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Determinants of Adoption of Improved Cookstoves in the Dundori Forest Adjacent Community, Kenya

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Abstract: Improved cookstove programs worldwide are characterized by low success due to low adoption rates. However, there is a lack of detailed analysis of factors affecting the adoption of improved cookstoves in specific socioecological contexts, including in forest-adjacent communities. Therefore, this study aimed to analyze the factors affecting the adoption of improved cookstoves in the Dundori Forest-adjacent community. This study used a descriptive study design and a multistage sampling design. Data analysis was performed using thematic analysis, descriptive statistics, Kendall's coefficient, Mann-Kendall Z-Test, and regression analysis. We found that most households (99.2%) use firewood and charcoal for cooking. In addition, only 25.5% of the households use improved cookstoves, and they are used once per week on average which indicates low adoption. There was a significant negative trend in the availability of firewood ($\tau b = 0.878^{**}$, $P<0.01$) and charcoal ($\tau b = 0.927^{**}$, $P <0.01$). The use of improved cookstoves had a significant negative relationship with the use of firewood ($\beta = - 0.687$, $P<0.05$) and charcoal ($\beta = - 0.153$, $P<0.05$). The adoption of improved cookstoves was affected by various factors including gender ($\beta 1 = -0.618 \pm 1.049$, $P < 0.05$), level of formal education ($\beta 1 = 0.347 \pm 1.049$, $P < 0.05$), and training on efficient and clean energy ($\beta 1 = 1.990 \pm 1.049$, $P < 0.05$). The study will inform policies, plans, and programs that effectively promote the adoption of improved cookstoves and enhance their benefits.

Keywords: Adoption, Biomass Fuel, Energy, Firewood, Forest Adjacent Community, Improved Cookstove

1. Introduction

Almost half of the world's population, particularly in low-income countries, depends on biomass fuels, including firewood and charcoal, as their main source of energy for cooking [1-3]. Biomass fuel contributes to about 70% of Kenya's energy demand and constitutes about 90% of the primary source of energy in Kenya's rural households [4]. Despite the observed shift towards the use of modern fuels such as liquefied petroleum gas and electrical energy for cooking in rural communities [5], the number of people who rely on biomass will increase to over 2.7 billion by 2030 in the backdrop of the growing human population and the absence of effective policy frameworks [6].

Moreover, the high dependence on inefficient energy technologies continues to be a key challenge globally, as depicted by the over 2.8 billion people who rely on inefficient biomass fuel-based cooking devices [7]. This is particularly the case in Sub-Saharan African countries, for example in Kenya where only 14% of the population had access to efficient cooking technologies by 2017 [8]. The use of inefficient cookstoves leads to unsustainable use of biomass fuel resources and excessive release of toxic emissions and hence results in many adverse health and environmental impacts [9-11]. Indoor air pollution due to the burning of biomass fuels is a major cause of health problems in developing countries and leads to 2 million deaths per year [12].

The inefficient burning of biomass fuels also contributes to climate change due to the emission of greenhouse gases such as methane, carbon monoxide, and black carbon which have a higher global warming potential than carbon dioxide [11, 13]. Moreover, the heavy reliance on and inefficient use of biomass fuels in the backdrop of a fast-growing global population is one of the leading causes of deforestation worldwide [14, 15]. It also has negative socioeconomic impacts due to the heavy time and energy costs incurred and the risks faced by women and children during the collection of firewood [16-18]. Spending more time on firewood collection and cooking negatively affects women's and children's access to education and economic development [19, 20].

In addressing these challenges, the use of improved cookstoves is thus being promoted through various programs, especially in developing countries [15]. Improved cookstoves have a higher combustion efficiency and thus reduce the consumption of biomass fuel and cooking time compared to traditional open fire cookstoves [21-23]. This translates to low pressure on forest resources, lower cost outlay in accessing biomass fuels [24, 21], and reduction in the time and energy spent by women and children in biomass fuel collection [25]. The use of improved cookstoves also reduces emissions thus resulting in lower indoor air pollution and associated health problems [26, 27]. It also lowers the emission of greenhouse gases hence contributing to climate change mitigation [28].

