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Influence of Farmland Factors on Adoption Intensity of Nutrient Management Practices in Tharaka-Nithi County, Kenya

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ABSTRACT

Background: The adoption of the recommended nutrient management practices can significantly improve agricultural production by up to 66.5% and potentially double farm yields. However, the rate of adoption of the practices is likely to be affected by farmland factors, including land ownership, farm terrain, soil type and farming system, among others. Although research on the adoption of agricultural practices has been widely undertaken, there is limited information on the probable influence of farmland factors on adoption intensity of nutrient management practices, especially among farmers in Tharaka Nithi County, Kenya. This study analyzed the adoption of nutrient management practices and examined the influence of farmland factors on the adoption of these practices among farmers in Tharaka Nithi County, Kenya.

Methods: A sample of 400 farmers was selected from a target population of 85,675 in the county through stratified random sampling. A semi-structured questionnaire was used to collect data from the respondents. Descriptive statistics were used to describe the results, while the Tobit regression model was used to analyze the inferential statistics using Stata version 15.

Result: The findings indicated that the use of cover crops was the most commonly practiced nutrient management practice (39.1%, n = 157), while precision nutrient management was the least adopted practice (0.7%, n = 3). The results also showed that the distance from the farm to the market (coefficient 0.036, $p<0.05$), mixed cropping (coefficient 0.069, $p<0.05$) and soil quality (coefficient -0.042, $p<0.05$) significantly influenced the adoption intensity of nutrient management practices. The adoption intensity of the practices was found to be low, primarily influenced by cropping systems. To enhance the adoption of nutrient management practices, national and county extension providers should design and implement training programs for farmers on soil nutrition.

Key words: Adoption intensity, Agricultural extension, Dissemination, Farmland factors, Nutrient management practices.

INTRODUCTION

Nutrient management is crucial for maintaining sustainable agriculture and enhancing soil health (Mamatha *et al.*, 2024). Efficient nutrient management, which combines the optimal use of fertilizers, crop residues and organic amendments, can precisely meet crop demands without harming the environment (Chejara *et al.*, 2021; Augustine *et al.*, 2026). For instance, integrating organic manure with a reduced dosage of inorganic fertilizers can reduce greenhouse gas (GHG) emissions by 11%-27% (Paramesh *et al.*, 2023). Additionally, the application of NPK together with organic amendments sustains soil health over a long period, boosting the levels of proteins, minerals and vitamins in crops beyond what single nutrients can achieve (Singh *et al.*, 2022; Osadebe *et al.*, 2025). Notably, nutrient management at the site-specific level further enhances these benefits by tailoring fertilizer applications to local soil fertility, environmentally friendly conditions and crop needs (Sarma *et al.*, 2024).

In the developed world, the adoption of nutrient management practices among farmers in cultivated farmland has increased from approximately 21% in 2017 to around 30% by 2023, although uptake varies significantly across regions (Noor *et al.*, 2019). In the Organization for Economic Co-operation and Development (OECD) countries, there was a considerable increase in the reliance on inorganic fertilizers, such as nitrogen and phosphorus, at 1.5% and 1.7% per year, respectively, from 2019 to 2021, emphasizing the urgent need for efficient nutrient-use management (Fawzy *et al.*, 2020; Lim *et al.*, 2021). Although moderate nitrogen surpluses have been maintained in some Western European countries at 50 kg/ha (Jordan-Meille *et al.*, 2023; Santo *et al.*, 2026), high-surplus nations

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have recorded a decline from over 300 kg/ha in the 1990s to approximately 200 kg/ha in recent years (Batool *et al.*, 2022).

In Sub-Saharan Africa (SSA), the uptake of nutrient management technologies is relatively low across the region, mostly linked to limited access to inputs, inadequate advisory services and high input costs (Chivenge *et al.*, 2022; Damanik and Tahitu, 2025). Studies have acknowledged the emergence of new technologies in East Africa, such as digital precision fertilization tools, tailored to advise on soil nutrition through smartphones and aid in soil analysis (Fue *et al.*, 2025; Sahoo *et al.*, 2026). However, the adoption of NMPs remains scattered and mostly experimental, with most farmers unable to access tools such as drones, sensors and Global Positioning System (GPS) devices that help in the management of soil nutrition (Onyango *et al.*, 2021).

