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Adapting innovation of information and communication technologies to climate change risks for agriculture sustainability in central Tanzania

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Abstract

Climate change is one of the most challenging and alarming global issues for threatening the existence of the living entities of ecosystems. Manifestations of climatic aberrations are evidently diverse and extensive in nature. Unfortunately, agricultural sector is heavily vulnerable to the vagaries of climate putting global food security at stake. Farming communities rarely have access to up-to-date weather and climate information, which hinders their ability to practice climate-smart agriculture. Extreme weather events variations in rainfall and temperature can result in reduced yields or even the destruction of crops, affecting farmers' incomes and livelihoods. Unsustainable agricultural practices compound the problem by reducing in soil fertility and the soils' capacity to retain water, contributing to soil erosion. This can drive ecosystem degradation and habitat loss, with a resulting loss of biodiversity. To cope up with this changing scenarios, strategic innovation is a must, especially for the highly populous developing countries like Tanzania. By virtue of the generative and systemic tools of Information and Communication Technologies (ICTs) and its efficient knowledge management system, ICTs offers a great potential to record, transform and disseminate information while strengthening adaptability to the changing situations in multifarious ways. Remote sensing tools and corresponding technological innovations can ensure a sustainable meal to the ever-surging population. Climate change can only be confronted when these future ready technologies will be coupled with efficient agricultural extension protocols. This paper was an attempt to snowball adapted ICTs tools to climate change adaptation strategies as an innovating way to sustain food security and climate resilience community. The recommended tools should cover agronomic data capture, on-farm data visualization, machine learning analysis, meteorological data curation, crop modeling and seasonal climate forecasting.

Keywords: Soil; Communication; Innovation; Climate change; Agriculture

1 Introduction

Climate change and variability (CCV) resulted to global warming evidenced in rapid increase in earth's surface temperature (Christopherson, 2018; IPCC, 2007). CCV increased severity of extreme climatic events including droughts, floods, sea level rise and storms (IPCC, 2007; NOAA, 2014; Christopherson, 2018). These changes already brought various impacts to both communities' livelihoods and ecosystems. However, some of the communities, particularly in the developing countries, are characterized by high vulnerability and adaptive capacities. One of the reasons for these characteristics is poor access to the reliable and timely climate information (Klein *et al.*, 2014).

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Most of the communities in central areas of Tanzania are highly impacted by climate change and variability due to semi-aridity climatic conditions but with low information on climate change and its adaptation strategies (Kahimba *et al.,* 2015). Livelihood of these communities have been negatively impacted due to changes in resources utilization and low production resulting into slowness in poverty eradication (Mwendwa *et al.*, 2017). Hence, there have been initiatives to reinforce communities' adaptation and copping strategies to increase resilience. Despite various copping and adaptation strategies that are in place, information and communication technology (ICT) have not well utilized to provide timely and reliable information to foster communities' adaptation and resilience.

ICTs are important for communities to be well informed about the potential changes in the climate systems and adaption to the associated impacts (Upadhyay & Bijalwan*.,* 2015). An effective adaptation requires quick responses to the changing situation. ICT is potential to provide an effective and timely as well as exchanging supportive mechanism and meteorological information necessary for adaptation. Through ICT, the effects of climate change could be assessed and monitored by developing data base that could trigger accessibility of current information to plan for adaptation. Besides, ICT reduce the lag of information. As such, it is important for mass awareness and fostering mass sensitivity to climate change impacts. Despite of the poor infrastructure to support well advanced ICT in many of the developing countries, yet the available potential of ICTs has not yet well integrated to outreach a wide range of communities to adapt with climate change impacts.

As in other developing countries, Tanzania has not well integrated ICT to adapt to climate change impacts, although there is recognized potentials such as presence of various telecommunication companies, accessibility of internets in many areas and institutions of ICTs. Meanwhile, the climate change and variability pose great impacts to the various communities including central Tanzania communities. Thus, ICTs have great potential to reduce the overall climate change impacts and aiding in meeting the Tanzania's sustainable development goals (SDGs).

1.1 Problem statement

Development of ICTs in 21st century play important roles in meeting the prevailing challenges of CCV. Agriculture development is among the sector negatively impacted by CCV; hence the existing lagging of CCV information hinder adaptation, mitigation and resilience transformation of communities. Power of ICTs provide new avenue of sharing, exchanging and disseminating knowledge and technologies. Currently ICTs have been recognized as a key agent in changing the agricultural extension services and knowledge services. Globalization, competitive market forces, need for value-added farming and sustainable use of natural resources demand a radical transformation of agriculture across the developing world.

New agricultural paradigm necessitates the use of ICTs. So far, we have been adopting the traditional systems such as literature, posters, radios and television to disseminate the agricultural information to the farmers. These systems have time gaps for information transfer from meteorological and research institutions to the farmers. The farmers may depend on extension personnel to get proper advice to cultivate crops. Weather forecasting is one of the important requirements of farming and it helps the farmers to take the right decision at right time. ICTs are seen as important means of achieving such a transformation. ICTs are most effective and faster partners for agricultural extension. The ICT enabled extension systems are acting as a key agent for changing agrarian situation and farmers' lives by improving access to information and sharing knowledge. ICT based agricultural extension brings incredible opportunities and has the potential of enabling the empowerment of farming communities.

