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Climate Information Services and Crop Production Enhancement among Sorghum and Maize Farmers in Kondoa and Kiteto Districts, Tanzania

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Abstract: *In recent years growing attention has been given to the use of climate information services (CSI) in improving farming decision making under uncertainty associated with climate variability. In Tanzania, this is generally important to tackle low agricultural productivity amongst farmers and to foster their adoption of CSI to meet the food needs of ever-increasing populations. However, common approaches, such as the use of radio and television for CSI knowledge exchange and dissemination have limitations in rural areas of Tanzania. Consequently, understanding the link between CIS usage and crop production enhancement has become increasingly important, particularly in semi-arid areas where drought is common. Hence, this article investigated the contribution of CIS to crop production enhancement among sorghum and maize farmers in the Kondoa and Kiteto districts, purposively selected, as part of the Global Framework for Climate Services Adoption Program in Africa (GFCS-APA) initiative implemented in four villages. The study adopted a quasi-experimental design using a Difference-in-Difference (DID) linear mixed model with pre-and post-period data samples of farmers exposed to GFCS-APA multi-agency program (treatment) and non-exposed (control group). As such, this study conducted a farmers' household survey for a total sample of 360 farmers who were part of the multi-agency program by GFCS-APA, of which, 151 farmers were directly involved with GFCS-APA (treatment group) and 209 farmers were set aside as non-beneficiaries (control group). Generally, the findings show that farmers are endogenously treated to improve maize yields rather than sorghum yields when they are exposed to CIS. It is concluded that the usage of CIS boosts maize yields dramatically as opposed to sorghum, and this is statistical significance. Therefore, it is recommended that the pathways for increasing the use of CIS should take into account the adoption hurdles that are inherent to farmers' traits and livelihood plans.*

Keywords: *climate information services, climate variability, maize productivity, sorghum productivity, semi-arid area*

1.0 Background Information

Climate variability is a major challenge, threatening all aspects of socioeconomic development, including agricultural production (Ullah *et al.*, 2018; Boliko, 2019). In many developing countries, increasing agricultural production during this period of climate fluctuation is widely recognized as a critical step toward the realization of SDGs 1 and 2 on poverty reduction and hunger eradication, respectively by 2030 (World Food Program, 2017). This is especially true in sub-Saharan African (SSA) countries, where agriculture provides the majority of the population's income (Mkonda and He, 2017; Boliko, 2019). Despite being a source of income, Onyutha (2018) discovered that crop production in SSA has dropped below the Comprehensive Africa Agricultural Development Program (CAADP) target of a 6% annual crop yield in Africa (World Food Program, 2017). Tanzania's crop production, like that of other SSA countries, has declined to less than 5% annually, below the national expectations of achieving 10% annually (URT, 2016). The problem has been exacerbated in semi-arid areas with uni-modal rainfall regimes as well as farmers' limited ability to use irrigation practice as an alternative to rainfall variability (Sawe, Mung'ong'o, and Kimaro, 2018; Mkonda and He, 2018).

Furthermore, numerous crops are cultivated in semi-arid locations, with sorghum and maize being the most commonly consumed (Msongaleli *et al.*, 2015; Mutayoba and Saruni, 2018). Despite the sorghum and maize's significance in assuring food security in semi-arid areas, their production declined to less than 50% (Sawe, Mung'ong'o, and Kimaro, 2018). For instance, Wilke and Wright (2015) forecasted that sorghum and maize yield will decline by 3.6% and 8.9% respectively by 2050. As such, according to Food and Agriculture Organization (2020) and Guido *et al.* (2020) therefore, to reverse the declining trends, the focus should be on enhancing knowledge, availability, and accessibility of localized climatic variability information to support on-farm decision-making processes to lessen the semi-arid characteristics and improve crop production.

Therefore, CIS is increasingly being regarded as a tool for cross-examining the declining trends of sorghum and maize yield through enhancing knowledge, availability, and accessibility of localized climatic variability information (Vaughan *et al.*, 2019). Climate information service is a decision-support tool that provides farmers with access to climate variability information, knowledge, and opportunities for social networking (Forsgren *et al.*, 2019).

Individual and organizational decision-making in the face of climate variability uncertainty is projected to improve with the provision of CIS (Kumar *et al.*, 2020). Weather prediction information, as well as relevant advice, is included in climate information services. In Tanzania, Tanzania Meteorological Authority (TMA) is responsible to produce and disseminate climate information services via radio and television programs (Kijazi *et al.*, 2019). While various studies have demonstrated the value of climate information services in reducing climatic variability uncertainty, research in Tanzania has focused on their limitations for farm decision-making. For example, the fundamental question remains whether the scaling up and coverage of information make it inaccurate and irrelevant for some parts of decision making. Furthermore, due to a lack of radio and television in their household, the majority of farmers are unable to acquire firsthand information (Mahoo *et al.*, 2015; Chengula and Nyambo, 2016; Tumbo *et al.*, 2018; Radeny *et al.*, 2019).

