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Constraints and Opportunities for Greenhouse Farming Technology as an Adaptation Strategy to Climate Variability by Smallholder Farmers of Nyandarua County of Kenya

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Abstract

Nyandarua County of Kenya has been for a long time, manifested itself as one of the major food baskets in the country. This is because of its high and sustainable output in crop farming i.e., maize, Irish potatoes, wheat, and other horticultural crops like vegetables and fruits. However, this scenario has recently changed because the usual high crop output has not been forthcoming due to recent changes in climatic patterns where rainfall has become very unreliable and temperatures very extreme. In an attempt to adapt to this climate variability and its associated negative impacts on crop farming, smallholder farmers have tried to apply the greenhouse farming technology for them to be able to maintain and or improve the various crop output amid the climatic changes. The study aims to examine and assess the socio-economic determinants and constraints associated with this attempt of adaptation strategy. Using the primary data of 300 respondents (Smallholder farmers) in the County, the study adopted a logistic regression analysis model to associate the demographic, socio-economic, and constraints encountered by the smallholder farmers with the adoption of the greenhouse farming technology. The study results indicate that this adaptation strategy was reported by 25 out the 300 smallholder farmers (5.83%). The study results further suggest that financial constraints (27%) and lack of information (22.3%) are the major constraints preventing smallholder farmers from effectively adopting this adaptation strategy. However, the probability results of logistic regression analysis (68%) indicate that if properly adopted, the method can provide a solution to the currently reduced food shortages and increase food security among the smallholder farmers of Nyandarua County of Kenya.

Keywords: *Adaptation strategies; climate variability; greenhouse farming technology; logistic regression model.*

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Introduction

Climate variability and its related impacts have become a common center of discussion in many economies worldwide (IPCC, 2017). Indeed, the medium and low-income countries in the African continent are incredibly susceptible to the dangers of climate variability due to overreliance on agriculture for food security and human livelihoods (Mikalitsa, 2010). Extreme temperatures and unpredictable rainfall in Kenya have contributed to the increased adverse effect on agricultural production (Wambua *et al.,* 2008; Nyandega *et al.,* 2020). Indeed, the socio-economic systems of many households in Kenya have significantly been disrupted by climate variability (Shah and Ayiemba, 2019). To minimize the negative impacts of climate variability on agriculture, the government of Kenya, through the national policy frameworks such as Kenya National Adaptation Plan 2015-2030 and Climate Change Framework Policy (31Nov2016), has partnered with international and local organizations to develop tools that can quickly evaluate how smallholder farmers can better prepare and adapt to the forthcoming unprecedented climatic variability (Republic of Kenya 2010, 2013&2014b).

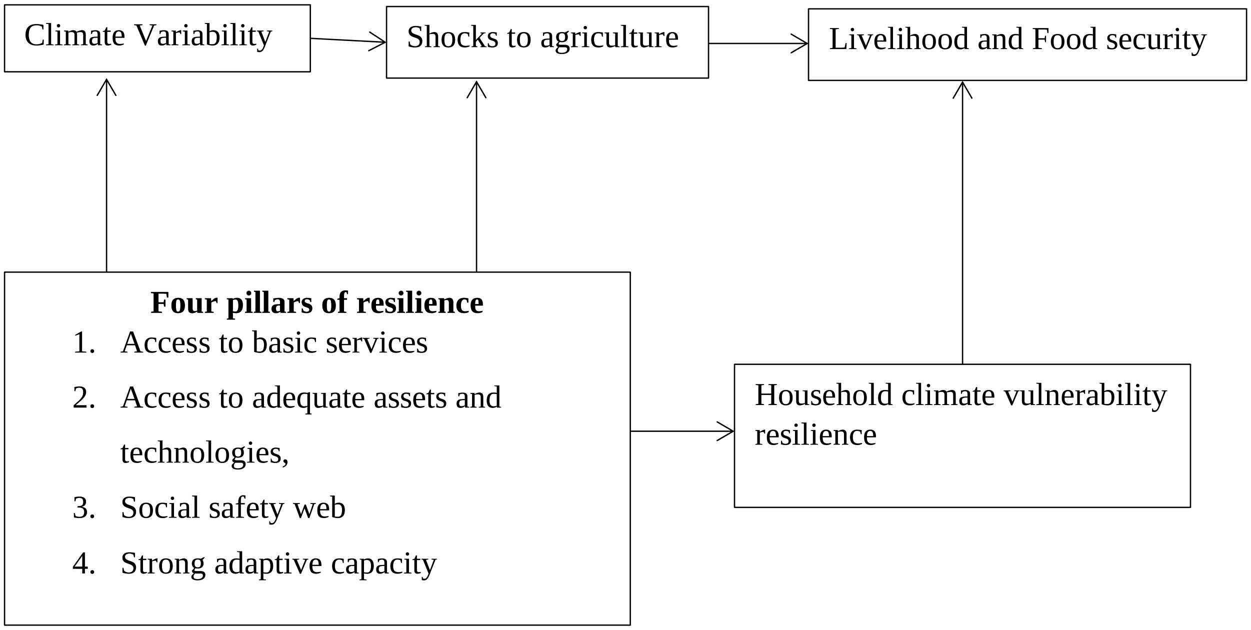
Production of greenhouses and installation of the necessary equipment and application of the technical expertise requires a considerable amount of resources (Heuvelink, 2018). Indeed, the general landscape and geomorphological conditions of land may make the cost of erecting greenhouses vary from one region to the other (Khroda, 1996). Nyandarua County is on a relatively flat landscape and has been cited as one of the favorable, cost-effective areas to erect greenhouse infrastructure for sustainable farming (Muriithi, 2020). Indeed, for greenhouse farming technologies to be effective, a unified tactic to crop farming through the development of practical skills of greenhouse farming and climate variability response in modern economies is necessary (Stanghellini *et al.,* 2019).

