EMPLOYING BINARY LOGISTIC REGRESSION ANALYSIS TO MODEL THE EFFECT OF DIFFERENT TREATMENTS ON QUALITY OF FRENCH BEANS (*PHASEOLUS VULGARIS)* PRODUCE

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ABSTRACT

French beans (Phaseolus vulgaris L.) is a significant agricultural product in developing countries, contributing to economic development, employment, and exports. Despite extensive research on French bean farming in Kenya, limited attention has been given to factors influencing produce quality. This study employed a binary logistic regression model to evaluate the effect of slope, soil deposition, and different mulching materials: Farmers' Practice (no mulch), polymer mulch, tea leaves mulch, and grass mulch on French bean quality in Ol' Lessos Ward, Nandi Hills Sub-County, Kenya. Quality was defined as the absence of disease incidence. Field experiments measured slope percentage, soil deposition (g), yield (kg/plant), and disease incidence across treatments. Results revealed that slope alone had no significant effect on quality, but mulching significantly reduced soil deposition, increased yield, and lowered disease incidence compared to Farmers' Practice. Polymer mulch recorded the highest yields and lowest soil deposits, while tea leaves and grass mulches also improved performance. Logistic regression analysis yielded a Cox and Snell's R^2 was 0.14 and Nagelkerke's $R^2$was 0.63 and the Nagelkerke R^2 which adjusts Cox and Snell's value to a scale ranging from 0 to 1 was 0.628, suggested that the model had a strong explanatory power and a good overall fit. The findings underscore the critical role of mulching materials in enhancing French bean quality, independent of slope effects. Adoption of mulching, particularly polymer mulch, is recommended for sustainable production and improved marketability.

Keywords: French Bean, Mulching, Binary Logistic Regression, Soil Deposition, Slope, Quality.

INTRODUCTION

Globally French bean *(Phaseolus vulgaris*) production is approximately 23.3 million metric tonnes annually, with major producers including China, India, Indonesia, and the United States (FAO, 2021). China is the largest producer, accounting for around 30% of global production, followed by India, Brazil, and Mexico (FAO, 2021). In Africa, production is more export-oriented, with Kenya, Ethiopia, Egypt, and Morocco leading due to favorable climates and access to European markets. Kenya is the top producer and exporter in East Africa accounting for over 60% of Africa's French bean exports (FAO 2021).

Several studies have been conducted on French beans in Kenya on employing logistic regression models to analyze binary outcomes related to farmers' behaviors and perceptions (Wambugu *et* al., 2017, Kihoro *et* al., 2019. A study done in Kirinyaga County used binary logistic regression to investigate determinants of income-poverty among smallholder French bean farmers (Kibet *et al*., 2019). Another study (Shimon, 2016) applied binary logit regression to examine factors influencing smallholder farmers' perceptions of climate change drought, delayed rains, pests, and floods in Central and Eastern Kenya, tracking how Global-GAP certification and access to extension and credit shaped those climate-change risk perceptions. None of the studies have considered factors influencing quality of French beans.

The quality of French bean produce is often compromised due to the inadequate implementation of agronomic soil conservation measures during cultivation (Karavidas *et* al 2022). Practices like cover cropping, contour ploughing, and terracing are known to influence crop productivity, yet their specific influence on the quality of French beans produce due to the improvement of environmental conditions (Blanco-Canqui, 2018). Existing studies have largely prioritized optimization of yield and managing pestcontrol (Smith & Jones (2023), with limited attention to quality parameters like nutritional value, flavor and bean appearance. This gap has limited the development of measures that address productivity and quality of the French bean produce.

Binary logistic regression model analyses the interaction between a single response variable and several predictor variables and examines possible connections between the variables. The response variable is provided as dichotomous qualitative data (Hosmer et al. 2013), where 1 indicated the presence of a characteristic and 0 indicated the absence of a personality trait. In other words, a value can be either positive or negative. That is to say, the response variable can either be present or absent. Binary logistic regression model is typically utilized (Hosmer et al 2013) when the response variable creates two categories with values of 0 and 1 For this study, 0 was for presence of diseases and hence no quality while 1 represented quality where there was no disease incidences recorded.