Considering attention-grabbing advantages of ICTs, extension practitioners are excited to experiment innovative ICT initiatives. Experiences on "ICTs for Agricultural Extension" initiatives are showing encouraging results in some developing countries like India (Chauhan *et al*., 2016) and also complementing conventional extension communication methods. On the other hand, it is also a challenge to place rural ICTs infrastructures, developing appropriate content, ensuring sustainability and scaling-up. This paper tries to link ICTs to climate information so as to reverse CCV impacts and vulnerabilities and fasten adaptive strategies that will transform communities to be CCV resilient.

Objectives

- General objective

This study is undertaken with the general objective of finding ways to create communities with high adaptive capacity to the impacts of climate change through enriched application of ICTs.

- Specific objectives

Specifically, the study intended to:

- Devise innovative ways of linking information and communication technologies to climate change impacts and vulnerabilities.
- Adapt a spatial-temporal plan that provide efficient movements and quick access of information to climate change vulnerable communities.

2 Material and methods

2.1 Materials

The study was conducted at Mpwapwa District in Dodoma Region. Data have been collected in three wards of Matomondo, Kimagai and Berege specifically in one village purposely selected in each ward namely Mbori, Kimagai and Berege respectively (Figure 1). Selected villages are leading in agriculture production and highly affected with CCV.

Source: Mpwapwa District Strategic Plan 2016 – 2021

Figure 1 Mpwapwa District

2.2 Methods

2.2.1 Data collection methods

Both primary and secondary data were collected. Semi-structured questionnaire for household questionnaire survey, checklist of questions for in-depth interview with key informants, checklist of themes for focus group discussions, and checklist of things/indicators for direct field observation. Data set for climate obtained from Tanzania Metrological Authority (TMA). Documentary review used to collect secondary data.

2.2.2 Sample and Sampling Procedures

The research adopted a mixed design which allows collection and analysis of qualitative and quantitative data. Ten percent of 33 wards equivalent to three wards forming Mpwapwa District were randomly selected for the study. The selected wards were Matomondo, Kimagai and Berege. One village was purposely selected from each ward for a detailed study, namely, Mbori, Kimagai and Berege respectively. The sampling frame of the study was the list of households in study villages. Sampling unit of the study is the household. Household is defined as a group of people living together and choose the authority of one person as a household head. The sampling frame was useful in determination of sample size and selection of a representative sample. It was found that the selected villages had a total of 2867 households. Judgmental sampling technique used to select seven key informants (Ward Executive Officers, Ward Agriculture Officers, and District Agriculture Officer). Table 1 present distribution of sampling frame in study villages.

Table 1 Distribution of households in study villages

Ward	**Village**	**Number of households**
Matomondo	Mbori	1,447
Kimagai	Kimagai	814
Berege	Berege	906
Total		2,867

Sample size was determined using the equation for determination of sample size for unknown population and proportion by (Cochran, 1977) which is given as:

$$n = z^2 / 4e^2$$

n = sample size
p = the population proportions
e = acceptable sampling error (e = 0.05)
z = z value at reliability level or significance level.
- Reliability level 95% or significance level 0.05; z = 1.96
$n = (1.96)^2/4(0.05)^2 = 384.16 \approx 384$

Thus, 384 respondents were interviewed during structured interviews. Number of respondents from each village was determined through proportionate stratified sampling which allowed for sampling of the proportional number of respondents from each village according to its population size. The following equation for proportionate sampling by Salland (2010) was used:

$$P_i = \frac{N_i}{N} n$$

Where,
P_i = Proportional sample of each village
N_i = Number of household in each village
N = Total household forming the sampling frame
n = Sample size.

The computations and sample size for each study village depicted in Table 2.

Therefore, one hundred and fifty-four (154) households' heads were selected from Mbori village, one hundred and nine (109) from Kimagai village, and one hundred and twenty-one (121) from Mitawa village. These sample units were randomly selected using rottenly system.

Table 2 Proportional sample in study villages

Village	Number of households	Sample size
Mbori	1,447	1,447/2,867 x 384 = 154
Kimagai	814	814/2,867 x 384 = 109
Berege	906	906/2,867 x 384 = 121
Total	2,867	384

2.2.3 Data analysis

Quantitative data from household survey were analysed statistically using SPSS and excel softwares. Descriptive statistical analysis used to obtain measures of central tendencies and dispersion. Benefit transfer method used to propose innovative model for sustainable agriculture development so as to link ICTs in spatial-temporal plan that provide efficient movements and quick access of information to climate change vulnerable communities as adapted from Chauhan *et al*. (2018). Qualitative data from key informants' interview (KII), focus group discussions (FGDs) and direct field observation were analysed contently.

3 Results and discussion

3.1 Status of the study communities on ICTs and climate change impacts & adaptation

3.1.1 Socio-demographic characteristics of respondents

Socio-demographic characteristics of the respondents is important in various parameters of climate change. Age of respondents, for instance influences experience and perceptions on climate change together with ways to adaptation to its impacts. Besides, sex and household size may affect access to various resources and adaptive capacity which may impact adaptation to climate change negatively or positively. The socio-economic characteristics of the respondents in this study are presented in Table 3. Of the household heads interviewed, 84.4% were female. This implies that women do most of home and farm activities and always to be at home after farm activities compared to men. This is justified as 99.2% of respondents are married. Also, 76% of the respondents are at least 25 years old. This was important to the climate change adaptation and mitigation because they understand the historical trend of their areas as well as existing indigenous technical knowledge (ITK).

