Determinants of Animal Manure Adoption Among Smallholder Farmers in Garbatulla Sub-County, Isiolo County, Kenya

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Abstract

Animal manure is an important component of sustainable soil fertility management, yet its adoption among smallholder farmers remains limited in many arid and semi-arid regions of Kenya. This study investigated the determinants of animal manure adoption among smallholder farmers in Garbatulla Sub-County, Isiolo County, Kenya. A cross-sectional mixed-methods design was employed, involving 202 randomly selected farmers. Quantitative data were analyzed using descriptive statistics and binary logistic regression, while qualitative data from key informant interviews and focus group discussions were analyzed thematically. The findings revealed that farm location and pesticide use were significant determinants of animal manure adoption, whereas socio-demographic factors such as age, gender, education, household size, and farm size did not significantly influence adoption decisions. Qualitative findings further identified transportation costs, labor requirements, and limited extension support as key barriers to effective manure utilization. The study concludes that improving access to manure resources, strengthening agricultural extension services, promoting integrated crop–livestock farming, and implementing location-specific interventions are essential for increasing adoption of animal manure. These measures will enhance sustainable soil fertility management, improve agricultural productivity, and contribute to climate-smart agriculture and food security in Kenya's arid and semi-arid regions.

Keywords: *Animal manure adoption, Smallholder farmers, Soil fertility management, Sustainable agriculture*

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1.0 Introduction

Declining soil fertility and the depletion of soil organic matter pose significant threats to agricultural productivity across sub-Saharan Africa, where continuous cultivation and an overreliance on costly inorganic fertilizers have accelerated nutrient loss (Muluneh, 2021). In response, international frameworks like the United Nations Sustainable Development Goals advocate for integrated soil fertility management to enhance food security and climate resilience (United Nations [UN], 2019). Animal manure offers a chemically and biologically superior alternative that restores long-term soil structure and microbial activity; however, its potential remains underutilized in many rural economies (Belete & Yadete, 2023; Ndambi et al., 2019).

The transition toward organic nutrient management is hindered by complex socio-economic and institutional barriers that vary significantly across agroecological zones (Tan et al., 2021). Common constraints include limited livestock ownership, high labor requirements for collection, and prohibitive transportation costs, which are particularly acute in arid and semi-arid lands (ASALs) characterized by seasonal livestock mobility (Lawal & Babalola, 2014). Furthermore, a persistent farmer preference for the immediate, predictable yield boosts provided by synthetic inputs often outweighs the recognized long-term structural benefits of organic manure, especially where institutional extension support is inadequate (Chelang'a et al., 2023).

In Kenya, empirical evidence regarding organic input adoption remains concentrated in high-potential highland regions, leaving a distinct research gap in irrigation-based systems within ASAL counties like Isiolo. Existing studies offer inconsistent findings on the roles of education, labor availability, and farm size, highlighting that adoption decisions are highly context-specific (Núñez & McCann, 2004; Waithaka et al., 2007). This study addresses this gap by investigating the socio-demographic, farm-level, and institutional determinants of animal manure adoption in Garbatulla Sub-County, Isiolo County, providing essential evidence to design targeted interventions for sustainable soil management in fragile environments.

2.0 Materials and Methods

Study Area

The study was conducted in Garbatulla Sub-County, located in Isiolo County, one of Kenya's arid and semi-arid land (ASAL) regions. The area is characterized by low and erratic rainfall, recurrent droughts, and fragile soils, making sustainable soil fertility management essential for improving agricultural productivity. Crop production is mainly undertaken within irrigation schemes, including Rapsu, Gafarsa, and Guba Dida, where farmers cultivate vegetables, maize, onions, tomatoes, and other horticultural crops alongside livestock keeping. Livestock production provides an important source of animal manure, although its utilization varies considerably among farmers due to socio-economic and institutional factors. The study area was selected because of its reliance on irrigated agriculture, mixed crop-livestock production systems, and the increasing need to promote sustainable soil fertility management practices.

