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Understanding the socioeconomic determinants of adoption of climate-smart agricultural practices among smallholder potato farmers in Gilgil Sub-County, Kenya

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Abstract
Besides climate-smart agriculture's (CSA) potential to meet the world's increasing food demands in the face of climate variability through sustainably increasing food production, its acceptance among farmers is still low. This could be partly because of limited insight into the contextual underpinnings of its uptake. Therefore, the purpose of this study was to establish the relationship between selected socioeconomic factors and the adoption of CSA in Gilgil Sub-County. This study's results were attained from a binary logistic regression model, using a sample of 120 smallholder potato farmers in two wards of Gilgil Sub-County of Nakuru County, Kenya. An analysis of the five hypothesized explanatory socioeconomic variables contained in the model disclosed that a relationship between socioeconomic factors and adoption of CSAPs was statistically significant at a 5% level of significance ($\chi^2=17.966$, df = 5, $p<0.05$). It further revealed that only two variables had a significant relationship with the adoption of CSAPs. Among these, included gender which was negative and statistically significant at a 5% level of significance (Wald $\chi^2=6.701$, df = 1, $p<0.05$) and annual farm income, which was positive and statistically significant at a 5% level of significance (Wald $\chi^2=8.402$, df = 1, $p<0.05$). Therefore, securing access to vital resources for women farmers is indispensable to enhance their capacity and compliance to adjust production methods in response to climate change. Facilitating increased farm output and income among the farmers is greatly recommended.

Keywords Agricultural productivity · Climate change · Climate change adaptation · Climate-smart agriculture · Potato production · Socioeconomic factors · Adoption

1 Introduction

Climate change dramatically affects socioeconomic and biophysical systems since these are profoundly and intricately interrelated [1–3]. Variation in any of these causes an alteration in another. In that event, distinctive consideration should be given to climate change, notably to mitigate greenhouse gas (GHG) emissions [2, 4]. By 2030, its concentration in the atmosphere is forecasted to double, which induces a notable rise in temperature globally [5–7]. Yet, an increase in GHG emissions produces severe implications for the farming sector worldwide.

Adaptation energies, especially among farmers, are interconnected in climate-smart agriculture (CSA), which utilizes the most advanced technological executions while mitigating climate change [6, 8]. Notwithstanding the possible gains

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of CSA, its adoption is still low amongst smallholder farmers in several developing nations [9–11]. Climate change effects in terms of declining soil fertility, climate extremes, and food and nutritional insecurity continue to significantly prevail, especially in the sub-Saharan [12], with over 23% of the people being undernourished and an estimation of 35 million individuals suspected to be vulnerable to food insecurity by 2050 [13, 14]. Previous studies have mapped some of the reasons why CSA has received low attention besides its potentials [10, 15]. These studies claimed that resources, especially fiscal capital limitations, cause low acceptance rates.

Extensive research has now emerged on climate-smart agricultural practices (CSAPs) uptake, but the contextual underpinnings of the event need eminent study [9, 16]. To generate context-specific farmer support services, factors within their contexts need to be studied. This has also been demanded by the efforts geared towards scaling out CSAPs that have recommended learning farmers' socioeconomic contexts to aid increased and sustained aggregate adoption [17]. Surprisingly, the study area (Gilgil Sub-County) had not been studied. Neither generalizations had been made from the previous studies from other contexts, besides CSA practices being implemented in the area. Like any other agricultural community, the adoption of some CSAPs in this area has continuously received less attention. This could be partly because efforts directed towards generating and promoting the practice of CSA assume that the CSAPs could be accessed by the farmers and translated into the desired results. Therefore, CSAPs are diffused to the target farmers without thoroughly understanding their contexts, especially the socioeconomic ones. Socioeconomic factors like farmers' age, gender, education level, on-farm, and off-farm income have been essential determinants of technology adoption [4]. These factors are influential in exacerbating levels of vulnerability among farmers. For example, Kaabi et al. [18] pointed out income, capital, and education, among other factors, as crucial determinants of adopting climate change adaptation strategies. For instance, in some areas, farmer's age may hinder the adoption of labor-demanding agricultural technologies, income may ease access to advanced technologies, and gender may pose restrictions for women in different societies to access innovative practices [4, 19].

Knowing how these factors relate to the adoption of CSAPs is pivotal in informing policies and, subsequently, sustainable development that CSA seeks to achieve [20]. In addition, Kaabi et al. [18] notes that understanding the social, environmental, and economic costs from climatic changes aids in developing actionable strategies to cushion farmers against adverse effects by optimizing resources allocation. Aziz-Khalkheili et al. [21] add that not understanding why some farmers show certain behaviors complicates the possibilities of offering them advice on which climate change adaptation strategy to adopt. Yet, smallholder farmers may not make sound decisions to cope with climate change effects if not supported.

Gilgil Sub County was considered for this study because it is located in the climate change risk area [22]. Additionally, farmers' active engagement in potato production has attracted attention from various institutions that foster the uptake of CSAPs to help them get better cushioned against climate change shock [4]. On the other hand, socioeconomic factors were a focal point because they are likely to affect both the uptake and sustainability of CSAPs like they have done in other areas. Also, it is hard to separate acclimatization to climate change effects from changes in socioeconomic factors [23, 24] because farmers acclimate to climatic changes. At the same time, they are entangled in a compact socioeconomic-ecological system. Figure 1 is a hypothetical illustration of how the selected socioeconomic factors interact with the interventions to cause the adoption of CSAPs and the desired outcome of increasing farmers' resilience to climate change effects, sustainably increasing agricultural productivity and incomes, and reducing greenhouse gases (GHG). This is based on previous literature of the ongoing debates and CSAPs scaling efforts in both Nakuru County and elsewhere in the world [4, 17, 20, 25–31].

The selected socioeconomic factors considered for this study were statistically and significantly related to adopting CSAPs and other climate change adaptation strategies elsewhere [32–37]. The CSAPs that formed this study's outcome variable and whose adoption was investigated included drainage management; agroforestry; synthetic fertilizers; composting; ridge planting; crop rotation; improved crop varieties; intercropping; irrigation; minimum tillage; mulching; rainwater harvesting and storage; terracing; apical rooted cuttings and mini-tubes. Nyongesa et al. [17] and Waaswa et al. [4] stated that these are significant CSAPs being scaled out among the potato farmers in the study area and Nakuru County at large, which serve as an excellent method of safeguard against climatic changes.

