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Driving Technology Adoption for Pasture Production: Socio-Economic Insights from Isiolo County's Climate Extremes

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Abstract
This study investigates the socio-economic determinants influencing the adoption of technologies, innovations, and management practices (TIMPs) for pasture production in Isiolo County, Kenya. Using a descriptive survey design, data were collected from 382 household heads, two field extension officers, and two focus group discussions. Analysis, is based on the Diffusion of Innovation Theory, applied multiple linear regression to explore correlations between TIMP adoption and factors such as gender, education, income, livelihood activity, group membership, and financial assistance. The outcome of the correlation test is as follows: TIMP Adoption = 3.52628 + 0.13028 (Gender) - 0.03457 (Land Size) + 0.18103 (Education Level) + 0.21995 (Annual Income) + 0.21426 (Livelihood Activity) + 0.15072 (Group Membership) + 0.05913 (Financial Assistance). The results indicate that effective policies should prioritize gender inclusion, enhance education, increase financial support, and promote cooperative frameworks to improve TIMP adoption, particularly for small-scale livestock keepers.

Introduction

Pastoralists in East Africa have endured severe livestock losses due to climate-related challenges, such as frequent droughts, which jeopardise their livelihoods and food security (Mutiga, 2021). The impacts of climate change, including rising temperatures and unpredictable rainfall, intensify food insecurity and dependence on aid by disrupting natural resource management and pasture production (Verschuur, Wolski, & Otto, 2021). This situation further exacerbates poverty and inequality within pastoral communities (Habte et al., 2022; Codjoe & Atiglo, 2020).

In Kenya's ASAL regions, a significant portion of the population lives in extreme poverty and is highly susceptible to climate shocks (Opiyo, Wasonga, & Nyangito, 2014). More than 50% of the population falls below the poverty line of $2.15 per day (PPP, 2017 prices, poverty threshold), heightening their risk of disaster management (World Bank, 2022; Nyika, 2022). Their reliance on natural resources for survival increases their vulnerability (Praveen & Sharma, 2019). Building resilience hinges on their ability to adapt to climate change and manage resource degradation (Thomas, 2019).

Isiolo County, located within Kenya's arid and semi-arid lands (ASALs), is highly susceptible to climatic extremes, including rising temperatures, erratic rainfall, and frequent droughts, all of which pose significant threats to pasture production and livestock (Girvetz et al., 2019). Addressing these challenges requires effective adaptation and mitigation strategies to improve food security and livelihoods. Pasture restoration technologies, such as reseeding, can bolster resilience, enhance livestock productivity, and mitigate climate impacts through carbon sequestration (Harrison, Cullen, & Rawnsley, 2016). However, the successful adoption of these technologies hinges on factors like access to reliable seed sources and the selection of well-suited species to the local environment and livestock needs (Mbuthia, Rewe, & Kahi, 2015; Ericksen & Crane, 2018).

Government agencies and development partners have been working to advance fodder production and rehabilitate rangelands in Isiolo County (Mureithi, 2018). In 2019, the World Food Programme (WFP) rolled out a project in thirteen dryland counties, including Isiolo, focused on creating Food for Assets (FA) and distributing a range of pasture and fodder technologies. The Range Management and Pastoralism Strategy (RMPS) 2021-2031 was rolled out in June 2021. It focuses on enhancing productivity and conserving and sustainably managing rangeland resources in ASAL areas. This strategy supports Kenya's constitutional objectives and Vision 2030 by prioritising the restoration and improvement of rangelands to ensure food and nutritional security and sustainable resource management.

Theoretical Framework

The study is guided by the Diffusion of Innovation Theory (Rogers, 2003), which examines how, why, and at what rate new ideas and technologies spread through cultures. In the context of pasture production in Isiolo County, where climate extremes necessitate new farming methods, the diffusion of innovation theory is used to understand the stages of technology adoption. It provides insights into how social and economic factors (e.g., income levels, education, access to information) influence the willingness of farmers to adopt new technologies for pasture production. Adopting pasture production technologies is crucial for countering land degradation, boosting livestock and agricultural output, and improving food security and livelihoods in arid regions such as Isiolo County. Despite these efforts, pastoralists in Isiolo continue to be vulnerable to climate extremes, highlighting the need to evaluate current technology adoption and its effectiveness in addressing climate impacts.

