to four months to mature. Also we change planting date according to instructions that we receive from the experts based on the starting of the rainfall season. The nature of our environment, however, is not appropriate to use some adaptation strategies such as practicing mulching (organic* *fertilizer) because the soil does not have enough moisture to decay the organic matter. Consequently, organic fertilizers (manure) application enhances crop disease attacks such as maize stalk borers (sulenge/sulenje). Similarly, we do not apply inorganic fertilizer because the inorganic fertilizer requires enough soil moisture to solute it, while, rainfall is not reliable to cause enough soil moisture"*

Combinations of adaptation strategies practice in a season of farming (2020/2021)

Table 4 presents nineteen (19) combinations of CCASs adopted by farmers of maize crop. Majority (15%) of the farmers adopted a combination of tractor ploughing, inter-cropping, and varying plant date, a combination of tractor ploughing, intercropping, and improved seed varieties (12.4%), then a combination of tractor ploughing, inter-cropping, improved seed varieties, and varying plant date (8.2%). Very few respondents (0.8%) adopted a combination of tilling by an ox-plough, and improved seed varieties. Tractor plough, improved seeds, intercropping and change of planting date have frequently listed in many combinations. Mligo *et al.,*(2022) found intercropping, mixed farming, drought resistant crops, irrigation farming, early maturing crop varieties and off-farming activities. However, Mligo *et al.,*(2022) did not put adaptation strategies in combinations.

Table 4

combination of adaptation strategies practiced in maize farming (N-206)

SN	Climate change adaptation strategies Adopted by small-holder farmers	N	(%)
1	Tractor ploughing, intercropping, and improved seed varieties	26	12.4
2	An ox-plough, intercropping, varying plant date, and improved seeds varieties	3	1.4
3	An ox-plough, intercropping, and improved seed varieties	4	1.8
4	Intercropping, and varying planting date	10	4.8
5	Inter-cropping	6	2.9
6	Tilling by an ox-plough, and varying plant date	4	1.8
7	An ox-plough, intercropping, varying plant date, and improved seed varieties.	3	1.4
8	Zero tillage , and intercropping	3	1.4
9	Zero tillage, inter-cropping, varying plant date, and improved seed varieties.	5	2.4
10	Inter-cropping, varying plant date, improved seed varieties	10	4.8
11	An ox-plough, intercropping, and varying plant date	8	3.8
12	Tractor ploughing, inter-cropping, Improved seed varieties, and varying plant date	17	8.2
13	Tractor ploughing, inter-cropping	14	6.7
14	Inter-cropping, and improved seeds varieties	8	3.7
15	Tilling by an ox-plough, and intercropping	12	5.7
16	Tractor ploughing, inter-cropping, and varying plant date	31	15.0
17	Tractor ploughing, and varying plant date	16	7.7
18	Tractor ploughing, inter-cropping, varying plant date,	8	3.6

SN	Climate change adaptation strategies Adopted by small-holder farmers	N	(%)
	Improved seed varieties.		
19	Tilling by an ox-plough, and improved seed varieties.	2	0.8
20	No adaptation	20	9.7
	Total /(Total Average)	206	100

During key informant interviews, the WEOs revealed that farmers of maize crops have been applying various CCASs at various stage of farming practices such as during tilling time, types of seeds and the farming types. Similarly, the AEOs explain that they advice farmers to use different CCASs at different stages of farming, since, each stage are important to adopt appropriate adaptation strategy. Box 3 presents

key informant perceptions on adopted combination of CCAS.

Agricultural extension officer, Kongwa, ward. 13th May, 2021.

"... you know farming is a process that consists various stages and each stage is important if you want to get high productivity. Thus, I advice farmers to adopt CCASs at each stage that will reduce risk. For instance, I advice them to observe the right time to prepare their farm as due to climate change, farming season may varies in different years. Such changes are also important for farmers to plant their maize seeds in appropriate time based on the beginning of rainfall seasons. However, I advice the farmers to plant short maturity seeds because rainfall season might be short, not enough for maize plants to mature and get harvest. In various years, many farmers got lost because maize plants become dry before harvesting time. Therefore, each stage of farming is important for farmers to adopt appropriate CCAS".