Besides the several CSA strategies developed to increase potato production in the face of climate variability and the efforts to scale out the CSAPs, climate variability has threatened potato production. Climate variability is characterized by low precipitation, flooding, high temperatures, prolonged sunshine, and delayed rains leading to a decline in productivity [22, 38]. As a result, smallholder potato farmers continue to register low yields and, in some cases, total losses. This has led to food insecurity challenges among the smallholder potato farmers in the study area [4]. Investigation of the factors that affect the adoption of CSA would therefore go a long way in informing the efforts to adapt potato production to

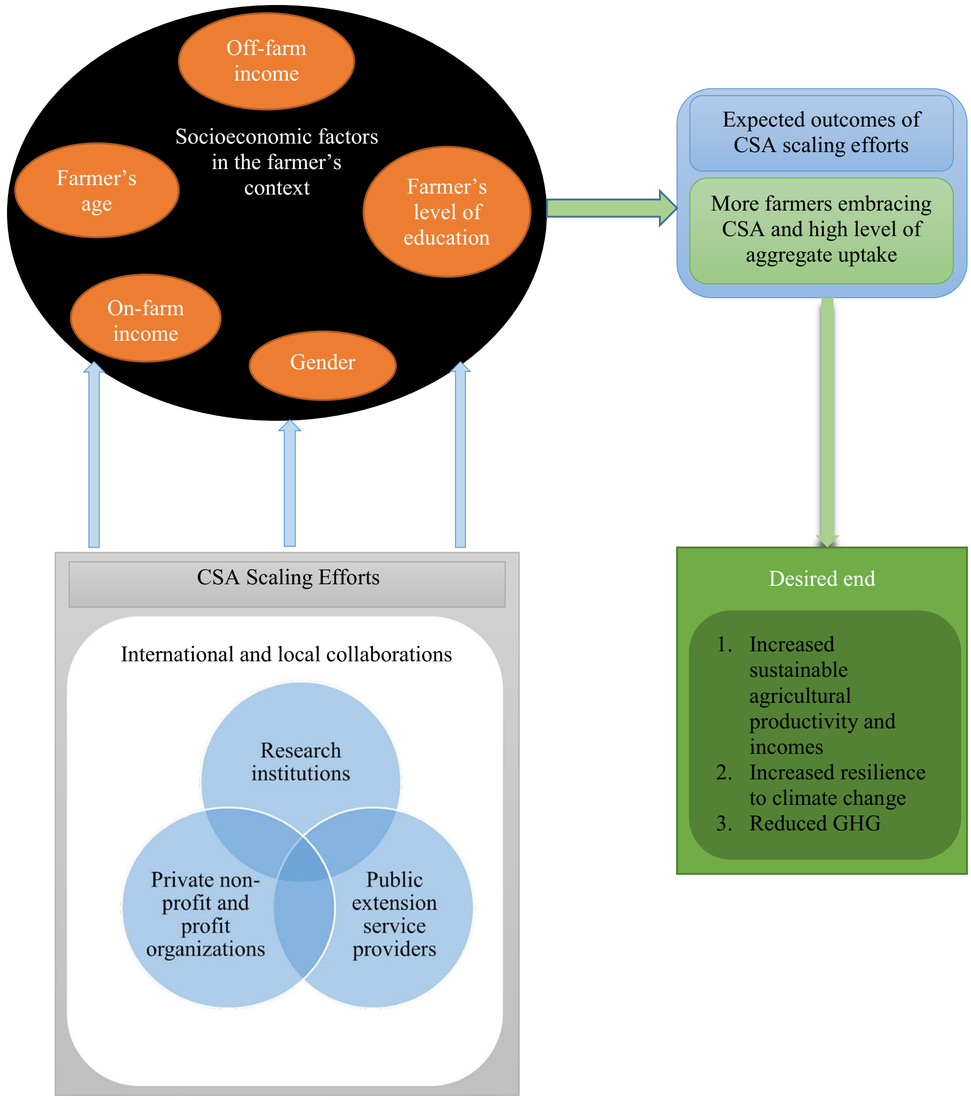

Fig. 1 Illustration of how the selected socioeconomic factors interact with the interventions to cause the practice of CSAPs and the desired outcome

the effects of climate change. In addition, such an investigation would help draw insights that may guide future efforts working on scaling out various CSA practices. Therefore, this study intended to contribute to increased adoption of CSAPs, by establishing the relationship between selected socioeconomic factors and the adoption of CSAPs among the smallholder potato farmers in Gilgil Sub County, Kenya.

2 Materials and methods

2.1 Study area and research approval

National Commission for Science Technology and Innovation (NACOSTI) approved this study under license No. NACOSTI/P/21/9627. The study area is located in Gilgil Sub County, Nakuru County, Kenya (Fig. 2) and its found at coordinates 36° 10′ 0″ E 0° 40′ 0″ S in agro-ecological zone III of Kenya. The total area of the Sub-County is about 1348.43 km^2, with a total population of 171,839 [39]. Undulating plains characterize it, and rainfall distribution in the study area is bimodal. It is characterized by a heavy rainy season from March to May and a scanty rainy season from October to December. The average annual rainfall ranges from 500 and 870 mm, with maize, beans, and potatoes as the significant crops covering 86.4% of the arable land area.