TMA and the World Food Program (WFP) performed a capacity-building program in the districts of Kondoa, Kiteto, and Longido to support government efforts to enhance the uptake of CIS under the GFCS-APA (West, Meaghan, and Yanda, 2018). To improve CIS availability, accessibility, and usability, these programs include the use of visual aid diagrams using Participatory Integrated Climate Service in Agriculture (PICSA) (Kijazi *et al.*, 2019). Likewise, Kijazi *et al.* (2019) reported the use of on-farm demos (for example farmers' field schools), mobile phone short messages, and interactive radio programs aimed at providing short-term weather forecasts and agronomic advice. Studies substantiated the increased awareness among farmers in the GFCS-APA area, yet its impact on reducing climate variability uncertainty on sorghum and maize yield requires scholastic intervention.

Numerous studies have been conducted on climate information services and agriculture. Although studies have concluded that there is observed increased availability, awareness, and usability of CIS (Kijazi *et al.*, 2019; Ebhuoma *et al.*, 2020; Guido *et al.*, 2020; Kumar *et al.*, 2020), their impact on increasing crop yield remains uncertain. While there has been little evaluation of the impact of CIS on yields, controversial results also persist. For example, while CIS has been observed to increase crop productivity in India (Kumar *et al.*, 2020), there were only minor impacts on coffee farmers in Jamaica (Guido *et al.*, 2020) and no impact on the oil-rich Niger Delta (Ebhuoma *et al.*, 2020) and Ghana (Naab, Abubakari and Ahmed, 2019). This contentious information on the impact of CIS prompted rigorous policy and development investment decisions about the actual relevance of CIS in informing farmers' decisions in the face of climate variability uncertainties. Apart from the contentious results, the study raises concerns about the context and the methodologies used (Guido *et al.*, 2020; Sebaggala and Matovu, 2020).

According to Sebaggala and Matovu (2020), the controversial result may be brought about by the problem of endogeneity due to the unobservable characteristics of participants and non-participants of the initiative. While it is widely acknowledged that farmers can choose from a variety of mechanisms to improve crop yield, such as farmer-to-farmer networks and information exchange behaviours via farmer-to-farmer, television, and radios, among others. As a result, the estimated coefficient on the climate information variable from several studies is skewed. This work fills in the gaps by addressing endogeneity, a methodological issue that has been noted in prior studies that assessed the effect of CIS on crop output (Mahoo *et al.*, 2015; Chengula and Nyambo, 2016; Tumbo *et al.*, 2018; Kijazi *et al.*, 2019; Sebaggala and Matovu, 2020). Therefore, this study investigated the impact of climate information services on sorghum and maize production in the Kiteto and Kondoa districts found in Tanzania's semi-arid regions.

2.0 Theoretical Framework

The study drew on the concept elaborated in the Decision Theory developed by Tryfos (1989) and modified by Parmigiani and Inoue (2009). This theory is one of the theories within the economics and statistics research domain and appears to have broad applicability in CIS. According to Parmigiani and Inoue (2009) in the Decision Theory, there are two ways in which decisions are made: the ways people make decisions and discussions on the mechanisms underlying this behaviour. Therefore, "descriptive" Decision Theory is a theory about how decisions are made. That is the way that people make decisions. On the other hand, one can also find discussions about the principles to consider making rational decisions. This is called a "normative" Decision Theory. The normative theory is a theory about how decisions should be made. This study adopted a normative Decision theory to assess how best farmers make decisions under uncertainty associated with climate variability.

According to the theory, in an era of climate variability, judgments should be made based on the world's conceivable states (for example state of the world), such as weather forecasts. This should be accompanied by the associated probabilities of this world state occurring. The utility function of the forecasted weather is then referred to as a potential decision tool. The theory went on to argue that there should be potential learning for decision-makers to understand the meaning of the information provided, as well as a decision criterion rule whereby farmers select the relevant option from a range of available alternatives (Parmigiani and Inoue, 2009). These information bundles enable decision-makers (farmers) to envision and implement options that improve farm efficiency and effectiveness. While providing all necessary possible state of the world, climate information service is also accompanied by relevant advice required in its application to farmer decision making. According to Guido *et al.* (2020), making decisions in this manner allows farmers to better manage their resources. As a result, climate information services are likely to help farmers design and implement appropriate options for dealing with the effects of climate variability on crop yield and their livelihood in general. Capacity building and knowledge of climate information services are likely to inform farmers and identify relevant options as a source of climate information. Vaughan *et al.* (2019) stated that climate information services are critical in providing foundations for farm planning and management, particularly in the face of climate variability challenges.

