Heliyon 7 (2021) e07873

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Communicating climate change adaptation strategies: climate-smart agriculture information dissemination pathways among smallholder potato farmers in Gilgil Sub-County, Kenya

Andrew Waaswa[a,*], Agnes Oywaya Nkurumwa[a], Anthony Mwangi Kibe[b], Ng'eno Joel Kipkemoi[c]

[a] Department of Agricultural Education and Extension, Egerton University, Kenya
[b] Department of Crops, Horticulture, and Soils, Egerton University, Kenya
[c] Department of Curriculum, Instruction and Education Management, Egerton University, Kenya

ARTICLE INFO

Keywords:
Climate change
Climate-smart agriculture
Sustainable development
Information dissemination pathways
Gender
Adoption
Potato production
Smallholder farmers
Kenya

ABSTRACT

Proven and sustainable practices like climate-smart agricultural practices (CSAPs) need to be prioritized and promoted for uptake especially by the farmers to achieve sustainable development. These are capable of contributing to the realization of sustainable development goals through averting food and nutritional insecurity, increasing and sustaining yields that translate into increased incomes and later reduced poverty. This is because CSAPs enable farmers to adapt and mitigate climate change effects. However, due to inappropriate communication of CSAPs to the farmers, to date, some farmers still see no escape route from the frightening effects of climate change and they are currently adopting a rather fatalistic attitude. This study investigated the information dissemination pathways used by different categories of smallholder potato farmers for and practice of CSAPs. It found a difference between information sources and practice of CSAPs at a 5% level of significance ($\chi2 = 100.12139$, df = 2, $p < 0.05$, Cramer's V = 1.0), and a difference in the use of the three information dissemination pathways between men and women at a 5% level of significance ($\chi2 = 6.05949$, df = 2, $p < 0.05$, Cramer's V = 0.17406). The three information dissemination pathways included media, neighbors and friends, and extension officers. Generally, farmers were aware and practiced the CSAPs investigated in this study except for irrigation with high awareness yet with low uptake percentage and potato seedlings and minitubers both with low awareness and practice respectively. This study recommended mainstreaming of CSAPs information.

1. Introduction

The consequences of climate change on people and agricultural production have attracted global attention (Acosta et al., 2021; Amadou, 2020). Public, private, and non-profit development agencies have broadened their scope to cushion farmers against the climate change effects, more so on the smallholder farmers in Africa where the magnitude of the effect is exorbitant (Alliagbor et al., 2020; Derbile et al., 2021). Dissemination and practice of climate-smart agricultural practices (CSAPs) are principal strategies to cope with the impacts of climate change (Alliagbor et al., 2020; Waaswa et al., 2021). The practice of CSAPs portrays the potential to boost and sustain agricultural productivity and improve farmers' resilience to climate change shocks (Arslan et al., 2014; García de Jalón et al., 2017; Martey et al., 2021). The practice of CSAPs is also a fundamental remedy in alleviating poverty, food, and nutritional insecurity by improving agricultural output plus incomes of farm families beyond Africa. For example, in the Sub-Saharan, CSAPs are continuously being scaled up to adapt to climate change and increase yields (Chirambo, 2018; García de Jalón et al., 2017).

CSAPs are of a farm, international level, and of financial matters of concern (Amadu et al., 2020). They are a present strategy to reposition and modify agricultural systems to battle food and nutritional insecurity under climate change. Climate change increases the inabilities of smallholder farmers to meet their present and future needs by threatening agriculture on which they solely depend for their livelihoods (Derbile et al., 2021; Lipper et al., 2014). It reduces their resilience and copying potential by destructing agricultural food systems (Ingutia, 2021; Waaswa and Satognon, 2020). CSAP is an integrated and

* Corresponding author.
E-mail address: waaswa22@gmail.com (A. Waaswa).

https://doi.org/10.1016/j.heliyon.2021.e07873
Received 9 May 2021; Received in revised form 17 June 2021; Accepted 23 August 2021

interdisciplinary approach tailored towards transforming and repositioning agricultural and food systems to promote growth and development while cushioning food security against climate change (Chandra et al., 2016, 2018). CSAPs relate to diverse production methods blended as a unified strategy to complement one another to increase and sustain agricultural outputs and incomes of the farmers (Food and Agriculture Organisation (FAO), 2010, 2014). CSAPs do not certainly comprise of new production methods and practices, but rather any technology used in production with the ability to contribute to climate change mitigation and suppression of its fatal outcomes on the agricultural and food systems (Lipper, 2017).

This study defined CSAPs as any common farming production practice that has been reliably examined and deemed most reliable in reducing or dismissing climate change effects on a given system, especially in potato production. Examples of CSAPs entail but not limited to (i) drought-tolerant and high-yielding crop varieties, (ii) synthetic fertilizers, (iii) rainwater harvesting and storage, (iv) agroforestry, (v) irrigation, (vi) mulching, (v) composting, (vii) terracing, (viii) potato apical rooted cuttings (potato seedlings), (ix) potato minitubers, (x) crop rotation, (xii) intercropping, (xiii) drainage management and (xiv) minimum tillage (Waaswa et al., 2021, p. 6). Since the rebranding of some agricultural practices into CSAPs, some farmers react to climate change by practicing these CSAPs on their farms (Nyongesa et al., 2019; Wekesa et al., 2018). However, it's on record that farmers' choice of CSAPs in Kenya has remained low and consequently resulting in noticeable climate change effects on their livelihoods (Cavanagh et al., 2017; Faling, 2020; Kogo et al., 2021). Several determinants including methods used to reach farmers with the CSAPs messages as climate change adaptation strategies are liable for the low uptake of the practices proposed to farmers to sabotage the impacts of climate change on their means of survival. These barriers constrain both the initial and aggregate use of CSAPs (McCarthy et al., 2011).

Yet, the growth and development of Kenya's economy cannot be achieved without sufficient investments to reposition the agricultural sector (Faling, 2020). Most farmers in Kenya are smallholder farmers and mostly rural dwellers of which 98% rely on rain-fed agriculture (Ongoma, 2019). Climate change is anticipated to beget adverse effects on the welfare and livelihoods of smallholder farmers especially in the tropics, including Kenya (Derbile et al., 2021; Satognon et al., 2021a, b). Poverty among smallholder Kenyan farmers is expected to heighten followed by food and nutritional insecurity (Ambrosino et al., 2020). Existing literature on climate change in Kenya implies that Nakuru County comprises of Sub-Counties like Mauche and Gilgil that are most exposed and insufficiently cushioned against stresses and shocks accruing to climate change (MoALF, 2016).

The most certain way to lessen these consequences is by uptaking of CSAPs. Research organizations, like Universities, the Kenya Agricultural and Livestock Research Organization (KALRO), Non-government Organizations (NGOs), and Kenya's Ministry of Agriculture, Livestock and Fisheries (MoALF) have come up with several CSAPs directed towards enhancing farmers' climate change adaptation potentials (GoK, 2017; Nyongesa et al., 2019; Satognon et al., 2021a, b). Sadly, farmers' uptake of these practices remains low, discouraging additional research toward CSAPs. Several studies on the uptake and practice of CSAPs normally evaluate general factors determining farmers' use of CSAPs, without deep investigations into individual information dissemination pathways used for sourcing awareness on CSAPs and the differences in practice caused by the information sources. Hence, an empirical investigation of the different information dissemination pathways used by smallholder potato farmers (with an emphasis on gender) for awareness and practice of CSAPs. CSAPs information dissemination pathways among smallholder potato farmers in Nakuru County and specifically Gilgil Sub-County have not been adequately studied. Based on records, this article is the first investigation carried out in Gilgil to examine different information sources used by different categories of farmers. This article provides a guide to key players on the fundamental approach required to reach the right farmers with the right CSAPs information to enable “preaching beyond the choir”. This is expected to accelerate the uptake and high extent of the practice of CSAPs among farmers.