Many political and social researchers have described Nyandarua County though being in the country's central region, as having been marginalized for an extended period, especially after the white settlers vacated the area in the middle sixties (Kidiga, 2017). This marginalization has manifested itself through poor and inaccessible roads, lower education levels, higher poverty levels, inadequate piped water for household use and irrigation purposes, and weak political representation (Kiara, 2015). These elements of inadequacies have increased the vulnerability of smallholder farmers in the region due to limited resources and capital to invest in proper adaptation strategies like setting up greenhouses and their related infrastructural technologies (Muriithi *et al.,* 2020). Besides, due to a variety of constraints, the smallholder farmers are often left exposed to adverse effects of climate variability, which drives the smallholder farmers to make poor decisions regarding proper adaptation measures and their significant timing (Wambua *et al.,* 2018).

According to FAO (2010), the adoption of greenhouse farming technologies is guided by four pillars of resilience i.e., access to essential services, access to adequate assets and technologies, social safety web, and strong adaptive capacity. Access to basic services comprises essentials such as proper transport, adequate security, electricity, water, credit facilities, etc. Adaptive capacity, on the other hand, is a function of the diversity of income sources, employment levels, education levels, food availability, adaptation strategies, early warning system, and knowledge of climate change (Sen *et al.,* 2020). These factors are paramount in evaluating whether an adaptation strategy is effective or not.

Problem and Objective Statement

Nyandarua County of Kenya has been for a long time, manifested itself as one of the major food baskets in the country. This is because of its high and sustainable output in crop farming i.e., maize, Irish potatoes, wheat, and other horticultural crops like vegetables and fruits. However, this scenario has recently changed because the usual high crop output has not been forthcoming due to recent changes in climatic patterns where rainfall has become very unreliable and temperatures very extreme. In an attempt to adapt to this climate variability and its associated negative impacts on crop farming, smallholder farmers have tried to apply the greenhouse farming technology for them to be able to maintain and or improve the various crop output amid the climatic changes. The study aims to examine and assess the socio-economic determinants and constraints associated with this attempt of adaptation strategy.