As applied to this study, normatively, a farmer (decision maker) analyses the possible outcomes resulting from his/her available alternatives in two dimensions: value and probability of occurrence. Then, the farmer chooses the option that is expected to have the highest value. The farmer cannot guarantee that the outcome will be as good as might hope for but has made the best decision he/she can, based on his preferences and available knowledge. Inference using decision rules allows the farmers to evaluate information-gathering activities that will reduce uncertainty.

3.0 Methodology

This research was carried out among farmers in the Kiteto (Emarty and Sunya villages) and Kondoa (Bukulu and Mafai villages) districts, which are located in the Manyara and Dodoma Regions, respectively. Kiteto and Kondoa districts were chosen purposely because the majority of farmers had been exposed to GFCS-APA, which aimed at increasing awareness and availability of climate information services. While the GFCS-APA was also conducted in the Longido district, Longido was excluded because the vast majority of its residents (90%) are pastoralists with a few (10%) farmers. Therefore, the identification and selection of these areas were guided in semi-arid areas purposively by specific features related to most farmers' populations being exposed to multi-agency climate information service programmes of the Global Framework for Climate Services (GFCS) Adaptation in Africa. A quasi-experimental design was used to study two groups: treatment (Emarty and Bukulu villages) and control (Sunya and Mafai villages).

This study conducted a farmers' household survey for a total sample of 360 farmers who were part of the multi-agency program by GFCS-APA, of which, 151 farmers were directly involved with GFCS-APA (treatment group) and 209 farmers were set aside as non-beneficiaries (control group). The sample is in accordance with Beal and Kupzyk (2014) who reported that the control group should outnumber the treatment group to allow for comparison. The sampling procedure was carried out in three stages. The villages were stratified using pre-experimental data based on participants and non-participants in the first stage. The data gathered from district councils were used to identify relevant villages. Four villages were found to be significant in terms of area (location) and GFCS-APA activities. Second, GFCS-APA classified crops according to their relevance in ensuring food access in villages, to ensure a desire to take a consistent effort to mitigate the impact of climate variability on agriculture. Households from the specified villages were chosen randomly in the third step using simple random sampling. The average distance between the nearest control and treatment households was more than 50 kilometres. The available distance ensures that the connection is minimized and the flow of information between the two groups is reduced.

The dataset includes pre-and-post-GFCS-APA intervention periods for both groups, and the crop yield was estimated during six growing seasons (2013/2014 to 2010/2019). Six seasons, according to Diskin (1997), are required to establish a reliable impact of the intervention. This study used a proportional allocation of all crops in the plot with mixed crops to address the mixed approach challenge. This strategy implies that all of the plot's farming demands are spread evenly. Farmers' recall was also used since, according to Diskin (1997), it was more trustworthy than the crop-cut approach in supplying accurate information. The data received through farmer recall was compared to crop yield records available at the districts to guarantee its veracity.

Data was gathered through the use of a household survey. Data collection entailed distributing a detailed questionnaire to farmers via direct administration. The data were analyzed using a quantitative strategy that incorporated descriptive and inferential statistics. For basic socioeconomic characteristics of households, descriptive data included mean, and percentage. A chi-square p-value test and a mixture of analysis approaches were used as inferential statistics. Technical Efficient (TE) was used to explain farmers' efficiency in crop production supplemented with Data Envelop Analysis (DEA) and Difference in Difference (DiD) as the inferential methods.

Data envelops on time series between 2014 and 2019 were recorded and run using this method to reveal TE scores of maize and sorghum yields for each household. Then, in this study, the DEA technique of analysis was primarily used to evaluate and offer the important role of CIS on sorghum and maize yields for both participants and non-participants households. The data was then analyzed and recalculated to produce scenario change TE, which was used to determine yield differences between farmers in the treatment and control groups. Throughout the paper, a 0.05 significance level was used. Then it was discovered that a CIS with a p-value of 0.05 had a significant impact on the household's sorghum and maize yield.