In Kenya, farmers in regions such as Murang'a and Tharaka-Nithi have progressively adopted nutrient management technologies over time, with up to 97% acceleration, driven by factors such as access to extension services and education (Mwaura *et al.*, 2021; Ogutu *et al.*, 2020). In particular, NMPs such as the use of zai pits, organic-inorganic fertilizer application and mulching have been promoted in Tharaka-Nithi County under the framework of integrated soil fertility management (ISFM) (Kebenei *et al.*, 2023). However, despite the intervention, the adoption rate has stagnated in some areas due to various reasons related to farmer and farm characteristics (Astuti *et al.*, 2020).

Farmland-related factors play a crucial role in shaping farmers' decisions to adopt and maintain climate-smart agriculture (CSA) practices, such as nutrient management practices (Ntihinyurwa and de Vries, 2021; Matthew *et al.*, 2025). The high costs and logistical difficulties of managing these fragmented parcels further discourage the uptake of nutrient management practices, with adoption rates declining by as much as 25-30% in such contexts (Zhu *et al.*, 2020; Cishahayo *et al.*, 2024). Therefore, a conducive environment with secure tenure, appropriate land-use policies and farm sizes that enable efficient resource management is crucial for the successful implementation and sustainability of the CSA (Autio *et al.*, 2021). Existing studies have largely explored various factors influencing the adoption of nutrient management practices among farmers, such as institutional and socioeconomic factors. However, specific farmland factors and how they influence the uptake intensity of nutrient management practices, especially among farmers in Tharaka-Nithi County, Kenya, have received limited attention. This has left insufficient empirical evidence on the role that farmland-related factors play in farmers' uptake intensity of nutrient management practices. Therefore, this study sought to fill this gap by describing the intensity of NMPs' adoption and examining the likelihood of farmland factors influencing NMPs' adoption.

MATERIALS AND METHODS

The research was conducted in Tharaka-Nithi County, Eastern Kenya, within the Department of Agricultural Economics and Extension at the University of Embu. Data collection was carried out between May and July 2025. The area is characterized by low and unreliable rainfall, low agricultural inputs, declining soil health and general environmental degradation. The county's population is approximately 400,000, the majority of whom are farmers engaged in mixed farming. Most farmers are small-scale and rely heavily on bimodal rainfall to produce crops and livestock. The county's development is hindered by socio-economic factors such as land fragmentation, poverty and limited infrastructure.

This study utilized a stratified sampling procedure. Based on the sample size determination table developed by Krejcie and Morgan (1970), a sample of 384 farmers was selected from a target population of 85,675. The sample size was subsequently increased to 400 to account for potential attrition and non-response. Stratified random sampling was selected because the target population was stratified based on wards. The 15 wards in the county constituted the strata. To achieve a representative sample, 400 farmers were randomly selected proportionally from the 15 wards. Before data collection, the validity and reliability of the research instrument were checked. The reliability of the instrument tested using Cronbach's alpha resulted in the following coefficients: adoption intensity (α =0.721), distance from the farm to market (α =0.691), soil quality (α =0.672), land ownership (α =0.671), type of farming system (α =0.729), reason for farming (α = 0.683), infrastructure around the farm (α =0.721) and type of terrain (α =0.665). The instrument was validated by peers and experts in agricultural extension education in Kenya and content validity was ensured. Before data collection, however, the questionnaire was pretested among farmers outside the study area to assess the clarity, relevance and appropriateness of the items.

The data were analyzed using descriptive and inferential statistics. The descriptive results are presented in tables, frequencies and percentages. A Tobit regression model was used to determine the likelihood of farmland factors influencing the adoption intensity of nutrient management practices. The dependent variable, adoption intensity, had a lower limit, zero, when no nutrient management was adopted. Since the dependent variable was censored and bounded within a limited range, the Tobit model was deemed appropriate. The model specification is as follows:

$$Y_i^* = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots \beta nXn + \varepsilon \qquad \ldots(1)$$

Where,

Y_i^*= Latent (unobserved) variable representing true adoption intensity.

$\beta 0$ = Intercept term.

X1X2…. Xn = Independent variables.

$\beta 1$, $\beta 2 \ldots \beta n$ = Coefficients of the independent variables.

ε = Error term.