Potato farmers formed the target population because potato is a staple and cash crop in Nakuru County and is sensitive to adverse weather conditions during its growth compared to other crops (Taiy et al., 2017). Crop production in Nakuru is majorly rain-fed, and the irregular rains in the study area sometimes lead either to drought due to extended water curtailment or to floods due to extreme rains. Therefore, potato farmers need more CSAPs to enhance and sustain yield. However, due to inappropriate communication of the CSAPs to the farmers, to date, some farmers still see no escape route from the frightening effects of climate change and they are currently adopting a rather fatalistic attitude (Singh et al., 2018). This thinking emanates from unreliable, inconsistent, inaccurate, and poor audience targeting with information on CSAPs that tends to encumber its use (Mujeyi et al., 2020). However, communicating the right information on CSAPs using the right dissemination pathways for the right people may guarantee increased uptake, and once everyone is reached, empowering all farmers including women will be the result. Eventually, this will contribute to the realization of sustainable development goals (SDGs) by presenting a longed solution to food and nutritional insecurity, and poverty checks. All the earlier stated CSAPs by Waaswa et al. (2021) were considered for this study.

1.1. Proof of climate change and effect on potato productivity

According to Ongoma (2019), the largest parts of Kenya receive two rain seasons that is March to May (long rains), Figure 1, and October to December (short rains), Figure 2. June to August are essentially cool and dry months across most areas of Kenya except some areas on the western side that receive some rains. January and February are characterized by warm and dry conditions that are witnessed across the country.

There is a growing pattern in the irregularities of rains for both the first and second rainy seasons as seen in figures one and two, respectively (Dunning et al., 2016; World Bank, 2021). This partly accounts for the recurrent crop failures reported by farmers (see Figure 5). Kenya has experienced irregular rainfall patterns since the 1990s with a noticeable rise in the temperature (World Bank, 2021). Experiencing warm temperatures especially in months formerly characterized by rains proves the prevalence of climate change. Rainfall and temperature climatic variables were regarded due to their significant effects on crop growth and productivity. An examination of the time-order data of rainfall from the World Bank Climate Change Knowledge Portal disclosed variation in the average seasonal rainfall across years with considerable stability across decades. Additionally, an examination of the temperature data covering the years 1991–2016 shows the average temperature for both short and long rainy cropping seasons (March–May, Figure 3 and October–December, Figure 4).

Throughout the rainy season, daytime temperatures range between 24 °C and 27 °C at elevated altitudes. At low altitudes, consistent daytime temperatures are registered and these are within a range of 30 °C (Ham, 2021). The temperature trends in Figures 2 and 3 for the two respective rainy seasons are averages of daytime and nighttime temperatures of every year. The repercussions of irregular rains and rising temperatures are felt mostly by crops that are unable to endure floods from heavy rains, warm temperatures, and dry spells because of prolonged lack of rainfall. These conditions compel farmers to embrace CSAPs as a cushion against effects like total crop failure. This claim is supported by MoALF (2016) that reported heightened temperatures and lessened rainfall amount in Nakuru County. Further, this authenticates the Intergovernmental Panel

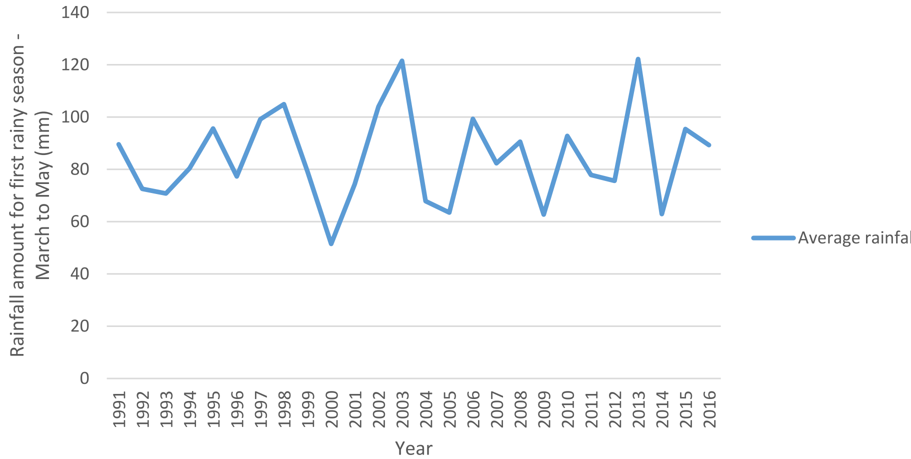

Figure 1. Rainfall amount in the first rainy season of Kenya (1991–2016). Source: Authors' computation of rainfall data from World Bank Climate Change Knowledge Portal, (2021).

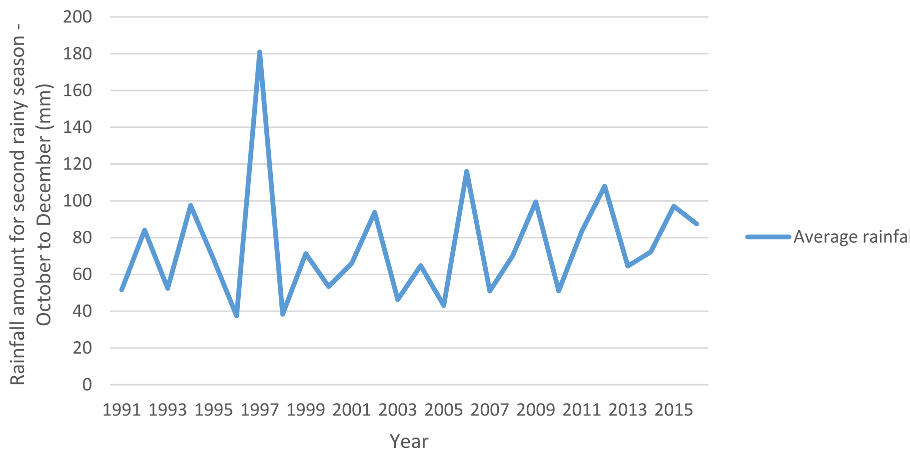

Figure 2. Rainfall amount in the second rainy season of Kenya (1991–2016). Source: Authors' computation of rainfall data from World Bank Climate Change Knowledge Portal, (2021).

on Climate Change [IPCC] (2015) forecast of average temperature rise between 1 and 3 °C in the subsequent 20 years. The data on the average yield of potatoes over the time 2009–2019 shows fluctuations in the average potato yield in Kenya (Figure 5).

The decline in potato yield was estimated at an annual average of 1.41 tons/ha (Figure 5). The trend in potato yield portrayed is in line with earlier assertions by Taiy et al. (2017) and Waaswa et al. (2021). Potato being both a staple and economic crop in Nakuru, this decline in yield

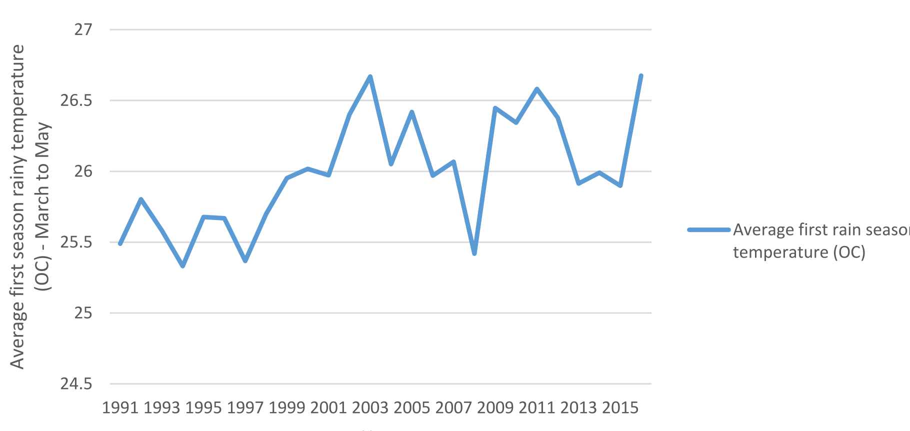

Figure 3. Average first rain seasonal temperatures (1991–2016) for Kenya. Source: Authors' computation of temperature data from World Bank Climate Change Knowledge Portal, (2021).