Research Design

The study adopted a cross-sectional mixed-methods research design, combining quantitative and qualitative approaches to obtain a comprehensive understanding of the factors influencing animal manure adoption among smallholder farmers. Mixed-methods research enables the integration of numerical data with qualitative insights, thereby providing a more complete understanding of complex agricultural adoption behaviour than either approach alone (Creswell & Plano Clark, 2018; Nassaji, 2020). The quantitative component generated measurable evidence on the determinants of manure adoption, while qualitative data helped explain farmers' perceptions, experiences, and contextual factors influencing adoption decisions.

"The study concludes that although the majority of farmers recognize the importance of animal manure for improving soil fertility, its adoption is primarily influenced by farm location"

Target Population

The target population comprised all smallholder farmers practicing irrigated crop production within the selected irrigation schemes in Garbatulla Sub-County. These farmers represented the primary decision-makers regarding soil fertility management and fertilizer use. In addition, agricultural extension officers, irrigation scheme leaders, and farmer cooperative representatives participated as key informants because of their knowledge of agricultural production systems and extension services in the study area.

Sample Size and Sampling Procedure

A total of 202 smallholder farming households participated in the study. A multistage sampling procedure was employed. First, the irrigation schemes were purposively selected because of their importance in irrigated agriculture and livestock production. Thereafter, proportionate sampling was used to allocate respondents across the irrigation schemes based on the number of registered farming households. Finally, individual households were selected using simple random sampling to ensure that each eligible household had an equal probability of inclusion in the study. Key informants were selected purposively based on their professional responsibilities and experience in agricultural extension and irrigation management.

Data Collection

Primary data were collected using structured questionnaires, key informant interviews, focus group discussions, and field observations. The structured questionnaire gathered quantitative information on farmers' socio-demographic characteristics, farm characteristics, institutional support, input use, and animal manure adoption practices. Key informant interviews with extension officers and irrigation scheme leaders provided contextual information regarding extension services, manure availability, and local agricultural practices. Focus group discussions were conducted to validate survey findings and explore farmers' perceptions of the benefits and constraints associated with animal manure use. Direct field observations were undertaken to verify farming practices, manure storage, livestock ownership, and crop production activities. The use of multiple data collection methods enhanced the credibility of the findings through methodological triangulation (Creswell & Creswell, 2018).

Data Analysis

Quantitative data were coded, cleaned, and analysed using the IBM SPSS Statistics. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize respondents' socio-economic characteristics and farming practices. To identify the determinants of animal manure adoption, a binary logistic regression model was estimated because the dependent variable was dichotomous, taking the value of 1 if a farmer adopted animal manure and 0 otherwise. Logistic regression is widely used in technology adoption studies because it estimates the probability of adoption as a function of several explanatory variables while accommodating binary response variables (Hosmer et al., 2013; Gujarati & Porter, 2009). Odds ratios and significance levels were used to interpret the influence of each explanatory variable on the likelihood of adopting animal manure.

Qualitative data obtained from interviews and focus group discussions were transcribed, organized, and analysed using thematic content analysis. Responses were coded into emerging themes relating to manure availability, extension support, labour requirements, transportation challenges, perceptions of organic fertilizers, and institutional factors influencing adoption. The qualitative findings were then integrated with the quantitative results to provide richer explanations of the observed statistical relationships.

Model Specification

The probability of a farmer adopting animal manure was estimated using the binary logistic regression model:

ln⁡(Pi1−Pi)=β0+β1X1+β2X2+⋯+βnXn+ε\ln \left(\frac{P_i}{1-P_i}\right)=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n+\varepsilonln(1−PiPi)=β0+β1X1+β2X2+⋯+βnXn+ε

where:

- PiP_iPi = probability of adopting animal manure;
- 1−Pi1-P_i1−Pi = probability of not adopting animal manure;
- β0\beta_0β0 = intercept;
- β1…βn\beta_1 \ldots \beta_nβ1…βn = regression coefficients;
- X1…XnX_1 \ldots X_nX1…Xn = explanatory variables (such as age, education, farm size, land ownership, extension contact, livestock ownership, irrigation scheme location, household size, pesticide use, synthetic fertilizer use, and farmer organization membership);
- ε\varepsilonε = random error term.