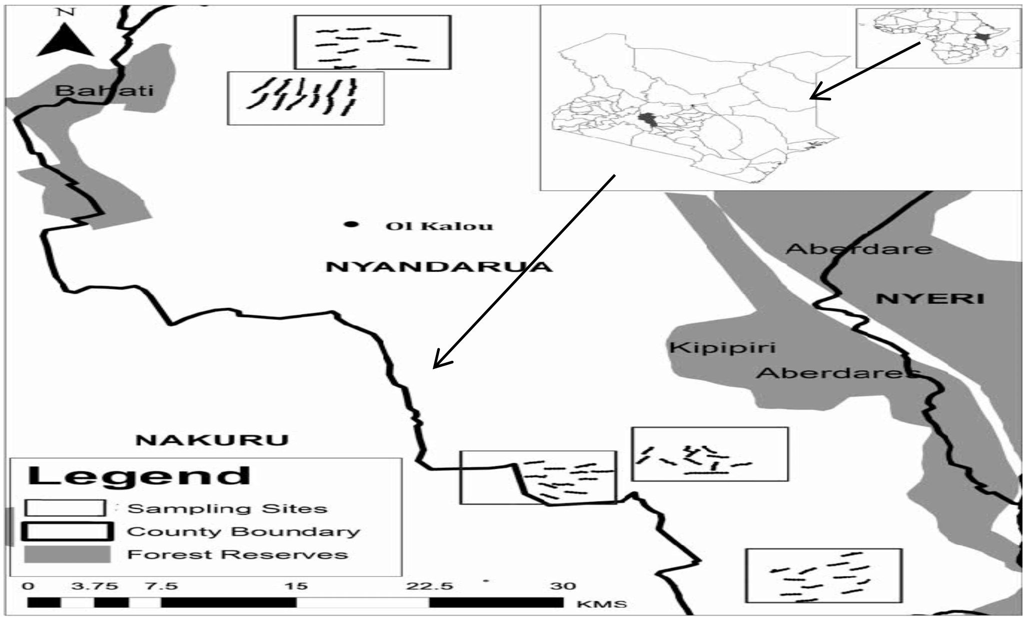
Source: Adapted from FAO, 2007
Figure 1: Conceptual Framework

In Kenya, the usual open land farming technique has traditionally dominated agricultural systems (Oluoko-Odingo, 2011). However, given the magnitude of the environmental threat caused by the world's ongoing climatic changes (Kithiia, 2012), modern greenhouse farming has attracted significant popularity in many countries as an appropriate alternative (Wang *et al.*, 2017). An overview of China's modern greenhouse farming technology reveals that the technology can reduce the effect of heat loss and retain optimum moisture in the soil for a longer time (Chai L *et al.*, 2012). This integration of farming technologies becomes promising potential to respond to declining crop output in many parts of the world (Dong HJ, 2014).

Materials and Methods

Study Area

Nyandarua County is situated on coordinates Latitude: 0° 32' 59.99" N and Longitude: 36° 36' 59.99" E. The County lies within the equatorial climatic region of Kenya, experiencing low to moderate temperatures. The lowest temperatures have been documented in July, with the average mean temperature going below 12^0c. On the other hand, the highest temperatures recorded have been in December, with the mean temperature rising to 25^0c. During the periods of clear nights, the cold air rises in the slopes of Aberdare ranges and flows down the west of plateaus valleys where temperatures fall to -1.3^0 C for a short time before the sun rises. The County receives two bimodal rainfall seasons with short rains from September to December with 700mm as maximum rainfall and long rains from March to May with a maximum of 1600mm (Omwoyo and Akivaga, 2015). The County is known for significant crops such as maize, wheat, vegetables, and Irish potatoes. These crops are not entirely for subsistence because some are sold to account for a substantial income for most households (Kaguongo *et al.*, 2007). The entire arable land in Nyandarua is 184,900.0 ha, but only 96,062 ha land is under cultivation. The current climatic conditions have shown that some parts of the County are receiving periods of dry spells and low temperatures at times leading to crop failure and reduced crop yields (Jaetzold *et al.*, 2007).



Source: Ndang'ang'a (2013)
Figure 2: *Map of Nyandarua County showing the study area*

Study design and sampling technique

The descriptive survey design is used to observe and analyze the adaptation mechanisms applied by the smallholder farmers against the checklist in the conceptual framework. The sample size of 300 respondents is arrived at using the Morgan and Krejcie, (1970) formula customarily used to compute a sample size from a given predetermined population (P).

1. $$s = \frac{X^2 nP(1-P)}{d^2(N-1)+X^2P(1-P)}$$

Where: s = Sample size

N = size of population, in this case 596,268 (Census, 2009)

n = total number of households in Nyandarua county. In this case 119,254

P = population ratio assumed to be 0.5 to provide the maximum sample size

d = degree of freedom in accuracy stated as 0.05

The target population comprised all the small-scale farmers in Nyandarua County and the unit of analysis was the household head. The data collection instrument used was questionnaires administered by the researcher and one research assistant. The questionnaires were used to collect key bio data and socio-economic information about the respondents in relation to crop farming adaptation strategies applied to mitigate effect of climate variability. The selection of households was drawn using a systematic random technique.