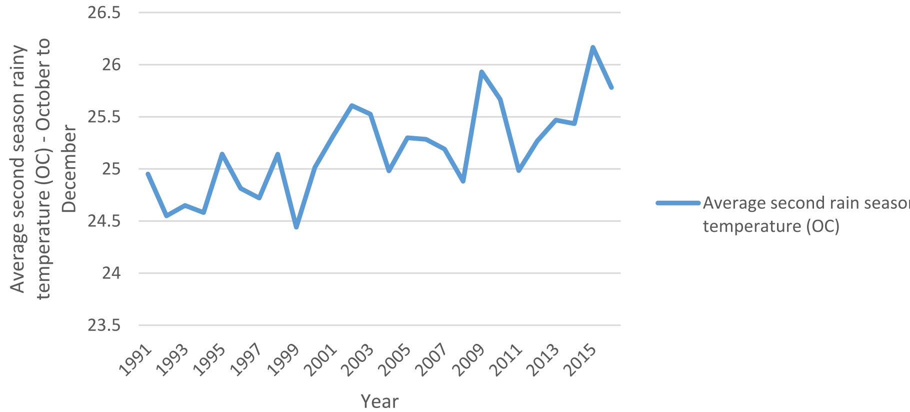

Figure 4. Average second rain seasonal temperatures (1991–2016) for Kenya. Source: Authors' computation of temperature data from World Bank Climate Change Knowledge Portal, (2021).

may be noticeably accountable for the increased food and nutritional insecurity and poverty trends among potato farmers, especially smallholder farmers in Nakuru County, Kenya. Due to a steady population increase, the per capita farm household earnings and food intake are anticipated to decline, and this will necessitate farmers to embrace CSAPs for increased productivity in the amelioration of poverty and food and nutrition insecurity provoked by climate change (Adhikari et al., 2015).

2. Materials and methods

2.1. Study area and protocol approval

National Commission for Science Technology and Innovation (NACOSTI) of Kenya approved the protocols used in this study under license No. NACOSTI/P/21/9627. The study was conducted in Gilgil Sub-County of Nakuru County, Kenya. Gilgil is subdivided into five wards, namely; Gilgil, Elementaita, Malewa West, Mbaruk/Eburu, and Morendat wards (Figure 6).

Gilgil Sub-County covers an area of 1,348.43 square kilometers, with a total population of 171,839 (Rampa and Knaepen, 2019). The study area is located at coordinates 36°10′0″E 0°40′0″S in agro-ecological zone III of Kenya. It is known for its annual rainfall of between 500 and 870 mm with maize, beans, and potatoes as the significant crops covering 86.4% of the arable land area (Rampa and Knaepen, 2019).

2.1.1. Target population

The study targeted smallholder potato farmers in Gilgil Sub-County. According to the 2019 agricultural census, there are 15,359 smallholder farmers actively engaged in potato production in Gilgil Sub-County (MoALF, 2019). These formed the study target population. The accessible population consisted of all the 10,889 potato farmers found in Morendat ward (4,287) and Mbaruk/Eburu ward [6,602] (Gilgil Sub-County, 2019).

2.2. Sampling procedure and sample size

Gilgil Sub-County was purposively considered for this study because of its susceptibility to the effects of climate change (MoALF, 2016). This has attracted several interventions to foster CSA practices to cushion the area against the shock. For example interventions by the Netherlands Development Organisation (SNV), Climate, and Water Smart Agriculture Centre (CaWSA-C) project under Community Action Research Project Plus (CARP+), and the Kenyan government through the Sub County and Ward extension officers. The Kenyan government implements the CSAPs in the study area under its CSA implementation framework. The SNV has fostered the practice of CSA among the smallholder potato farmers in the study area. Besides, farmers in the study area are actively engaged in potato growing.

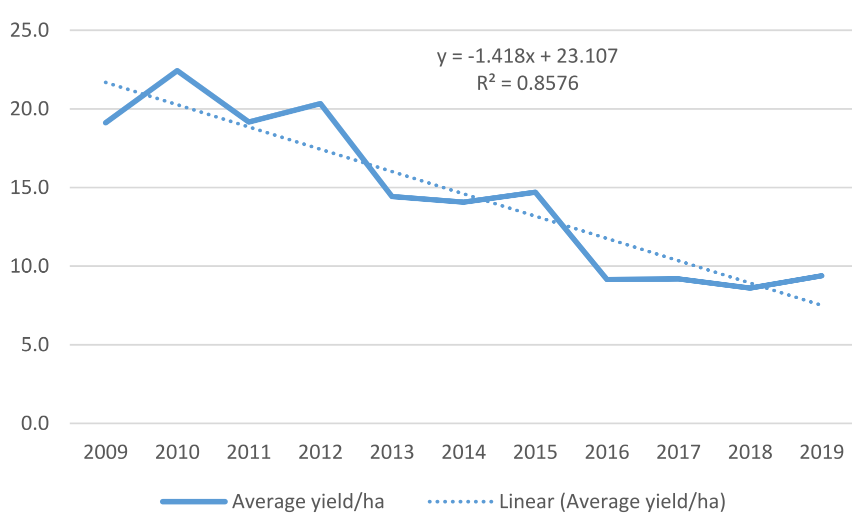

Figure 5. Average annual yield of potato in Kenya (2009–2019). Source: Authors' computation of data from FAOSTAT (2021).