Furthermore, the study used the difference-in-difference (DID) method to produce a yield comparison between treatment and control groups in the two districts throughout six seasons. Before conducting DID, it was also critical to understand the quality of matching in this study. The practice of doing a balance test and then running a common support condition before performing DID is recommended in the liter (Gertler *et al.,* 2016). Maize and sorghum yields, income diversification, and farmer characteristics were employed as indicators of interest. Therefore, crop yield data in pre-post GFCS-APA and across participants and non-participants were used to make the estimates. Because of its capacity to cope with independent and dependent variable invariant unobservable properties through time, the difference-in-difference technique is considered the most appropriate method. The difference in difference model is presented as follows:

$$Y_{it} = \beta_0 + \beta_1 * Time + \beta_2 * Treatment + \beta_3 * Time * Treatment + \varepsilon_{it}$$

$$\Rightarrow \mu_t = E(Y_{it}) = \beta_0 + \beta_1 * Time + \beta_2 * Treatment + \beta_3 * Time * Treatment$$

Where Y_{it} is the resulting yield for household i at time t. Time is a variable for the time, with 1 indicating that the household yield estimate was made after the GFCS-APA initiatives and 0 indicating that it was made before the GFCS-APA initiatives. Treatment is a dummy variable that has one value for participants, and zero for non-participants. Furthermore, Time* Treatment expresses the interactions that exist between growing seasons and the participant group, as well as the error term=ε_{it} for crop yields of household at time t. The intercept, which is the mean outcome variable for participants pre-intervention, is the model's parameter. In this scenario, β_1 represents the change in mean household crop yield in the non-participants from the beginning to the end of the period. The difference in mean household crop yield between beneficiaries and non-beneficiaries pre-intervention is expressed by parameter β_2, whereas interaction is the measure of the difference in slopes between participants and non-participants and is expressed by coefficient β_3. The coefficient of the interaction term is used to calculate the DID between participants and non-participants.

3.0 Findings and Discussion

3.1 Determinants of Farmers' Participation in the GFCA-APA

The goal of the study was to figure out what factors influence farmers' involvement in the GFCS-APA initiatives. This was made possible by comparing and balancing participants and non-participants of the GFCS-APA climate information services using baseline data. In this situation, the data was analyzed using a probit model. Because, as shown in Table 1, coefficients are substantially equivalent to zero and significant at p-value=0.0000, the model fits the data. The results in Table 1 show that all socioeconomic indices are in balance. The age of the household head has a significant impact on the chance of farmers obtaining GFCS-APA climate information services, according to these data. Years of farming experience, years of schooling, access to funding, membership in a farmers' network, and the size of maize and sorghum plots were all discovered to have a significant impact on profiting from the GFCS-APA climate information services effort.

Table 1: Socio-Demographic Indicators Blended for Treatment and Control Groups

Variable	Coefficient	SE
Age	0.323	0.004
Plot size	0.043	0.031
Size of household	0.021	0.001
Access to credit	0.030	0.081
Years of education	0.031	0.003
Years of experience	0.005	0.002
Farmers network	0.001	0.017
Constant	0.159	
LR Chi1	19.78	
Prob>Chi1	21.78	

The results in Table 1 indicate that farmers of all ages and experience levels are likely to adapt to new external knowledge as it becomes accessible to increase maize and sorghum yields. The results contradict Ouédraogo *et al.* (2019) who indicated that rural farmers are wary of outside guidance for managing their crops systematically. Apart from the differing arguments, the findings of this study are comparable to those of Asare-Nuamah, Botchway, and Onumah (2019) and Dobardzic *et al.* (2019) who made a similar claim as presented in this study. Similarly, farm size is a major indication that encourages farmers to use the GFCS-APA climate information services to gain additional knowledge that will help them maximize their sorghum and maize yields. Access to loans, education levels, and the farmers' network are all proven by this study to have a role in sorghum and maize yields. Therefore, according to the results in Table 1 and Decision Theory, access to credit, education levels, and farmer networks promote farmer-to-farmer guidance and allow knowledge and ideas on managing climatic unpredictability to be transformed.

3.2 Climate Information Services Adoption

In this study, different sorts of climate information services that are utilized for farm decision-making by both participants and non-participants were investigated. The services were divided into two categories well known by farmers: weather information services and agronomic advice. Expected dates for commencement of rainfall, the volume of rainfall, end dates of rainfall, and expectations of the incidence of pests and diseases were among the weather information services examined in this study. Agronomic services, on the other hand, include all necessary advice on how to use services such as crop varieties, where to till, and when to start growing, among other things. In comparison to non-participants, the majority of farmers that participated in the GFCS-APA program in Kondoa and Kiteto highly accepted both weather information services (76.5 per cent) and agronomic services (84.03 per cent). According to the findings of this study, the majority of non-adopters of CIS were farmers who did not participate in the GFCS-APA initiative in the districts.