The adoption intensity of nutrient management was measured using a composite scoring approach. The approach was based on three parameters, including the number of management practices adopted, the size of land under NMP and the number of years NMPs have been used. Similar scoring approaches have been widely used in technology adoption studies to quantify levels of technology utilization among farmers (Mwaura *et al.*, 2021; Otara, 2023).

RESULTS AND DISCUSSION

Characteristics of farmers

The demographic characteristics were examined to describe the respondents. Table 1 shows the distribution of the sampled farmers based on their characteristics.

As shown in Table 1, the majority of the farmers (67.8%) were male, possibly because in the Tharakani-Nithi community, most households were headed by men. This also resulted from cultural bias, since in the Ameru community, women are not allowed to own land and/or make farming decisions. Similar findings on culture bias have been reported to deter women and youth from participating in agricultural activities (Gikunda *et al.,* 2021). The majority of the farmers who participated in farming were middle-aged, between 41 and 60 years old. This is because, at this age, farmers will have either acquired agricultural land through inheritance or by buying. Ji *et al.* (2023) also noted a significant degree of dependence on middle-aged family members from agricultural inheritance among farm household heads. The study, however, found low involvement of youth under 30 years (4.3%), although not employed, in agriculture, possibly due to their limited ability to acquire farming resources such as land and inputs involved in farming.

The results also indicated that the majority of farmers (60%) had attained secondary school education or above, meaning that most farmers who engaged in farming had formal education. This also implies that many farmers had the requisite educational background needed for the adoption and practice of agricultural innovations (Olum *et al.*, 2020). Farmer education is key to the acquisition and adoption of agricultural technologies, since knowledge and skills are required. Most farmers owned farms ranging from 2 to 3 acres, while a smaller percentage had farms ranging from 3 to 5 acres. This implies that many of the farmers were small-scale. This scale of farming has been contributed by land fragmentation and subdivision, witnessed in the Tharaka-Nithi community, especially during the inheritance process. The small size of land not only affects the scale of production but also technology adoption, such as mechanization. As such, many farmers in the study area engage in subsistence agriculture. These results were in concurrence with the study by Mayele *et al.* (2024), who noted that land fragmentation and continuous subdivision of farms led to small-sized land holdings, which harmed productivity.

Since many of the farmers were middle-aged, most of them owned the land with title deeds. Permanent ownership of land is vital for farmers in making decisions to adopt and sustain innovations. Farmers operating on leased lands or without title deeds are reluctant to make permanent investments in the land. Therefore, the adoption of practices, including nutrient management, is likely to be affected by the land tenure system. The findings confirm those of Gikunda (2021), who found that the adoption and sustenance of agricultural practices are dependent on land tenure, among other factors.

Intensity of nutrient management practices' adoption

The first objective was to describe the intensity of NMPs adoption. The intensity of NMPs' adoption was examined using three parameters: the number of management practices adopted, the size of land under NMP and the number of years NMPs have been used. The practices examined included fertilizer application, soil testing, organic amendments, cover cropping, crop rotation and precision nutrient management. Regarding the number of nutrient management practices, farmers who adopted zero NMP were awarded one score,1 to 3 practices; two scores,3 to 5 practices; three scores and above 5 practices four scores.

In terms of the size of land under NMP, farmers who adopted NMPs on less than one acre were awarded one

Table 1: Farmers' demographic characteristics (N =400).

Variable	Freq. (*f*)	Per cent. (%)
Gender		
Female	129	32.2
Male	271	67.8
Age(blanket)		
20-30 yrs	17	4.3
31-40 yrs	37	9.2
41-50 yrs	190	47.5
51-60 yrs	128	32.0
61 and above	28	7.0
Education level		
None	16	4.0
Pry school	51	12.7
Secondary school	83	20.8
Certificate	82	20.5
Diploma	56	14.0
Bachelors	86	21.5
Master's degree	20	5.0
Doctorate	6	1.5
Farm size (in acres)		
<1	18	4.5
2-3	205	51.3
3-5	161	40.3
Above 5	16	4.0
Ownership status (title deed)		
Yes	352	88.0
No	48	12.0

score, 2-3 acres two scores, 3-5 three scores and above 5 acres, four scores. Respondents who had adopted NMP for less than 5 years were awarded one score, 5-10 years two scores, 10-15 years three scores and 15-20 years four scores. A score of 1 represented low adoption, 2 scores represented slight adoption, 3 scores represented moderate adoption and 4 scores represented full adoption, as shown in Table 2.