MATERIALS AND METHODS

Study Area

Location

It is administratively divided into four wards and spans an area of 432 km², Nandi Hills Sub County is one of the six Sub Counties within Nandi County. The study employed French beans (*Phaseolus vulgaris*), which are commonly cultivated in the region due to the favourable climatic and soil conditions. The sub-county had a population of 107,724 people as reported by the Kenya National Bureau of Statistics (KNBS) in 2019. Ol' lessos Ward is located in the northern part of Nandi Hills Sub County, which is one of the six Sub Counties in Nandi County, Kenya. Nandi Hills Sub County covers an area of 432 km² and is divided into four wards, with Ol' Lessos Ward situated towards the northeast of this sub-county according to the Nandi County Development Plan of 2019. The ward lies at the foothills of the Nandi Hills, contributing to its unique topography and fertile agricultural land. Ol' Lessos benefits from its strategic location with access to major roads, including the Eldoret-Kapsabet road, which connects it to surrounding areas and facilitates its economic activities.

Climate

The climate of Nandi Hills Sub County is marked by a range of temperatures from 10ºC to 30ºC, creating a temperate environment conducive to agriculture. The region enjoys a lengthy cropping season from March to October, benefiting from intermediate rains that are divided into two distinct periods (KNBS 2019). The first rainy season usually starts at the end of March, and the second at the end of June. Annual rainfall in Nandi Hills varies significantly, ranging from 624.9 mm to 1,560.4 mm, with peak rainfall occurring between March-May and July-September. This ample and well-distributed rainfall supports the region's agricultural activities, contributing to its fertility and the successful cultivation of various crops. The moderate temperatures and consistent precipitation make Nandi Hills Sub County an ideal location for both subsistence and commercial farming.