Methods of Study

The research was conducted in Isiolo County, 285 kilometres north of Nairobi, Kenya's capital. Marsabit County borders the county to the north, Samburu and Laikipia Counties to the west, Garissa County to the east, Wajir County to the north, Tana River and Kitui Counties to the south, and Meru County to the west. It lies between longitudes 36°50′ and 39°50′ East and latitudes 0°00' South and 2°10′ North, covering an area of approximately 25,700 km².

Research Design

A descriptive survey design was employed for the study, as it effectively gathers both qualitative and quantitative data. This method is ideal for formulating clear recommendations to address research issues. It is particularly useful for examining rainfall and temperature variability and technology adoption among pastoralists in Isiolo County. It is time-efficient and centers on the research participants.

Sampling Frame

The study's accessible population included 48,514 households in Isiolo and Garbatulla sub-counties. A sample of 382 household heads and field extension officers, chosen as key informants, was determined using the Krejcie and Morgan (1970) formula. Interviews were conducted with household heads at convenient locations and Focus Group Discussions (FGDs) were held at the locations selected by the key informants.

Table 1: Accessible Population of the Study

Sub counties	Population	Households
Garbatulla	99,730	18,661
Isiolo	121,061	29,853
Total	99,851	48,514

Source: *Kenya National Bureau of Statistics, 2019*

Sampling Procedure and Sample Size

The study sample was determined using a multistage sampling approach. In the first stage, Isiolo and Garbatulla sub-counties were purposively selected due to their location, reliance on pastoralism, vulnerability to drought, and the influence of neighbouring ASAL counties. In the second stage, two extension officers were chosen through a simple random selection method.

Heads of the Households

A sample is drawn proportionally as presented in the study's accessible population. The formula by Krejcie and Morgan (1970) was used to calculate the sample size for the heads of households, as shown below. A total sample size of 382 subjects was obtained from an accessible population of 48,514 from Isiolo and Garbatulla Sub-counties, as shown below and in Table 1.

S=X2NP(1-P) +X2P(1-P) d2(N-1)

Where S = the required sample size, $X2$ = 3.841, N = 48,514, P = 0.50, d=0.05 at a 95% confidence level.

N= 48,514, X2= 3.841 P= 0.5 d=0.05P

S = 381.09 =382

Table 2: A sample size obtained proportionally from the two targeted sub-counties

Sub-county	No of households	Extension Officers	Sample Size
Isiolo	18,661	1	148
Garbatulla	29,853	1	236
Total	48,514		384

Source: (KNBS 2019 and Author)

Household heads were selected by first stratifying them into two groups, as detailed in Table 2. Each sub-county was treated as a distinct cluster, from which a proportional sample of household heads was extracted. The proportion of respondents in each sub-county was calculated by dividing the total population of household heads by the accessible population. This process resulted in 147 household heads from Isiolo and 235 from Garbatulla, as shown in Table 2.

Data Collection

Data on the adoption of TIMPs was gathered using three methods. Questionnaires were distributed to household heads to collect quantitative data: two extension officers and two Focus Group Discussions (FGDs) included 8 participants per group, ensuring gender balance with three men, three women, and two youths (one male and one female) from selected villages to validate responses from households.

Data Analysis

Data were analysed using multiple linear regression models (Fisher, 1922) to explore the relationship between socioeconomic factors and TIMP adoption. Descriptive statistics such as frequency and percentage were used to summarise the data, graphs and tables were used to present the data, and inferential statistics were employed to identify significant correlations.

Research findings

This section analyses the research findings. It first addresses the adopted TIMPs, the socio-economic determinants of the respondents to the adoption, and the conclusion and recommendations.