Ethical Considerations

Ethical approval for the study was obtained from the relevant institutional authorities before commencement of data collection. Permission to conduct the research was obtained from county agricultural offices, irrigation scheme management committees, and local administrative authorities. Participation was voluntary, and informed consent was obtained from all respondents before interviews were conducted. Participants were assured of confidentiality, anonymity, and the right to withdraw from the study at any stage without any consequences. Data collected were used solely for academic purposes and stored securely to protect respondents' privacy.

Table 1

Variables included in the logit model, their descriptions and expected signs

Variable	Description and measurement	Expected signs
	Independent variables	
Age	Age of the household head (years)	+
Gender	Gender of the household head (Male=1, Female=0)	+/-
Education	Completed highest level of formal education of household head (years)	+

Household size	Total number of members (family, relatives, workers) in a household (proxy for labour).	+
Prepared manure	If the farmer produced manure (yes=1, no=0).	+
Use of pesticides	If the household used pesticides (yes=1, no=0).	+
Use of synthetic fertilizers in irrigation schemes	If the household used chemical fertilizers (yes=1, no=0).	-
Farm location	If the farm was located in three irrigation schemes (1=Rapsu irrigation scheme, 2=Guba Dida irrigation scheme and 3=Gafarsa irrigation scheme0	+/-
Farm type	If the farm type was 1=Smallholder farmer (less than 5 acres), 2=Medium commercial farmer (5 – 10 acres) and 3=Large commercial intensive (> 10 acres)	-
Extension contact	Access to advice on problems and adoption of new innovations like animal manure from agricultural extension agents (yes=1, no=0).	+
Membership to a farmer group	If the household was a member of any farmer group (yes=1, no=0).	+
Acres of land owned	All land operated for agricultural purposes by the farmer (acres).	-
	Dependent variable	
Animal manure use	If the farmer used animal manure (yes=1, no=0).	

In this study, a cross-sectional data was used and taking into its account the varying nature problems like multi-collinearity, linearity and endogeneity were checked. The assumptions of normality and homoscedasticity usually does not apply to logistic regression but linearity, independence, no multicollinearity and no outlier effects apply. Residuals in the logistic regression do not need to be normally distributed since outcome variable is categorical rather than continuous meaning residuals will follow binomial distribution. Homoscedasticity assumes that the variance of error term is constant across all values of predictor variables and in logistic regression the variance is directly tied to the predicted probability and probability changes with predictors and variance is inherently heteroscedastic.

In endogeneity problem, the few variables that were suspected of causing the endogeneity problem were added in the model and consistency achieved for instance, human capital usually affect adoption but it’s hard to estimate human capital and thus education variable have been used as a proxy variable for human capital (Tsamadias & Pegkas, 2012). In the measure of model fit, the test statistic is the difference between the residual deviance for the model with predictors and the null model (46.864-19.759= 27.105) and the chi-square of 27.10493 with 13 degrees of freedom and an associated p-value of 0.012 tells us that our model as a whole fit significantly better than an empty model (Table 3). According to Box-Tidwell test for linearity, linearity assumption is met when the interaction term(s) of all continuous predictors (age and household size) are non-significant and if one or more of these terms is significant the linearity assumption fails and results showed that both the interaction terms are insignificant and hence linearity assumption has been met (Table 3). The variables included in the logit were also tested for multicollinearity using Variance Inflation Factor (VIF) which ranged from 1 to 3.44 and a value of VIF less than 5 means that virtually no multicollinearity in the model.

3.0 Results and Discussion

The majority of farmers used and prepared (97.5%, 96% respectively) manure from animals. On average, farmers owned fifteen animals and farmers who produce manure from their animals are more likely to use and adopt manure use. 78.7%, 19.3% and 1.5% of farmers used cow, goat and sheep manure respectively that was majorly from their own production (Table 2).