Data Analysis and Presentation

The data collected is converted to percentages to make it more meaningful and allow easy comparisons of proportionality. The mean is obtained by dividing the sum of the total number of all the values with the number of observations made. Descriptive statistics of mean, percentage frequencies, standard deviation, and variance are used in this study. The inferential statistics of logistic regression analysis are used to associate the demographic, socio-economic, and constraints encountered by the smallholder farmers with the adoption of greenhouse farming technology. The researcher has ensured that the respondents understood that the exercise was voluntary and that any personal information is confidential. Data presentation is done using tables, figures, graphs, and photographs.

Logistic Regression Model

These inferential statistics are adopted in studies where the dependent variable is categorical (Thoai *et al.,* 2018). The LR_{X2} is further used to test the significance of the model, i.e., there is no significant difference between the null and final models; the final model will have all the independent variables, while the null model will not have any independent variables (Stephan, 2015). When the P-value is less than 0.05, the null hypothesis is rejected, meaning that the final model is adequately fit.

In reporting the logistic regression analysis, Pseudo R squared measures the variations between two or more independent variables. While the variation is between 1 and 0, 1 means perfect variation, while 0 means no variation (Thoai *et al.,* 2018). Logistic regression analysis is used in the current study where the categorical dependent variable Y has two possibilities i.e.; farmers have adopted greenhouse technology or not (Yes or No). The independent variables X_1, X_2……..X_k is the demographic and socio-economic conditions under which the categorical variable prevails. The study's independent variables include; the level of education, age, marital status, gender, level of income, access to information, and size of cultivatable land. Therefore, the key challenges obtained in descriptive analyses are considered an additional influencing variable in the logistic regression. The following equation gives the logistic regression model;

2. $\text{Logit}(Pg)=\beta0+\beta1x1,i+\beta2x2,i+\ldots\beta kxk,i$

The Pg is the likelihood that an individual Y through values X_1, X_2……..X_k is in the outcome g, which is, in this case, the adoption of greenhouse technology and $\beta1x_1,i+\beta_2x_2,i+\ldots\beta_kx_k$, on the other hand, are model regression coefficients that are predicted from the populate data representing the probability of the outcome with independent values of X_1, X_2……..X_k. The regression logit coefficient β_1 is the odds ratio log obtained after comparing the odds after every unit rise in X to the last odds. To establish the probability levels of Y, a common transformation for p_g (logit transformation) is used

3. $\text{Logit }(p_g)=\text{loge}\left(\frac{P1}{1-P1}\right)$

The logit transformation due to the multiple independent variables can therefore be rewritten as the transformation equation using the logit transformation of P_g as follows;

4. $\text{loge}\left(\frac{P1}{1-P1}\right)=\beta0+\beta1x1,i+\beta2x2,i+\ldots\beta kxk,i$

The "No" categorical outcome in the logistic regression model is considered as the reference value. Considering that the logistic equations generated are non-linear, interpretation of the results cannot be complete without stating the constant value (β0) and the odds ratio Exp *(*β1) (Adam *et al.,* 2020).

Results

Socio-economic characteristics of the sampled smallholder farmers

Table 1 indicates that most of the respondents were found to be within the age bracket of 46-55 years (25.42%), followed by 36-45 years (23.75%). Respondents aged below 25 years recorded the lowest response of 9.03%. Out of the 300 questionnaires administered, 191 (63.67%) respondents were male, and 106 (36.33%) were females. Regarding marital status, most 223 (74.3%) of the respondents were married while 75 (25%) were single. However, due to the question's sensitivity, 2 (0.7%) respondents declined to declare their status. This variable description could mean that the smallholder farmers were settled in the County with stable families, and therefore labor mobility was less.

Table 1. Marital status of the respondent

Marital status of the respondent	Frequency	Percentage	Cumulative %
Single	75	25.0	25.0
Married	223	74.3	99.3
No response	2	0.7	100.0
Total	300	100.0	

Source: Muriithi, *2020*

The study results showed that farming is one of the significant sources of income among the smallholder farmers in Nyandarua County (53%). At the same time, casual labor (8.3%) and livestock keeping (7.3%) are the least income sources. However, most of the respondents said they have more than one income source, revealing that they had engaged in income diversification. Also, the majority of the respondents reported that their monthly income was below KShs. 10,000. This income level was perceived to be low. Therefore, it was anticipated that it could be one of the challenges/limitations that would hamper proper and effective adaptations to climate variability.