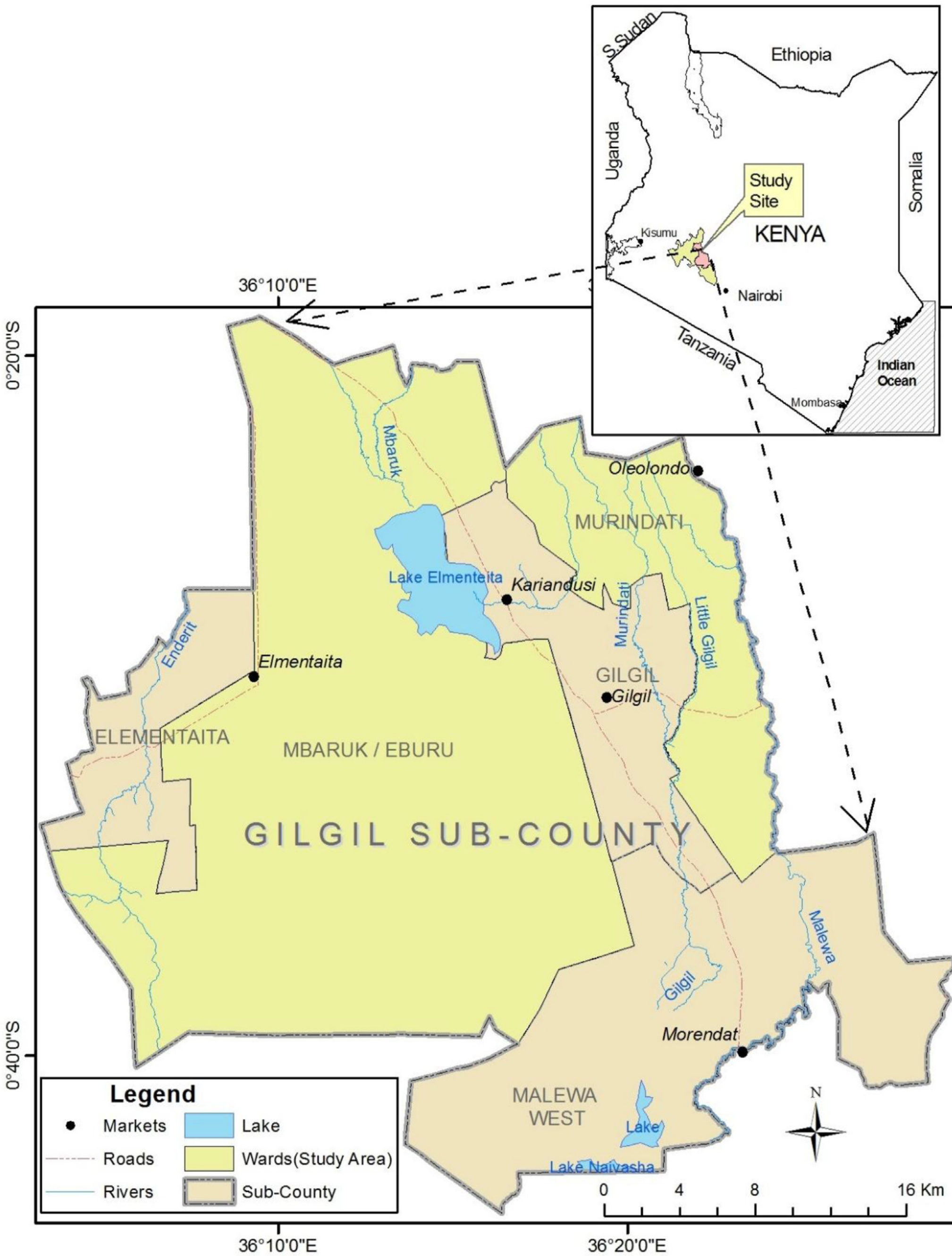

Figure 6. Map showing the location of the study area.

Out of the five wards in Gilgil Sub-County, Mbaruk/Eburu and Morendat wards were purposively selected because they comprise the most significant number of potato farmers in the Sub-County. Additionally, these two form the major farming communities in the Sub-county unlike other wards like Gilgil ward, which is a town with rocky soils that result in low farming activities (Rampa and Knaepen, 2019). In addition, because Mbaruk/Eburu is the largest ward in Gilgil Sub-County. The sample size was calculated basing on the coefficient of variation formula suggested by Nassiuma (2000). For this study, a 21% coefficient of variation and 0.02 standard error were used to compute the sample size using Nassiuma (2000) equation. These parameters were chosen, assuming the lower coefficient of variation and standard error to minimize variability and error in the sample. Besides, in consideration of the fact that the maximum coefficient of variation is 30% and above, which is not justified and a low coefficient of variation leads to small sample size, and this may not be suitable for the survey research. Below (Equation 1) is the earlier mentioned Nassiuma's formula used to calculate the sample size considered for this study.

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \quad (1)$$

where:

n = sample
N = population
C= Coefficient of variation

Table 1. Proportion of sample size per ward.

Ward	Number of Potato Farmers	Proportion	Sample size
Mbaruk/Eburu	6,602	60.63	73
Morendat	4,287	39.37	47
Total	**10,889**	**100**	**120**

Source: (Gilgil Sub-County, 2019).

e = standard error

$$n = \frac{10889 \times (21\%)^2}{(21\%)^2 + (10889 - 1)0.02^2}$$

n = 109

Since the n value is above 100 which is the minimum recommended sample size for survey studies (Kathuri and Pals, 1993), it is considered appropriate to give the required level of accuracy.

To cater for non-responses, attrition, and the purposes of a representative sample, the researchers revised the sample size to 120 by adding 10% of 109. The wards, Sub-County extension officers, and Nakuru smallholder farmers' association chairperson helped in coming up with the list of all the potato smallholder farmers in the study area. Proportionate random sampling was used in determining the number of respondents for the purposively sampled wards (Table 1), and simple random sampling was then used in obtaining the actual respondents from the wards.

2.3. Data collection procedure and analysis

The primary data was collected using a structured researcher-administered questionnaire. Visits to the sampled potato farmers were made with the assistance of the chairperson Gilgil Sub-County smallholder farmers' association, ward, and the Sub-County Agricultural Officers. The researchers collected data with the assistance of a translator, to counteract the challenge of language barrier. A translator helped some farmers who know the CSAPs investigated by different local names to have a full understanding of what was being asked. The collected data was organized and coded in consideration of the variables and keyed into the IBM Statistical Package for Social Sciences (SPSS) version 25. Two programs were used for data analysis, SPSS and Microsoft excel. To generate the trends between the farmers who were aware of CSAPs, the source of information used, and those who practiced some of the CSAPs, cross-tabulations were used and some of the results were used to develop frequencies and percentages presented in the results and discussion section of this article. Cramer's V was used to ascertain the strength and nature of the association between farmer characteristics (gender) and CSA information dissemination pathways.

3. Results and discussion

3.1. Awareness, information dissemination pathways and practice of CSAPs

Table 2 shows the descriptive statistics for the awareness level, information sources, and practice of CSA. These show the potato farmers who were aware of CSA, their source of information, and the farmers who practiced CSA. Importantly, the data disaggregates awareness of CSA to specific CSA practices and the same with the overall practice of CSA. The results indicated that 97.5% of the smallholder potato farmers were aware of rainwater harvesting and this was the CSAP with the leading percentage of awareness followed by intercropping and use of synthetic fertilizers both at 95% and crop rotation (94.2%). Of the 97.5% potato farmers who were aware of rainwater harvesting and storage, 35.9% learned about it from the media (telephone/radio/television), 38.5% from the neighbors and friends while 25.6% from extension officers. Additionally, 83.3% of the farmers who were aware of rainwater harvesting put it into practice.

Similarly, 33.3%, 22.8%, and 43.9% of the potato farmers who were aware of synthetic fertilizer use heard from media, neighbors, and friends, and extension officers respectively. Unlike rainwater harvesting, 95% of the farmers who reported being aware of synthetic fertilizers, practiced it. Like the latter, intercropping registered a relatively big percentage (89.2%) of farmers who reported about its practice out of the

Table 2. Awareness, information dissemination pathways and Practice of CSAPs (N = 120).

Climate-Smart Agriculture Technology	Smallholder potato farmers									
	Aware		Media		N/F		Ext Off		Practice of CSA	
	F	%	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	117	97.5	42	35.9	45	38.5	30	25.6	100	83.3
Irrigation	95	79.2	26	27.4	39	41.1	30	31.6	38	31.7
Mulching	104	86.7	25	24.0	36	34.6	43	41.3	77	64.2
Minimal tillage	99	82.5	27	27.3	31	31.3	41	41.4	87	72.5
Improved crop varieties	97	80.8	40	41.2	20	20.6	37	38.1	71	59.2
Terracing	105	87.5	30	28.6	29	27.6	46	43.8	90	75
Drainage management	105	87.5	22	21.0	33	31.4	50	47.6	85	70.8
Intercropping	114	95	24	21.0	49	43.0	41	36.0	107	89.2
Agroforestry	107	89.2	25	23.4	31	29.0	51	47.7	102	85
Synthetic fertilizers	114	95	38	33.3	26	22.8	50	43.9	114	95
Composting	102	85	28	27.5	37	36.3	37	36.3	91	75.8
Furrow/ridge planting	96	80	29	30.2	26	27.1	41	42.7	89	74.2
Crop rotation	113	94.2	27	23.9	33	29.2	53	46.9	100	83.3
Apical rooted cuttings (potato seedlings)	27	22.5	3	14.3	1	3.6	23	82.1	9	7.5
Mini-tubers	7	5.8	2	28.6	1	14.3	4	57.1	2	1.7

Source: Authors' computation of survey data, 2021.

95% who were aware. Moreover, 21%, 43%, and 36% of the potato farmers sourced information on intercropping from media, neighbors, and friends, and extension officers respectively.