Table 2

Summary statistics of animal manure characteristics

Name of variable	Type of variable	Mean	Sd	Percentage (Yes)	Percentage (No)
Animal manure use.(Yes, No)	Categorical			97.5%	2.5%
Prepare manure.(Yes, No)	Categorical			96%	4%
Animals owned by farmer.	Numerical	14.9	10		
Animals from which manure was used (cow).	Categorical			78.7%	18.8%
Animals from which manure was used (Goat).	Categorical			19.3%	78.2%
Animals from which manure was used (Sheep).	Categorical			1.5%	96%
Animals from which manure was used (Poultry).	Categorical			0%	97.5%
Source of manure cow own production.	Categorical			74.3%	0%
Source of manure goat own production.	Categorical			17.3%	0%
Source of manure sheep own production.	Categorical			1.5%	0%

Characteristics of Animal Manure Use

The descriptive results indicate that animal manure is widely recognized and utilized among the sampled farmers, although the intensity and consistency of its application vary across households. Approximately 97.5% of the respondents reported using animal manure, while 96% indicated that they prepared manure before application. Farmers owned an average of 15 livestock, suggesting that livestock production provides an important source of organic manure for crop production.

Cattle were the predominant source of manure, with 78.7% of respondents using cattle manure, followed by goat manure (19.3%) and sheep manure (1.5%). Poultry manure was not used by any respondent. Most farmers obtained manure from their own livestock rather than purchasing it, demonstrating the importance of integrated crop–livestock farming systems in supporting sustainable soil fertility management. These findings indicate that manure availability is generally not the principal constraint to adoption; instead, the effective utilization of available manure appears to be influenced by socio-economic, institutional, and farm-level factors. Similar observations have been reported in previous studies, which found that livestock ownership enhances farmers' access to organic nutrient resources and reduces dependence on purchased fertilizers (Núñez & McCann, 2008; Niles et al., 2019).

Table 3

Factors influencing use and adoption of animal manure.

Coefficients:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	14.8633	5329.163	0.003	0.9978
Farm type Smallholder farmer (less than 5 acres)	-22.3557	5329.159	-0.004	0.9967
Farm location Guba Dida irrigation scheme	20.1249	4737.12	0.004	0.9966
Farm location Rapsu irrigation scheme	4.7217	2.1593	2.187	0.0288 *
Used synthetic fertilizer in irrigation schemes1	-0.95	2.8614	-0.332	0.7399
Used pesticides in irrigation schemes1	4.6277	2.3701	1.952	0.0509.
Prepared manure yesno1	2.9125	2.0004	1.456	0.1454
Household size	-0.4081	0.415	-0.983	0.3254
Gender male	0.984	1.841	0.534	0.593
Age	0.1728	0.1558	1.11	0.2672
Education	-0.2048	0.1956	-1.047	0.2952
Extension contact on manure use1	17.4985	23607.38	0.001	0.9994
Fo yesno1	0.2796	1.6121	0.173	0.8623
Acres land owned irrigation schemes	0.6102	2.3275	0.262	0.7932
Household size: log(household size)	16.973	32.087	0.529	0.597
Age: log(age)	13.653	12.907	1.058	0.290

Significant codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Dispersion parameter for binomial family taken to be 1)
Null deviance: 46.864 on 201 degrees of freedom
Residual deviance: 19.759 on 188 degrees of freedom
AIC: 47.759
Number of Fisher Scoring iterations: 21

Significant codes:

- ‘**’ - 1% level of significance
- ‘*’ - 5 % level of significance
- ‘.’ – 10 % level of significance

Logistic Regression Model Performance

Prior to estimating the logistic regression model, the assumptions underlying binary logistic regression were evaluated. Model adequacy was confirmed through a comparison of the null and residual deviance. The reduction in deviance from 46.864 to 19.759 produced a chi-square statistic of 27.105 ($p = 0.012$), indicating that the fitted model explained adoption behaviour significantly better than the intercept-only model.