The study indicates that 67.7% of respondents lived in the study villages for at least 30 years. This is important as climate change can be determined and documented for at least past 30 years. Besides, study villages found to have large household sizes. Results show that 53.6% have 1-3 persons per household and 46.4% have at least 4 persons. This is due to the culture of marrying many wives (polygamy) which results into a lot of dependents to feed and take care of. Education background of the surveyed population was at most primary education (86.5%). This is due to shortages of schools especially primary schools resulting into children walking long distances to school.

There was no nearby secondary school in in study villages. This implies that, low education level provides low payment employment opportunities to other sectors different from agriculture. The study villages found to have low income per month resulted mostly from small-scale farming compared to standard living cost needed in the study area. Results show that 85.5% have income of at most TZS 100,000 which means below TZS 3,500 per day (Table 2). This shows that households in the study villages are living in abject poverty and small-scale farming is not well rewarding then there is a need of commercializing and improve agriculture production and productivity to sustain human wellbeing and welfare. Moreover, the chi-square test indicated statistical insignificance on all socio-demographic characteristics of respondents in study villages.

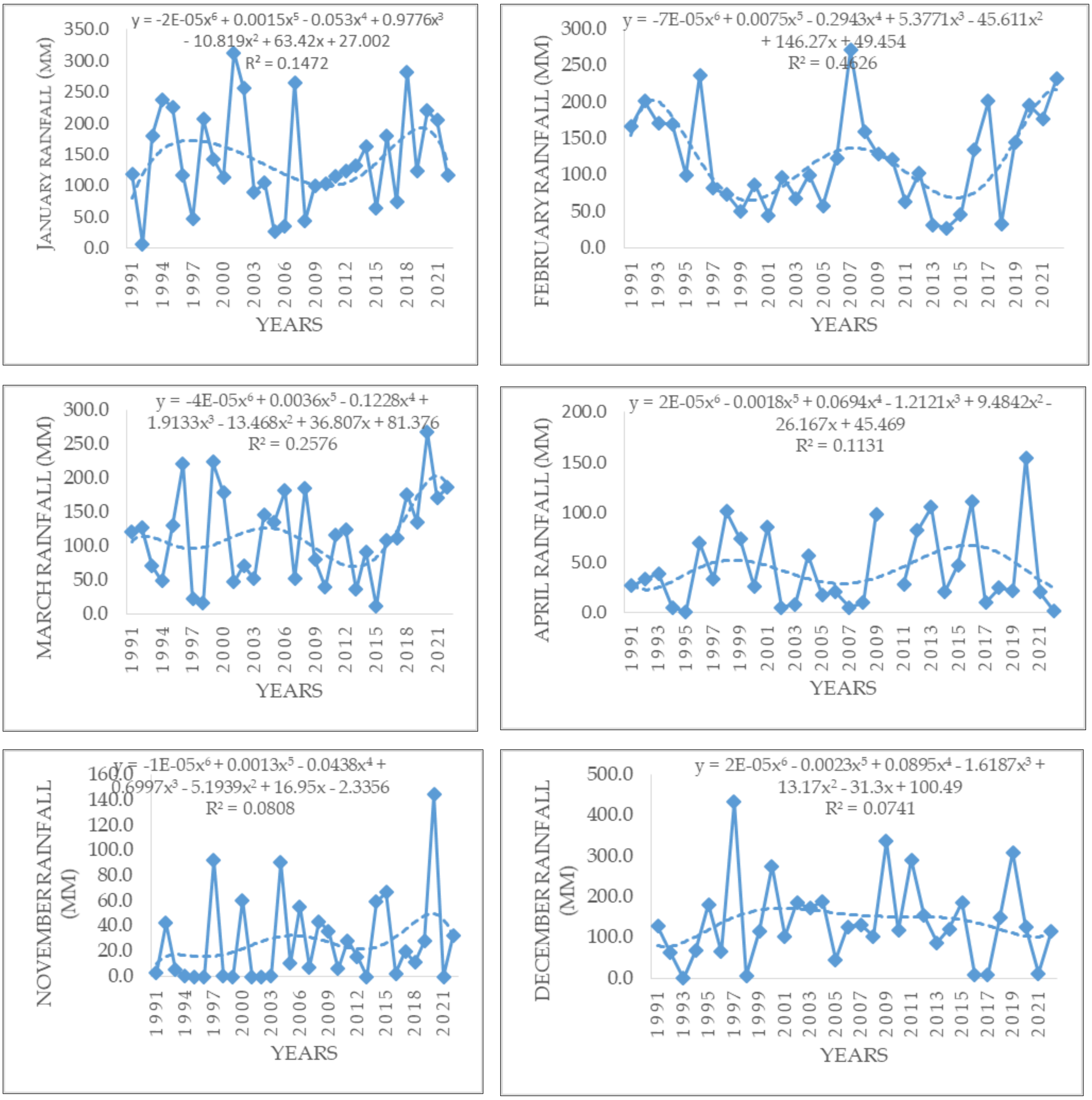
Table 3 Socio-demographic characteristics of respondents