Nevertheless, despite their multiple benefits, improved cookstoves have not yet been adequately adopted worldwide due to social, cultural, economic, technological, and institutional barriers [29, 14, 20]. Therefore, integrating the enabling and constraining factors in improved cookstove design and program development could improve their adoption [29]. However, the factors that affect the adoption and sustained use of improved cookstoves in rural households have not been fully examined [30] although understanding them is key to the development of effective policies and plans that will lead to the success of improved cookstoves programs [31]. Context-specific analysis of the factors that affect the adoption of improved cookstoves is thus imperative [32].

Despite this, studies about the factors that affect the adoption of improved cookstoves in Kenya have not been done fully, especially regarding studies in specific local contexts [33, 34]. However, the determinants of the adoption of improved cookstoves vary in space and time and across different socioecological contexts [4]. There is thus a need for more contextual analysis on the adoption of improved cookstove technology [35, 17]. This includes forest-adjacent communities that are usually characterized by high levels of interaction between the community and the natural resource base resulting in complex and unique socioecological systems.

Therefore, the study aimed to analyze the factors affecting the adoption of improved cookstoves in the Dundori forest adjacent community. This focused on a broad range of factors including social, economic, technical, institutional, ecological, and cultural factors. The study will inform the development and implementation of effective policies, plans, and programs to improve the adoption of improved cookstoves.

2. Materials and methods

2.1. The Study Area

The study took place in the Dundori forest adjacent community. The forest-adjacent community includes 12 sublocations that lie in Nakuru County to the West and Nyandarua County to the East. Dundori forest covers an area of 3,609.3 Kilometers Squared and is in a hilly area with an altitude of 2,200-3,000 Meters above sea level. The forest has a community forest association.

The forest faces various threats including encroachment and over-exploitation of forest resources due to rapid population growth and poverty, inadequate institutional capacity for forest management, and poor land use practices. This has led to environmental degradation, scarcity of livelihood resources, deterioration of community well-being, and increased vulnerability to the effects of climate change.

2.2. Study Design and Sampling Design

The study used a descriptive study design. Further, a multistage sampling design was used to select the respondents who were involved in the household questionnaire survey. This first involved purposively selecting the 12 sublocations, in Nyandarua and Nakuru Counties that border the Dundori Forest, which is the forest adjacent community. The number of households to be sampled in each location was then allocated proportionately based on the total number of households in the location. Systematic sampling was then used to select the households to be studied in each of the chosen sublocations. The systematic sampling involved sampling every 5th household but along randomly distributed transects within the study sublocations. The number of respondents involved in the household questionnaire survey was determined using Cochran's method. This resulted in a sample size of 385 respondents.

2.3. Data Collection

The study used both secondary and primary data. Secondary data was collected through a desk review of existing literature on the topic. Primary data was collected using a variety of methods including a reconnaissance survey, household questionnaire survey, focus group discussion, key informant interviews, and observation.

The reconnaissance survey involved holding a preliminary meeting with community members and leaders and undertaking transect drives and walks within the study area. The reconnaissance survey also involved a review of documents on the study area. The survey thus informed the design of the research tools and planning of the study.

Moreover, a household questionnaire survey was undertaken. This involve the administration of a semi-structured questionnaire to the households that were selected for the study. One focus group discussion was also undertaken. The focus group discussion had twelve participants who were selected purposively based on their knowledge and experience of the issues being addressed by the study. In addition, key informant interviews were also conducted targeting purposively selected key people with jurisdiction, and great knowledge and experience concerning the study. Observations were also done to collect information about the actual situation in the area regarding the study.

Participatory trend analysis was used to collect data on changing trends in tree cover, biomass energy resources availability, and biomass energy resources in the study. This involved a participatory quantification of the changes that occurred regarding these variables over 10 decades, from the 1930s to the 2020s. The quantification of the changes was done by participatory rating the status of a given variable in a specific decade against the other decades on a scale of 1 to 10. This yielded trend lines that showed what was increasing or decreasing over time. In doing the rating the participants engaged in discussions based on their knowledge and experience of the status of the study area from the past to the present and gave a score upon reaching an agreement. The participants also discussed the interactions and linkages between the different trends to establish their causes and effects, and thus associations between them, and thus what could be done better to address the causes.