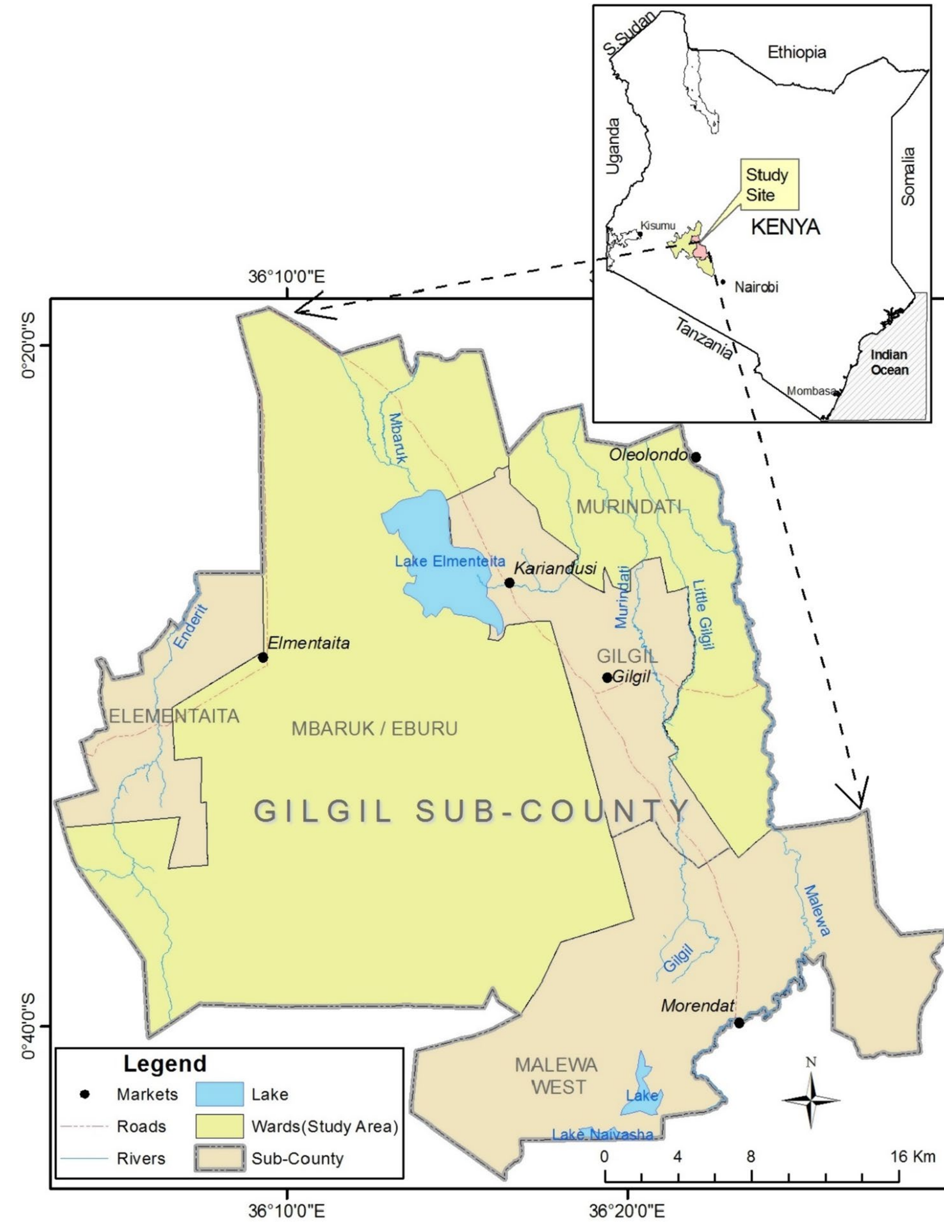

Fig. 2 Map showing the location of the study area

Out of the five wards in Gilgil Sub-County, Mbaruk/Eburu and Morendat were purposively selected because they comprise the most significant number of potato farmers in the Sub-County. Additionally, these two wards form the major farming communities in the Sub-county; unlike other neighborhoods like the Gilgil ward, a town with rocky soils that result in low farming activities [39], Mbaruk/Eburu is also the largest ward in Gilgil Sub-County.

The sample size was drawn from the accessible population of all the 10,889 potato farmers found in Morendat ward (4287), Mbaruk/Eburu ward [6602], and it was calculated basing on the coefficient of variation formula suggested by Nassiuma [40]. For this study, a 21% coefficient of variation and 0.02 standard error were used to compute the sample size using Nassiuma [40] equation (see equation below).

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

where n = sample, N = population, C = Coefficient of variation, e = standard error

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

$$n = 109$$

To cater for non-responses, attrition, and a representative sample, the researchers revised the sample size to 120 by adding 10% of 109. The wards and Sub-County extension officer helped come up with the list of all the potato smallholder farmers in the study area. Proportionate random sampling was used to determine the number of respondents for the purposively sampled wards (Table 1). Simple random sampling was used to obtain the actual respondents from the wards.

2.2 Instrumentation

The primary data was collected using a structured researcher-administered questionnaire. It was administered to the sampled smallholder farmers in the Mbaruk/Eburu and Morendat wards of the Gilgil Sub-County. The questionnaire was used for data collection because it is easy to administer, and it makes scoring and analysis of the data realistic. Besides, responses to items captured in the questionnaire are consistent across the respondents [42]. The questionnaire items were developed based on the study objective and captured information on the information dissemination pathways and the practice of CSA, respectively.

2.2.1 Validity

The validity of a questionnaire means its ability to measure what it is intended to measure [43]. The study established the aspects of face validity, which involved experts looking at the questions in the questionnaire and approving that they are a valid measure of the idea that was investigated just on its face. In addition, content validity ensured that the instrument captured all aspects of the study was done. Research experts from Egerton University, Kenya, validated the questionnaire. Recommendations given were used to improve the instrument.

2.2.2 Reliability

The ability of an instrument to yield the same results repeatedly is referred to as reliability [44]. Thus, reliability measures the consistency of the instrument. This study's questionnaire reliability was ascertained by conducting a pilot study using 30 potato farmers in Mauche Ward of Njoro Sub-County within Nakuru County. The potato farmers in Mauche with related socioeconomic features to the target population were considered for the pilot study. Mauche was chosen for the pilot because it is also exposed to the effects of climate change [22] and with farmers actively engaged in potato production like in the study area. The reliability coefficient was estimated using Cronbach Alpha Scale to 0.805. The questionnaire was regarded as reliable after realizing a reliability coefficient of above 0.70. According to Fraenkel et al. [45], this is recommended considering that a research instrument is reliable if it can yield a reliability coefficient of 0.70 and above.

2.3 Data analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) software, version 25.0. Descriptive analysis was used to compute the percentages and frequencies for some socioeconomic variables against the adoption of CSAPs. A binary logistic regression model was used to analyze the relationship between socioeconomic factors and the adoption of CSAPs. Logistic regression allows predicting a distinct outcome from a set of variables that may be discrete, dichotomous, and continuous, or a combination. Some results for select CSAPs were presented and discussed in terms

Table 1 Proportion of sample size per ward. Source: [41]

Ward	Number of potato farmers	Proportion	Sample size
Mbaruk/Eburu	6602	60.63	73
Morendat	4287	39.37	47
Total	10,889	100	120

of averages for better presentation and discussion. Whereby percentage of farmers practicing some CSAPs within the same range were averaged along with the affected practices. The same was applied to the overall (average) adoption of CSAPs by different categories of farmers.

3 Results and discussions

3.1 Relationship between socioeconomic factors and adoption of climate-smart agriculture

The objective of the study was stated as:

To determine the relationship between socioeconomic factors and the adoption of climate-smart agriculture among smallholder potato farmers in Gilgil Sub County, Kenya

Table 2 shows the selected socioeconomic factors whose relationship with the adoption of CSAPs was deemed necessary for investigation among smallholder potato farmers in Gilgil Sub County, Kenya.

Table 2 reveals that 60% of the respondents were males and 40% females, 30% were between 18 and 35 years, 37.5% were between 36 and 50 years, 25% were between 51 and 65 years, and 7.5% were 66 years and above. It further portrays that 5% of the respondents did not go to school, 50.8% attained primary education, 33.3% secondary education, 8.3% post-secondary, and 2.5% had a university education. About 30.8% earned an annual farm income of less than KES 10,000, 37.5% earned between KES 10,001 and KES 25,000, 15% between KES 25,001 and KES 35,000 while 16.7% earned over KES 35,000. Unlike annual farm income, 23.3% of the respondents earned an annual off-farm income of less than KES 10,000, 34.2% earned between KES 10,001 and KES 25,000, 17.5% earned between KES 25,001 and KES 35,000, whereas 25% earned over KES 35,000.