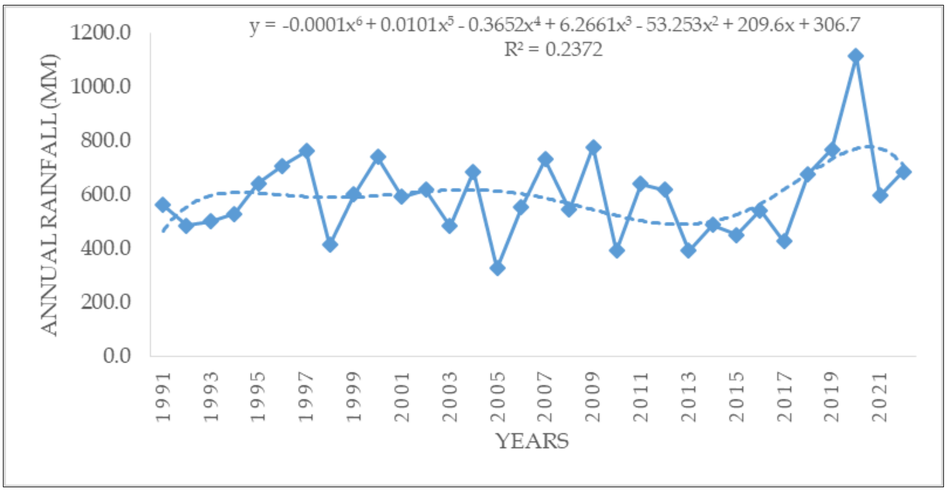
Information	Study villages				Pearson's chi-square
	Berege n=121	**Mbori n=154**	**Kimagai n=109**	**Overall N=384**	**Exact Significance: (2-sided)(1-sided)**
Sex					
Male	21(17.4)[1]	21(3.6)	18(16.5)	60(15.6)	0.670 0.667
Female	100(82.7)	133(86.4)	91(83.5)	324(84.4)	
Marital status					
Single	2(1.7)	0(0)	1(0.9)	3(0.8)	0.298 0.188
Married	119(98.3)	154(100)	108(99.1)	381(99.2)	
Age class					
15-24 Years	7(5.8)	10(6.5)	7(6.4)	24(6.2)	0.950 0.851
25-34 Years	2(1.7)	0(0)	1(0.9)	3(0.8)	
35-44 Years	46(38.0)	61(39.6)	43(39.4)	150(39.1)	
45-54 Years	41(33.9)	52(33.8)	35(32.1)	128(33.3)	
55-64 Years	24(19.8)	31(20.1)	22(20.2)	77(20.1)	
≥ 65 Years	1(0.8)	0(0)	1(0.9)	2(0.5)	
Village's living period					
01-10 Years	23(19.0)	30(19.5)	21(19.3)	74(19.3)	0.998 0.993
11-20 Years	15(12.4)	20(13.0)	13(11.9)	48(12.5)	
21-30 Years	1(0.8)	0(0)	1(0.9)	2(0.5)	
31-40 Years	17(14.0)	21(13.1)	16(14.7)	54(14.1)	
41-50 Years	38(31.4)	51(33.1)	34(31.2)	123(32.0)	
> 50 Years	27(22.3)	32(20.8)	24(22.0)	83(21.6)	
Education background					
Informal education	16(13.2)	21(13.6)	15(13.8)	52(13.5)	0.992 0.992
Primary	105(86.8)	133(86.4)	94(86.2)	332(86.5)	
Household size:					
1-3 Persons	65(53.7)	82(53.2)	**59**(54.1)	206(53.6)	0.646 0.482
4-6 Persons	54(44.6)	72(46.8)	49(45.0)	175(45.6)	
7-9 Persons	2(1.7)	0(0)	1(0.9)	3(0.8)	
Average household's income per month					
≤ TZS 50,000	72(59.5)	93(60.4)	66(60.6)	231(60.2)	0.727 0.502
TZS 50 000-100,000	30(24.8)	40(26.0)	27(24.8)	67(25.3)	
TZS 100,000-300, 000	3(2.5)	0(0)	2(1.8)	5(1.3)	
≥TZS500,000	16(13.2)	21(13.6)	14(12.8)	51(13.3)	

[1] Figures outside and inside the parentheses are frequencies and percentages respectively.

3.1.2 Climatic trends at Mpwapwa District

The study found that annual rainfall and monthly rainfall in rains season in the area decreases with fluctuating rate throughout the study period (Figure 2). On the other hand, the minimum average monthly rainfall for the rain seasons found in the years 2005 (49 mm), 2010 (64.9 mm) and 2013 (65.6 mm); and maximum average monthly rainfall found in the years 2009 (130 mm), 2019 (127.4 mm) and 2020 (185.3 mm).