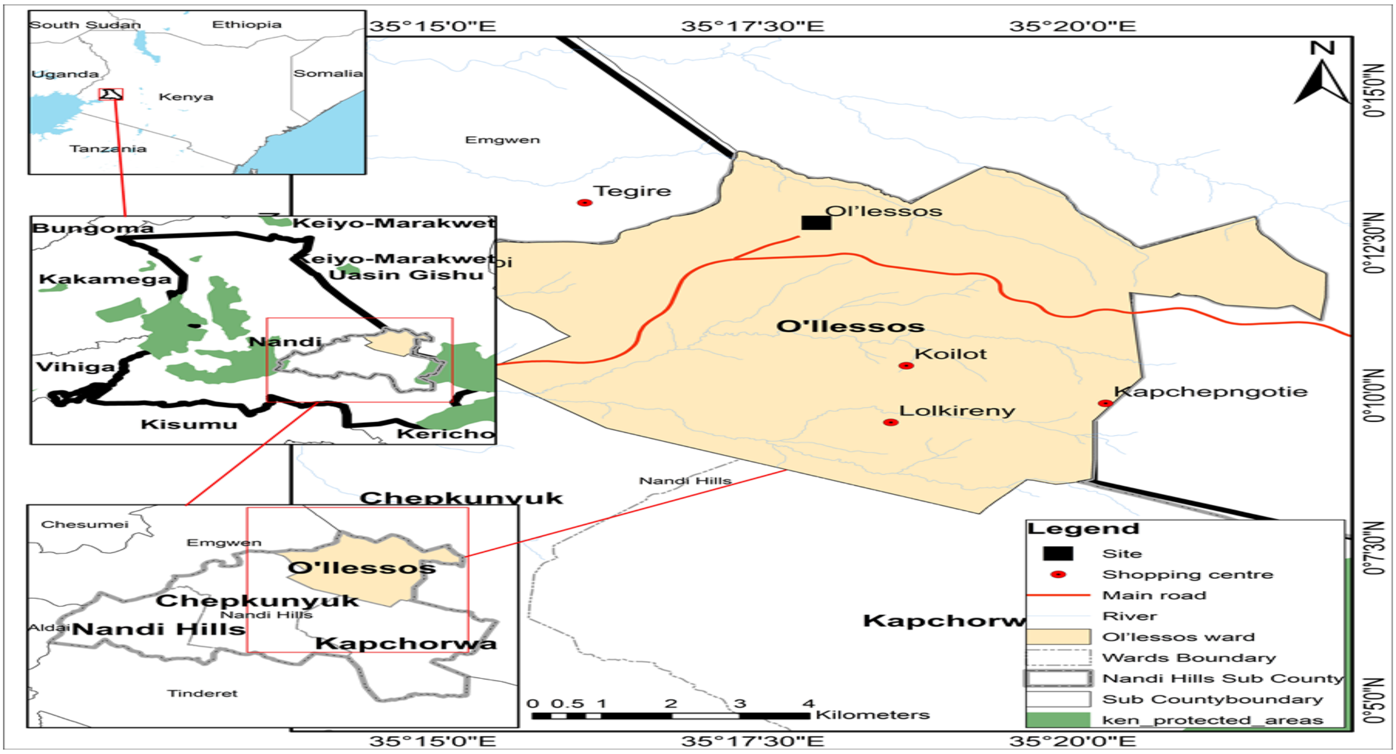

Figure 2.1: Study Area Map Showing Location of Ol'lessos in Nandi Hills Sub County, in Nandi County, Kenya. Source: Author, 2024

Layout of Plots

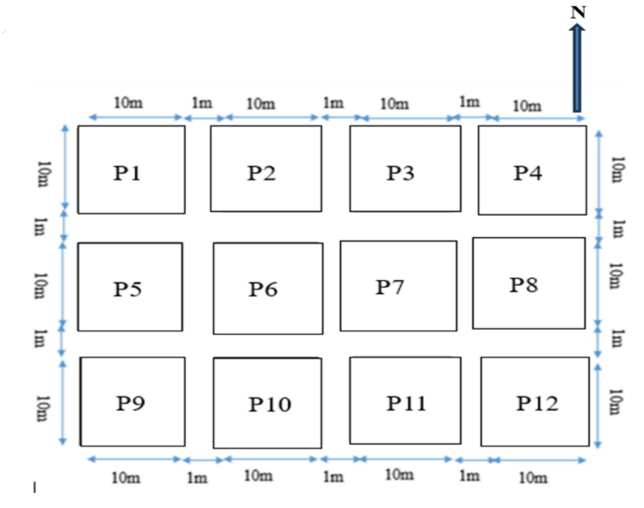

***Figure 2.2**: Plot Layout*

Logistic Regression

A regression model is a statistical technique used to evaluate the effect of independent variables on a dependent variable. This method is used to assess the relationship between these two variables. The logistic expression is represented by Equation (Hosmer et al 2013) Equation 1:

$$Y_i = logit\ P_i = LN\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n \quad \text{Eqn 1}$$

Where:

Y=dependable variable that has only two outcomes (binary).

Y has a value of 1 for yes and 0 for no

β= coefficients for independent variables x_i for i = 0…, k.

P_i = the probability and is calculated using Equation 2:

$$P_i = \frac{EXPONENTIAL(\beta_0+\beta_1 x_1+\cdots+\beta_n x_n)}{1+EXPONENTIAL(\beta_0+\beta_1 x_1+\cdots+\beta_n x_n)} \quad \text{Eqn 2}$$

Test sample size (n) for logistic expression is given by n > 10(k+1) where k is the number of independent variables (Borucka, 2019) and in no case should the sample size be less than 100 (Park, 2013). Continuous variables have more than two outcomes Table 2.1.

***Table 2.1**: Independent Variables*

Variable	Category	Detail
X_1 Treatment	Continuous variable	X_1 (1): Farmers' practice X_1 (2): Polymer mulch X_1 (3): Tea leaves mulch X_1 (4): grass mulch
X_2 Percent slope	Continuous variable	X_2 (1): 0.2-5.4
X_3 Soil deposits (grams)	Continuous variable	X_3 (1): 0.9-8.6

All Calculations were done using Microsoft Excel® following the formulae outlined by Zaiontz, (2020). Since there were three parameters, four (coefficients) were chosen. β_0 as a constant coefficient, β_1 coefficient for treatment type, β_2 percentage slope, β_3 amount of soil deposited on the leaves and pods in grams Equation 3.

$$\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 \quad \text{Eqn 3}$$

The probability (p_i) was calculated using Equation 4:

$$p_i = \frac{1}{1+e^{-(\beta_0+\beta_1 x_1+\beta_2 x_2+\beta_3 x_3+\beta_4 x_4)}} \quad \text{Eqn 4}$$

The log-likelihood (LL) statistic was calculated using

Equation 5:

$$LL = \ln L = [y_i ln(p_i) + (1-y_i)\ln(1-p_i)] \quad \text{Eqn 5}$$

The summation of log-likelihood was done to get LL_1. The cell with the sum was maximized using excel solver by changing the cell with the coefficients β_0, β_1, β_2, β_3 and β_4. The checkbox for Make Unconstrained Variables Non-negative was unchecked.
The Wald statistic was calculated using Equation 6:

$$Wald\ statistic = \frac{\beta^2}{Standard\ error^2} \quad \text{Eqn 6}$$

To test the model there was need to find first, n_0 as number of observations with values 0 and n_1 as number of observations with value 1. Adding n_0 and n_1 gave n the total sample size.