The linearity assumption was examined using the Box–Tidwell test, and none of the interaction terms for continuous predictors were statistically significant, confirming that the assumption of linearity in the logit was satisfied. Furthermore, multicollinearity diagnostics indicated Variance Inflation Factor (VIF) values ranging between 1.0 and 3.44, well below the commonly accepted threshold of 5.0, suggesting that multicollinearity was not a concern. These diagnostic results demonstrate that the estimated regression coefficients are statistically reliable and suitable for interpretation.

Table 4

Odds Ratio or relative risk ratios of factors influencing animal manure adoption

	Dependent variable: Animal_manure_use_yesno
Farm type Smallholder farmer (less than 5 acres)	0.000
	(5,329.159)
Farm location Guba Dida irrigation scheme	549,649,845.000
	(4,737.120)
Farm location Rapsu irrigation scheme	112.361**
	(2.159)
Used synthetic fertilizer in irrigation schemes1	0.387
	(2.861)
Used pesticides in irrigation schemes1	102.276*
	(2.370)
Prepared manure (yes/no1)	18.403
	(2.000)
Household size	0.665
	(0.415)
Gender male	2.675
	(1.841)
Age	1.189
	(0.156)
Education	0.815
	(0.196)
Extension contact on manure use1	39,766,406
	(23,706.38)
For (yes/no1)	1.323
	(1.612)
Acres land owned irrigation schemes	1.841
	(2.327)
Constant	2,851,254.000
	(5,329.163)
Observations	202
Log likelihood	-9.879
Akaike inf. Crit.	47.759
Note:	*p<0.1; **p<0.05; ***p<0.01

Significant codes:

- ***p - 1% level of significance
- **p - 5 % level of significance
- *p – 10 % level of significance

Determinants of Animal Manure Adoption

The logistic regression analysis revealed that only a few explanatory variables significantly influenced farmers' adoption of animal manure. Specifically, farm location (Rapsu irrigation scheme) and pesticide use were statistically significant predictors, whereas the remaining variables, including education, age, household size, farm size, extension contact, membership in farmer organizations, and synthetic fertilizer use, did not exert statistically significant effects.

Farm Location

Farm location emerged as the strongest determinant of manure adoption. Farmers located in the Rapsu irrigation scheme were approximately 112 times more likely to adopt animal manure than farmers in the other irrigation schemes. This finding suggests that local agroecological and institutional conditions substantially influence technology adoption. Information obtained through key informant interviews indicated that livestock are commonly kept within the Rapsu irrigation scheme, providing farmers with easier access to manure. In contrast, livestock in Gafarsa and Guba Dida are generally grazed away from crop fields, increasing transportation costs and reducing manure utilization. This finding supports the argument that proximity to organic nutrient resources is a critical determinant of manure adoption (Núñez & McCann, 2008; Liu et al., 2018).

Pesticide Use

The use of pesticides was positively associated with manure adoption and was statistically significant at the 10% level. Farmers using pesticides were substantially more likely to adopt animal manure than those who did not. This relationship suggests that farmers who invest in crop protection are also more likely to implement complementary soil fertility management practices as part of an integrated crop management strategy. Rather than viewing manure and pesticides as substitutes, these farmers appear to combine multiple agricultural technologies to improve crop productivity and reduce production risks.

Land Ownership

Although the coefficient for land ownership was not statistically significant, the estimated odds ratio indicated that an additional acre of land increased the likelihood of manure adoption by approximately 1.84 times. Larger landholdings may encourage investment in long-term soil fertility improvements because farmers with secure land tenure are more likely to realize future returns from soil conservation investments. This observation is consistent with previous studies that have reported positive relationships between land ownership security and adoption of sustainable agricultural technologies (Liu et al., 2018).

Synthetic Fertilizer Use

Synthetic fertilizer use exhibited a negative relationship with manure adoption, although the coefficient was not statistically significant. Farmers using inorganic fertilizers were approximately 0.39 times less likely to adopt animal manure than non-users. This finding suggests that synthetic fertilizers may partially substitute for organic nutrient sources because they provide readily available nutrients, require less labour, and are easier to transport and apply. Similar findings have been reported by Zhang et al. (2020), who observed that increased reliance on chemical fertilizers often reduces farmers' demand for organic manure.