The data in Table 3 illustrate several important concepts regarding adopting adaptation technologies for pasture production. Each concept shows varied adoption levels and access, highlighted through statistical measures, particularly the mean and standard deviation.

Table 3: Adopted TIMPs for Pasture Production

Variable	Std. Dev	Mean	Min	Max
Access to Information on TIMPs	3.38	1.51	1	5
Adoption of Reseeding Technologies	3.60	1.46	1	5
Access to Quality Seeds for Pasture Production	2.71	1.42	1	5
Affordability of Quality Seeds	2.79	1.53	1	5
Timely Information on Pasture Improvement from Extension Officer	2.75	1.42	1	5
Preservation of Excess Pasture	3.27	1.51	1	5
Use of Indigenous Knowledge to Manage Land	2.97	1.47	1	5
Access to Pasture Supplementary Feeds	3.20	1.59	1	5
Construction of Feed Conservation Structures	3.29	1.52	1	5
Soil Conservation	3.368	1.45	1	5
Use of *Prosopis Juliflora* Flour for Livestock	3.19	1.59	1	5
Seed Bulking and Management Practices	3.04	1.60	1	5
Use of Irrigation for Pasture Production	3.31	1.53	1	5
Use of Acacia *Tortilis* Pods Supplement	3.34	1.63	1	5
Use of Range Pits for Water Conservation	3.33	1.63	1	5

Source: Ground Data

Access to information on technological innovations and management practices (TIMPs) for pasture production is notably low, with a mean score of 1.51 and a high standard deviation of 3.38, indicating significant inconsistencies in access among respondents.

Adopting reseeding technologies also shows a low mean score of 1.46, with a substantial standard deviation of 3.60. This variability suggests that while some farmers may access these technologies, others lack the necessary resources or awareness, leading to uneven adoption across regions. Access to quality seeds for pasture production is similarly limited, with a low mean score of 1.42 and a standard deviation of 2.71. The uneven distribution of seeds reflects disparities in access, suggesting that improvements in seed distribution networks are needed to support more equitable access.

The affordability of quality seeds is a significant barrier, as indicated by a low mean score of 1.53 and a standard deviation of 2.79. This suggests that the cost of seeds is prohibitive for many farmers, making it difficult to adopt these essential inputs (Anderson & Thompson, 2018). Timely information from extension officers is lacking, with a mean score of 1.42 and a standard deviation of 2.75. This indicates that many farmers do not receive timely or adequate support from extension officers.

Preserving excess pasture shows low adoption, with a mean score of 1.54 and a standard deviation of 3.21, indicating variability in the effectiveness of preservation techniques. The use of indigenous knowledge for land management is limited, with a mean score of 1.49 and a standard deviation of 2.97, reflecting differences based on regional and personal factors.

Access to supplementary feeds is limited, with a mean score of 1.59 and a standard deviation of 3.20. This indicates that while some farmers can access supplementary feeds, many do not, underscoring the need for more robust distribution systems. On the other hand, the construction of feed conservation structures is minimal, with a mean score of 1.52 and a standard deviation of 3.29. This indicates a low level of engagement in building structures that could help conserve feed, suggesting that more education and support are needed to promote their benefits. Adopting soil conservation practices is low, with a mean score of 1.45 and a standard deviation of 3.37. The variability indicates that soil conservation efforts are not uniformly adopted across regions, suggesting the need for more widespread education and resources to encourage greater adoption.

The use of *Prosopis Juliflora* flour for livestock feed is low, with a mean score of 1.59 and a standard deviation of 3.19. This reflects inconsistent utilisation across regions, indicating that efforts to promote its benefits and improve access could help increase its adoption. The study sought socio-economic determinants of the adoption of TIMPs. The outcomes are shown in Table 4.