Secondly, LL_0which refers to a model with only the intercept β_0 and was computed in Excel using the Equation 7:

$$LL_o = \ln L_0 = n_0 \ln\frac{n_0}{n} + n_1 ln\frac{n_1}{n} \quad \text{Eqn 7}$$

After finding LL_0 and LL_1 the next stage was to compute the test statistics for the model. The formula for pseudo-R^2 statistics is Equation 8:

$$R_L^2 = 1 - \frac{LL_1}{LL_0} \quad \text{Eqn 8}$$

Cox and Snell's R^2 was computed using Equation 9:

$$R_{CS}^2 = 1 - e^{-\frac{2}{n}(LL_1 - LL_0)} \quad \text{Eqn 9}$$

Nagelkerke's R^2 was computed using Equation 10:

$$R_N^2 = \frac{R_{CS}^2}{1 - e^{2LL_0/n}} \quad \text{Eqn 10}$$

RESULTS AND DISCUSSION

In farmers practice non mulched (Table 3.1), the slopes varied from 0.2 percent (P1) to 4.0 percent (P10). The mean slopes per plot were 0.27, 1.27 and 3.8 percent for P1, P8 and P10, respectively. Farmers' practice plots had average slope of 1.78±1.58 percent. The mass of soil (grams) deposited on leaves of ten plants ranged from 8.0 g to 8.6 g, both being recorded in Treatment 10. The average masses per plot for every ten plants were 8.3g, 8.27g, and 8.27g for P1, P8 and P10, respectively with the mean average mass for farmers' practice being 8.28±0.17g. The yield (kg per plant) varied from 0.28 in plot 10 to 0.81 in plot 1. Average yields (kg per plant) for each plot were 0.74, 0.41 and 0.31 for P1, P8 and P10, respectively with the average yields for farmers' practice of 0.49 ±0.20 kg per plant. Disease incidences for every plot varied from 1 in plot 10 to 3 in plot 1 and 8. Average disease incidences per plot were 3, 3 and 1 for P1, P8 and P10, respectively with the average disease incidences for farmers' practice of 2.33 ± 1.0 per plant.

Table 3.1: *Farmers' Practice (Non-Mulched) Plots*

Plot	Slope %	Amount of soil deposited in g per 10 plants	Yield in kg per plant	Disease incidences
P1	0.20	8.30	0.81	3
P1	0.40	8.20	0.69	3
P1	0.20	8.40	0.72	3
P8	1.20	8.40	0.49	3
P8	1.40	8.20	0.41	3
P8	1.20	8.20	0.43	3
P10	3.60	8.00	0.32	1
P10	4.00	8.20	0.28	1
P10	3.80	8.60	0.29	1
Average	1.78	8.28	0.49	2.33
Standard deviation	1.49	0.16	0.19	0.94

Polymer Mulchs

In polymer mulch treatment (Table 3.2), the slopes varied from 0.8 percent(P2) to 3.8 percent (P11). The mean slopes per plot were 0.80, 1.53 and 3.50 percent for T2, T5 and T11, respectively. Polymer plots had average slope of 1.94±1.25 percent. The mass of soil (grams) deposited on leaves of ten plants ranged from 0.9 g in P2, P5 and P11 to 1.20 g in P2 and P11. The average masses per plot for every ten plants were 1.03g, 1.00g, and 1.03g for P2, P5 and P11, respectively with the mean average mass for polymer treatment being 1.02 ± 0.12g. The yield (kg per plant) varied from 1.05 in plot P11 to 1.48 in P2. Average yields (kg per plant) for each plot were 1.41, 1.27 and 1.13 for P2, P5 and P11, respectively with the average yields for polymer treatment of 1.27 ± 0.14 kg per plant. Disease incidences for every plot varied from 0 in P11 to 1 in P2, P5 and P11. Average disease incidences per plot were 1, 1 and 0.67 for P2, P5 and P11, respectively with the average disease incidences for polymer mulch treatment of 0.89 ± 0.33 per plant.