Education

Education showed a negative but statistically insignificant association with manure adoption. Although higher educational attainment is generally expected to improve technology adoption by enhancing farmers' access to information and decision-making capacity, the results suggest that more educated farmers may increasingly favour modern agricultural technologies, including commercial fertilizers, over traditional soil fertility management practices. Similar findings were reported by Núñez and McCann (2008), although other studies have found positive effects of education on sustainable agricultural technology adoption (Tan et al., 2021). These contrasting findings indicate that the influence of education is context-dependent and may vary according to farmers' access to agricultural information and market opportunities.

Household Size

Household size was negatively associated with manure adoption, although the relationship was not statistically significant. Contrary to expectations that larger households provide additional labour for manure collection and application, many households consisted of school-age children who contributed little to farm labour. Consequently, larger household size did not necessarily translate into greater labour availability for manure management.

Other Variables

Farm size, gender, age, extension contact, farmer organization membership, and manure preparation all showed the expected directions of association but were not statistically significant. Their lack of statistical significance suggests that manure adoption in Garbatulla Sub-County is influenced more strongly by contextual factors, particularly local resource availability and farming systems, than by individual demographic characteristics.

Policy Implications

The findings demonstrate that improving access to animal manure requires interventions beyond increasing farmer awareness. Policies should prioritize strengthening integrated crop–livestock production systems, reducing manure transportation costs, promoting localized manure collection centres, and improving extension services that encourage integrated nutrient management. Given the strong influence of farm location, interventions should also be tailored to local farming conditions rather than adopting uniform approaches across irrigation schemes. Such context-specific strategies are likely to enhance adoption of sustainable soil fertility management practices and contribute to increased agricultural productivity and resilience among smallholder farmers in Kenya's arid and semi-arid regions.

4.0 Conclusion

This study examined the determinants of animal manure adoption among smallholder farmers in Garbatulla Sub-County, Isiolo County, Kenya. The findings indicate that although the majority of farmers recognize the importance of animal manure for improving soil fertility, its adoption is primarily influenced by farm location and pesticide use rather than by socio-demographic characteristics such as age, gender, education, or household size. Farmers in the Rapsu irrigation scheme were significantly more likely to adopt animal manure due to better access to livestock and manure resources. The study further revealed that logistical and institutional challenges, including transportation costs, labour requirements, and limited extension support, constrain the effective utilization of animal manure despite its availability.

The study concludes that promoting sustainable soil fertility management requires context-specific interventions that improve farmers' access to manure resources and strengthen institutional support systems. Enhancing agricultural extension services, promoting integrated crop–livestock farming, improving manure handling and composting technologies, and establishing community-based manure collection and distribution systems would increase adoption among smallholder farmers. These interventions would contribute to improved soil fertility, increased agricultural productivity, enhanced climate resilience, and sustainable food security in Kenya's arid and semi-arid regions.

5.0 Recommendations

Based on the findings of this study, several recommendations are proposed to enhance the adoption of animal manure among smallholder farmers in Garbatulla Sub-County and similar arid and semi-arid regions.

First, county governments and agricultural extension agencies should strengthen extension services by providing regular farmer training on integrated soil fertility management, proper manure composting techniques, and efficient manure application practices. Improved extension support will enhance farmers' knowledge of the long-term agronomic and environmental benefits of animal manure and encourage its effective utilization.

Second, policymakers and development partners should improve farmers' access to animal manure by supporting integrated crop–livestock farming systems and establishing community-based manure collection, composting, and distribution centres. Such initiatives would reduce transportation costs, improve manure availability, and increase adoption, particularly among farmers with limited livestock ownership.

Finally, future agricultural programmes should adopt location-specific approaches when promoting organic soil fertility technologies. Since farm location significantly influenced manure adoption, interventions should be tailored to the unique socio-economic, institutional, and agroecological conditions of individual irrigation schemes. Future research should also investigate additional factors, such as farmers' perceptions, market incentives, and climate variability, using longitudinal and mixed-methods approaches to provide a more comprehensive understanding of sustainable soil fertility management among smallholder farmers.

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