Table 2 Descriptive statistics of the smallholder potato farmers' socioeconomic factors. Source: Own computation of survey data, 2021

Socioeconomic factor	Frequency	Percentage
Gender of the respondent		
Male	72	60
Female	48	40
Age bracket		
18–35	36	30
36–50	45	37.5
51–65	30	25
66 years and above	9	7.5
Education level		
Did not go to school	6	5
Primary	61	50.8
Secondary	40	33.3
Post-secondary	10	8.3
University	3	2.5
Annual farm income		
< KES[a] 10,000	37	30.8
KES 10,001–KES 25,000	45	37.5
KES 25,001–KES 35,000	18	15
> KES 35,000	20	16.7
Annual off-farm income		
< KES 10,000	28	23.3
KES 10,001–KES 25,000	41	34.2
KES 25,001–KES 35,000	21	17.5
> KES 35,000	30	25

[a]Kenyan Shillings (1 USD to KES = 108.8709 as of 06th August 2021)

A high percentage of male smallholder potato farmers may imply that more CSAPs could be adopted since men tend to own and have access to most production resources like land. Yet, most of the CSAPs considered for this study may require land tenure [4], for example, agroforestry. Following Kennedy et al.'s [46] categorization of farmers into young, adults, and elderly of age ≤ 35, 36–64, and ≥ 65 respectively, these farmers were most likely to embrace the adoption of CSAPs for adapting to climate change effects while improving productivity. According to Arimi [47], most productive African farmers are adults of age ranges 40 to 50.

The respondents' education trend shows that most (50.8% and 33.3%) of the smallholder potato farmers had primary and secondary education, respectively, a sign of low adoption of CSAPs. This is because learned farmers are more inclined to engage in other secondary enterprises like salaried employment and owning a business that may narrow their chances of being available for agriculture. In addition, they have increased livelihood options and thus are less likely to worry about the effects of climate change [32]. However, Arimi [47] and Ayelagbe [48] refute this submission and further claim that high literacy levels incapacitate farmers to seek and utilize the information that may exacerbate the wide use of CSAPs.

On average, the respondents reported low incomes (both annual farm and off-farm incomes) where most (30.8% and 37.5%) earned less than KES 10,000 and between KES 10,001 and KES 25,000 respectively for annual farm income. Similarly, the 23.3% and 34.2% that made an annual farm income of less than KES 10,000, and between KES 10,001 and KES 25,000 respectively are still high compared to the lower percentage of 16.7% and 25% who earned both annual farm and off-farm income of above KES 35,000 respectively. This may deter the adoption of some CSAPs like terracing, irrigation, and drainage management that require more labor and considerable investment in purchasing the required installation materials. For example, a study conducted in the North-Western Highlands of Ethiopia by Moges and Taye [49] found that though terracing was used to lessen the soil erosion caused by the water runoff due to the nature of the slope, farmers lamented that its establishment plus that of drainage channels was associated with high costs by demanding a reasonable labor force. This contention is consistent with Shikuku et al. [50], who asserted that high-income farmers might be in a position to afford irrigation equipment and the required labor force. On the contrary, a study by Gibreel [51] disclosed that farmers with less income were most likely to adopt agroforestry.

3.1.1 Gender and the adoption of climate-smart agriculture

Results on gender and adoption of CSAPs are presented in Table 3 in percentages (%) and frequencies (F).

An average of 67.3% of the 48 female smallholder potato farmers and 60.8% of the 72 male smallholder potato farmers embraced CSAPs. The most adopted CSAPs by the female farmers were the use of synthetic fertilizers and intercropping,

Table 3 Gender and adoption of climate-smart agriculture. Source: Own computation of survey data, 2021

Climate-smart agricultural practices	Smallholder farmers (N = 120)			
	Female (n = 48)		Male (n = 72)	
	F	%	F	%
Rainwater harvesting and storage	39	81.3	63	87.5
Irrigation	17	35.4	18	25.0
Mulching	33	68.8	42	58.3
Minimal tillage	37	77.0	48	66.7
Improved crop varieties	29	60.4	42	58.3
Terracing	36	75.0	54	75.0
Drainage management	36	75.0	47	65.3
Intercropping	45	93.8	60	83.3
Agroforestry	42	87.5	59	81.9
Synthetic fertilizers	46	95.8	68	94.4
Composting	41	85.4	43	59.7
Furrow/ridge planting	37	77.0	50	69.4
Crop rotation	42	87.5	56	77.8
Apical rooted cuttings (potato seedlings)	4	8.3	5	6.9
Mini-tubers	1	2.0	2	2.8

with an average score of 94.8%. This was followed by 85.4% for rainwater harvesting and storage, agroforestry, composting, and crop rotation. Relatively adopted CSAPs by women included minimal tillage, terracing, drainage management, and furrow/ridge planting, with an average score of 76.0%. While mulching and improved crop varieties scored an average of 64.6%, other CSAPs (irrigation, potato seedlings, and minitubers) scored below average (35.4%, 8.3%, and 2.0%, respectively). On the other hand, the most adopted CSAPs among male smallholder potato farmers were synthetic fertilizers (94.4%), followed by rainwater harvesting and storage, intercropping, and agroforestry, with an average of 84.2% of smallholder male farmers practicing them. Around 76.4% of male farmers adopted terracing and crop rotation, 67.1% adopted minimum tillage, drainage management, and furrow/ridge planting, and 58.3% adopted mulching and improved crop varieties. Irrigation, potato seedlings, and mini-tubers were adopted by 25.0%, 6.9%, and 2.8%, respectively.

Overall, female farmers adopted more CSAPs than males. This contradicts findings from previous studies [34, 52–54] where male farmers adopted more CSAPs than females to lessen the effects of climate change. High use of synthetic fertilizers and intercropping by women may be explained by the fact that women are major food producers [55] and these CSAPs tend to yield results in the shortest time possible. For example, urea releases nutrients easily, and intercropping allows various crops for food and nutritional security.

Contrarily, slightly low use of synthetic fertilizers and intercropping by men compared to women could be due to men's risk averseness that may make them hesitant in venturing in short-term CSAPs. This claim is in line with Asfaw and Admassie [56], who found that males are inclined to be risk-averse and reluctant to adapt to climate change by obtaining new CSAPs and changing their farming methods. The high-level adoption of rainwater harvesting by men than women maybe because of the cost associated with the initial installation of rainwater harvesting equipment. This is because, in Africa, men own productive resources that generate household income [57], limiting women in accessing CSAPs that require high initial installation costs. Additionally, rainwater harvesting and storage may necessitate the digging of water pans, and this is a labor-intensive activity that most women may not welcome.

However, women's high percentage in the overall use of most CSAPs other than rainwater harvesting, potato seedlings, and minitubers can be because of being conservative to change from traditionally known practices. Most of the CSAPs where women ranked high are traditionally known practices rebranded into climate-smart agriculture ('old wine in new bottles'). This contention is empirically supported by Tenge et al. [58], who found that women farmers are not liable to change the farming methods to which they are used. Limited access to information may be responsible for the low adoption of potato seedlings and minitubers by women compared to men. These being new CSAPs among potato farmers, access and utilization of information inform early adopters' decisions. This assertion is consistent with that of Di Falco [59], who asserted that male farmers are expected to embrace new crop varieties than their counterparts who, due to cultural norms, have inadequate access to information.