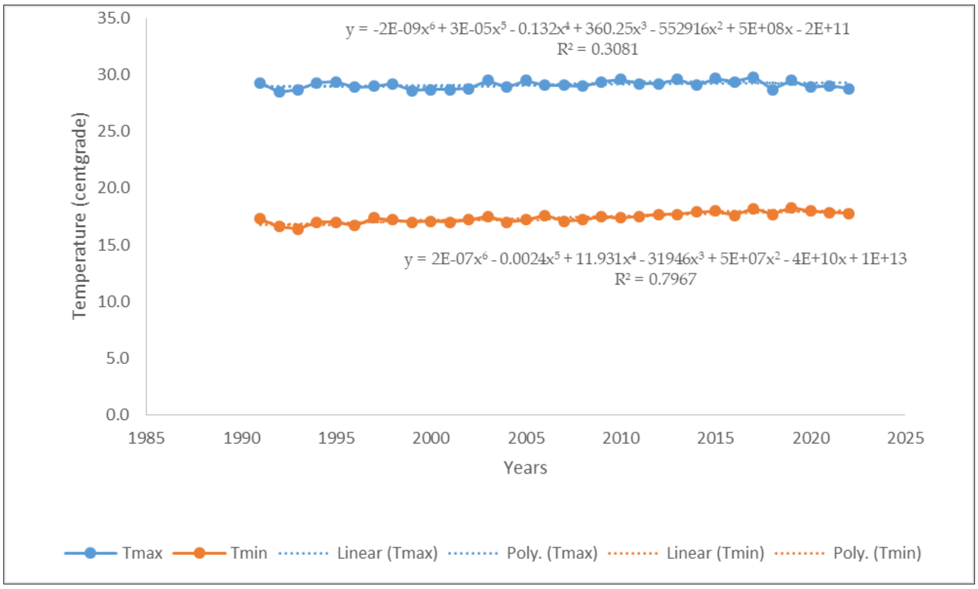




Source: Tanzania Meteorological Authority (TMA) (2023)

Figure 2 Mpwapwa District **a**nnual and monthly (January – April & November –December) rainfall for the period 1991-2022

The study found that annual average minimum temperature are increasing compared to the deceasing annual maximum temperature throughout the study period (Figure 3). The annual maximum temperature increases for the period 1991 – 2002 (0.6 ºC), 2003 – 2012 (0.3 ºC), and 2013 -2022 (0.8 ºC); and annual minimum temperature decreases for the period 1991 – 2002 (0.2 ºC), 2003 – 2012 (0.8 ºC), and increases for the period 2013 -2022 (0.4 ºC)



Source: Tanzania Meteorological Authority (TMA) (2023)

Figure 3 Annual average maximum and minimum temperatures for Mpwapwa District 1991 - 2022

3.1.3 Communities' knowledge and access to climate change information

The results in Table 4 revealed linkages of communities' knowledge and access to climate change information (CCI) as a result of effective participation in climate change adaptation (CCA). The study indicates 78.9% of households acquired education and skills on participation in CCA. Also, households can access climate information frequently (45.8%) and occasionally (54.2%). Media (70.8%) and fellow farmers (27.6%) are the leading means of access to climate information. Most households own mobile phones (80.5%), yet few (26.3%) use it as an aid of obtaining climate information. Furthermore, 65.4% of the respondents in the study villages indicates presence of community based organizations (CBOs), non-governmental organizations (NGOs), and governmental organizations (GOs) deal with CCA on farming. Chi-square test indicates all variables tested are gendered significant at P<0.01 on communities' knowledge and access to climate change information.

Table 4 Communities' knowledge and access to climate change information

Information	**Sex of the respondents**			**Pearson's chi-square**
	Male n=60	**Female n=324**	**Overall N=384**	**Exact Significance: (2-sided) (1-sided**
Acquired education and skills on participation in CCA:				
Yes	35(58.3)[1]	268(82.7)	303(78.9)	0.000 0.000*
No	23(38.3)	0(0)	23(6)	
Don't know	2(3.3)	56(17.3)	58(15.1)	
Access to climate information (CI):				
Frequently	8(13.3)	168(51.8)	176(45.8)	0.000 0.000*
Occasionally	52(86.7)	156(48.2)	208(54.2)	
Means of access to CI:				
Media	5(8.3)	267(82.4)	272(70.8)	
Peers	0(0)	3(0.9)	3(0.8)	0.000 0.000*
Fellow farmers	52(86.7)	54(16.7)	106(27.6)	
Extension officers	3(5)	0(0)	3(0.8)	
Mobile phone ownership:				
Yes	58(96.7)	251(77.5)	309(80.5)	0.002 0.000*
No	2(3.3)	73(22.5)	75(19.5)	
Aid of mobile phone in obtaining CI:				
Yes	5(8.3)	96(29.6)	101(26.3)	0.000 0.000*
No	55(91.7)	228(70.4)	283(73.7)	
Presence of CBO/NGO/GO deal with CCA on farming:				
Yes	8(13.3)	245(75.6)	251(65.4)	0.000 0.000*
No	52(86.7)	79(24.4)	133(34.6)	

3.2 Innovative ways of linking information and communication technologies (ICTs) to climate change impacts and vulnerabilities

Presently, the ratio between farmers and extension workers is nearly 1: 2000 (Hella, 2013), which is really a very demanding issue to contact more number of farmers by extension personal. Although the appointed village extension workers disseminate the information, they hardly accept any accountability. These two issues have created toe urgency to help and guide the poor farmers properly. The cost factor in face-to-face information dissemination at the right time and difficulties in reaching the target audiences have created the urgency to introduce ICTs. It is by the introduction of ICTs, information can also be upgraded at the least cost.