Table 2: Level of income of respondents

Monthly income in Ksh.	Frequency	Percentage	Cumulative %
<10,000	114	38.0	38.0
10,001-20,000	95	31.7	69.7
20,001-30,000	40	13.3	83.0
30,001-50,000	44	14.7	97.7
>50,0001	7	2.3	100.0
Total	300	100.0	

From the results, the researcher established that most of the smallholder farmers had attained average to high levels of education, which was anticipated that it could have had some positive contributions to crop farming adaptations; Secondary level (43.33%), College level (20%), and University level (11.3%). Low levels of education (25%) could have been attributed to high drop out at the primary level, especially for girls due to early pregnancies and early marriages (Glennerster *et al.,* 2011).

Climate variability preparedness and adaptation measures

About 13.1% of the smallholder farmers said they had changed dates for planting as an adaptation strategy. About 20.3 % of the smallholder farmers had cultivated different crop varieties, which were perceived to be more resistant to climate variations. Crop diversification had been adopted by the majority of smallholder farmers (20.3%). About 13.1% of smallholder farmers had decided to apply some crop irrigation to improve the crop yields. In comparison, 4.9% of the smallholder farmers observed the search for extra jobs i.e., income diversification as an adaptation strategy. Greenhouse technology and crop insurance registered the lowest adaptation score of 5.9% and 2.1%, respectively. 15.2% of the respondents indicated that they had used other adaptation strategies captured by the questionnaire as descriptive and open-ended responses. These strategies included; agroforestry, mixed cropping, increasing the size of cultivatable land areas, switching from crops to livestock and fertilizers, and manure application for soil conservation strategies.

Table 3: Adaptation strategies applied by the respondents

Adaptation strategy	Frequency	Percentage	Cumulative %
Crops diversification	87	20.28	20.28
New crop variety	87	20.28	40.56
Other adaptations technique	65	15.15	55.71
Use of crop irrigation	56	13.05	68.76
Adjusting planting dates	56	13.05	81.81
*Greenhouse technology	25	5.83	87.64
No response	23	5.36	93
Income diversification	21	4.9	97.9
Crop insurance	9	2.1	100
Total	**429**	**100**	

*Adaptation strategy to be subjected to Logistic Regression Analysis
Notes: Multiple responses reported

Respondent's perceptions about the effectiveness of the adaptation measures adopted

Results of the perceptions about how the adaptation strategies adopted were effective in improving the crop yields are presented in Table 4. The Likert scale analysis indicated that crop diversification and planting new crop varieties resistant to climate variability and its related effects were the most effective perceived adaptation strategies. In this case, the adoption of greenhouse farming technology recorded a low standard deviation of 0.27 with 17 out 25 respondents who had adopted it, perceiving it as an effective strategy to caution farmers against loss arising from adverse climatic variations. Based on these findings, it is evident that if many smallholder farmers are willing and able to adopt greenhouse farming technology, this strategy can be among the most effective approach. However, due to this strategy's low adaptive capacity, more resources and information should be provided to the smallholder farmers to enable them to adapt more effectively (Wambua, 2019).

Figure 3: *Greenhouse farming technology adopted by one of the respondents*

Table 4. Small holder's perception about the success of the adaptation strategies

Adaptation strategy	Very effective	Effective	Less effective	Not effective	Total	Mean	SD
Crops diversification	15	55	2	15	87	1.71	0.45
New crop variety	16	50	1	20	87	1.71	0.45
Use of crop irrigation	12	38	0	6	56	1.81	0.39
Adjusting planting dates	7	24	2	23	56	1.81	0.39
*Greenhouse technology	7	17	1	0	25	1.92	0.27
Income diversification	1	13	1	16	31	1.93	0.26
Crop insurance	2	6	1	0	9	1.97	0.17