Another category of the CSAPs to be relatively known by the smallholder potato farmers comprised of mulching, terracing, drainage management, agroforestry, and composting, and on average, 87.18% of the farmers were aware of these CSAPs. Averagely, the largest percentage (42.3%) of smallholder potato farmers got information on this category of CSAPs from extension officers, 32.5% from neighbors and friends, and the least percentage (25.3%) from media. However, an average of 71.5% practiced these CSAPs. This is a slightly lower percentage compared to those (87.18%) who indicated that they were aware of these CSAPs. While the category of minimal tillage, improved crop varieties, and furrow/ridge planting ranked third in being known by the farmers, and on average 81.1% of the smallholder potato farmers were aware of their existence. The results further revealed an average of 32.9% of the potato farmers were enlightened about this category of CSAPs from media, 26.3% from neighbors and friends, while the largest percentage (40.7%) of the potato farmers learned about these from extension officers. Notably, an average of 68.6% of potato farmers practiced this category of CSAPs.

Furthermore, 79.2% of the farmers were aware of irrigation, and the least known CSAPs were apical rooted cuttings [potato seedlings] (22.5%) and minitubers (5.8%). Around 27.4% of the farmers who were aware of irrigation obtained information from media, 41.1% from neighbors and friends, and 31.6% from extension officers. Out of those who were aware, 31.7% practiced irrigation. Potato seedlings were the second last CSAPs to be known by the farmers, and among those who indicated they knew about it, 14.3% got information from media, 3.6% from neighbors and friends, and 82.1% from extension officers, while only 7.5% practiced it. Findings further portray that overall, 77.9% of the surveyed potato farmers were aware of the CSAPs investigated in this study.

High percentages of the practice of most CSAPs with a high rate of awareness might be explained by the fact that information raises possibilities of practice of CSAPs. These findings agree with García de Jalón et al. (2015) who asserted that awareness may further support farmers' decision to use a given CSAP. This is because information helps the farmers to gain a full understanding of a given technology, and therefore they may be willing to try it out (Deressa et al., 2009; Gebrehiwot and van der Veen, 2013). On the contrary, CSAPs like irrigation attracted a high percentage of awareness yet with a low percentage of farmers practicing them. For this case, factors beyond awareness come into play. For example, such CSAPs may require heavy capital investment which may not readily be available or accessed by some farmers. Similarly, cultural bias on some CSAPs may curtail their widespread use. This assertion commensurate Nyasimi et al. (2017) findings that revealed cultural constraints as bottlenecks to the practice of CSA. Yet, facilitating the practice of such CSAPs may deter crop losses and increase agricultural output per area by enabling dry season production and eventually reduce over-reliance on rain-fed agriculture (Gebrehiwot and van der Veen, 2013; Orindi and Eriksen, 2005; Waaswa et al., 2021).

Another possible reason for the high percentage in the practice of most CSAPs is the undulating topography nature of Gilgil Sub County. This contention is in tandem with findings from previous studies (Bryan et al., 2013; Nkonya et al., 2015; Nkuba et al., 2020), which stated that some farmers' adaptation strategies are influenced by the nature/slop of their land. Additionally, given the nature of their terrain which is steep plus being exposed to the effects of climate change (Rampa and Knaepen, 2019; Waaswa et al., 2021), farmers from the study area are forced to seek information to guide their decisions in preventing further loss of soils, retain water, sustain and increase yields. This claim is supported by Bryan et al. (2009) and Nkuba et al. (2020) who concluded that area agro-ecological situations influence the choice of the adaptation strategies, hence the CSAPs practiced by the framers.

On the contrary, some CSAPs like potato seedlings and minitubers recorded low awareness and practice. These practices seem to be new in the area, and according to literature (Rogers, 1995, 2003; Rogers and Ban, 1963), farmers are always skeptical to take up new technologies unless they gain a full understanding of their benefits. Another cause of low use of traditionally dressed farming practices into CSAPs like mulching and improved crop varieties might be associated with the information sources used to communicate these. For example, televisions, telephones, and radios (media) may not fully orient the farmers to get the full knowledge required to execute a given CSAP. This is in line with findings by Arimi (2014) who found that the farmers were half-baked regarding the practice of adaptation strategies like the growth of biennial root and tuber crops, yet they received information from media. The reasoning behind this is that these tend to give general information (Comoé and Siegrist, 2015).

3.1.1. Information dissemination pathways and practice of CSAPs

Analysis of the information dissemination pathways and practice of CSA affirmed that there is a strong difference between information sources and practice of CSA at a 5% level of significance ($\chi2 = 100.12139$, df = 2, $p < 0.05$, Cramer's V = 1.0) among the smallholder potato farmers (Table 3). Around 44.1% of the 93 potato farmers who were aware of CSAPs get information on CSAPs from the extension officers, while 28.7% and 27.2% get information from neighbors and friends, and media respectively. Similarly, 45.3% of the farmers who practiced CSA sourced information from extension officers, 27.9% and 26.8 from media, and neighbors and friends respectively.

Overall, extension officers emerged with the highest percentage as an information source and this may partly explain high percentages of CSA practice among farmers with high awareness. Because, according to Alam (2015) and Mandleni and Anim (2011), extension officers create satisfactory awareness of climate-smart farming practices. Though on the contrary, inappropriate extension services smoother efforts tailored to foster CSAPs (Alam, 2015). Additionally, neighbors and friends scoring second notable information source could be because first learning farmers and early technology adopters in the communities devote their land and garden for fellow farmers to observe and imitate successful technologies. This allegation is consistent with the results of other studies which showed that farmers with experienced and progressing neighbors were more likely to devote more land to try out new agricultural technologies (Abbas et al., 2003). Similarly, Kalungu and Leal Filho (2018) found farmers imitating the cultivation of improved plant varieties and other practices from successful neighbors.

While media scoring the least information sources for CSAPs awareness and practice might be linked to the farmers' busy schedules in the fields since they have to cascade around the undulating tenure. This makes them very tired at the end of the day to the extent that they may not have the zeal to sit and listen to the radio and or watch television. In addition, most parts of the study area are not electrified and this could explain the low use of television as a media component. However, these results contradict study findings from other places where farmers reported media as the chief information source on climate change adaptation (Kalungu and Leal Filho, 2018; Nzeadibe & African Technology Policy Studies Network, 2011).

3.1.2. CSAPs awareness and gender

Study results indicated that out of the 48 women surveyed, 79.5% were aware of the CSAPs. Unlike women, only 75.4% of the 72 men who participated in the study were aware of CSAPs as climate change adaptation strategies. These findings contradict those of Kalungu and Leal

Table 3. Information dissemination pathways and practice of CSA.

Awareness and Practice of CSA	% of smallholder potato farmers		
	Media	Neighbors and friends	Extension Officers
Aware (n = 93)	27.2	28.7	44.1
Practice (n = 77)	26.8	27.9	45.3

Source: Authors' computation of survey data, 2021.

Table 4. CSAPs information dissemination pathways and gender (N = 120).