As presented in Table 2, a small portion of farmers (5.5%) did not adopt any nutrient management practice. This group possibly represents laggards who are resistant to change and slow to adopt new agricultural practices. Some of these farmers may have been old and less educated. The non-adoption may also have resulted from farmers' inability to visualize how the practices' applicability on the farm will help them realize better returns in the short to medium run, especially in the study area. Adnan *et al.* (2025) also reported that many farmers may lack awareness and understanding of smart farming technology and their benefits in crop productivity. The results showed that most of the farmers (78%) adopted at least one to three NMPs, suggesting a slight adoption level. This may be due to the declining sizes of agricultural land, inadequate access to agricultural inputs and limited access to extension services. The results also indicated that very few farmers moderately (8.5%) and fully adopted (8%) the NMPs. These farmers may have recognized the advantages of adopting multiple nutrient management practices to enhance soil health and thus improve agricultural production.

Almost half of the farmers (47.3%) had adopted NMPs on between 1 and 2 acres of their land. This showed that the majority of farmers were willing to allocate a significant portion of their farmland to nutrient management practices, indicating a slight adoption intensity. The results showed that about a third of respondents (34.3%) applied NMPs on less than one acre of their land. This may have resulted from the unavailability of resources, inadequate access to extension services and an impermanent land tenure system, among other factors (Wang *et al*, 2025). A smaller proportion of respondents (16.3%) applied NMPs over 2 to 3 acres, indicating a moderate adoption intensity. These farmers may have had better access to information, been more educated and had better access to farm inputs. Only a small fraction of farmers (2.1%) were able to apply NMPs on more than 3 acres. This represented progressive farmers who apply NMPs as a core part of their farming strategy and are willing to take risks.

Table 2: Level of nutrient management practices adoption (N=400).

	Score	Freq. (*f*)	Per cent. (%)
Number of NMPs adopted			
None	1	22	5.5
1 to 3	2	312	78
3 to 5	3	34	8.5
above 5	4	32	8
Size of land under NMPs (in acres)			
<1	1	137	34.3
1 to 2	2	189	47.3
2 to 3	3	65	16.3
Above 3	4	9	2.1
Years after adoption			
Below 5	1	10	2.5
5 to 10	2	22	5.5
10 to 15	3	226	56.5
15 to 20	4	142	35.5

The majority of farmers (56.5%) had practiced NMPs for 10-15 years, with a significant proportion (35.5%) having practiced for 15 to 20 years. This high-intensity adoption showed that the majority of farmers had long-term integration of NMPs in the cropping systems. Few respondents (2.5%) had adopted the practices for less than 5 years, while a small portion (5.5%) had between 5-10 years since they adopted the practices. The variation in the number of years these farmers had adopted the practices is a clear confirmation of Rogers' (2003) categorization of adopters, where some are quick to adopt (innovators) while others take a long time to apply the practices (laggards).

Influence of farmland factors on adoption intensity of nutrient management practices

Objective two sought to determine the likelihood of selected farmland factors influencing the adoption intensity of nutrient management practices among farmers. A Tobit regression model was run to address the research question, as shown in Table 3.

As shown in Table 3, the infrastructure around the farm (*Coef.* 0.05, $p<0.05$), the distance from the farm to the market (*Coef.* 0.04, $p<0.05$) and farm type (*Coef.* 0.07, $p<0.05$) positively and significantly influenced the adoption of NMPs. This implied that farmers who had access to good infrastructure near their farms, such as roads and irrigation systems, exhibited higher adoption intensity of nutrient management practices. For instance, access to good roads makes it easier for farmers to market their produce, which boosts their morale to increase production through the adoption of recommended practices (Kaiser and Barstow, 2022).

Farmers located near the markets were more likely to adopt NMPs than those living far from the markets because they incurred less transportation cost for inputs and it was easier to sell their produce, especially perishable ones. Closeness to the markets improved farmers' access to inputs and extension services. This served as an incentive for the adoption of NMPs, as reported by Kumar *et al.* (2020). Farmers in remote areas faced significant challenges in accessing fertilizers and other inputs, which deterred them from adopting integrated soil fertility management practices (Kiprotich *et al.*, 2024).