Constraints facing the adoption of adaptation strategies to climate variability

This variable though not in the research question, was perceived to be one of the factors either directly or indirectly influenced the type of adaptation taken by smallholder farmers. Results of the smallholder farmer's responses on the question "which challenges prevented them from coping well to climate variability", 97% of the respondents gave diverse challenges, as shown in the chart below. However, 3% of the respondents did not respond to this question. Assessment of the challenges indicates that there are five significant constraints to adaptation which includes: - Lack of resources/financial constraint/low income (27%), Limited awareness/lack of information/lack of relevant skills (22.3%), Fluctuations of market prices for farm produce (11%), Lack of government support/inadequate policies (8.7%) and shortage of water for irrigation (7%). Other challenges suggested by respondents include; Shortage of land for cultivation, low farmers health status, less labor/ work force to work on the cultivated farms, limited certified seeds, high cost of fertilizers and seeds, unsuitable government policies such as supply chains of fertilizers and irrigation projects. Lack of public awareness and effective communication and high cost of necessary supplies such as food were highlighted.

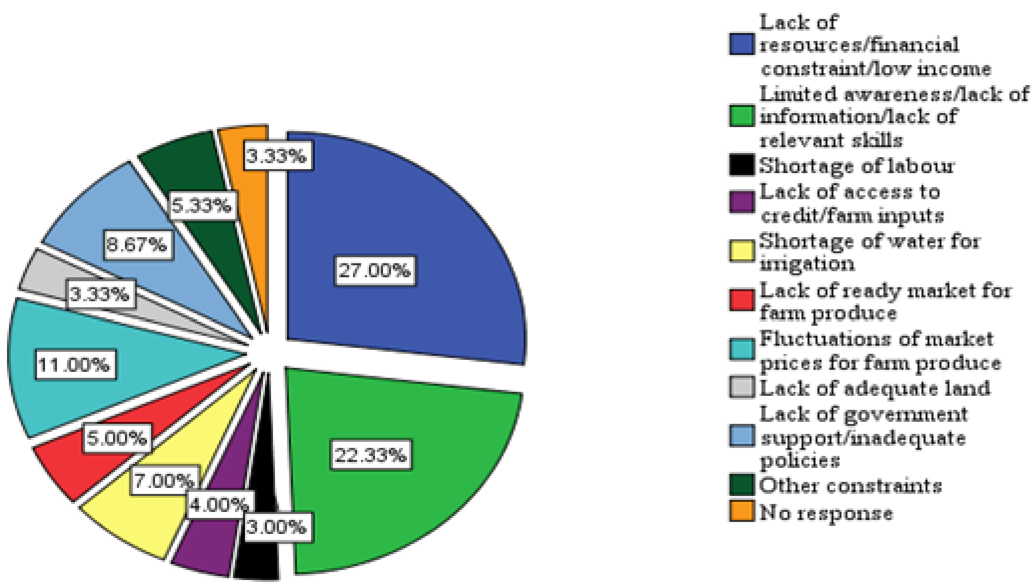


Figure 4: *Constraints associated with adapting to climate variability*

The logistic regression is used to assess the factors influencing the uptake of greenhouse farming technology as an adaptation mechanism. The study results indicate only 8.33% of the smallholder farmers had applied this adaptation strategy while the rest, 91.67%, were not able to use this adaptation strategy.

Table 5. Response to the adoption of Greenhouse farming as an adaptation strategy

Greenhouse farming					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Yes (1)	25	8.33	8.33	8.33
	No (2)	275	91.67	91.67	100.0
	Total	300	100.0	100.0	

The overall significance test of the logistic model in table 6 indicates that it was significant at P=0.05. This result illustrated that the independent variables of age, gender, marital status, level of income, level of education and access to information influenced the occurrence of the dependent variable altogether. Likewise, the likelihood test ratio given by the LR_{X2} test value of 17.020 was statistically significant at P=0.007. This result meant that the group of independent variables chosen in the logistic regression model had an overall significant explanatory decision on adopting greenhouse farming technology, which was the dependent variable.