2.4. Data Analysis

Qualitative data were analyzed using thematic analysis. Moreover, quantitative data was analyzed using descriptive statistics including percentages and averages. The trends in biomass fuel availability and demand, and tree cover on farmlands and the forest were tested for significance and directionality using the Mann-Kendall Z statistical test. The association between the trends was tested using Kendall's tau-b correlation coefficient.

Moreover, the two-stage least squares (2SLS) regression analysis was used to analyze the relationship between the adoption of improved cookstoves and the use of biomass, including firewood and charcoal. The two-stage least squares (2SLS) regression analysis helped to address endogeneity between the variables. Multiple regression analysis was used to determine the relationships between factors affecting the adoption of improved cookstoves and their adoption.

3. Results

3.1. Household Characteristics

Most of the households in the study area were male-headed (82.7%) while 17.3% were female-headed. The average household size was 4 members. Moreover, most of the household heads were married (72.6%) and 27.4% were not married. Most household heads (41.8%) had attained a primary school level of formal education, 43.1% had attained secondary school education, and 15.2% had attained tertiary-level education. Also, the study found that 47.1% of the households belonged to community-based organizations while 52.9% did not. As appertains to income level, 48.9% of the households earned Kenya Shillings >0 – 10,000, 25.8% Kenya Shillings >10,000 – 20,000, 14.4% Kenya Shillings >20,000 – 30,000, and 10.9% of the households earned Kenya Shillings >30,000.

The average size of land owned by a household was 2.2 Acres. The study also found that 42.8% of the people engaged in environmental conservation activities, as measured by the number of trees planted in Dundori Forest in the last year, while 57.2% did not engage in environmental conservation activities. Besides, the average number of trees planted on household farms was found to be 162 trees. Regarding the perception of climate change, 66.5% observed that local climate and climate patterns had changed to a high extent while 12% observed it had changed to a very high extent. Further, 19.4% of the people observed that the local climate and climate patterns had changed to a low extent while 2.1% observed that the extent of change was very low. The study found that 33.2% of the respondents had attended training on clean and efficient energy technology while 66.8% had not attended the training. Clean and efficient technologies mean those that cause low pollution and use less biomass energy resources.

3.2. Household Energy Use

The study found that most of the households (96.3%) use firewood for cooking while only 3.7% did not use firewood. The household's use of firewood was measured based on the average number of backloads that a household used for cooking per month and found to be 7 backloads. A backload is the average amount of firewood that a person can carry on her back or head. Most of the households (84.3%) source firewood from their household farms while 15.7% don't source firewood from their household farms. On how adequately the household farm meets its firewood requirements, 48.1% said that it is inadequate 17% said that it is very inadequate, 29.6% said that it is adequate and 5.3% said that the household farm is very adequate in meeting their firewood requirements. Firewood is sourced from the forest by 60.4% of the households while 39.6% of the households don't use firewood sourced from the forest. The average proportion of the household's total firewood use that is sourced from the forest is 41%.

Also, 77.9% of the households use charcoal for cooking while 22.1% don't use charcoal. The household's use of charcoal was measured based on the average number of *debes* that a household used for cooking per month and found to be 1.2 *debes*. A *debe* is a container that has a volume of about 10 liters.

Alternative sources of energy for cooking at the domestic level (other than firewood and charcoal) are used in 65.4% of the households while 34.6% of the households don't use alternative sources of energy for cooking. The alternative sources of energy used for cooking by households included liquefied petroleum gas, electricity, solar, biogas, and kerosene with the main alternative source of energy for cooking used in the area being liquefied petroleum gas. The household's use of alternative energy sources was measured based on the number of times that a household used alternative sources of energy for cooking per week which was found to be three times.

Improved cookstoves are used for cooking by 25.5% of the households while 74.5% of the households don't use improved cookstoves for cooking. The household's use of improved cookstoves was measured based on the number of times that a household used improved cookstoves for cooking per week which was found to be one time.

3.3. Trend Analysis of the Availability of Biomass Fuel

The participatory trend analysis revealed that the tree cover on farmlands in the study area was found to have a significant negative trend (Z = -3.46, $P<0.001$). The forest cover was also found to be on a negative trend (Z = -3.43, $P<0.001$). In addition, the study found the availability of firewood to have a significant negative trend (Z = -3.46, $P<0.001$) while the availability of charcoal was also found to have a significant negative trend (Z = -3.65, $P<0.001$). However, the demand for firewood was found to have a significant positive trend (Z = 3.72, $P<0.001$), and the demand for charcoal also had a positive trend (Z = 3.86, $P<0.001$).