Climate Smart Agriculture Practices	% of smallholder potato farmers							
	Female (n = 72)				Male (n = 48)			
	Aware of CSA	Information Source			Aware of CSA	Information Source		
		Media	N/F	Ext Off		Media	N/F	Ext Off
Rainwater harvesting and storage	98.6	29.6	47.9	22.5	95.8	45.7	23.9	30.4
Irrigation	79.2	24.6	45.6	29.8	79.2	31.6	34.2	34.2
Mulching	87.5	20.6	38.1	41.3	85.4	29.3	29.3	41.5
Minimal tillage	84.7	23.0	34.4	42.6	79.2	34.2	26.3	39.5
Improved crop varieties	79.2	42.1	24.6	33.3	83.3	40.0	15.0	45.0
Terracing	90.3	26.2	30.8	43.1	83.3	32.5	22.5	45.0
Drainage management	93.1	17.9	38.8	43.3	79.2	26.3	18.4	55.3
Intercropping	97.2	17.1	54.3	28.6	91.7	27.3	25.0	47.7
Agroforestry	91.7	19.7	33.3	47.0	85.4	29.3	22.0	48.8
Synthetic fertilizers	95.8	34.8	24.6	40.6	93.8	31.1	20.0	48.9
Composting	87.5	25.4	47.6	27.0	81.3	30.8	17.9	51.3
Furrow/ridge planting	83.3	28.3	31.7	40.0	75.0	33.3	19.4	47.2
Crop rotation	97.2	25.7	35.7	38.6	89.6	20.9	18.6	60.5
Apical rooted cuttings (potato seedlings)	23.6	5.9	5.9	88.2	20.8	27.3	0.0	72.7
Mini-tubers	4.2	33.3	33.3	33.3	8.3	25.0	0.0	75.0

Source: Authors' computation of survey data, 2021.

Filho (2018) who found a large discrepancy in awareness about the adaptation strategies between women and men. The latter claimed that women are always loaded with domestic work and that this stifles their opportunities of seeking or being available in areas where information on CSAPs is disseminated. Nevertheless, this study's findings are supported by Nyasimi et al. (2017) who appreciated the relevancy of equal information sharing between men and women. Further, the study area is highly exposed to harsh weather conditions and therefore prone to crop failure (MoALF, 2016; Rampa and Knaepen, 2019). So, given the fact that women are more affected by the effects of climate change (Okello et al., 2018; Waaswa et al., 2021), this could be the reason why they highly seek information on adaptation strategies accounting for their high percentage of awareness on CSAPs.

3.1.3. CSAPs information dissemination pathways and gender

Generally, except for potato seedlings and minitubers, 89.6% and 84.8% of women and men respectively, were aware of the CSAPs examined by this study (Table 4). The high level of awareness exhibited by both women and men can be explained by the development initiatives by the Government of Kenya, Universities like Egerton University, KALRO, SNV among others that have risen to rescue farmers especially in areas like the study area as highlighted by MoALF (2016) in the Nakuru climate risk profile. In addition, potato farmers have been awakened by the recurrent yield losses to actively seek information to rebut the dilemma posed by climate change.

Averagely, 13.9% and 14.6% of the women and men respectively, were aware of potato seedlings and minitubers. Moreover, on average, 60.8% and 73.9% of the awareness was caused by extension officers among women and men respectively. This is because these are newly developed CSAPs which farmers need to see work elsewhere before embracing them, and in most cases, information on such is diffused by extension officers. This is because these can directly interact with researchers liable for the development of new CSA technologies compared to their counterparts, the media and, neighbors and friends (Rogers, 2003).

From Table 5, gender investigation of the information dissemination pathways attested that though weak, a discrepancy existed in the use of the three information dissemination pathways between men and women at a 5% level of significance ($\chi2 = 6.05949$, df = 2, $p < 0.05$, Cramer's V = 0.17406) among the female and male smallholder potato farmers. Extension officers are the principal CSAPs awareness source for both women (40%) and men (49.5%), while neighbors and friends (35%) ranked second for women followed by media (25%). This was different for men whose second main information source was media (31%) followed by neighbors and friends (19.5%).

Extension officers being the major information may imply that extension officers attend potato farmers' gatherings in their farming places especially if they have to offer advice to women. This is because women usually have regular women's gatherings that congregate at predestined periods. This may have an implication in case of absence and or inappropriate targeting of the farmers by the extension officers. Because reluctance of extension officers in rendering information on adaptation to climate change and available adaptation strategies thwarts farmers' decisions on how to cushion themselves against the shock (Nkonya et al., 2015; Nkuba et al., 2020; Vogel & O'Brien, 2006). Arimi (2014) supports these results and argues that extension officers are needed ad-libitumly and that their absence or low numbers may impair useful information from reaching the farmers but rather keep them in the darkness and un-cushioned against the wreck.

However, though extension ranked the first source of awareness among women and men, its percentage among women (40%) was low compared to that among men (49.5%). This could prove Quisumbing

Table 5. CSAPs information dissemination pathways by gender.

Gender	% of smallholder potato farmers by information source		
	Media	Neighbors/Friends	Extension Officers
Female (n = 48)	25	35	40
Male (n = 72)	31	19.5	49.5

Source: Authors' computation of survey data, 2021.

et al. (1996) declarations that women are given little attention in many countries by extension providers. This enfeebles women as pivotal actors in food production, yet in the Sub Saharan, these render over 50% of the farm labor (Kalungu and Leal Filho, 2018). On the other hand, this study's findings contradict those of Team and Doss (2011) who found higher awareness among women accruing from extension officers than among men, the authors argued that this was expected since women are the major food producers (60–80%), especially in the Sub-Saharan. Traditionally, extension officers have piloted the diffusion of, especially newly developed technologies. Therefore, extension officers scoring highly as the main information source regarded by both men and women could be because, they have been in this ‘thing’ of diffusing information for ages (Gautam, 2000). This claim is further backed by empirical evidence from previous research by Bryan et al. (2009) and Mandleni and Anim (2011) that found that extension appeared to be a considerable means to be used to raise awareness on climate change adaptation.

Further, a relatively high percentage of awareness by women from neighbors and friends can be explained by the fact that information from neighbors and friends can easily be sought, and also integrated with information from other sources. This contention is in line with the previous research which contended that some women farmers adapted to climate change by augmenting information sourced locally with that from external sources (Nkuba et al., 2020). Thus, women who are limited by most cultures and customs find this a convenient and easy way of learning about CSAPs. Similarly, women foster and seek mutual interaction, a sense of closeness, and embrace trust within their communities. This increases their possibility of learning from each other. These results are consistent with studies conducted by Bedeke et al. (2019) and Kassie et al. (2008) who found that established social relations with neighbors and friends present incentives and confidence for the farmer to learn about CSAPs and take coping action against crop and other losses caused by severe circumstances, like prolonged dry spells and floods. The information received from other sources may not be sufficient for women unless clarified by their neighbors and friends. This can best be explained by this example, where a woman farmer stated that:

> *I have heard that we will have less rainfall this year. But what does that mean? What crops should I plant when we have less rain? That is a difficult question to answer because the information provided is not enough to assist me to plan what crops to grow, when, what fertilizer to use, what livestock should I save since I might not have enough water for the animals (*In Nyasimi et al., 2017*, p. 11).*

Such a farmer may only find immediate support from her neighbors or friends, other means like media that in most cases disseminate general information may not be the solution. Furthermore, a contradiction exists between this study's findings with those of Kalungu and Leal Filho (2018) who found high awareness from neighbors and friends among men.

Nonetheless, a moderate-high awareness (31%) created by media especially among men can be associated with the media's edutainment ability and this is in accord with Comoé and Siegrist (2015) who found that media influenced a relatively high level of awareness on adaptation strategies in Côte d’Ivoire. Furthermore, men conduce ownership of telephones and radios (Singh et al., 2018). Hence, women have low access to media. Low awareness percentages from media by women could owe to their having a limited chance to listen to the radio (which is often a man's property) or view television (Kalungu and Leal Filho, 2018). This contradicts findings by Manfre and Nordehn (2013) and Waaswa et al. (2021) who affirmed that women find it convenient to listen to the radio since it can be done simultaneously while performing other tasks like cooking.