Table 2: Climate Information Services Used by Farmers (n = 360)

Climate Service	Participants	Non-participants	P-value
Weather Information Service	76.5%	25.01%	0.0132
Agronomic Advisory Service	84.03%	11.23%	0.0142

Note: Significant at 0.05(5%) level

However, a Chi-square P-value test found variations in CIS uptake between participants and non-participants, with p-values of 0.0132 and 0.0142, respectively, for weather information and agronomic advice services. The results suggest that participants farmers use both services to manage the influence of climate variability on maize and sorghum output. Although both services are used, agronomic advisory services are the most frequently used climate information service, according to the respondents. The findings indicate that non-participants had a slight possibility of using the two CIS provided.

Furthermore, data were analyzed to offer results on the variances to compare treatment and control groups, as well as maize and sorghum yields. Similarly, the performance of climate information services (weather information and agronomic services) was compared using the same method. Table 3 shows the differences in maize and sorghum yields, service performance against groups, and factors that influence maize and sorghum yields.

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Table 3: Results for the Difference between Treatment and Control Groups (N = 360)

Variables	Weather Information Service				Agronomic Advisory Services			
	Pre-period		Post-period		Pre-period		Post-period	
	Participants	Non-participants	Participants	Non-participants	participants	Non-participant	participants	Non-participants
Sorghum (maize) Yield (kg)	2.99 (6.3)	2.54 (6.5)	3.7(2.43)	3.21(2.75)	2.43(5.32)	2.5(5.6)	3.7 (3.23)	2.4 (2.57)
Plot size	3	3	3.2	3.4	3.5	3	3.2	3.4
Labour (ha)	3	2	4	3	3	2	4	3
Experience in farming (years)	9	11	13	15	9	11	13	15
Manure Application per ha (kg)	1.23	1.292	1.20	1.08	1.48	1.19	1.30	1.03
Use of mechanization	1	0.47	0.62	0.43	1	0.47	0.47	0.48
Off-farm income (Tshs)	122,276	99,480	152,784	110,288	114,243	101,460	123,902	120,086
Receiving subsides	0.36	0.27	0.23	0.25	0.40	0.25	0.26	0.24
Access to credit	0.32	0.26	0.21	0.23	0.41	0.25	0.25	0.23
Member of farmers groups	0.75	0.74	0.70	0.76	0.77	0.73	0.78	0.73
Household size	4	4	6	5	4	4	5	6

Significant at 0.05(5%) level

Farmers who participated (treatment) and their counterpart farmers who were non-participants (control) of both weather and agronomic services had similar characteristics, according to the findings of this study. Education, sorghum yield variability, maize yield variability, and manure added per hector all yielded similar results. Information from GFCS-APA shows that in the 2019 (post-period) growing season, however, farmers who participated in CIS produced higher yields than their non-participant counterparts in Kondoa and Kiteto districts. In general, the results in Table 3 show that farmers who took part in the GFCS-APA program had better results than non-participants. These findings depict the substantial differences predicted by the GFCS-APA program to be discovered in sorghum and maize yields between control and treatment groups. While the findings revealed differences between groups and crops, maize yields show more substantial differences than sorghum yields.

During the reference period (2013/2014 to 2010/2019), however, the results demonstrate a difference in manure use between the participants and non-participants groups. These distinctions proved significant. The findings in Table 3 revealed that non-participant farmers applied more manure than their counterpart participants. This suggests that in the Kondoa and Kiteto areas, manure application was lower among GFCS-APA participants than non-participants for both advisory and weather information. The biggest application of manure is likely to reflect the efforts of non-beneficiaries who want to boost their output. Beneficiaries, as opposed to non-beneficiaries, had the best chance of making effective decisions due to the availability of climate information services. Farmers who participated in GFCS-APA agronomic services and non-participants have different fertilizer application practices. Farmers who received GFCS-APA climate information services reported using more fertilizers on their farms than those who did not. In addition, participants and non-participants of GFCS-APA climate information services experienced significant differences in off-farm income diversifications throughout the reference period. Furthermore, the findings of this study demonstrate that all the participants are individuals who have spent more time in the educational system than their counterparts. As a result of these findings, farmers' formal education level has an impact on their likelihood of participating in climate information services distributed through the GFCS-APA initiative. While this is true, all the non-participants lacked formal education as explained by the GFCS-APA program initiative, particularly those who were not exposed to advising services, which could limit their ability to engage in off-farm income-generating activities.

Table 4 shows the results of the balancing tests. Most covariates mean disparities between participants and non-participants of GFCS-APA climate information services were eliminated as a result of these findings. While the disparities were erased, certain differences remained in select circumstances. The rate of bias in these differences, on the other hand, was reduced by 18% and 47%, respectively. The application of matching minimizes the possibility of a biased influence on treatment. This shows that matching increased the likelihood of unbiased treatment.