A significant positive correlation was found between the trend of tree cover on farmlands and the availability of firewood (τb = 0.878**, $P<0.01$), and the availability of charcoal (τb = 0.927**, $P<0.01$). Besides, a significant positive correlation was found between the trend of forest tree cover and the availability of firewood (τb = 0.810**, $P<0.01$), and the availability of charcoal (τb = 0.857**, $P<0.01$).

The results of the trend analysis of tree cover and the availability and demand of firewood and charcoal are shown in Table 1.

Table 1. *Trend analysis of tree cover and availability and demand of firewood and charcoal.*

Trend analysis of tree cover and availability and demand of firewood and charcoal										
Trend	**1930s**	**1940s**	**1950s**	**1960s**	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**	**2020s**
The tree covers the forest	10	10	9	8	7	4	3	1	2	2
The tree covers farmlands	10	10	10	9	7	6	4	5	4	3
Availability of firewood	10	10	10	9	7	8	7	5	3	2
Availability of charcoal	10	10	10	9	8	8	7	6	4	2
Demand for firewood	1	2	3	4	5	6	8	9	10	10
Demand for charcoal	2	3	4	5	6	7	8	10	10	10

3.4. Effect of Improved Cookstove Adoption on the Use of Biomass Fuel Use

Two-stage least squares (2SLS) regression analysis was used to analyze the relationship between the use of improved cookstoves and the amount of firewood used by the household. This found a significant negative relationship between the use of the improved cookstove, and the amount of firewood used by the household (β = - 0.687, $P<0.05$) with the Y-intercept being 7.758. This means there is a - 0.687 unit decrease in firewood consumption for every unit increase in the use of improved cookstoves. Thus, based on the model arrived at from the 2SLS estimation, the amount of firewood used = 7.758 - 0.687 (use of the improved cookstove).

Moreover, the two-stage least squares (2SLS) regression analysis was used to analyze the relationship between the use of improved cookstoves and the amount of charcoal used by the household. This found a significant negative relationship between the use of the improved cookstove, and the amount of charcoal used by the household (β = - 0.153, $P<0.05$) with the Y-intercept being 1.381. This means there is a - 0.153 unit decrease in charcoal consumption for every unit increase in the use of improved cookstoves. Thus, based on the model arrived at from the 2SLS estimation, the amount of charcoal used = 1.381 - 0.153 (use of the improved cookstove).

3.5. Factors Affecting Household's Adoption of Improved Cookstoves

A multiple linear regression analysis was calculated to analyze the factors affecting households' use of improved cookstoves. The regression model was found to be statistically significant ($F(15, 360) = 76.757$, $P<0.05$) indicating the independent variables significantly predict the adoption of improved cookstoves. The coefficient of determination (R^2) was 0.762 meaning 76.2% of the variance in the adoption of improved cookstoves could be explained by the independent variables.

The test of the effect of the independent variables on the adoption of improved cookstoves is shown in Table 2.

Table 2. *Multiple regression analysis of factors affecting the adoption of improved cookstoves.*

Coefficients					
Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	β	**Std. Error**	**Beta**		
(Constant)	-2.333	0.887		-2.631	0.009
Gender	-0.531	0.181	-0.087	-2.928	0.004
Age of household head	0.004	0.005	0.021	0.737	0.462
Marital status	0.141	0.143	0.027	0.988	0.324
Level of formal education	0.210	0.094	0.065	2.242	0.026

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	β	Std. Error	Beta		
Household size	-0.051	0.038	-0.037	-1.348	0.179
Income	1.149	0.095	0.514	12.070	0.000
Land size	-0.012	0.026	-0.014	-0.457	0.648
Number of trees in household's farm	-0.0001	0.0001	-0.029	-1.016	0.310
Membership in a community-based-organizations	0.418	0.136	0.091	3.080	0.002
Involvement in environmental conservation activities	0.339	0.158	0.073	2.150	0.032
Perception of climate change	0.145	0.116	0.039	1.244	0.214
Training on clean and efficient energy technology	0.769	0.201	0.158	3.830	0.000
Number of times household uses alternative energy per week	0.033	0.017	0.051	1.879	0.061
Adequacy of the household farm in meeting wood fuel needs	-0.278	0.103	-0.095	-2.712	0.007
Sourcing of firewood from the forest	-0.288	0.139	-0.061	-2.071	0.039