The Economic viability of Climate Change Adaptation Strategies adopted by Maize Maize Farmers

The economic viability of CCASs adopted by maize farmers were examined through the benefit-cost analysis model. BCR at discount rate of 5% for 1 year was employed in this analysis. As presented in the Table 4, the respondents were arbitrarily adopting CCASs in the range of one to more than two strategies at once which they applied in a farming season in the same farmland.

The average cost and its associated benefits of adopting CCASs were TZS. 343364 (USD 145.38) and TZS 657640 (USD 278.44) respectively, thus resulting to the overall BCR of 2.1. Such average BCR of 2.1 correspond to Azumah *et al.,*(2020) who found that the overall BCR of CCAS in Ghana is 2.4. Overall, the first five combinations of the CCASs with high BCRs are tractor ploughing, intercropping, and improved seed varieties (BCR=2.9), an ox-plough, intercropping, varying plant date, and improved seeds varieties (BCR=2.8), an ox-plough, intercropping, and improved seed varieties (2.6), intercropping, and varying planting date (CBR=2.5) and inter-cropping (CBR=2.5). Furthermore, the findings of this study, however, shows that many (15%) of the respondents adopted a combination of tractor ploughing, inter-cropping, and varying plant date which has a BCR of 1.5 and ranked number 15 in the list of all listed adopted CCAS. About 12.4% of the respondents adopted a combination of tractor ploughing, intercropping, and improved seed varieties which ranked number one (1) among the listed combination of CCASs.

Table 5

Benefit-Cost Analysis of adopting CCAS

SN	Climate change adaptation strategies Adopted by small-holder farmers	N	(%)	Cost TZS (USD)	Benefit TZS (USD)	BCR	Rank
1	Tractor ploughing, intercropping, and improved seed varieties	26	12.4	1286750 (544.81)	3337500 (1413.10)	2.9	1
2	An ox-plough, intercropping, varying plant date, and improved seeds varieties	3	1.4	291400 (123.38)	680000 (287.91)	2.8	2
3	An ox-plough, intercropping, and improved seed varieties	4	1.8	282000 (119.40)	795000 (336.60)	2.6	3
4	Intercropping, and varying planting date	10	4.8	225345 (95.41)	377091 (159.66)	2.5	4
5	Inter-cropping	6	2.9	385432 (163.19)	691131 (292.62)	2.5	4
6	Tilling by an ox-plough, and varying plant date	4	1.8	177050 (74.96)	360000 (152.42)	2.4	6
7	An ox-plough, intercropping, varying plant date, and improved seed varieties.	3	1.4	414833 (175.64)	1100000 (465.74)	2.3	7
8	Zero tillage , and intercropping	3	1.4	112500 (47.63)	300000 (127.02)	2.2	8
9	Zero tillage, inter-cropping, varying plant date, and improved seed varieties.	5	2.4	122540 (51.88)	312000 (132.10)	2.1	9
10	Inter-cropping, varying plant date, improved seed varieties	10	4.8	468480 (198.35)	1013000 (428.90)	2.0	10
11	An ox-plough, intercropping, and varying plant date	8	3.8	279213 (118.22)	397500 (168.30)	2.0	10
12	Tractor ploughing, inter-cropping, Improved seed varieties, and varying plant date	17	8.2	725629 (307.23)	1295294 (548.43)	1.9	12
13	Tractor ploughing, inter-cropping	14	6.7	306950 (129.96)	460714 (195.07)	1.6	13
14	Inter-cropping, and improved seeds varieties	8	3.7	392250 (166.08)	672000 (284.52)	1.6	13
15	Tilling by an ox-plough, and intercropping	12	5.7	187100 (79.22)	300000 (127.02)	1.5	15
16	Tractor ploughing, inter-cropping, and varying plant date	31	15.0	479127 (202.86)	776129 (328.61)	1.5	15
17	Tractor ploughing, and varying plant date	16	7.7	576507 (244.09)	861000 (364.55)	1.4	17
18	Tractor ploughing, inter-cropping, varying plant date, Improved seed varieties.	8	3.6	1342375 (568.36)	1845000 (781.17)	1.2	18
19	Tilling by an ox-plough, and improved	2	0.8	185250	210000	1.1	19