There was a visual examination of the propensity score matching results to check if there was any overlap. The graph demonstrated, however, that the propensity scores of participants and non-participants farmers in the GFCS-APA CIS distribution in the Kondoa and Kiteto districts are fairly similar.

Table 4: Covariance Mean on Pre to Post-Period Matching

Indicator	Sample	Mean				T-test	
		Part.	Non-Part.	% Bias	% Reduced bias	T-test	P-value
Age	Unmatched	63.853	62.903	4.7	54.4	0.81	0.461
	Matched	63.688	63.16	3.6		0.60	0.517
Education	Unmatched	.31813	.2126	32.9	80.6	8.33	0.000
	Matched	.31502	.32338	-3.1		-0.72	0.424
Fertilizer use	Unmatched	.74336	.66	27.1	83.1	6.15	0.000
	Matched	.85125	.85841	-1.8		-0.24	0.625
Off-farm income	Unmatched	1.6e+05	1.4e+05	16.4	67.9	3.53	0.001
	Matched	1.4e+05	1.6e+05	-5.9		-0.68	0.374
Manure use	Unmatched	.26815	.5621	-48.6	67.3	-7.68	0.000
	Matched	.26957	.32751	-11.2		-0.10	0.026
Plot size	Unmatched	1.117	1.1138	27.1	97.5	5.05	0.000
	Matched	.75810	1.6448	0.4		0.06	0.842
Credit access	Unmatched	.18622	.25905	6.1	94.5	1.27	0.103
	Matched	.18136	.27986	0.3		0.06	0.855
Districts	Unmatched	.8947	.86708	52.0	92.5	8.87	0.000
	Matched	.89462	.98511	3.9		1.59	0.123
Household size	Unmatched	4.2303	4.4457	31.6	82.0	6.66	0.000
	Matched	4.1204	5.0771	5.7		0.94	0.339
Sorghum yield	Unmatched	2.7e+05	1.6e+05	18.3	27.3	5.01	0.000
	Matched	1.5e+05	1.9e+05	-14.9		-.16	0.020
Maize yield	Unmatched	3.9e+05	2.3e+05	18.3	36.4	7.04	0.000
	Matched	3.8e+05	2.6e+05	-14.9		-1.18	0.040

Significant at 0.05(5%) level

Table 5 of the DEA output revealed that all farmers' technical efficiency was low, with an average TE score of 61%. This finding implies that sorghum and maize would have succeeded even with a small amount of capital. When inputs are predicted to be decreased by 39%, this can be achieved. The Propensity Score Matching (PSM) results of sorghum and maize divergences across participants and non-participants of the GFCS-APA climate information service-based program are on the 59% TE levels, as shown in Table 5.

Table 5: DID Estimation of the Impact of Climate Information Services on Yields Using Propensity Score Matching (PSM)

CIS	Estimated Effect on Yield			
	Sample	Q75th	Q50th	Q25th
Weather Information vs. non-part.	279.6* (262)	48.190 (41)	162.3*(334)	204.3*(308)
Advisory Service vs. non-part.	264 (39)	-129.28* (-149)	-31.045 (-152)	73.5* (165)

*Note: *Significant at 0.05(5%) level*

The findings in Table 5 demonstrate the estimated effect on yield among farmers exposed to the GFCS-APA-based CIS and non-exposed. While the results in Table 5 demonstrated a correlation, there were also variances across crop yield quantiles and among climate information services provided for on-farm decision making. Positive correlations exist between program participants and non-participants for the median levels, total sample, and at the 25th quantile, according to these findings. At the 25th and 50th quantiles, weather information recipients realized 213kg and 172kg more yield than their non-participant counterparts, respectively. On average, participants of weather information by GFCS-APA had 279kgs more yield than non-participants. The findings also reveal that there is an uncertain direction effect between program participants who additionally received advice services and non-program participants. The data at the 25th quantile suggested that, despite all of the program's benefits, participants have a weak dominance over non-participants. In contrast, non-participants were outnumbered by the 75th quantile participant. Farmers who were exposed to GFCS-APA advisory services were more likely to achieve higher yields than those who only received weather information. At the 25th quantile, participants in the GFCS-APA were predicted to weigh 55 kilograms more, and at the 50th quantile, they were projected to weigh 84 kilograms more. In general, advisory services provided by GFCS-APA to climate information service users increased the likelihood of farmers harvesting 244kg more than those who only received weather information.