Table 4: Regression Coefficient for Socio-Economic Determinants to Adoption of TIMPs

Independent Variables	B	Std. Error	T	P Value
Constant	3.52628	0.5544104	6.36	0.000
Gender	0.1302818	0.0914579	1.42	0.155
Total Size of the Grazing Land	-0.0345664	0.1590947	1.16	0.247
Highest Level Attained	0.1810262	0.837471	0.22	0.829
Average Income Per Year	0.219949	0.2150987	1.02	0.307
Primary Livelihood Activity	0.2142617	0.7099521	0.30	0.763
Membership in a Group	0.150722	0.238804	0.63	0.528
Financial Assistance	0.0591346	0.0958708	0.62	0.528

Source: Author

The equation for the Multiple Linear Regression model is represented by:

$Y= \alpha_0+ \alpha_1 X_1+\alpha_2 X_2+ \alpha_3 X_3+\alpha_4 X_4+\alpha_5 X_5+\alpha_6 X_6+e_t$

Where Y =adaptation of technologies, X_1-gender, X_2-age, X_3-size of glazing land, X_4-education attainment, X_4-average income, X_5-primary livelihood, X_6-membership in a group and $X_{(6)}$–financial assistance

et= random error term

α = constant

Adaptation of TIMPs = 3.52628+0.1302818 (Gender) + -0.0345664 (size of the land) + 0.1810262 (education level) + 0.219949 (average income per year) + 0.2142617 (primary livelihood activity) + 0.150722 (membership in a group) + 0.0591346 (financial Assistance).

Gender of the Respondents

Climate change impacts men and women differently. Table 5 shows that 64.08% of households are male-headed, while 34.92% are female-headed. This gender disparity affects vulnerability and access to resources, with women often facing greater challenges due to their roles and limited decision-making power (Njuki et al., 2021; Melesse et al., 2021).

Table 5: Households Heads Disaggregated by Gender

Gender	Frequency	Percentage
Male	239	64.08
Female	134	34..92

Source: Ground Data

The regression analysis indicates a positive beta coefficient value of 0.1302818 for gender, suggesting that gender positively influences the adoption of Technology and Innovation Management Practices (TIMPs). This implies that being of a particular gender is associated with a greater likelihood of adopting new technologies. For instance, in many contexts, men might have more access to resources and decision-making power, which could lead to higher adoption rates of TIMPs (Kassie et al., 2021; Melesse et al., 2021).

Total Size of the Grazing Land

Since all the TIMPs occur on land, the study needed to determine the size of the households' land holdings. The results obtained are presented in Table 6.

Table 6: Total Size of the Grazing Land

Acreage	Frequency	Percentage
1-5	192	51.47
6-10	133	35.66
Over 10	48	12.87

Source: Ground Data

The regression analysis results indicate a negative correlation between the size of grazing land and the adoption of Technology and Innovation Management Practices (TIMPs), as shown by the negative beta coefficient value of -0.0345664. This suggests that larger landholders may be less inclined to adopt new technologies, potentially due to their reliance on traditional methods or because they perceive less need for innovations when managing larger land areas. On the other hand, smaller landholders might be more willing to embrace TIMPs to maximise productivity within their limited grazing areas (Teklewold et al., 2020; Abdulai et al., 2018).

Primary Livelihood Activity

Table 7 shows that 98.39% of respondents in Isiolo County practice pastoralism as their primary livelihood. Additionally, 9% are engaged in business, 2% in formal employment, 1% are retired without a pension, and 0.5% are retired with a pension scheme.

Table 7: Primary Livelihood Activity

Items	Frequency	Percentage
Business	33	8.85
Formal Employment	9	2.41
Livestock Keeping	325	98.39
Retired with Pension	2	0.54
Retired Without Pension	4	1.07

Source: Ground Data

In Isiolo County, 98.39% of households rely on pastoralism, aligning with Erick's (2022) finding that 80% of ASAL residents practice pastoralism. The regression analysis shows a positive correlation of 0.2142617 between primary livelihood activity and the adoption of Technology and Innovation Management Practices (TIMPs), indicating that farmers focused on pastoralism are more likely to adopt new technologies to boost productivity and ensure income sustainability (Melesse et al., 2021; Tambo & Mockshell, 2018).