4. Conclusions and policy implications

This study investigated the information dissemination pathways used by different categories of smallholder potato farmers for the awareness and practice of CSAPs. It found a difference between information sources and practice of CSAPs and a difference in the use of the three information dissemination pathways between men and women. Extension officers scored higher for both men and women, though men sourced more information from them than women did. However, women sourced more information from neighbors and friends than men did, while media was mostly used by men. Averagely, extension officers were the most used source of awareness followed by neighbors and friends, and media respectively. Additionally, women were more aware of CSAPs than men were. Broadly, farmers were aware of the CSAPs investigated in this study except for potato seedlings and minitubers that yielded low awareness percentages. Additionally, a relatively large number of farmers practiced most CSAPs, which they indicated they were aware of, except for irrigation that scored high on awareness yet with a low score on practice. Following these conclusions, there is a need to appreciate differences in the use of different information dissemination pathways by men and women for the awareness and practice of CSAPs. In addition, broad consideration of different information sources with the potential to result in bumper uptake of CSAPs would go a long way in ameliorating climate change impacts among farmers. Further, this study recommends mainstreaming of CSAPs information.

Declarations

Author contribution statement

Andrew Waaswa; Agnes Oywaya Nkurumwa; Anthony Mwangi Kibe; Ng'eno Joel Kipkemoi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by the MasterCard Foundation through Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

The authors acknowledged the support provided by the MasterCard Foundation through Regional Universities Forum for Capacity Building in Agriculture (RUFORUM). The authors also acknowledged the family of Mr. Bernard Mwenja Ngigi of Gilgil, Kenya for hosting the researchers and ensuring that the sampled smallholder potato farmers were successfully reached to participate in the study. The authors are indebted to the three anonymous reviewers whose invaluable input gave this work its current shape.

References

Abbas, M., Sheikh, A.D., Muhammad, S., Ashfaq, M., 2003. Role of electronic media in the adoption of agricultural technologies by farmers in the central Punjab–Pakistan. Int. J. Agric. Biol. 5 (1), 4.

Acosta, M., van Wessel, M., van Bommel, S., Feindt, P.H., 2021. Examining the promise of 'the local' for improving gender equality in agriculture and climate change adaptation. Third World Q. 1–22.

Adhikari, U., Nejadhashemi, A.P., Woznicki, S.A., 2015. Climate change and eastern Africa: a review of impact on major crops. Food Energy Sec. 4 (2), 110–132.

Alam, K., 2015. Farmers' adaptation to water scarcity in drought-prone environments: a case study of Rajshahi District, Bangladesh. Agric. Water Manag. 148, 196–206.

Alliagbor, R., Awolala, D.O., Ajibefun, I.A., 2020. Smallholders use of weather information as smart adaptation strategy in the savannah area of Ondo state, Nigeria. In: Leal Filho, W., Ogugu, N., Adelake, L., Ayal, D., da Silva, I. (Eds.), African Handbook of Climate Change Adaptation. Springer International Publishing, pp. 1–11.

Amadou, Z., 2020. Agropastoralists' climate change adaptation strategy modeling: software and coding method accuracies for best-worst scaling data. In: Leal Filho, W., Ogugu, N., Adelake, L., Ayal, D., da Silva, I. (Eds.), African Handbook of Climate Change Adaptation. Springer International Publishing, pp. 1–10.

Amadu, F.O., McNamara, P.E., Miller, D.C., 2020. Understanding the adoption of climate-smart agriculture: a farm-level typology with empirical evidence from southern Malawi. World Dev. 126, 104692.

Ambrosino, C., Hufton, B., Nyawade, B.O., Osimbo, H., Owiti, P., 2020. Integrating climate adaptation, poverty reduction, and environmental conservation in Kwale county, Kenya. In: Leal Filho, W., Ogugu, N., Adelake, L., Ayal, D., da Silva, I. (Eds.), African Handbook of Climate Change Adaptation. Springer International Publishing, pp. 1–18.

Arimi, K.S., 2014. Determinants of climate change adaptation strategies used by fish farmers in Epe Local Government Area of Lagos State, Nigeria: determinants of fish farmers' climate change adaptation. J. Sci. Food Agric. 94 (7), 1470–1476.

Arslan, A., Ju, J., Lipper, L., 2014. Evidence and Knowledge Gaps on Climate Smart Agriculture in Vietnam: A Review on the Potential of Agroforestry and Sustainable Land Management in the Northern Mountainous Region. FAO.

Bedeke, S., Vanhove, W., Gezahegn, M., Natarajan, K., Van Damme, P., 2019. Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. NJAS - Wageningen J. Life Sci. 88, 96–104.

Bryan, E., Deressa, T., Gbetibouo, G.A., Ringler, C., 2009. Adaptation to climate change in Ethiopia and South Africa: Options and constraints. Environ. Sci. Pol. 12 (4), 413–426.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., Herrero, M., 2013. Adapting agriculture to climate change in Kenya: household strategies and determinants. J. Environ. Manag. 114, 26–35.

Cavanagh, C.J., Chemarum, A.K., Vedeld, P.O., Petursson, J.G., 2017. Old wine, new bottles? Investigating the differential adoption of 'climate-smart' agricultural practices in western Kenya. J. Rural Stud. 56, 114–123.

Chandra, A., McNamara, K.E., Dargusch, P., Damen, B., Rioux, J., Dallinger, J., Bacudo, I., 2016. Resolving the UNFCCC divide on climate-smart agriculture. Carbon Manag. 7 (5–6), 295–299.

Chandra, A., McNamara, K.E., Dargusch, P., 2018. Climate-smart agriculture: perspectives and framings. Clim. Pol. 18 (4), 526–541.

Chirambo, D., 2018. Towards the achievement of SDG 7 in sub-Saharan Africa: creating synergies between Power Africa, Sustainable Energy for All and climate finance in-order to achieve universal energy access before 2030. Renew. Sustain. Energy Rev. 94, 600–608.

Comoé, H., Siegrist, M., 2015. Relevant drivers of farmers' decision behavior regarding their adaptation to climate change: a case study of two regions in Côte d'Ivoire. Mitig. Adapt. Strategies Glob. Change 20 (2), 179–199.

de Jalón, García, Silvestri, S., Granados, A., Iglesias, A., 2015. Behavioural barriers in response to climate change in agricultural communities: an example from Kenya. Reg. Environ. Change 15 (5), 851–865.

de Jalón, García, Silvestri, S., Barnes, A.P., 2017. The potential for adoption of climate smart agricultural practices in Sub-Saharan livestock systems. Reg. Environ. Change 17 (2), 399–410.

Derbile, E.K., Chirawurah, D., Naab, F.X., 2021. Vulnerability of smallholder agriculture to environmental change in North-Western Ghana and implications for development planning. Clim. Dev. 1–13.

Deressa, Hassan, R., Ringler, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environ. Change 19 (2), 248–255.

Dunning, C.M., Black, E.C.L., Allan, R.P., 2016. The onset and cessation of seasonal rainfall over Africa. J. Geophys. Res.: Atmos. 121 (19), 405–411, 11, 424.

Faling, M., 2020. Framing agriculture and climate in Kenyan policies: a longitudinal perspective. Environ. Sci. Pol. 106, 228–239.

FAOSTAT, 2021. FAOSTAT–Data. http://www.fao.org/faostat/en/#data/QC.

Food and Agriculture Organisation FAO, 2014. Climate-smart Agriculture Sourcebook. Food and Agriculture Organization (FAO).

Food and Agriculture Organisation FAO, 2010. Climate-smart'agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Food and Agricultural Organisation (FAO).

Gautam, M., 2000. Agricultural Extension: the Kenya Experience: an Impact Evaluation, first ed. World Bank.

Gebrehiwot, T., van der Veen, A., 2013. Farm level adaptation to climate change: the case of farmer's in the Ethiopian highlands. Environ. Manag. 52 (1), 29–44.

Gilgil Sub-County, 2019. Circular References: Area Seasonal Crops. Unpublished.

GoK, 2017. *Kenya Climate Smart Agriculture Strategy—2017-2026*. UNDP Climate Change Adaptation.

Ham, A., 2021. Kenya Weather & Climate. SafariBookings.Com. https://www.safaribookings.com/kenya/climate.