The adoption of improved cookstoves had a significant negative relationship with gender (β_1 = - 0.531 ± 0.181, P < 0.05), adequacy of the household farm in meeting wood fuel needs (β_1 = - 0.278 ± 0.103, P < 0.05), and sourcing of firewood from the forest (β_1 = - 0.288 ± 0.139, P < 0.05). However, the adoption of improved cookstoves had a non-significant negative relationship with the household size (β_1 = - 0.051 ± 0.038, P > 0.05), land size (β_1 = - 0.012 ± 0.026, P > 0.05), and number of trees in household's farm (β_1 = - 0.0001 ± 0.0001, P < 0.05).

The adoption of improved cookstoves had a significant positive relationship with the level of formal education (β_1 = 0.210 ± 0.094, P < 0.05), income (β_1 = 1.149 ± 0.095, P < 0.05), membership to community-based-organizations (β_1 = 0.418 ± 0.136, P < 0.05), involvement in conservation activities (β_1 = 0.339 ± 0.158, P < 0.05), and training on clean and efficient energy technology (β_1 = 0.769 ± 0.201, P < 0.05). Further, the adoption of improved cookstoves had a non-significant positive relationship with age (β_1 = 0.004 ± 0.005, P > 0.05), marital status (β_1 = 0.141 ± 0.143, P > 0.05), perception of climate change (β_1 = 0.145 ± 0.116, P < 0.05), household's use of alternative energy sources (β_1 = 0.033 ± 0.017, P < 0.05),

Therefore, the multiple regression model predicts that the adoption of improved cookstoves is equal to -2.333 – 0.531 (gender) – 0.278 (adequacy of the household farm in meeting wood fuel needs) – 0.288 (sourcing of firewood from the forest) – 0.051 (household size) – 0.012 (land size) – 0.0001(Number of trees in household's farm) + 0.210 (level of formal education) + 1.149 (income) + 0.418 (membership to community-based-organizations) + 0.339 (involvement in conservation activities) + 0.769 (training on clean and efficient energy technology) + 0.004 (age) + 0.141 (marital status) + 0.145 (perception of climate change) + 0.033 (use of alternative energy sources).

In addition, the discussants and interviewees identified various barriers that hinder the adoption of efficient cookstoves. These include poor implementation of related policy and strategic frameworks, low institutional capacity, and poor implementation of improved cookstove programs. Also, there is low access to improved cookstoves in local markets, a proliferation of poor-quality improved cookstoves, and a lack of local production. Furthermore, it was noted that at times their incompatibility of the design and sizes of the available improved cookstoves with some of the people's cooking needs and their multiple-use nature of cookstoves. Cultural barriers especially due to the local people's connection with the traditional cookstoves were also identified as a barrier. In addition, lack of capital and poverty were also identified as barriers to the adoption of improved cookstoves.

4. Discussion

The study found that most households in the study area used wood fuel for cooking. This could be because it is a rural area and thus households have access to firewood from their farmlands. The area is also adjacent to the Dundori Forest which, although facing degradation, offers a source of firewood hence the observed high use of wood fuel. This finding agrees with [1, 36] who noted that biomass fuel is the main source of cooking and heating energy for almost half of the world's population, particularly in developing countries. Besides, biomass fuel contributes about 90% of the energy needs in Kenya's rural areas [4].

Despite the importance of wood fuel as a source of energy, its availability is declining as shown by the downward trend in the availability of charcoal and firewood. This is happening against the backdrop of rising demand for charcoal and firewood. Similarly, Githiomi J. and Odour N. [37] predicted that there will be a significant increase in the demand for biomass fuel and a deficit in the supply of firewood and charcoal in Kenya by 2032. The decline in the availability of wood fuel is associated with the observed decline in tree cover in forests and farmlands. Conversely, this decline in forest and farmland tree cover is caused by the rising demand and the heavy reliance on wood fuel locally which could be causing unsustainable exploitation of biomass resources. Jan [15] and Drigo R. et al. [38] deduced that the heavy reliance on biomass fuel as a source of energy at the domestic level ranks among the main causes of deforestation globally. The declining tree cover and availability of wood fuel in the study area was also attributed to the growing population and hence pressure on the natural resources base which led to high demand and unsustainable utilization of biomass resources. Previous studies [4, 14, 39] gathered that the burgeoning human population and poverty were among the factors that drove the high demand and unsustainable use of biomass resources.