3.1.2 Farmer's age and adoption of climate-smart agriculture

Table 4 presents results on smallholder potato farmers' age and adoption of CSAPs in percentages and frequencies. Averagely, 61.8% of the farmers within the age bracket of 18–35 years, younger farmers, according to Kennedy et al. [46], adopted the CSAPs with 86.6% embracing rainwater harvesting and storage, intercropping, use of synthetic fertilizers, and crop rotation. Agroforestry and furrow/ridge planting were adopted by 75.0%, mulching, minimum tillage, terracing, drainage management, and compositing by 67.8%, and improved crop varieties by 58.3%. In contrast, irrigation was adopted by 33.3%, and no farmer within this age category adopted potato seedlings and minitubers.

According to Kennedy et al. [46], farmers within the age category of 36 to 65 years are regarded as adult farmers. The most adopted CSAPs by the adult farmers included rainwater harvesting and storage, mulching, minimal tillage, terracing, drainage management, intercropping, agroforestry, synthetic fertilizers, composting, furrow/ridge planting, and crop rotation. These were adopted by over 70% of the adult farmers; this was followed by intercropping, which was adopted by over 50%. Irrigation was the second last CSAPs adopted by adult farmers, and it was embraced by over 30%. In comparison, potato seedlings and minitubers were adopted by around 8.0% of the adult smallholder potato farmers, and these were the least adopted CSAPs. On the other hand, over 78% of the old farmers adopted most of the CSAPs except for irrigation, which was adopted by 33.3%, mulching (44.4%), potato seedlings (11.1%), and minitubers, which was adopted by none.

Based on the findings, there is no significant difference in the CSAPs adopted by young farmers, adults, and old farmers except for potato seedlings and minitubers, which were not adopted at all by the young farmers yet adopted by the adult farmers, and minitubers adopted by the old farmers. Non-adoption of potato seedlings and minitubers by the young smallholder potato farmers could be because of their inability to access land and other production resources controlled

Table 4 Age and adoption of climate-smart agriculture. Source: Own computation of survey data, 2021

Climate-smart agricultural practices	Smallholder potato farmers (N = 120)							
	18–35 (n = 36)		36–50 (n = 45)		51–65 (n = 30)		66 years and above (n = 9)	
	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	30	83.3	36	80.0	26	86.7	8	88.9
Irrigation	12	33.3	13	28.9	10	33.3	3	33.3
Mulching	24	66.7	32	71.1	17	56.7	4	44.4
Minimal tillage	25	69.4	37	82.2	20	66.7	5	55.6
Improved crop varieties	21	58.3	28	62.2	16	53.3	6	66.7
Terracing	24	66.7	35	77.8	24	80.0	7	77.8
Drainage management	25	69.4	34	75.6	20	66.7	6	66.7
Intercropping	32	88.9	42	93.3	26	86.7	7	77.8
Agroforestry	27	75.0	39	86.7	27	90.0	9	100.0
Synthetic fertilizers	32	88.9	43	95.6	30	100.0	9	100.0
Composting	24	66.7	38	84.4	22	73.3	7	77.8
Furrow/ridge planting	27	75.0	32	71.1	22	73.3	8	88.9
Crop rotation	31	86.1	40	88.9	23	76.7	6	66.7
Apical rooted cuttings (potato seedlings)	0	0.0	5	11.1	3	10.0	1	11.1
Mini-tubers	0	0.0	2	4.4	0	0.0	0	0.0

by the adults and old farmers. This claim is in line with Gumucio et al. [60], who found that young farmers are constrained to act on some CSAPs and other climate change adaptation strategies due to lack of control on land. The overall high adoption of CSAPs across all age categories of smallholder potato farmers could be associated with; young farmers are always perpetrated not only to acting towards climate change for adaption but also aesthetic value. This contention is supported by previous studies [61–64] where young farmers were regarded to have immense environmental committal. While adult and older farmers have experience and would not wish to succumb to food shortages, this drives them to adopt CSAPs as adaptive strategies. This agrees with Zahidul Islam et al. [65], who purported that adult and older farmers are experienced and readily embrace new practices.

3.1.3 Education level and adoption of climate-smart agriculture

Table 5 displays the frequencies and percentages of smallholder potato farmers practicing CSAPs. The majority (an average of over 60%) of the farmers across all education categories adopted CSA. Some CSAPs were embraced by 100% of the farmers who did not go to school, by those who attained secondary, post-secondary, and university education. Similarly, certain CSAPs were adopted by over 95.1% of the farmers with primary education.

However, a disparity in the adoption of some CSAPs existed. First, only 50% of the farmers who did not go to school and those who attained post-secondary education adopted mulching. This is a slightly lower percentage than over 65% of the farmers with primary, secondary, and university education who adopted mulching. Additionally, the smallholder potato farmers with university education adopted improved crop varieties and agroforestry below average (33.3%). Still, though above average, improved crop varieties were adopted by 59% and 57.5% of the farmers with primary and secondary education, respectively. Yet, generally, the overall trend shows that over 60% of the farmers across all education categories put this into practice. Except for farmers with a university education, of which 66.7% adopted irrigation, its adoption among the rest of the farmers within other education categories was below average.

Nevertheless, the farmers with primary and post-secondary education adopted all potato seedlings and minitubers, though at a low percentage of 8.2% and 1.6%, and 10% and 10%, respectively. Unlike the potato farmers with university education who adopted neither potato seedlings nor minitubers, at least those who did not go to school and those with secondary education at a percentage of 16.7% and 5.0% respectively adopted minitubers.

Generally, the high rate of adoption of CSAPs across all education categories could be because agriculture is the primary source of income in the study area [39], coupled with recurrent changes in the weather, all farmers, regardless of their education levels, are being forced to take measures to protect their primary income source. Mulching received an

Table 5 Education level and adoption of climate-smart agriculture. Source: Own computation of survey data, 2021

Climate-smart agricultural practices	Smallholder potato farmers (N = 120)									
	Did not go to School (n = 6)		Primary (n = 61)		Secondary (n = 40)		Post-secondary (n = 10)		University (n = 3)	
	F	%	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	5	83.3	46	75.4	37	92.5	9	90.0	3	100.0
Irrigation	1	16.7	18	29.5	15	37.5	2	20.0	2	66.7
Mulching	3	50.0	41	67.2	26	65.0	5	50.0	2	66.7
Minimal tillage	4	66.7	42	68.9	28	70.0	10	100.0	3	100.0
Improved crop varieties	4	66.7	36	59.0	23	57.5	7	70.0	1	33.3
Terracing	4	66.7	45	73.8	30	75.0	8	80.0	3	100.0
Drainage management	5	83.3	44	72.1	26	65.0	8	80.0	2	66.7
Intercropping	6	100.0	57	93.4	33	82.5	8	80.0	3	100.0
Agroforestry	6	100.0	53	86.9	36	90.0	6	60.0	1	33.3
Synthetic fertilizers	6	100.0	58	95.1	40	100.0	8	80.0	2	66.7
Composting	5	83.3	45	73.8	31	77.5	8	80.0	2	66.7
Furrow/ridge planting	4	66.7	42	68.9	32	80.0	8	80.0	3	100.0
Crop rotation	5	83.3	51	83.6	33	82.5	8	80.0	3	100.0
Apical rooted cuttings (potato seedlings)	1	16.7	5	8.2	2	5.0	1	10.0	0	0.0
Mini-tubers	0	0.0	1	1.6	0	0.0	1	10.0	0	0.0

average score, especially among farmers who did not go to school and those with post-secondary education; this can be associated with the high demand for mulches in the area where other factors like income come into play. Farmers with low income may not afford to source mulches from distant places or even may instead be tempted to sell theirs to meet overarching family needs.