Key features of ICTs extension in Tanzania agriculture includes strengthens research-extension-farmer linkages on issues related to agriculture and allied sectors; disseminates the technical knowhow to the farmers through ICTs; serves as a single point of contact and direct interaction of farmers with the scientists and sectoral officials in obtaining information and clarification of doubts; and online solutions for the problems encountered day to day on field crops and horticultural crops in the production and protection aspects.

Application of ICTs in agricultural extension as proposed by Chauhan *et al*. (2016) and agreed during focus group discussions (FGDs) conducted in each village and key informants' interview (KII) includes tremendous potential of ICTs to improve the reach, credibility and impact of agricultural extension, if used appropriately; expands the role of agricultural extension from "Transfer of Technology" to "Agricultural Information sharing and Building Agricultural Knowledge Networks"; and the type of ICT application needed is decided once we understand the context of "agricultural extension" to provide "total information and advisory support to farmers" on all aspects of farming, marketing, and management. Furthermore, the areas in which ICTs can be deployed were proposed as online services for information on each crop; online interaction facility to interact with nearest research station; agriculture and allied departments for advice on current schemes, projects, varieties etc.; information on all sources of Agricultural credit and crop insurance and their terms and conditions; information sharing mechanisms among the farmers, extension workers and scientists of every district, division, ward, and village; question Answer service (on all lines in the country) for each district in the country; online information on market prices of all commodities at village, ward, district, region and major national market level; online monitoring and information sharing on all agricultural development projects in the country; online sharing of District Agriculture development plans, (example- strategic Research and extension plans (SREP's) of different districts; online information on market prices of all commodities at village, ward, district, region and major national market level; market intelligence on major crops; online weather forecasting and its impact on major crops, on a weekly basis, including early warning systems; online service on land records; e-commerce for direct linkages between local producers, traders, retailers, and farmers; information on availability and rates of agricultural inputs viz. seeds, fertilizers, pesticides, machinery etc.; and information on all Government and Non-Government Organizations working directly or indirectly in the agricultural sector.

Also, Chauhan *et al*. (2016) suggestions on future course of action were agreed by FGDs and KII as may result from an active integration of ICTs initiatives for agricultural extension. However households' survey results indicates 21 future course of action priotised highly and 07 course of actions had less priority as shown in Table 5.the les priotised future course of action includes availability of videos on phones, collaboration with progressive farmers to make them more receptive to ICTs, combination of allied branches of agriculture through ICTs, creation of database for efficient monitoring and action, portal should contain indigenous practices and follow-up, possibility to work in offline mode, and promotion of active participation. The results from household survey shows that, farmers in the study area are not fully aware of the ICTs contribution and integration to agriculture development in affordable and effective linkage.

Table 5 Future course of action of ICTs on agriculture development

Future course of action	Households' responses				
	SA	A	N	D	SD
Achieve Better Connectivity	323(84.1)[1]	58(15.1)	0(0)	3(0.8)	0(0)
Achieve low-cost connectivity	323(84.1)	58(15.1)	0(0)	8(0.8)	0(0)
Adequate linkages	325(84.6)	56(14.6)	0(0)	3(0.8)	0(0)
Availability of videos on phones	50(13)	51(13.3)	27(7)	47(12.2)	0(0)
Collaboration with progressive farmers to make them more receptive to ICTs	2(0.5)	2(0.5	278(72.4)	51(13.3)	51(13.3)
Combination of allied branches of agriculture through ICTs	47(12.2)	147(38.3)	2(0.5)	188(49.0)	0(0)
Creation of database for efficient monitoring and action	29(7.6)	3(0.8)	225(58.6)	125(32.6)	2(0.5)
Design to meet farmer's individual requirements	278(72.4)	51(13.3)	29(7.6)	3(0.8)	23(6)
Farmer's friendly character	260(67.7)	48(12.5)	73(19)	3(0.8)	0(0)
Free helpline numbers for immediate solution	349(90.9)	3(0.8)	32(8.4)	0(0)	0(0)
Incentives for e-ICT personnel (kiosk operators)	275(71.6)	54(14.1)	26(6.8)	29(7.6)	0(0)
Include all stakeholders to generate farming interest	93(24.2)	149(38.8)	3(0.8)	59(15.4)	80(20.8)
Kiosk should also contain other agricultural services	374(97.4)	7(1.8)	0(0)	3(0.8)	0(0)