Further, the study found a significant negative relationship between the use of improved cookstoves and the amount of charcoal and firewood used by a household. This shows that the improved cookstoves are more energy efficient and thus result in lower and more sustainable use of biomass fuel resources. Likewise, past studies [25, 23, 39] observed that improved cookstoves were more efficient and consumed less biomass fuel compared to traditional open fire cookstoves.

Despite the many benefits that are associated with the use of improved cookstoves, their adoption among households in the study area was found to be low. Also, the number of times that the adopting households used the cookstoves per week was found to be lower. The low number of times that households use the cookstoves could indicate that those who adopt the improved cookstoves use them in combination with the traditional cookstoves. This finding aligns with previous studies [14, 29, 40] which found there was a low adoption of improved cookstoves despite the many benefits that are associated with them.

The study found that the adoption of improved cookstoves was affected by various factors. These included the gender of the household head whereby female-headed households were found to use improved cookstoves more than male-headed households. This could be because women bear the greatest burden of wood fuel collection and thus would prefer to adopt the improved cookstoves more to reduce the associated costs, drudgery, and risks, including health risks. This is in line with previous studies [41, 13, 42] which gathered that female household heads were more likely to adopt improved cookstoves compared to men. However, Karanja A. et al. [40] found that male household heads were more likely to adopt improved cookstoves since they had a higher level of education and income.

Higher formal education was found to have a significant positive relationship with the adoption of improved cookstoves. This could be because more educated people have greater knowledge and awareness of the risks associated with the use of inefficient cookstoves and thus adopt the improved cookstoves more. They are also better able to understand the benefits associated with the adoption of cookstoves and thus make the decision to adopt them. More educated people are thus better able to undertake a comparative analysis of the costs and benefits of the improved versus traditional cookstoves and make the rational decision to adopt the improved cookstoves. Furthermore, earlier studies [29, 43, 44] concluded that a higher level of formal education led to higher adoption of improved cookstoves.

The age of the household head had a positive but non-significant relationship with the adoption of improved cookstoves. This could be because older people have more access to resources which they could invest in acquiring the improved cookstoves. Older people are also more averse to the risks associated with traditional biomass cookstoves and thus are more likely to use improved cookstoves. Furthermore, older people have more experience and knowledge regarding the costs and benefits associated with improved cookstoves vis-à-vis traditional cookstoves. This finding concurs with [14, 44] who worked out that older people were more likely to adopt the improved cookstoves. However, Onyekuru N. and Apeh C. [41] and Sulo T. et al. [45] found that older household heads were less likely to adopt improved cookstoves.

Also, the size of the household had a negative but non-significant relationship with the adoption of improved cookstoves. The low adoption of the larger household could be because they cook more food on larger pots that are not compatible with the often-small size of the improved cookstove's design. The larger households also have greater access to labor and thus may not have the urgency to adopt improved cookstoves to save on the labor required for firewood collection. Gitau et al. [25] and Rehfuess E. et al. [46] also inferred that larger households have a lower adoption of improved cookstoves due to their often small sizes and higher access to labor. Contrarily, other studies [14, 41, 47] found that household size had a significant positive relationship with the adoption of improved cookstoves due to the higher consumption of biomass fuel which may necessitate the adoption of efficient cooking technologies to reduce the related costs.

The level of income had a significant positive relationship with the adoption of improved cookstoves. This could be because having a higher income means a greater capacity to purchase the improved cookstove. Lack of adequate financial capital to purchase improved cookstoves is thus a barrier to the adoption of improved cookstoves. Households that have a low income may also find it hard to hard to invest in an improved cookstove due to the presence of competing financial needs. Therefore, poorer households may not purchase the improved cookstoves even if they are aware of their benefits since they are compelled to commit the available money to meet their immediate subsistence needs. This observation agrees with previous studies [48-50] which established that households with greater income are more likely to adopt improved cookstoves.