Ingutia, R., 2021. The impacts of COVID-19 and climate change on smallholders through the lens of SDGs; and ways to keep smallholders on 2030 agenda. Int. J. Sustain. Dev. World Ecol. 1–16.

Intergovernmental Panel on Climate Change, 2015. Climate Change 2014: Impacts, Adaptation and Vulnerability, Volume 1, Global and Sectoral Aspects: Working Group II Contribution to the IPCC Fifth Assessment Report. Cambridge University Press.

Kalungu, J.W., Leal Filho, W., 2018. Adoption of appropriate technologies among smallholder farmers in Kenya. Clim. Dev. 10 (1), 84–96.

Kassie, M., Zikhali, P., Manjur, K., Edwards, S., 2008. Adoption of Organic Farming Technologies: Evidence from Semi-arid Regions of Ethiopia. Working Paper No. 335. School of Business, Economics and Law, p. 19.

Kathuri, N., Pals, D., 1993. Introduction to Education Research. Egerton University.

Kogo, B.K., Kumar, L., Koech, R., Hasan, K., 2021. Climatic and non-climatic risks in rainfed crop production systems: insights from maize farmers of western Kenya. Clim. Dev. 1–10.

Lipper, L., 2017. Climate Smart Agriculture: Building Resilience to Climate Change, first ed. Springer Science+Business Media.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Torquebiau, E.F., 2014. Climate-smart agriculture for food security. Nat. Clim. Change 4 (12), 1068–1072.

Mandleni, B., Anim, F.D.K., 2011. Climate Change Awareness and Decision on Adaptation Measures by Livestock Farmers, p. 26.

Manfre, C., Nordehn, C., 2013. Exploring the Promise of Information and Communication Technologies for Women Farmers in Kenya: MEAS Case Study, p. 10. www.measextension.org/meas-offers/case-studies.

Martey, E., Etwire, P.M., Adogoba, D.S., Tengey, T.K., 2021. Farmers' preferences for climate-smart cowpea varieties: implications for crop breeding programmes. Clim. Dev. 1–16.

McCarthy, N., Lipper, L., Branca, G., 2011. Climate Smart Agriculture: Smallholder Adoption and Implications for Climate Change Adaptation and Mitigation [Working Paper].

MoALF, 2016. Climate Risk Profile for Nakuru County. Kenya County Climate Risk Profile Series. The Kenya Ministry of Agriculture, Livestock and Fisheries (MoALF).

MoALF, 2019. Agriculture Census. Ministry of Agriculture, Livestock and Fisheries.

Mujeyi, A., Mudhara, M., Mutenje, M.J., 2020. Adoption determinants of multiple climate smart agricultural technologies in Zimbabwe: considerations for scaling-up and out. Afr. J. Sci. Technol. Innov. Dev. 12 (6), 735–746.

Nassiuma, D.K., 2000. Survey Sampling: Theory and Methods. Egerton University press.

Nkonya, E., Place, F., Kato, E., Mwanjololo, M., 2015. Climate risk management through sustainable land management in sub-saharan Africa. In: Lal, R., Singh, B.R., Mwaseba, D.L., Kraybill, D., Hansen, D.O., Eik, L.O. (Eds.), Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa. Springer International Publishing, pp. 75–111.

Nkuba, M.R., Chanda, R., Mmopelwa, G., Kato, E., Mangheni, M.N., Lesolle, D., 2020. Influence of indigenous knowledge and scientific climate forecasts on arable farmers' climate adaptation methods in the rwenzori region, western Uganda. Environ. Manag. 65 (4), 500–516.

Nyasimi, M., Kimeli, P., Sayula, G., Radeny, M., Kinyangi, J., Mungai, C., 2017. Adoption and dissemination pathways for climate-smart agriculture technologies and practices for climate-resilient livelihoods in Lushoto, northeast Tanzania. Climate 5 (3), 63.

Nyongesa, M., Oyoo, J., Ng'ang'a, N., Lung'aho, C., Mbiyu, M., Otieno, S., Onditi, J., Nderitu, J., 2019. Inventory of Climate Smart Agriculture Potato Technologies, Innovations & Management Practices. Kenya Agricultural and Livestock Research Organization.

Nzeadibe, T.C., African Technology Policy Studies Network, 2011. In: Climate Change Awareness and Adaptation in the Niger Delta Region of Nigeria. African Technology Policy Studies Network.

Okello, D., Mayega, R.W., Muhumuza, C., Amuge, P.O., Kakamagi, E., Amollo, M., Amuka, I., Kayiwa, R., Bazeyo, W., 2018. Gender and Innovation for Climate-Smart

Agriculture. Assessment of Gender-Responsiveness of RAN's Agricultural-Focused Innovations [CCAFS Working Paper no. 260]. https://cgspace.cgiar.org/handle/10568/100324.

Ongoma, V., 2019. Why Kenya's Seasonal rains Keep Failing and what Needs to Be Done—Kenya. ReliefWeb. https://reliefweb.int/report/kenya/why-kenya-s-seasonal-rains-keep-failing-and-what-needs-be-done.

Orindi, V.A., Eriksen, S.H., 2005. Mainstreaming Adaptation to Climate Change in the Development Process in Uganda. Acts Press, African Centre for Technology Studies.

Quisumbing, A.R., Brown, L.R., Feldstein, H.S., Haddad, L., Peña, C., 1996. Women: the key to food security. Food Nutr. Bull. 17 (1), 1–2.

Rampa, F., Knaepen, H., 2019. Sustainable Food Systems through Diversification and Indigenous Vegetables: an Analysis of the Southern Nakuru County, p. 124 [Sustainable Agrifood Systems Strategies]. https://ecdpm.org/wp-content/uploads/SASS-report-I_Sustainable-food-systems-through-diversification-and-indigenous-vegetables.pdf.

Rogers, E.M., 1995. Lessons for guidelines from the diffusion of innovations. Joint Comm. J. Qual. Improv. 21 (7), 324–328.

Rogers, E.M., 2003. Diffusion of Innovations, fifth ed. Free Press.

Rogers, E.M., Ban, A.W.V.D., 1963. Research on the diffusion of agricultural innovations in the United States and The Netherlands. Sociol. Rural. 3 (1), 38–49.

Satognon, F., Lelei, J.J., Owido, S.F.O., 2021a. Use of GreenSeeker and CM-100 as manual tools for nitrogen management and yield prediction in irrigated potato (Solanum tuberosum) production. Arch. Agric. Environ. Sci. 6 (2), 121–128.

Satognon, F., Owido, S.F.O., Lelei, J.J., 2021b. Effects of supplemental irrigation on yield, water use efficiency and nitrogen use efficiency of potato grown in mollic Andosols. Environ. Syst. Res. 10 (1), 38.

Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnaswamy, J., Zaroug, M., Kituyi, E., 2018. The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. Clim. Dev. 10 (5), 389–405.

Taiy, R.J., Onyango, C., Nkurumwa, A., 2017. Climate change challenges and knowledge gaps in smallholder potato production: the case of Mauche ward in Nakuru county, Kenya. Int. J. Agric. Sci. Res. 7 (4), 719–730.

Team, S., Doss, C., 2011. *The Role of Women in Agriculture* (Working Paper No. 11–02. Agricultural Development Economics Division of Food and Agricultural Organization, p. 48.

Vogel, C., O'Brien, K., 2006. Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. Clim. Res. 33, 111–122.

Waaswa, A., Satognon, F., 2020. Development and the environment: Overview of the development planning process in agricultural sector, in Uganda. J. Sustain. Dev. 13 (6), 1.

Waaswa, A., Oywaya Nkurumwa, A., Mwangi Kibe, A., Ngeno Kipkemoi, J., 2021. Climate-Smart agriculture and potato production in Kenya: review of the determinants of practice. Clim. Dev. 1–16.

Wekesa, B.M., Ayuya, O.I., Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. Agric. Food Secur. 7 (1), 80.

World Bank, 2021. World Bank Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/.