The results further indicated that the type of farming system significantly influenced the adoption of NMPs. Farmers engaged in mixed farming were more likely to

Table 3: Tobit regression for farmland factors and adoption intensity of nutrient management.

Adoption intensity	Coef.	St. Err.	t-value	p-value
Number of nutrient management practices	.176	.023	7.79	.000
Land ownership	-.021	.013	-1.56	.12
Title deed	-.037	.041	-0.91	.363
Nature of the farm	-.022	.017	-1.30	.194
Type of terrain	-.012	.025	-0.46	.646
Type of soil	-.069	.037	-1.88	.061
Soil quality perception	-.042	.021	-1.98	.049
Natural features on a farm	.003	.011	0.31	.758
Infrastructure around the farm	.050	.017	2.84	.005
Market distance	.036	.014	2.50	.013
Weather conditions	.018	.017	1.05	.294
Reason for farming	-.024	.023	-1.04	.297
Type of farming system	.069	.018	3.92	.000
Constant	1.733	.161	10.75	.000
var (e)	.064	.005	.b	.b

Number of obs = 400; LR chi2(13) = 102.41; Prob > chi2 = 0.0000 Log likelihood = -83.975089; Pseudo R2 = 0.379.

adopt NMPs than those practicing crop production only. Those who kept livestock and produced crops applied manure to crops and practiced cover cropping, where the cover crops, such as sweet potato, served as livestock feed. Farmers who produced crops alone were sometimes unable to fertilize their farms adequately, as some could not afford manure or inorganic fertilizers. Similar findings were also reported by Mucheru-Muna *et al.* (2021), that mixed farming has advantages over monocropping practices.

The results also indicated that soil quality played a key role in the adoption of NMPs (*Coef.* -0.042, $p<0.05$). As the quality of the soil improved, most farmers tended to apply fewer NMPs. For instance, most farmers would apply manure and stop the application when they thought the soil had enough. In situations where the soil nutrients were depleted, farmers applied more NMPs to the fields. It is also worth noting that soil quality management was dependent on farmers' understanding. Farmers who were more knowledgeable about climate-smart practices that improved soil quality, such as soil conservation practices, adopted more of these technologies than those who had little knowledge, as noted by Oparaojiaku *et al.* (2025).

According to the findings, land ownership, title deed, nature of the farm, terrain of the farm, type of soil, natural features on a farm, weather conditions and reasons for farming were not significant predictors of NMPs adoption intensity ($p>0.5$). These results suggested that farmers' decisions to adopt nutrient management practices were mostly predicted by external factors rather than by the inherent characteristics of their farmland (Chichongue *et al.*, 2020).

CONCLUSION

To improve farm productivity, farmers in Tharaka Nithi County have adopted a variety of NMPs, including soil testing, organic amendments, cover cropping, crop rotation and precision nutrient management. Among these practices, cover cropping was the most commonly adopted, whereas precision nutrient management was the least adopted. However, the overall adoption intensity of NMPs was low among farmers. Therefore, there is a need for county extension agents to design and implement training programs on soil nutrition. Additionally, farmers need to diversify their enterprises to raise more money to cater for farm inputs and also cushion them in times of crop failure or when the prices of some produce fluctuate. Farmland factors, including market distance, infrastructure around the farm, type of farming system and soil quality, mainly influenced the adoption of NMPs. The county and national governments should improve the condition of the infrastructure by constructing better roads that are motorable, building new markets, improving the condition of existing markets, providing access to extension services and farm inputs. With the help of extension agents, farmers need to explore better markets for their produce to secure higher prices that will motivate them to adopt NMPs. Farmland factors, such as land ownership, title deeds, nature of the farm, terrain, type of soil, natural features, weather conditions and reasons for farming, did not influence the adoption intensity of nutrient management practices among the farmers.

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Disclaimers

The views expressed in this article are those of the authors and do not necessarily reflect those of their affiliated institutions. The authors are responsible for the accuracy of the data and information presented.

Informed consent

Informed consent was obtained from all participants before data collection. The purpose of the study was clearly explained and participation was voluntary. Participants were assured of confidentiality and anonymity. The study procedures were conducted in accordance with ethical research standards.

Conflict of interest

The authors have declared no conflict of interest regarding the publication of this manuscript.

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