SN	Climate change adaptation strategies Adopted by small-holder farmers	N	(%)	Cost TZS (USD)	Benefit TZS (USD)	BCR	Rank
	seed varieties.			(78.43)	(88.91)		
20	No adaptation	20	9.7	0(0)	0 (0)	0	0
	Total /(Total Average)	206	100	343364 (145.38)	657640 (278.44)	2.1	

Discussion

Climate change adaptation strategies for maize crop

Farmers of maize crops have taken initiative of adopting various CCASs to reduce impact of climate change, improve maize productivity and gain profit in Kongwa district. IPCC (2022) urges that adaptation initiatives should be mainstreamed in planning and policies; there is a need for collective efforts for implementation. The findings of this paper found adaptation initiatives are taken in collective efforts that include farmers and agricultural experts. Masuku and Manyatsi, (2014) also explain that AEOs need to work closely with farmers to assists maize farmers to adopt CCASs, as the maize crop is vulnerable to climate change. AEOs advice farmers to adopt CCASs to reduce climate change risk as maize crop is vulnerable to climate change impacts. The initiatives have included information technology (IT) through the use of mobile phone in a system known as *M-Kilimo*. IT has been used to widely reach as many farmers as possible and provides required services on time, since; adaptation to climate change requires accessibility of climate change information on time for quick response. However, the findings of this study indicate that the accessibility of agriculture extension services is still limited to some of the maize farmers in Kongwa district. Such situation could have contributed to fail for the some of the farmers to adopt CCASs as indicated in Table 3. Belay *et al.*, (2017) maintained that access to extension services increases the likelihood to the adoption of different climate change adaptation strategies. Farmers have adopted CCASs such as intercropping, improved seeds, varying planting date, tilling by tractor/power tiller, tilling by an ox-plough and zero tillage. The reported CCASs include a mixture of indigenous knowledge such as intercropping and modern knowledge such as tilling by tractors and use of improved seeds. Such findings indicate that farmers are willing to adopt both traditional and new technology as long as the technology reduces loses. The findings of this study reflect the Prospect theory of Kahneman and Tversky (2013) which suggests that individuals assess the outcomes and give priority to the alternative with low risk of lose(Levy, 1992). Similarly, Mutenje et al. (2019) found that a mixed of traditional and modern adaptation strategies to climate change in agriculture improve production and are economic vialble.

Many previous studies including Thamo *et al.*, (2017), Bastidas-Arteaga and Stewart, (2013) and Claessens *et al.*, (2012) have been conducted to analyse economic viability of the CCASs, however, these studies have analysed each adaptation strategy separately. Contrary to this paper, the economic viability of CCASs has been analyzed based on number of strategies employed by famer at different farming stages to a corresponding season. This paper shows that farmers of maize crops may employ one or multiple adaptation strategies per a farming season for one crop.

Lists of nineteen (19) CCASs have been found to be adopted by farmers of maize. Many of the listed combinations, however, consist intercropping, improved seeds, change of planting dates and tilling by tractors. Probably, these are the most CCASs with low risk of losing productivity and give benefits. The findings of this study correspond to studies of Mligo *et al.*,(2022) and Mtwanga *et al.*,(2022) who also found CCASs such as intercropping, improved seeds and plant varying dates have been widely adopted by farmers in Tanzania. Azumah *et al.*,(2020) that, the inter-cropping strategy is the most effective in controlling pests and diseases.

Also intercropping maize with other crops like legumes, allows seed rate to be reduced (Stephen *et al.,*2014). These findings align with those by Azumah *et al.,*(2020) that the adoption of varying planting date strategy, were mostly adopted due to improved seeds like early maturing varieties and drought resistance varieties that responded to altered rainfall distribution and short rainfall duration due to climate change and viability. Besides, farming is a system which consists various activities at different stages, thus, each farming stage needs appropriate CCAS for the succession of the next stage. For instance, the farmers of maize have to adopt adaptation strategies for tilling, planting time, verities of maize seeds and method of farming. Application of all CCASs, however, requires cost evaluation to project benefits.