Low levels of adoption of improved crop varieties and agroforestry and no adoption of potato seedlings and mini-tubers by the smallholder potato farmers with university education could be because these have other alternative sources of livelihood. Thus, using yield-enhancing varieties and agroforestry for diversification and adaptation to climate change is not a priority. This claim contradicts Leake and Adam [66], who found that farmers with more years of formal education have a higher likelihood of allotting a notable proportion of their farming land to improved crop varieties. Further, Dang et al. [23] added that education enables farmers to locate relevant information and inspires the acceptance of modern technologies like improved crop varieties. Again, for some practices like irrigation, a high percentage of adoption among farmers with university education may mean that these can afford to meet the high cost of equipment required to install an irrigation system or buy equipment like watering cans. This accrues to their being able to find salaried employment. This agrees with Kabubo-Mariara and Mulwa [67], who noticed that learned farmers had other sources of income.

3.1.4 Annual farm income and adoption of climate-smart agriculture

From Table 6, smallholder potato farmers with an annual farm income of KES 10,000–KES 25,000 and above KES 35,000 adopted all the CSAPs investigated in this study. With all the CSAPs being adopted by over 65% and 62.2% except for irrigation (40.0% and 35.0%), potato seedlings (13.3% and 10.0%), and mini-tubers (2.2% and 5.0%) respectively among farmers of this category.

The other farmers with high percentages of adoption of CSAPs was KES 25,001–KES 35,000 annual farm income category. Like the latter, except for the minitubers, these adopted all the CSAPs with an overall average of 66.7%. However, mulching and minimum tillage were averagely adopted, followed by irrigation and potato seedlings adopted by only 16.7% and 5.6% of the potato smallholder farmers within this income category. On the contrary, an average of 57.7% of the smallholder potato farmers with an annual farm income of less than KES 10,000 adopted the CSAPs. Unlike the other annual farm income category farmers, for this category, two CSAPs (irrigation and improved crop varieties) were adopted below average, and two (potato seedlings and mini-tubers) were not adopted at all.

As observed, at least every category of smallholder potato farmers adopted some CSAPs to a considerable level besides the differences in the percentages. Reason(s) for this could be that most farmers are poor with a keen eye on agriculture,

Table 6 Annual farm income and adoption of climate-smart agriculture. Source: Own computation of survey data, 2021

Climate-smart agricultural practices	Smallholder potato farmers (N = 120)							
	< KES 10,000 (n = 37)		KES 10,000–KES 25,000 (n = 45)		KES 25,001–KES 35,000 (n = 18)		> KES 35,000 (n = 20)	
	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	27	73.0	37	82.2	16	88.9	20	100.0
Irrigation	10	27.0	18	40.0	3	16.7	7	35.0
Mulching	27	73.0	28	62.2	9	50.0	13	65.0
Minimal tillage	20	54.1	34	75.6	15	83.3	18	90.0
Improved crop varieties	18	48.6	29	64.4	10	55.6	14	70.0
Terracing	24	64.9	34	75.6	15	83.3	17	85.0
Drainage management	24	64.9	31	68.9	13	72.2	17	85.0
Intercropping	34	91.9	41	91.1	15	83.3	17	85.0
Agroforestry	29	78.4	41	91.1	15	83.3	17	85.0
Synthetic fertilizers	34	91.9	43	95.6	18	100.0	20	100.0
Composting	23	62.2	34	75.6	16	88.9	18	90.0
Furrow/ridge planting	24	64.9	32	71.1	17	94.4	16	80.0
Crop rotation	26	70.3	38	84.4	17	94.4	19	95.0
Apical rooted cuttings (potato seedlings)	0	0.0	6	13.3	1	5.6	2	10.0
Mini-tubers	0	0.0	1	2.2	0	0.0	1	5.0

which they have to cushion against the effects of climate change using the returns obtained from their harvests. This claim is supported by Alam [68], who found that for poor farmers whose survival depends on farming, the costs of lengthened droughts are enormous. Therefore, adaptation is required to reduce these disasters. Additionally, the non-adoption of potato seedlings and minitubers by farmers within the income category of less than KES 10,000 can be explained by the high cost of acquiring and establishing these CSAPs. This contention is in line with previous studies [69, 70] that found minimal uptake levels of most agricultural technologies that needed more monetary input.

While the overall high percentage of the adoption of CSAPs among farmers with more annual farm income can be caused by their desire to increase the number of crops produced. This is because as farmers get more revenue from their farms, they always think of increasing production, and an increase in farmland results in more CSAPs a farmer has to adopt. This argument is consistent with Awotide et al. [32], who argued that the more land farmers devote to crop production, the more the need arises for adaptation strategies like synthetic fertilizers, improved crop varieties, and herbicides for minimum tillage, etc. A low percentage of irrigation adoption across all annual farm income categories could be due to limited access to water sources in the area that limits farmers even when they can meet the costs of irrigation equipment to support cultivation.

3.1.5 Annual off-farm income and adoption of climate-smart agriculture

Table 7 revealed that other than potato seedlings and minitubers, synthetic fertilizers was the highly adopted CSAP by the smallholder potato farmers with the annual off-farm income category of KES 10,000–KES 25,000, KES 25,001–KES 35,000, and above KES 35,000. It also shows that this was the least adopted CSAP by the smallholder potato farmers within an annual off-farm income category of less than KES 10,000.

Surprisingly, irrigation was highly (39.3%) adopted by farmers within the low annual off-farm income category (less than KES 10,000), followed by farmers within KES 25,001–KES 35,000 (33.3%), KES 10,000–KES 25,000 (29.3%), and lastly by high annual off-income category (26.7%). Averagely, this was the third last adopted CSAP following potato seedlings and minitubers for annual off-farm income categories of above KES 10,000, and the fourth last for annual off-farm income categories of less than KES 10,000. The rest of the CSAPs were adopted by over 61% for farmers within the annual farm income categories of less than KES 10,000, KES 10,000–KES 25,000 and above KES 35,000, and around 76.2% for the KES 25,001–KES 35,000 category except the two (mulching and improved crop varieties).