Despite the unpredictability of the results, farmers who use GFCS- APA's climate information services were more likely to outperform their non-participant counterparts in terms of sorghum and maize yield. Participants who received agronomic consulting services, on the other hand, were more likely to raise their sorghum and maize yields than those who merely received weather information. According to this study, advisory services increase sorghum and maize output by 130kg at the median quantile, compared to farmers who simply receive weather information. In general, given that all farmers are technically efficient, having agronomic advising services enhances the likelihood of harvesting more than 130 kilograms over those who merely receive meteorological information.

4.3 The Influence of GFCS-APA CIS on Maize Yield

The influence of CIS on crop yields was also investigated in this study. To explain the influence of climate information services, the entire reference period, including before and after periods were considered. Table 6 shows the specific estimation results, which indicate how climate information services affect maize production in the Kondoa and Kiteto districts. The results show that anticipated outcomes are quite comparable in terms of robustness and directions. Participants and non-participant farmers were suitably equivalent in terms of average maize before the intervention by GFCS-APA (pre-period/baseline period), according to the results of the fixed linear mixed model difference in different statistical estimations. This means that the observed maize yield differences between program participants and non-participants were not statistically significant (β =-0.1431, p=0.1262). That is, both participants' and non-participants' estimated average maize crop yields were lower than baseline data by GFCS-APA. In the DID estimation, both participants and non-participants experience a decline in maize yield even after the GFCS-APA climate information services efforts. However, the findings show that engaging in the GFCS-APA climate information service reduced maize yield variability by 125.10kg/ha.

Table 6: DID Estimates on the Influence of Climate Information Services on Maize Yield

Effect	Estimate (β)	Standard Error	P-Value
Intercept	4.1376	0.0765	<0.0001
Duration *(Time)*			
Post-period	-140.03	0.1120	<0.0001
Pre-period	Control		
Groups involved *(Treatment)*			
Participants	-14.31	0.1168	0.2612
Non-Participants	Control		
Influence *(Time*Treatment)*			
Duration* Beneficiaries	1.2509	0.1709	<0.0001

Note: *Significance at 0.05*

The large disparity observed in the magnitude of the effects can be explained in part by differences in unobserved variation among maize farm households. Table 6 shows the interaction term coefficient of 1.5092 for DID repeated regression estimated output, which was significant at the 0.05 level (p=0.0010). As a result, the supposition is that, despite similar socioeconomic features, participation in GFCS-APA climate information services increases the possibility of reducing climate variability uncertainty in semi-arid locations. The results in Table 6 also suggest that for participating farmers to benefit equally from GFCS-APA CIS, they must change their behaviour and start using CIS in their decision-making. As a result, the primary purpose of CIS is to connect farmers with reliable information at the right moment and with appropriate help.

The findings of the DID model challenge the conclusions of Ebhuoma *et al.* (2020) and Naab, *et al* (2019), who found no effect of the climate information services program on agricultural yield. The findings of this study, however, are in line with those of other recent investigations (Dayamba *et al.*, 2018; Guido *et al.*, 2020; Kumar *et al.*, 2020) that have indicated a favourable contribution of CIS to improving farmers' decision efficiency. According to Wilson, *et al* (2019), farmers' business practices have altered as a result of trustworthy information, particularly in rural areas, however, the focus differs per crop.

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Farmers have gained a great deal of knowledge and are now able to schedule their planting and harvesting based on weather and environmental conditions as argued by Dobardzic *et al.* (2019). Several authors argue that climate information services can present acceptable yields and close the crop yield gap in this circumstance (Ebhuoma *et al.,* 2020; Guido *et al.*, 2020; Kumar *et al.*, 2020; Sebaggala and Matovu, 2020). Maize yields have been falling significantly as a result of increased variability in environmental components such as rainfall and temperature, according to AGSTAT (2019). This study, on the other hand, indicates that by giving farmers access to climate information and services, they may lessen the uncertainty associated with climatic unpredictability and, as a result, boost their output. Spreading agricultural information services has been identified as an effective technique for developing countries to help agriculture sector growth hence ensuring food security and poverty reduction (Sebaggala and Matovu, 2020).

4.4 The Influence of GFCS-APA CIS on Sorghum Yield

Table 7 shows the results of the fitted linear mixed model for sorghum production. At baseline (before the GFCS-APA distribution of climate information services), the difference in difference (DID) linear mixed model estimation findings suggest that there is no significant difference in sorghum output between CIS participants and non-participants (=-0.2333, p=0.3623). This suggests that pre-spread of climate information services by GFCS-APA, the two groups produced equivalent amounts of sorghum yield. It was also noted that after the GFCS-APA dissemination of climate information services, the average number of kilograms gathered for both groups was higher than the baseline. Non-participants of GFCS-APA climate information services increased their estimated mean number of kilograms harvested by 48.53 (246.32 to 294.85), whereas farmers who participated in GFCS-APA climate information services increased their estimated mean number of kilograms harvested by 24.22 (271.87 to 296.09). The fitted model's interaction term, however, was not significant at p=0.2674. This suggests that the quantity of kilogram of sorghum harvested by farmers who participated in GFCS-APA did not differ significantly from non-participants of GFCS-APA use of CIS from baseline to post period. This recommends that the adoption of climate information services disseminated by GFCS-APA had no discernible impact on sorghum production fluctuations.