From the estimates of the logistic regression table and analysis, it was observed that the gender of the respondent influenced the uptake of the adaptation strategy β0=0.611. However, the test wasn't statistically significant at P = 0.246. This finding was interpreted to mean that the male-headed household was more likely to consider applying this adaptation strategy than women. These findings concur with Obayelu *et al.,* (2014) and Adams *et al.,* (2020) but contradict the conclusions of Gutu (2014) who found out that gender characteristic does not influence the uptake of several adaptation strategies. Regarding the respondents' marital status, it was observed that married couples were at a better chance to apply greenhouse farming technology, unlike singles farmers. Married couples are likely to exchange ideas within the household and develop proper decisions regarding the application of technologies in farming. The respondents' age and access to information about climate variability and strategies of adaptation were also found to have influenced the adoption of greenhouse farming (β0=0.167 and β0=0.028, respectively). These findings concurred with Ngigi (2017) and Sen *et al.,* (2020). The constraints of education levels, monthly income, and the size of cultivable land were found not to have a direct effect on the adoption of greenhouse farming. The reason is that their respective odds ratio was negative (β0=-0.103, β0=-0.498 and β0=-0.287 respectively); however, their odds ratio indicated that these factors influenced more than 50% of smallholder farmers who did not apply this adaptation strategy (Exp (β1) =0.608 Exp (β1) =0.90.3 and Exp (β1) =0.751 respectively. This result meant that low education levels, low income, and small land sizes are significant inhibitors to applying greenhouse farming technology in Nyandarua County of Kenya.

Table 6: Results of the logit model for adoption of greenhouse farming technology

Indicator	**Coefficients β0**	**Std. Error**	**P-value**	**Marginal effects (ME)**	**Odds ratio β1**
Gender	0.611	0.526	0.246	1.345	1.841
Age	0.167	0.194	0.388	0.745	1.182
Marital status	0.668	0.484	0.168	1.901	1.949
Level of income	-0.498	0.194	0.001	6.578	0.608
Level of education	-0.103	0.244	0.675	0.176	0.903
Access to information	0.028	0.171	0.868	0.028	1.029
Size of land	-0.287	0.218	0.189	1.724	0.751

Constant	2.394	1.378	0.001	-	-
Log pseudo-likelihood	154.907	-	-	-	-
Wald χ2 (df 7)	17.02	-	-	-	-
Prob > χ2	0.055	-	-	-	-
Pseudo R^2	0.127	-	-	-	-
Overall ME	-	-	-	2.133	-

Discussion

Greenhouse technology in farming has been cited as one of the best ways to adapt to adverse weather conditions. According to this research, findings indicate that small-scale farmers have not managed to adapt well to climate variability using this strategy. Greenhouse farming technology is an expensive practice that requires adequate resources and expertise. In this case, the lack of resources obstructs farmers from acquiring the necessary greenhouse technologies. The intensity of mechanization involved in greenhouse technology makes it extremely difficult for smallholder farmers to adapt more effectively to climate (Wang *et al.*, 2017). The results of this study concurred with (Simotwo *et al.*, 2018), who carried out a study and identified the same barriers of climate awareness in Kenya. They recommended that impending food security in Africa requires assimilated long-term strategies to household vulnerability on governments, international partners, and civil society by integrating new expertise such as greenhouse farming and local capability.

According to FAO (1997), the majority of Sub Saharan African smallholder farmers are reserve poor. They cannot invest in greenhouse farming technologies to maintain and sustain their income and livelihood during unfavorable climate extremes such as shortage of rain, which often causes famine due to too high temperatures. The majority of the problems or constraints encountered by Smallholder farmers in adaptation to climate variability are associated with poverty. Lack of sustainable income deters smallholder farmers from acquiring the necessary capitals and know-how, which help adapt to climate variability. According to Mendelson (2006), Adapting to climate variability in most sub-Saharan Africa is a very costly venture. The reason is that the bulks of the people living in these region's rural areas are poor and have a low buying power. Indeed, the lack of resources obstructs farmers from acquiring the necessary greenhouse technologies to help them adapt well to climate variability.

Conclusion and Policy Recommendations

One of the significant limitations to effective adaptation is the lack of resources and financial constraints among the smallholder farmers. This challenge is mainly attributed to a lack of employment opportunities, low wages, and salaries, and inaccessible affordable credit facilities. Therefore, policies should be formulated to hearten the establishment and roll-out of micro-financial institutions across the country. Microcredit financial institutions lend money to low-income earners to adventure their full capacities for income creation e.g., through job development, business growth, and accelerated production. These affordable credit facilities may reduce the vulnerability of smallholder farmers and enable them to adapt effectively.

The study recommends that policymakers and other concerned stakeholders create awareness by providing information to integrate the smallholder farmer's indigenous perception about climate variability and its impact with the actual scientific meteorological data for better planning. Besides, policies about climate monitoring and early warning systems should be formulated to support appropriate adaptation policies and support adaptation planning.

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