Table 3.2: *Polymer Treatment*

Plot	Slope %	Amount of soil deposited in g per 10 plants	Yield in kg per plant	Disease incidences
P3	0.20	3.30	1.10	3.00
P3	0.40	3.20	1.32	2.00
P3	0.60	3.30	1.20	3.00
P6	1.40	3.30	0.77	3.00
P6	1.80	3.20	0.92	3.00
P6	1.60	3.30	0.84	3.00
P12	2.80	3.10	0.76	3.00
P12	2.60	3.20	0.79	2.00
P12	3.20	3.30	0.72	3.00
Average	1.62	3.24	0.94	2.78
Standard deviation	1.09	0.07	0.22	0.44

Tea Leaves Mulch

In tea leaves mulch treatment (Table 3.3), the slopes varied from 0.3 percent (P3) to 3.20 percent(P12). The mean slopes per plot were 0.40, 1.60 and 2.87 percent for P3, P6 and P12, respectively. Tea leaves mulched plots had average slope of 1.62 ± 1.09 percent. The mass of soil (grams) deposited on leaves of ten plants ranged from 3.10 g in P12 to 3.30 g in P3 and P6. The average masses of soil deposits per plot for every ten plants were 3.27g, 3.27g, and 3.20 g for P3, P6 and P12, respectively with the mean average mass of soil deposits for tea leaves treatment being 3.24 ± 0.07g. The yield (kg per plant) varied from 0.72 in P12 to 1.32 in P3. Average yields (kg per plant) for each plot were 1.21, 0.84 and 0.76 for P3, P6 and P12, respectively with the average yields for tea leaves treatment of 0.94 ± 0.22 kg per plant. Disease incidences for every plot varied from 2 in P3 to 3 in P3, P6 and P12. Average disease incidences per plot were 2.67, 3, and 2.67 for P3, P6 and P12, respectively with the average disease incidences for tea leaves mulched plots of 2.78 ± 0.44 per plant.

Table 3.3: *Tea Leaves Mulch Treatment*

Plot	Slope %	Amount of soil deposited in g per 10 plants	Yield in kg per plant	Disease incidences
P3	0.20	3.30	1.10	3.00
P3	0.40	3.20	1.32	2.00
P3	0.60	3.30	1.20	3.00
P6	1.40	3.30	0.77	3.00
P6	1.80	3.20	0.92	3.00
P6	1.60	3.30	0.84	3.00
P12	2.80	3.10	0.76	3.00
P12	2.60	3.20	0.79	2.00
P12	3.20	3.30	0.72	3.00
Average	1.62	3.24	0.94	2.78
Standard deviation	1.09	0.07	0.22	0.44

Grass Mulch

In grass mulch treatment (Table 3.4), the slopes varied from 0.4 percent (P4) to 5.4 percent(P9). The mean slopes per plot were 0.47, 1.60 and 4.80 percent for P4, P7 and P9, respectively. Grass mulched plots had average slope of 2.29 ± 2.02 percent. The mass of soil (grams) deposited on leaves of ten plants ranged from 2.50 g in P9 to 2.70 g in P4, P7 and P9. The average masses of soil deposits per plot for every ten plants were 2.63g, 2.63g, and 2.60 g for P4, P7 and P9, respectively with the mean average mass of soil deposits for grass mulch treatment being 2.62 ± 0.07g. The yield (kg per plant) varied from 0.72 in P9 to 1.30 in P4. Average yields (kg per plant) for each plot were 1.27, 0.89 and 0.76 for P4, P7 and P9, respectively with the average yields for grass mulch treatment of 0.97 ± 0.23 kg per plant. Disease incidences for every plot varied from 2 in treatment 4 and 9 to 3 in treatment P4, P7 and P9. Average disease incidences per plot were 2.33, 3, and 2.33 for P4, P7 and P9, respectively with the average disease incidences for grass mulched plots of 2.56 ± 0.53 per plant.