The main purpose of Practicing Pastoralism

Households engaged in farming are motivated by various factors. The main purpose and orientation of farming among the respondents, as found in the study, are as follows: The results presented in Figure 1 show that 61.13% kept livestock for both commercial and subsistence purposes, 24.93% for subsistence only, and 13.94 % for commercial only.

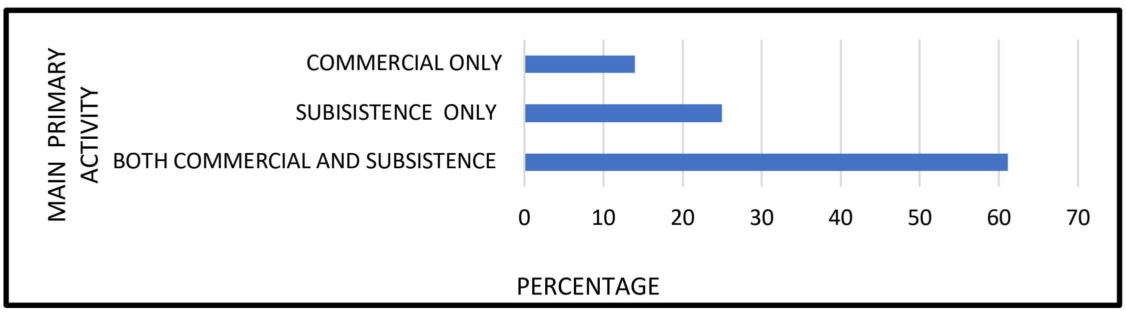

Figure 1: The Main Source of Livelihood

In Isiolo County, 61% of respondents practice pastoralism for commercial and subsistence purposes, 25% for subsistence only, and 14% exclusively for commercial gain. This underscores the dual role of pastoralism in meeting immediate food security needs and generating income, with some households focusing on livelihood sustainability while others aim for profit (Tari et al., 2022; Little et al., 2020).

The regression results indicate a positive correlation of 0.2142617 between the primary livelihood activity and adopting Technology and Innovation Management Practices (TIMPs). This suggests that a stronger focus on a primary livelihood activity is associated with a higher likelihood of adopting new technologies. Farmers dedicated to a specific livelihood are more inclined to invest in innovations to enhance their productivity and secure their primary income source (Melesse et al., 2021; Tambo & Mockshell, 2018).

The study found that 16.74% of households had no formal education, 47.28% had primary education, 26.78% had secondary education, and 8.8% had post-secondary education (Figure 2).

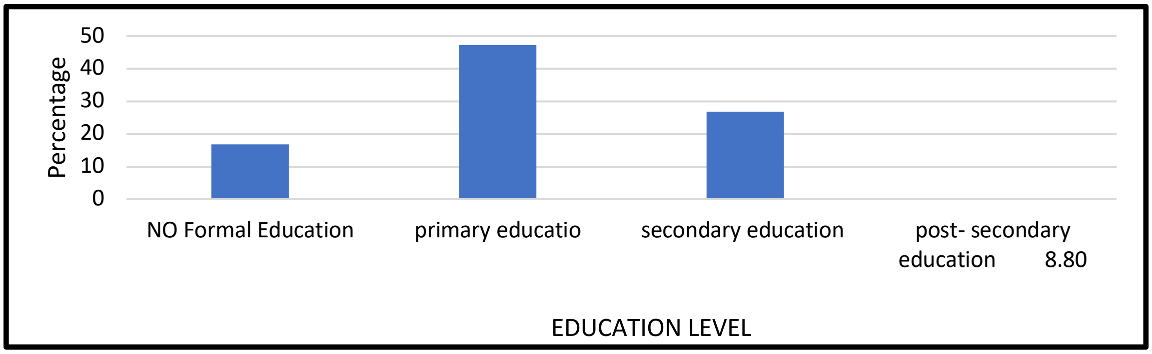

Figure 2: Level of Education

The regression results show a positive correlation of 0.1810262 between education level and adopting Technology and Innovation Management Practices (TIMPs). This indicates that higher education levels are associated with an increased likelihood of adopting new technologies. Educated individuals are generally better equipped to understand, evaluate, and implement innovations due to improved information access and problem-solving skills (Riddell & Song, 2017).