Unlike the earlier stated and other CSAPs, mulching was averagely adopted by 57.1% and 53.3% of smallholder potato farmers within the off-farm income category of KES 25,001–KES 35,000 and above KES 35,000, respectively. Additionally,

Table 7 Annual off-farm income and adoption of climate-smart agriculture. Source: Own computation of survey data, 2021

Climate-smart agricultural practices	Smallholder potato farmers (N = 120)							
	< KES 10,000 (n = 28)		KES 10,000–KES 25,000 (n = 41)		KES 25,001–KES 35,000 (n = 21)		> KES 35,000 (n = 30)	
	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	23	82.1	31	75.6	20	95.2	26	86.7
Irrigation	11	39.3	12	29.3	7	33.3	8	26.7
Mulching	20	71.4	29	70.7	12	57.1	16	53.3
Minimal tillage	18	64.3	30	73.2	16	76.2	23	76.7
Improved crop varieties	16	57.1	25	61.0	12	57.1	18	60.0
Terracing	18	64.3	30	73.2	18	85.7	24	80.0
Drainage management	19	67.9	27	65.9	18	85.7	21	70.0
Intercropping	28	100.0	35	85.4	18	85.7	26	86.7
Agroforestry	23	82.1	34	82.9	18	85.7	27	90.0
Synthetic fertilizers	2	7.1	40	97.6	21	100.0	29	96.7
Composting	20	71.4	28	68.3	19	90.5	24	80.0
Furrow/ridge planting	20	71.4	28	68.3	18	85.7	23	76.7
Crop rotation	21	75.0	34	82.9	20	95.2	25	83.3
Apical rooted cuttings (potato seedlings)	0	0.0	3	7.3	1	4.8	5	16.7
Mini-tubers	0	0.0	1	2.4	0	0.0	1	3.3

improved crop varieties were adopted by 57.1% by smallholder potato farmers within the off-farm income categories of less than KES 10,000 and KES 25,001–KES 35,000. Though least adopted, 16.7% and 3.3% within the off-farm income category of above KES 35,000 adopted potato seedlings and minitubers followed by 7.3% and 2.4%, 4.8% and 0.0% by KES 10,000–KES 25,000 and KES 25,001–KES 35,000 categories respectively. None of the smallholder potato farmers within the annual off-farm income category of less than KES 10,000 adopted potato seedlings and minitubers.

As noted, a high percentage of adoption of irrigation among farmers within the off-farm income category of less than KES 10,000 could be explained by the fact that such 'poor' farmers are always trying all possible means to uplift themselves from poverty. Therefore, these may find hardships in acquiring sophisticated irrigation equipment but maneuver with the locally available resources like digging water pans and diverting runoff to the water collection points in their farms. This contention is in line with Awotide et al. [32], who found that income-constrained farmers in Nigeria intensified production to stabilize their finances. It contradicts Alam [68], who found the progressive adoption of irrigation with increased income among farmers.

On the other hand, the low adoption of synthetic fertilizers and non-adoption of potato seedlings and minitubers by the farmers that fall within this category could be due to the high costs of these CSAPs. Unlike irrigation, where they can harvest rainwater, these CSAPs cannot be accessed without money. This explains an increased adoption of intercropping and agroforestry among this category because these increase the soil fertility that they would meet by adding synthetic fertilizers. This attestation is consistent with previous studies that found the increased adoption of intercropping among farmers who were constrained in accessing synthetic fertilizers [71]. The adoption of almost all CSAPs by farmers within the annual farm income category above KES 10,000 could be because these can meet the associated costs, especially for potato seedlings and minitubers. This declaration is empirically backed up by previous studies [34, 72–75] and an assertion by Mujeyi et al. [76] where farmers with high off-farm income were inclined to embrace CSAPs and other climate change adaptation strategies than their counterparts.

3.2 Test of hypothesis

The study objective was translated into the following hypothesis:

H0 There is no statistically significant relationship between socioeconomic factors and the adoption of CSA among smallholder potato farmers in Gilgil Sub–County, Kenya.

The hypothesis was tested using binary logistic regression, and an analysis of socioeconomic factors as independent variables against the adoption of CSAPs was statistically significant (Table 8). This was conducted by including all cases from which data was collected were selected and included in the statistical significance analysis.

Table 8 discloses that the relationship between socioeconomic factors and adoption of CSAPs was statistically significant at a 5% level of significance ($\chi^2 = 17.966$, df = 5, $p < 0.05$).

This implies that a relationship existed between socioeconomic factors and the adoption of CSAPs. Therefore, the null hypothesis is rejected. This deduction is in line with past studies' findings where socioeconomic factors were responsible for the uptake of agricultural technologies, including CSAPs like improved crop varieties [32, 33, 37]. Additionally, between 13.9% (Cox and Snell R Square) and 20.6% (Nagelkerke R Square) of the variance in CSA adoption is explained by socioeconomic factors.

Such a variance shows how relevant the socioeconomic factors are in the adoption of CSA and how well they relate. In addition, the socioeconomic factors' Binary Logistic Regression Model (BLRM) yielded a percentage accuracy classification (PAC) of 76.7% (Table 9).

This means that the explanatory variables in the socioeconomic factors' model accurately predict the adoption of CSA by the smallholder potato farmers by 76.7%. Implying that 76.7% of the time, we predict smallholder potato farmers to adopt CSAPs is correct. On the other hand, a goodness of fit test results attested that the model used was fit for the socioeconomic factors. This is affirmed by the insignificant values ($\chi^2 = 4.471$, df = 8, $p > 0.05$) which support the model. This, therefore, presents insufficient evidence to claim that the model does not fit the data adequately.

This implies that the socioeconomic factor's BLRM is responsible for the unseen traits across smallholder potato farmers' resolutions to adopt CSAPs. Further, the socioeconomic BLRM revealed that the relationship between the explanatory variables and the adoption of CSAPs among smallholder potato farmers vary considerably (Table 10).

Table 8 Omnibus tests of model coefficients for socioeconomic factors

Step 1	Chi-square	df	Sig.
Step	17.966	5	0.003
Block	17.966	5	0.003
Model	17.966	5	0.003

Table 9 Percentage accuracy classification table[a] for socioeconomic factors' BLRM

Observed		Predicted		
		Adoption of CSA		Percentage correct
		0.00	1.00	
Step 1				
Adoption of CSA	0.00	7	23	23.3
	1.00	5	85	94.4
Overall percentage				76.7

[a]The cut value is 0.500

Table 10 Socioeconomic variables in the binary logistic regression equation

Socioeconomic variables	B	S.E	Wald	df	Sig.	Exp(B)
Step 1[a]						
Age bracket	− 0.290	0.268	1.175	1	0.278	0.748
Gender of the respondent	− 1.257	0.486	6.701	1	0.010	0.284
Education level	− 0.226	0.318	0.507	1	0.476	0.797
Annual farm income	0.924	0.319	8.402	1	0.004	2.520
Annual off-farm income	− 0.021	0.256	0.007	1	0.936	0.980
Constant	1.076	1.114	0.933	1	0.334	2.932

[a]Variable(s) entered on step 1: age bracket, gender of the respondent, education level, annual farm income, annual off-farm income

The findings show that within the five hypothesized explanatory socioeconomic variables contained in the model, only two were affirmed to have a significant relationship with the adoption of CSAPs. Among these included gender and annual farm income. However, explanations for the relationship portrayed by all variables are as follows. At the outset, note that an odds ratio less than 1 indicates a negative relationship.