Table 3.4: *Grass Mulched Treatment*

Plot	Slope %	Amount of soil deposited in g per 10 plants	Yield in kg per plant	Disease incidences
P4	0.40	2.60	1.20	3.00
P4	0.60	2.60	1.30	2.00
P4	0.40	2.70	1.30	2.00
P7	1.40	2.60	0.84	3.00
P7	1.60	2.60	0.91	3.00
P7	1.80	2.70	0.91	3.00
P9	3.60	2.50	0.72	3.00
P9	5.40	2.60	0.78	2.00
P9	5.40	2.70	0.78	2.00
Average	2.29	2.62	0.97	2.56
Standard deviation	2.02	0.07	0.23	0.53

Analysis of Variance

There was no significant difference between the slopes for the four treatments, however, there was significant difference in amount of soil deposits, yield and diseases incidences for the treatments. On soil deposits it was found that Farmers Practice and polymer had significant difference, also, Farmers practice and tea leaves had significant difference. In addition, Farmers practice and grass had significant difference in terms of soil deposits. In terms of quantity of soil deposited, there was significant difference between Polymer and tea leaves, polymer and grass. Further there was significant difference in the amount of soil deposits between grass mulched and tea leaved plots.

There was significant difference between yield from farmers practice and polymer, farmers practice and tea leave as well as with grass mulched treatments. Comparing polymer and tea leaves there was significant differences as well as with polymer and grass mulched plots. However, there was no significant differences between yields of tea leaves and grass mulched plots in terms of yields. In terms of disease incidences, there was a significant difference between Farmers practice and polymer treatment. There was no significant difference between farmers practice and tea leaves plots. There was no significant difference in disease incidences between farmers practice and grass mulched plots. Comparing polymer and tea leaves there was significant differences in disease incidences. Also, polymer and grass had significant differences. When grass and tea leaves were compared, there was no significant difference.

The study established that slope alone had no significant influence on the measured variables: soil deposition, yield, and disease incidence across the various treatments. This could be attributed to the short plot lengths or effective control of surface runoff across all treatments. Nziguheba et al. (2020) suggested that the influence of slope may become secondary when conservation measures such as mulching are effectively implemented. however, the type of mulch used had a notable impact on soil deposition, yield, and disease incidence. These findings underscore the crucial role of mulching materials in influencing micro-environmental conditions, independent of topography.

A review by Singh and Patel (2024) emphasized that mulch efficiency is more dependent on coverage and thickness than on slope gradient. This indicated that mulch enhances infiltration, reduce evaporation, and limited soil splash thereby preventing soil degradation across various landscapes. Furthermore, East Africa regional studies, (2019–2024), covering Kenya, Uganda and Rwanda demonstrated that the combined use of terraces, contour grass strips, and organic mulching reduced soil loss by between 50% and 95%.

Soil Deposition

Significant differences in soil deposition were observed between the Farmers' Practice (no mulching) and other mulch treatments (polymer, tea leaves, and grass) indicated that Organic and synthetic mulches effectively reduced surface runoff and soil splash. This aligned with findings by Li et al. (2022), who reported that mulch application significantly reduced soil erosion in sloped vegetable fields in China, especially during heavy rains. Similarly, Mutetwa et al. (2023) found that polymer mulch significantly reduced soil loss compared to bare soil, especially on sloped areas. These results are consistent with the current findings, where polymer mulch outperformed the Farmers' Practice in minimizing soil deposition.

Yield Performance

Higher yields were recorded in mulched plots and were associated with mulching treatments particularly polymer and grass mulches. This concurs with earlier findings by Makokha et al. (2022) in Western Kenya, which showed that mulching conserved soil moisture, moderated soil temperature, and promoted nutrient availability, leading to improved French bean yields. Farmers' Practice yield decreased likely due to increased soil erosion, compaction and moisture losses. Ouma et al. (2016) similarly found that a lack of proper soil management practices, including mulching, significantly reduced productivity among smallholder French bean farmers in Kenya.

Disease Incidence

Disease incidence differed significantly across all the treatments. Mulching reduced soil splash, a key vector for soil borne pathogens which reduced leaf and pod contamination. This concurred with further findings by Kimani et al. (2021), who reported that organic mulches act as physical barriers, interrupting the soil to plant transmission of fungal spores and bacteria, lowering disease prevalence in French beans. Additionally, Emaru et al. (2024) demonstrated that improved soil management practices such as mulching, reduced pest infestations and enhanced pod quality.