Table 7: DID Estimates on the Influence of CIS on Sorghum Yield

Contribution	Approximation (β)	Error	P-Value
Coefficient	2.3212	0.1511	<0.0001
Time			
Pre-period	48.53	0.1320	0.0004
Post-period	Control		
Treatment			
participants	25.55	0.2671	0.3411
participants	Control		
Time*Treatment			
Time* participants	-0.2431	0.2333	0.2999

Note: *Critical level of significance=0.05*

These findings imply that access to CIS has no substantial impact on enhanced sorghum output. The hypothesis that adopting CIS enhances crop yields, especially in semi-arid areas with high climate variability, is supported by these results. Nonetheless, there are several reasons why CIS failed to produce favourable sorghum yield outcomes in this study as in Table 7. First, having access to CIS may not be sufficient to increase sorghum yields. Another reason for the decrease in sorghum output with the GFCS-APA climate information services could be that maize and sorghum crops compete for the same priorities and resources. Because maize is seen as a more valuable food crop than sorghum, it is expected to contribute to the reduction of food insecurity by increasing food satisfaction. For these and other reasons, farmers may devote more effort to enhancing the quality and quantity of maize farms than sorghum farms.

Likewise, the literature (Agricultural Statistics, 2019; Dobardzic *et al.*, 2019; Wilson, Akinola, and Chinecherem, 2019) suggests that the availability of adequate information services should improve on-farm production. This study's findings, on the other hand, are in line with AGSTAT (2019), which discovered that maize yield fluctuations are negative, whereas sorghum yield fluctuations are positive. As a result, maize yields have decreased while sorghum yields increased. As a result, the yield differential between farmers who participated in the GFCS-APA climate information services dissemination and those who did not is minimal. Although experimental field data for the two seasons demonstrate a significant increase in sorghum production, there is diversity among varieties, according to Msongaleli *et al.* (2017). In semi-arid areas, season weather variance caused an increase or decrease in sorghum yields, according to the same study. Mkonda and He, (2018) discovered that sorghum yields fluctuated across time, with extended dry spells yielding lower yields.

According to Decision Theory, farmers would always use distributed climate information and support services to make an informed choice from a variety of possibilities (Parmigiani and Inoue, 2009). Farmers, on the other hand, would rather make an educated decision about a crop that appears to be valuable to them. If no other considerations are taken into account, this suggests that increasing usage of climate information and support services will likely increase maize cultivation more than sorghum cultivation. Climate guidance and help are now widely regarded as necessary.

5. Conclusion and Recommendations

The provision of CIS is regarded to be a beneficial approach to help the expansion of the agricultural sector and the decreasing poverty in developing economies like Tanzania. Through various actions, resources have been channelled into expanding climate information services to abundant farmers' populations in developing countries. However, there is a scarcity of robust effect analyses to back up increased investment in climate information services. By presenting evidence from thorough baseline survey data collected from farmers through the recall method between the 2013/2014 and 2018/2019 growing seasons, this paper contributes to the impact evaluation studies on CIS.

The findings of this study provide insight into the impact of access to CIS on sorghum and maize yields, as well as important policy implications for increasing crop yield in the face of climate variability. When the selection of unobservables is controlled, the estimation findings imply that climate information services have a positive but small impact on farm maize yield. This is in contrast to previous studies on the impact of CIS, which found that access to CIS has a significant positive impact on farm-level outcomes. Because of the CIS contact variable, the conclusions of this research may be prone to selection and endogenous bias. The minimal positive impacts of access to CIS, on the other hand, emphasize that, due to Tanzania's farmers' scepticism, access to current CIS does not translate into significant-good effects on sorghum yields. Many critics have stated that Tanzania's climate information systems are unreliable and not likely to have a significant positive impact on minimizing the impact of climate variability on crop production.

In terms of policy, the findings of this study suggest that farmers gain differently concerning CIS by GFCS-APA depending on their relevant distinguishing elements that characterize their differences in household structure. In this regard, interventions like GFCS-APA that enhance farmer climate information services dissemination, access, and uptake should be supplemented with dynamic policies that encourage farmer growth and productivity in general.

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