4 Age

The binary logistic regression analysis results showed that farmer's age insignificantly relates to the adoption of CSAPs. Additionally, the age's odd ratio shows that an increase in the farmers' age diminished their likelihood of practicing CSAPs by 74.8% compared to the young farmers. This could be explained by their being less open to new opinions and less willing to take risks related to contemporary practices [77–79]. According to past studies, unwillingness to take risks is ranked among the major bottlenecks that curtail the uptake of new agricultural technologies [32, 34, 80, 81]. This finding is consistent with Kaliba et al. [82], who declared farmers' age to either enhance or reduce the possibility of embracing new practices. They further argued that as a farmer advances in age, the degree of risk averseness raises or drops based on the level of their self-confidence. Additionally, Dang et al. [23] asserted that the more aged a farmer is, the more unwilling to accept change. It becomes challenging for aged farmers to embrace technological modifications in their farming systems.

5 Gender

The findings show that the variable of gender is statistically significant but negative at a 5% significance level (Wald $\chi^2 = 6.701$, df = 1, $p < 0.05$). As observed, female smallholder potato farmers were likely to adopt CSAPs more than male farmers by 28.4%. This could be because women are responsible for most farming activities, especially in Africa, which inclines them to adapt to climate change and avoid damage being caused to their household food security. This contention is in line with several studies that have alleged that female farmers are more inclined to embrace adaptation strategies like CSAPs given their many responsibilities in farming that imbue them with more excellent knowledge and expertise on numerous farm management practices [4, 55, 83]. Additionally, it could be possible that males are likely to deny the presence and consequences of climate change [84], which makes them skeptical about embracing the CSAPs as adaptive strategies. Contrarily, numerous studies [34, 56] have found that male farmers were more likely to take up adaptation strategies and other agricultural technologies than females. These claimed that women are less exposed to climate change adaptation strategies, are culturally designated for domestic pursuits, and have restricted access to crucial resources like finances, labor force, and land, which often undermines their capacity to venture into labor-demanding farm enterprises [85].

6 Education

An insignificant relationship between education and the adoption of CSAPs existed. Results show that an increase in the farmers' education level reduced their possibilities of practicing CSAPs by 79.7% compared to farmers with less or no education. This could be justified by the reality that educated farmers have varied sources of livelihood and therefore worry less about the effects of climate change. This finding is consistent with Kabubo-Mariara [86], who found a negative relationship between education and adaptation strategies uptake among Kenya livestock farmers. On the contrary, other studies have found that farmers with no or less education are less knowledgeable of the possible and existing options [87–89]; they show a likelihood of ignoring adapting agriculture to the climate change effects. This finding also contradicts those of Ahmed [90] and Roy et al. [91], who found a positive and significant relationship between farmer's education level and execution of CSAPs, and other climate change adaptation strategies. These asserted that educated farmers readily understand information and adopt advanced technologies more comfortably than illiterate farmers.

7 Annual farm income

Annual farm income positively relates with the adoption of CSAPs at 5% significance level (Wald $\chi^2 = 8.402$, df = 1, $p < 0.05$). Results reveal that for every unit increase in annual farm income, the chance of practicing the CSAPs increases by 2.52 times more than for the farmers with low annual farm income. This could be because increasing the size of land consecrated to CSAPs such as planting improved crop varieties necessitates extra money to acquire the required inputs like herbicides, improved seeds, fertilizer, and to meet labor costs [68, 92]. These findings resonate with other studies [93, 94] that found increased investment in agrochemicals, growing of more than one crop and quality seeds of improved varieties, plus assertions by Deressa et al. [34] that increased farm income eminently increased the likelihood of adapting to climate change by practicing soil conservation measures, altering planting dates, and diversifying crop varieties. Nevertheless, these findings are disputed by Danso-Abbeam et al. [95], who found the low adoption of maize varieties as a CSAP among farmers with high farm income. This was attributed to the reality that farmers who garnered more income from the previous seasons' harvests could diversify their income into different agricultural or non-agricultural ventures.

8 Annual off-farm income

Results indicated an insignificant relationship between annual off-farm income and the adoption of CSAPs. Results further show that every unit increase in annual off-farm income decreases the farmers' likelihood of practicing CSAPs by 98% compared to farmers with low annual off-farm income. The reality could justify this that indulging in off-farm vocations usually disinclines farmers from committing themselves to farm work because off-farm revenue tends to trigger many off-farm activities. Similar results were found by many other studies [32, 72, 96, 97] and reasons for the insignificance rippled around non-farm ventures decreasing the possibility of practicing some adaptation strategies that needed time and commitment yet with long-term returns. However, inconsistency was observed between this study's findings and those of other researchers [98–100] who found that income from non-farm pursuits coaxes acceptance of CSAPs like improved crop varieties by enabling farmers to raise capital and meet costs related to new agricultural practices.

9 Conclusions and policy implication

This study used a binary logistic regression model to establish the relationship between selected socioeconomic factors and the adoption of CSAPs among smallholder potato farmers in Gilgil Sub-County, Kenya. An analysis of the five hypothesized explanatory socioeconomic variables in the model disclosed that a relationship between socioeconomic factors and the adoption of CSAPs was statistically significant. It further revealed that only two variables had a significant relationship with the adoption of CSAPs. Among these, included gender which was negative and statistically significant, and annual farm income that was positive and statistically significant. This study's empirical results present valuable advice for policymakers.

To begin with, the results in this article gives proof that annual farm income and gender are pivotal socioeconomic factors in affecting the possibilities of farmers to adopt CSAPs. Therefore, policies that support farmers to increase farm earnings should be prioritized. These will help create favorable requisites for the scaling and adoption of farming methods befitted to adapting agriculture to the effects of climate change. Additionally, facilitating increased farm output and increased incomes among the farmers is greatly recommended. Besides, gender turned out to be negative and significant, implying that women are pivotal in shaping the likelihood of practicing CSAPs in the face of climatic changes. Thus, agricultural technologies should not be developed without consideration of conditions that favor access to such technologies by women.

Consequently, securing access to vital resources for women farmers is indispensable to enhance their capacity and compliance to adjust production methods in response to climate change. Nevertheless, like other studies, this is not without imperfections. Principally the examination was restricted to cross-sectional data. This constrains the observation of long-term transitions and changes in farmers' decisions to adopt CSAPs. This flaw should be considered while assessing this study's deductions and forms a potential area for further research.

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Declarations

Competing interests The authors declare no competing interests.

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