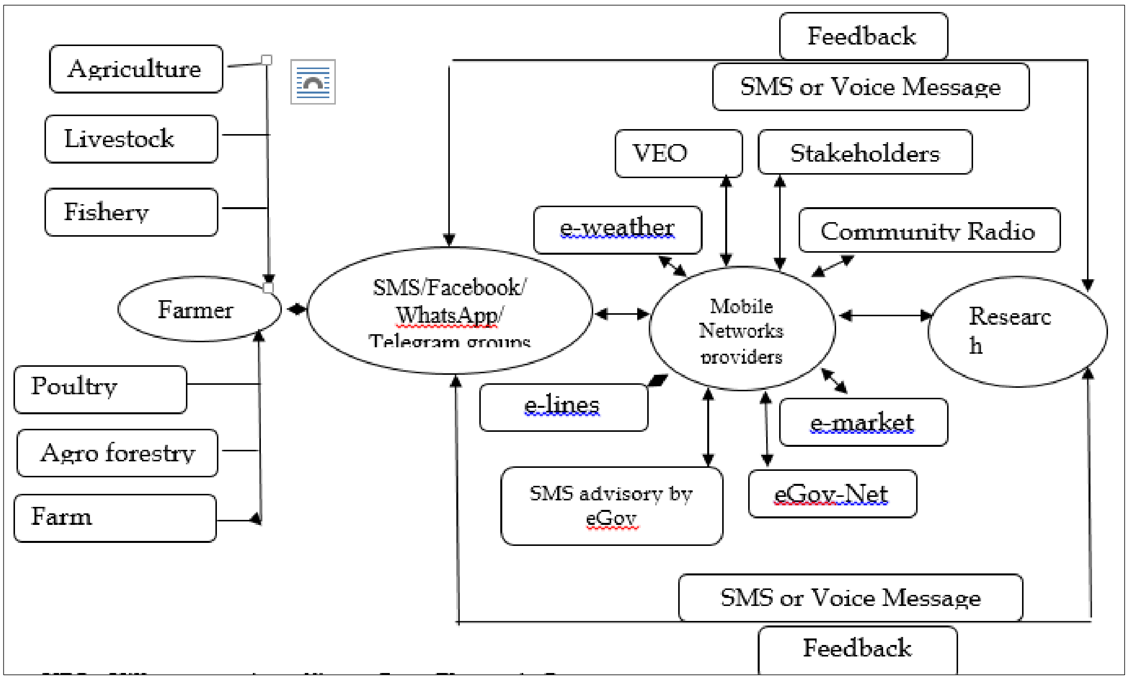
Multiple languages for easy understanding	376(97.9)	5(1.3)	0(0)	3(0.8)	0(0)
Paid-extension for creating more interest	376(97.9)	5(1.3)	0(0)	3(0.8)	0(0)
Portal should contain indigenous practices and follow-up	52(13.5)	96(25)	0(0)	0(0)	27(7)
Possibility to work in offline mode	2(0.5)	0(0)	278(72.4)	53(13.8)	51(13.3)
Promising Devices	376(97.9)	5(1.3)	0(0)	3(0.8)	0(0)
Promotion of active participation	29(7.6)	5(1.3)	225(58.6)	15(32.6)	0(0)
Proper linkages with newer technologies from abroad suited to region	301(78.4)	51(13.3)	29(7.6)	3(0.8)	0(0)
Quick response time	260(67.7)	48(12.3)	70(18.2)	3(0.8)	3(0.8)
Regular farm visits by experts for verification of result	349(90.9)	3(0.8)	29(7.6)	0(0)	0(0)
Semantic search–easy to manipulate	275(71.6)	54(14.1)	26(6.8)	29(7.6)	0(0)
Suitable business model for scaled-up action	93(24.2)	203(52.9)	26(6.8)	59(15.4)	3(0.8)
Synergy/partnership between organizations	275(71.6)	54(14.1)	26(6.8)	29(7.6)	0(0)
Use of GPS to monitor crop diseases efficiently	93(24.2)	149(38.8)	3(0.8)	59(15.4)	80(20.8)
Use of ICT tools other than the internet like cell phones with wider reach	374(97.4)	7(1.8)	0(0)	3(0.8)	0(0)
Use of more voice-based services for easy understanding	376(97.9)	5(1.3)	0(0)	3(0.8)	0(0)

SA = Strongly agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree; [1] Figures outside and inside the parentheses are frequencies and percentages respectively

3.3 Spatial-temporal plan that provide efficient movements and quick access of information to climate change vulnerable communities

The innovative ICT model for sustainable agriculture development indicated in Figure 4 was adapted from Chauhan *et al.* (2016) to suit socio-culture and geolocation of study area which is rural locality.

The implementation of the aforementioned model requires strategies that will not counterfeit the context of climate change and variability (CCV). Suggested strategies from Chauhan *et al*. (2016) that also agreed during FGDs and KII as suitable strategies for adapting to climate change and vulnerabilities in agricultural development of central Tanzania. However, results from households' survey indicated that, 82.3% of the strategies are at least agreed to be adapted and 17.7% of strategies are not supported by households to be adapted includes strategies "a", "c" and "p" as indicated in Table 6. Thus, based on households indigenous and taught knowledge, culture, and socio-economic development provides capability of choosing strategies that can be adapted. Leaving behind these three strategies will provide study gap that must fulfilled for sustainability of agriculture development in the study area.