These study findings show that tractor ploughing is the dominant tilling method adopted by majority of the respondents followed by an ox ploughing. This indicates that the agricultural tillage transformation from low to high advanced mechanized technologies application was successfully diffused among maize smallholder farmers in Kongwa District. In contrast, the study by Ismail (2020) reported that about 85% of the farmers in rural Tanzania were using hand hoe as the major tool of tilling. The results of this paper differ from Ismail (2020) because in Kongwa district there have been various agricultural initiatives to capacitate farmers to improve maize production. Among initiatives taken including application of modern tool of tillage, unlike many areas in rural Tanzania where there are no much efforts of helping farmers to use modern tools of tillage.

All combinations of CCASs adopted by the farmers were economically viable, as the expected BCRs were greater than one (1). These findings correspond to those findings of Azumah *et al.*, (2020) and Devkota *et al.*, (2017) who also found that all CCASs adopted by farmers in Ghana and Nepal respectively are economically viable. The findings of this paper could be interpreted that the adopted CCASs help to reduce uncertainty in maize productivity and contribute to improve livelihood of farmers. This paper supports the IPCC (2022) report which explains that adaptation helps to reduce risk, improve agricultural productivity and livelihood. The average benefit of adopting CCASs is two times more than the cost of adopting it. Likewise, Azumah *et al.,*(2020) found the average BCR of 2.4 for the CCAS among farmers. Contrary to study of Devkota et al. (2017) who found the average BCR of 1.14 for CCASs to farmers in Nepal. However, the findings of both previous studies (Devkota *et al.*, 2017; Azumah *et al.,* 2020) and this study have all found that CCASs are economically viable as the BCRs are greater than one (1).

Among the nineteen (19) listed combinations of CCASs found in the study area, eleven (11) of them which is 57.89% have BCRs ≥ 2; only eight (8) have BCRs < 2. Such findings imply that most of the adopted CCAs had benefits of more than or equal to two times compared to their costs, however, there are also some CCASs which have less BCRs. The variations of BCRs found among the adopted combinations of CCASs indicate the variation of costs and output. Furthermore, the findings could be interpreted that farmers of maize may adopt a combination of CCASs which may have lower BCR as long as it is economic viable and have lower risk, compare to CCASs which have high BCR but its risk is high. Very often, economic viable of CCASs are measured in term monetary gain against invested cash, however, Markanday *et al.,* (2019) explain that those methods which only focus on fiscal resource do not give comprehensive economic viability status of the adopted strategies. Since, other values such as environment, health and social which are also important are rarely considered.

Many of the famers (15%) adopted a combination of tractor ploughing, inter-cropping, and varying plant date which ranked at the position of 15 out of 19 with BCR of 1.5. Meanwhile, about 12.4% of the farmers adopted a combination of tractor ploughing, intercropping, and improved seed varieties which ranked number one (1) of 19 with BCR of 2.9. These findings explain that the benefit of adopting tractor ploughing, inter-cropping, and varying plant date was 1.5 times more to its one-unit cost, while the benefit of adopting of tractor ploughing, intercropping, and improved seed varieties was 2.9 times more to its one-unit cost.

However, many of the famers adopted CCAs which have lower BCR of 1.5 compared to the CCASs with BCR of 2.9. The difference between the two combinations of CCASs is improved seeds and planting varying date. Famers consider planting varying date consists low risk compared improved seeds, though, improved seeds have high benefits. Varying planting date is important in maize farming because even the improved maize seeds such as *ZM401, ZM521, Situka 1* and *Situka M1* are affected if rainfall season will be much shorter than the required days for the maize to mature.

Conclusion

Famers of maize in Kongwa have adopted various CCASs. The famers arbitrary adopt more than one strategy at different stages of farming. Therefore, the farmers use multiple CCASs. All CCASs are economically viable. However, there are variations; some of the adopted CCASs have high BCR compared to other strategies. The combination of tractor ploughing, intercropping, and improved seeds was more economically viable. However, we argue that planting varying dates is important as all other strategies need to be carried in appropriate time based on the changing of rainfall seasons. Also we argue that smallholder farmers need to adopt different relevant CCASs to use them at different stage of farming to maintain maize productivity. Therefore, there is need for all stakeholders including government, researchers and other development partners improve providing agricultural extension services of CCASs to the farmers. We recommend that farmers should be advised to adopt various adaptation strategies which are economic viable with low risk. The adopted strategies however, should be practical based on socioeconomic level of the farmers and environmental conditions.

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