Membership in community-based organizations was found to increase the adoption of improved cookstoves. This could be because community groups are platforms for information sharing which leads to greater knowledge and awareness of clean and efficient energy technologies. The social networks and hence social capital of the community-based organization allow for shared learning and faster diffusion of information and thus technology. Still, these groups often engage in informal saving and lending schemes that enable mobilization and accumulation of savings and access to affordable loans and hence the financial capital to invest in improved cookstoves. Community-based groups are often the entry points for development agencies in communities and this increases the likelihood of members participating in programs that promote and disseminate improved cookstoves. This finding concurs with [49, 40] who concluded that membership in community-based organizations increased the likelihood of adopting improved cookstoves.

Training on clean and efficient energy technologies led to greater adoption of improved cookstoves. This could be because training creates knowledge and awareness of the benefits, access, functioning, and use of the improved cookstoves thus increasing the likelihood of adoption. Having more knowledge also increases the capacity to weigh the costs and benefits associated with improved cookstoves hence increasing the likelihood of making the rational decision to adopt. Likewise, previous studies [32, 51, 52] found that training on clean and efficient energy technologies increased the adoption of improved cookstoves.

Moreover, the use of alternative sources of energy such as liquefied petroleum gas for cooking had a positive but non-significant relationship with the adoption of improved cookstoves. Households that use alternative fuels such as liquefied petroleum gas and electricity for cooking may be more aware and informed on the benefits of clean and efficient energy technologies and the risks associated with the use of inefficient cookstoves and thus adopt the improved cookstoves more. Such households could also be more financially endowed meaning they have a greater capacity for purchasing improved cookstoves. Preceding studies [41, 53, 43] concluded that increased awareness of clean and efficient technologies and the related benefits increased the adoption of improved cookstoves. However, this finding deviates from other previous studies [42, 54, 55] which deduced that the presence of substitute and complementing energy sources and technologies reduces the likelihood of adopting improved cookstoves.

People who engage in community-based conservation activities such as planting trees in the forest were found to adopt the improved cookstoves more. Also, a greater perception of climate change and variability leads to greater use of improved cookstoves. Such people may be more environmentally conscious and have a greater awareness of the linkage between inefficient and unclean energy use practices and environmental degradation and climate change. They are thus more likely to adopt improved cookstoves to mitigate the harmful effects of inefficient and unclean energy use practices. Also, Troncoso K. et al. [56] deduced that households that had a greater experience with climate change problems were more likely to adopt clean and efficient energy technologies.

Moreover, the number of trees in the household's farm had a significant negative relationship with the adoption of improved cookstoves. This may be because households that have greater and easier access to firewood may have less urgency to adopt wood-fuel-saving technologies. Therefore, the negative but non-significant relationship between land size and the adoption of improved cookstoves could also be because households that own bigger land have more to plant more trees and thus would more likely have greater access to fuel wood. Relatedly, the adequacy of the household farm in providing the household's wood fuel needs leads to a reduction in the use of improved cookstoves. Also, sourcing wood fuel from the forest leads to lower use of improved cookstoves since it could create a perception of high availability of biomass fuels and thus remove the urgency to adopt efficient energy-use technologies. Households that incur greater energy, time, financial, and other costs in accessing fuelwood are thus more likely to adopt the improved cookstoves since they will benefit significantly from the associated cost savings. These findings are in line with prior studies [49, 46, 57] which found that greater and easier access to biomass fuels leads to lower adoption of improved cookstoves.

5. Conclusion

The study area is marked by high reliance on biomass fuels including firewood and charcoal for cooking. Although the adoption of improved cookstoves leads to low consumption of biomass fuels, their adoption and use are still low. The low adoption of improved cookstoves is caused by various underlying social, economic, political, institutional, technical, environmental, and cultural factors. Understanding the effect of factors that affect the adoption of improved cookstoves is thus increasing their adoption and use. The study will lead to an improved understanding of the factors affecting the adoption of improved cookstoves, especially in forest-adjacent communities. This will enhance their adoption and use and result in environmental, health, and socioeconomic benefits. Further, the study will inform the design and implementation of effective policies, plans, and programs for promoting the adoption and use of improved cookstoves.

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Data Availability

The data used for this study is available in the Mendeley data repository.

https://data.mendeley.com/drafts/t2f4d852z6

Author Contributions

Caxton Gitonga Kaua: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

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