VEO= Village extension officer, eGov= Electronic Government; Source: Adapted from Chauhan et al. (2016)

Figure 4 Adapted innovative ICT model for sustainable agricultural development

Table 6 Adapted strategies for innovating ICTs to agricultural development in the context of CCV

Adapted strategies	Households' responses				
	SA	A	N	D	SD
Capacity building of extension professionals in terms of computer literacy by providing training through resource institutions.	2 (0.5)[1]	0(0)	278 (72.4)	53 (13.8)	51 (13.3)
Centre of extension in the country should play the role of coordinating agency for various electronic, print media and traditional media providing extension services. This can be achieved by pooling expert information on agriculture available with different media at one place and disseminating them in an appropriate mode.	376 (97.9)	5 (1.3)	0(0)	3 (0.8)	0(0)
Continuous updating of information support system is the need of the hour.	29 (7.6)	5 (1.3)	225 (58.6)	15 (32.6)	0(0)
Each village or group of villages should have one agricultural graduate to manage Public Agro Cyber Cafe (ACC).	301 (78.4)	51 (13.3)	29 (7.6)	3 (0.8)	0(0)

Educate farmers and make them capable of using the computer: The resource institutions should provide training to the farmers on the use of computer and internet based agriculture. In this regard, a campaign can also be launched to open an e-mail account of farmers so that farmers could be provided door to door e-mail information through a centralized agency of the area.	260 (67.7)	48 (12.3)	70 (18.2)	3 (0.8)	3 (0.8)
Establishment of Public Agro Cyber Cafe (ACC) at village levels to obtain latest information by the farmers.	349 (90.9)	3 (0.8)	29 (7.6)	0(0)	0(0)
Evolve mechanisms for developing situation based expert system for dissemination of information consisting of appropriate media mix. Trained personnel for the purpose should be made available by the extension scientists in different ICAR institutes and country's Agricultural colleges/Universities. This type of expert system will serve as a model for dissemination of situation-based information in different parts of the country.	275 (71.6)	54 (14.1)	26 (6.8)	29 (7.6)	0(0)
Intensify Human Resource Development initiatives through institutionalization (by providing training).	93 (24.2)	203 (52.9)	26 (6.8)	59 (15.4)	3 (0.8)
Tapping of human resource; opportunities are to be provided for reservoir of unemployed youth (10+, graduates and postgraduates in agriculture) for supporting agricultural production process by undertaking agribusiness ventures to meet the felt needs of technical and extension service support to the farming community.	275 (71.6)	54 (14.1)	26 (6.8)	29 (7.6)	0(0)
The budgetary support for extension services should be at par with research in agriculture.	93 (24.2)	149 (38.8)	3 (0.8)	59 (15.4)	80 (20.8)
The country Agricultural Universities/colleges should constitute a department of an expert system for agriculture on a priority basis. The department should concentrate on the creation of comprehensive database pertaining to the locality, the needs of the farmers and demand at the regional, national and international market. The department of an expert systems on agriculture be provided with internet and the latest multimedia facilities and should have readily available a team of experts for solving any situational problems.	374 (97.4)	7 (1.8)	0(0)	3 (0.8)	0(0)
The resource institution situated in a locality should take a lead in developing location specific; need-based expert systems for different agricultural, horticultural and animal husbandry practices. The centre extension at the national and regional level should make a pool of relevant expert system software's and website should be launched for the benefit of farmers and extension workers.	93 (24.2)	149 (38.8)	3 (0.8)	59 (15.4)	80 (20.8)
The Use of ICTs for extension service; the present day extension service requires modification and reorientation to meet the demand of changing agricultural scenario at the global level. To equip individual farmers for active participation in global market ICTs has to be used in extension services. Our existing ICTs should be redesigned to meet the requirements of the WTO.	374 (97.4)	7 (1.8)	0(0)	3 (0.8)	0(0)

Use ICTs for minimizing time lag between technology generation and adoption.	376 (97.9)	5 (1.3)	0(0)	3 (0.8)	0(0)
Use of Information and Communication Technologies (ICTs) in extension service. Conventional energy sources should not be the barrier for use of ICTs for extension service. Nonconventional energy sources like solar, rechargeable batteries, dynamo, etc. should be adopted for effective use of ICTs at village level.	376 (97.9)	5 (1.3)	0(0)	3 (0.8)	0(0)
Utilize Geographical Information System and Global Positioning System for agricultural extension purpose with the help of ICTs. The farmers and development workers can be facilitated to get access to the information pertaining to land, water, market, pest, weather etc. through these systems.	52 (13.5)	96 (25)	0(0)	0(0)	27 (7)

SA = Strongly agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree; 1 Figures outside and inside the parentheses are frequencies and percentages respectively

4 Conclusion

Agriculture is highly dependent upon the climate. Changes in the frequency and severity of droughts and floods pose challenges for farmers and threaten food security. Unpredictable, shifting weather patterns, and extreme weather events can harm crops and reduce yields. The need to develop ICT tools and applications to help farmers in Tanzania makes climate-smart decisions is unavoidable. The ICT tools and applications will enable extension officers to collect, analyze, and deliver information that allow farmers to understand variations in seasonal climate conditions, and thus adjust their management practices to cope with them. The tools should cover agronomic data capture, on-farm data visualization, machine learning analysis, meteorological data curation, crop modeling and seasonal climate forecasting. This will increase agricultural productivity, food and income security, and allows for more sustainable farming. To reach the intended output needs adaptation of discussed innovative ICT model and agreed strategies for implementing the model.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no any conflict of interest for publishing this paper.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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