Correlation

Amount of soil deposits were negatively correlated to treatments and percent slope of the plots. Table 3.5 shows that treatment were positively correlated in terms of slope. All the correlation values were less than 0.5 and hence there was no possibility of multi-collinearity.

Table 3.5*: Correlation for Variables*

	Treatment	Percent slope	Soil deposits (g)
Treatment	1.000	0.093	-0.607
Percent slope		1.000	-0.064

Soil deposits (g)	1.000

A logistic regression (Equation 11) with parameters shown in Table 3.6 modelled how different treatment methods as an independent parameter: Farmer's Practice, Polymer Mulch, Tea Leaves Mulch, and Grass Mulch affected the quality of French beans (*Phaseolus vulgaris*) using soil deposits, and percentage slope as other independent variables. The dependent variable was quality which was inferred by absence of disease incidences.

$$Logit\ for\ probability\ = -1.000 - 3.220X_1 + 3.134X_2 - 4.119X_3$$

Eqn 3.6

***Table 3.6**: Logistic Expression Parameters*

Variable	B	Standard error	Wald statistic	Exponential (β)
Constant	-1.000	10.948	0.008	
Treatment	-3.220	10.089	0.102	0.040
Percent slope	3.134	10.903	0.083	22.973
Soil deposits(g)	-4.119	15.164	0.074	0.016

From Table 3.7, the pseudo-R^2 was higher than 0.2 and meant that the model results were acceptable. It also means that the independent factors could explain 0.598 for the quality of French beans based on the presence of diseases. Cox and Snell's R^2 was 0.14 and Nagelkerke's R^2 was 0.63 and the Nagelkerke R^2 which adjusts Cox and Snell's value to a scale ranging from 0 to 1 was 0.628, suggested that the model had a strong explanatory power and a good overall fit and was higher while Odindo et al. (2025), reported a Nagelkerke R^2 of 0.376 for a logistic model with moderator variables, suggesting moderate explanatory power. In the other hand The West Pokot resilience study (2025), recorded an exceptionally high Nagelkerke R^2 of 0.96, indicating a very strong model fit in a livelihood prediction.

***Table 3.7**: Logistic Model Test Parameters*

Index	Value
p-value	0.02 <0.05
LLo	-4.569
LL1	-1.839
-2 log likelihood	3.678
Cox and Snell's R^2	0.141
Nagelkerke's R^2	0.628
pseudo-R^2	0.598

The model yielded a p-value of 0.02, indicating statistical significance at the 5% level. This suggests that the likelihood of the observed fit occurring by random chance is only 2%, hence the model provides a meaningful explanation of the outcome variable.

A study by Ngetich and Rangita (2025), on membership churn in professional organizations in Kenya, recorded a Nagelkerke $R^2 \approx 0.722$ suggesting a strong model fit and was higher than what the study recorded Nagelkerke R^2 of 0.628 supporting a strong model fit.

A study on cassava productivity in Sierra Leone (2024), reported Cox and Snell R^2 of $R^2 \approx 0.35$ and Nagelkerke R^2 of $R^2 \approx 0.47$. These indicated moderate explanatory power, yet fall below the values observed in the study.
Another study of rare-event logistic regression (ArXiv, 2024) emphasized that pseudo-R^2 values are sensitive to sample size, class imbalance, and event rarity, typically ranging from 0.2 to 0.6, concur with the study's Nagelkerke R^2 of 0.628 on upper limit.

A study on Real Estate Investment Trust (REIT) growth across Nigeria and South Africa (2024), reported R^2 of Cox & Snell R^2 was 0.256 and Nagelkerke R^2 was 0.364, For South Africa, and Cox & Snell $R^2 \approx 0.440$ and Nagelkerke $R^2 \approx 0.587$ and these values didn't differ much with the reported value of Cox & Snell R^2 was 0.14 and Nagelkerke R^2 was 0.625

CONCLUSIONS AND RECOMMENDATIONS

The findings of this study and other researchers confirm that mulching plays a crucial role in improving soil conservation, promoting crop yields, and minimizing disease occurrence in French bean farming. Farmers should be encouraged to adopt agronomic practices like mulching, especially using polymer, tea leaves, or grass, as they significantly reduce soil deposition, improve yields, and lower disease incidence. Future studies should investigate the long-term effects of mulching on soil health and productivity, as well as larger plot sizes and steeper slopes.

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