Average Level of Income Per Year

Economic and financial factors, such as income from farm and off-farm activities, influence adoption decisions (Ali & Deininger, 2015). The study found that 51.74% of respondents earn over Ksh. 80,000 annually, 16.09% earn between Ksh. 61,000 and 80,000, 13.94% earn between Ksh. 21,000 and 40,000, and 11.80% earn below Ksh. 10,000 per year (Figure 3)

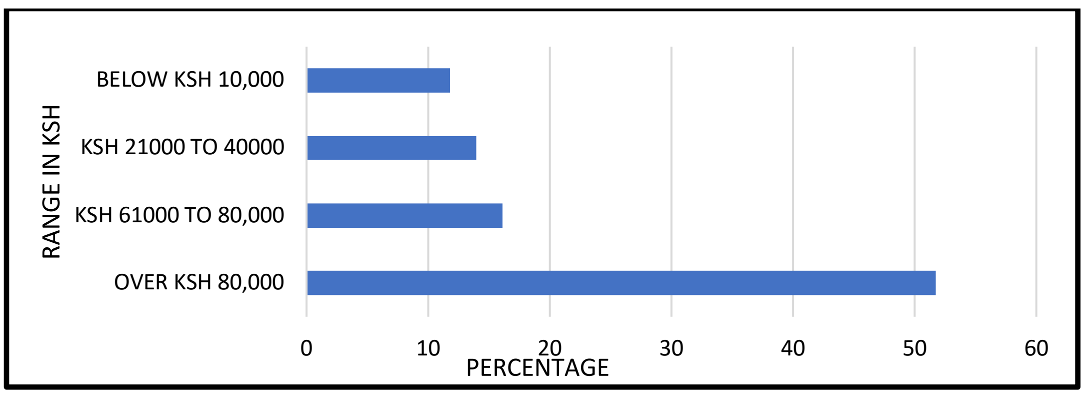

Figure 3: Average Level of Income Per Year

The regression results indicate a positive correlation of 0.219949 between average annual income and adopting Technology and Innovation Management Practices (TIMPs). This suggests that higher average income is associated with a greater likelihood of adopting new technologies. Households with higher income levels are generally better positioned to invest in and absorb the costs of new technologies, which can enhance their productivity and overall economic stability (Chowdhury et al., 2021; Melesse et al., 2021).

Membership to a Group

Membership in a community-based organisation (CBO) may influence the community's adoption of TIMPs. The results show that 97% of respondents are in groups focused on pasture production and marketing, while 13% are not. The main reasons for not joining groups include lack of market strategies (77%), delayed payments (15%), and poor leadership (8%). The high proportion of households in CBOs in Isiolo County reflects the significant role of community support in enhancing technology adoption in pastoral regions, as these areas often benefit from targeted development interventions (Barrett et al., 2022).

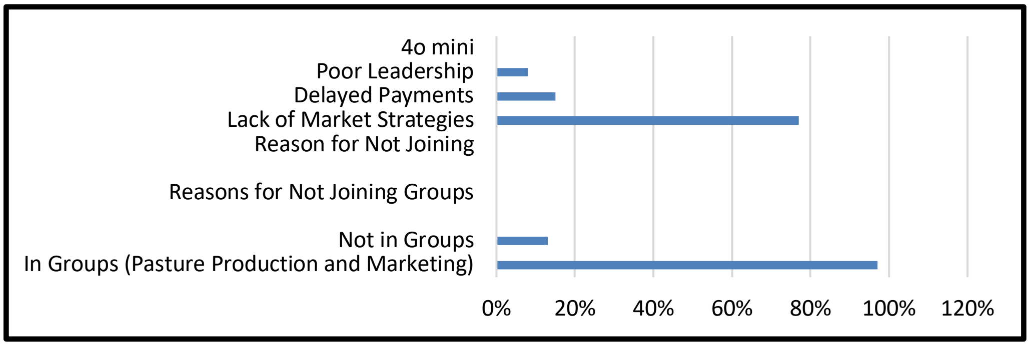

Figure 4: Group Membership

The regression results show a positive correlation of 0.150722 between group membership and adopting Technology and Innovation Management Practices (TIMPs). This suggests that being a group member is associated with a higher likelihood of adopting new technologies. Group membership often provides access to shared resources, information, and support networks, which can facilitate the adoption of innovations (Miller & Wanzenböck, 2019; Kassa et al., 2019).

The households' results in Figure 5 indicate that 59 per cent of the respondents get financial assistance, while 41 per cent do not. Most of the respondents get financial assistance from the government through CBOs and NGOs.

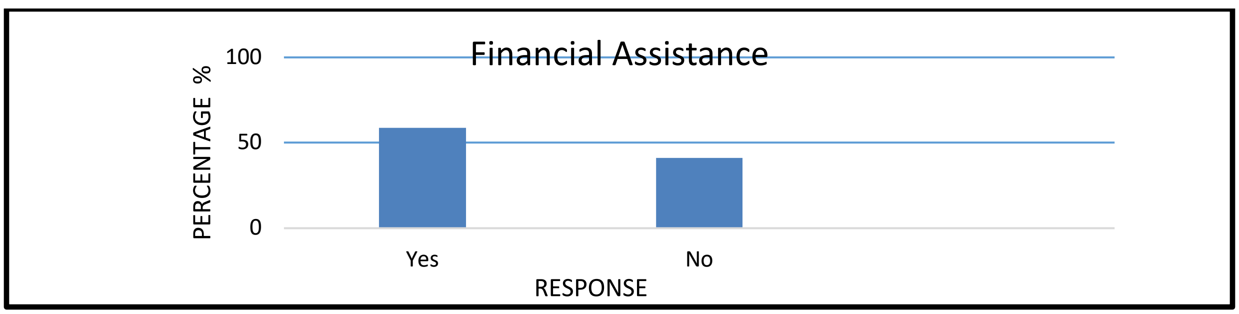

Figure 4: Financial Assistance

The financial efforts are directed towards training on new technologies, innovation and management practices, such as the construction of storage structures for pastures. Those who get financial assistance to support their trade are more likely to adopt their new technologies than those who don't have access to financial support (Gomez & Vargas 2009).

The regression analysis reveals a positive beta coefficient value of 0.0591346 for members' financial assistance, indicating that an increase in financial support from members is associated with a higher level of adoption of Technology and Innovation Management Practices (TIMPs). This suggests that as financial assistance improves, households are more likely to invest in and adopt new technologies, as they can better manage the costs associated with such innovations (Ragasa et al., 2021; Ndiritu et al., 2019).

Conclusion

Development interventions must be multifaceted to effectively drive technology adoption for pasture production in Isiolo County. They must address gender disparities, educational gaps, and income constraints. They should also foster group participation and provide financial support, all while acknowledging the farmers' diverse livelihood strategies. These recommendations aim to create a conducive environment for widespread adoption of TIMPs, enhancing productivity and resilience in the face of climate extremes.

Interventions should be targeted and strategic to effectively promote the adoption of Technologies, Innovations, and Management Practices (TIMPs) for pasture production in Isiolo County. Gender inclusivity is essential, as women and men need equal access to resources to enhance technology adoption. The negative impact of larger land sizes on adoption suggests that smallholder farmers should be prioritised for support, given their willingness to innovate.

Education is key in driving adoption, so increasing access to agricultural education and training will be vital. Similarly, higher incomes are linked to greater technology uptake, indicating the importance of improving farmers' financial capacity through income-generating activities and credit schemes.

Livelihood activities closely tied to pasture production motivate adoption, so investments in livestock-related enterprises could encourage more farmers to innovate. Group membership is also a strong influencer, suggesting that promoting farmer cooperatives and peer networks can enhance collective action and technology sharing. Lastly, although financial assistance has a more modest effect, ensuring access to affordable credit and support services remains important for enabling farmers to adopt and sustain new technologies.

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