Determinants of Fertilizer and Manure Use for Maize Production in **Kiambu District, Kenya**

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March 2001

KARI

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INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

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Abstract: Farms in Kiambu District are very small owing to high population pressure and need to be intensively farmed to provide enough food for consumption and sale. Since soil nitrogen levels are low, the use of inorganic fertilizers and manure needs to be increased to improve land productivity. This study identified the socioeconomic factors influencing the use of inorganic fertilizers and manure for maize production in Kiambu District. A multistage sampling procedure was used to select divisions and farmers to be included in the study. Three divisions were randomly selected, from which a sample of 97 farmers was obtained. Data were collected at the farm level using a structured questionnaire. Soil and manure samples were taken from sample farms for laboratory analysis. The soil analysis showed that soils in Kiambu District have a high organic carbon content (3-4%), which reflects high levels of applied organic matter, most likely coupled with low rates of mineralization. Soils are low in nitrogen (N), indicating that more N needs to be added. Phosphorus (P) levels are not severely limiting, which might reflect a build-up of previously applied P. The logistic regression showed that extension and off-farm income were significant factors influencing the adoption of manure. Age of household head, extension, membership in an organization, and off-farm income significantly influenced the use of inorganic fertilizer. The use of both inorganic fertilizer and manure was significantly influenced by extension, membership in an organization, household size, hired labor for manure application, livestock ownership, and off-farm income. Extension, the most significant factor affecting the use of manure and fertilizer, should promote adoption by providing advice on improved on-farm manure management and fertilizer recommendations, particularly in terms of crop suitability and timing and method of application. Also, the extension service should advise fertilizer dealers to supply the packages required by farmers. To further aid adoption, capital (credit) constraints faced by farmers need to be relieved. Improved market information will assist farmers in securing the best prices for their outputs and inputs.

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Acronyms and Abbreviations

AEZ	Agroecological zone
AFC	Agricultural Finance Corporation
C	Organic carbon
Ca	Calcium
CAN	Calcium ammonium nitrate
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
DAP	Diammonium phosphate
GDP	Gross domestic product
K	Potassium
KARI	Kenya Agricultural Research Institute
LH	Lower highland zone
masl	Meters above sea level
Mg	Magnesium
NARC	National Agricultural Research Centre
NARL	National Agricultural Research Laboratories
NPK	Nitrogen, phosphate, potassium
P	Phosphate
UH	Upper highland zone
UM	Upper midland zone

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Executive Summary

Farms in Kiambu District are very small due to high population pressure and need to be intensively farmed to provide enough food for consumption and sale. Since soil nitrogen (N) levels are low, the use of inorganic fertilizers and manure needs to be increased to improve land productivity. This study was carried out in three divisions of Kiambu District to identify the socioeconomic factors influencing the use of inorganic fertilizers and manure for maize production and their implications.

A multistage sampling procedure was used to select divisions and farmers to be included in the study. Three divisions (Kikuyu, Githunguri, and Kiambaa) were randomly selected, from which a sample of 97 farmers was obtained. Data, including information on farmers' socioeconomic circumstances and soil fertility management practices, were collected at the farm level using a structured questionnaire. Soil and manure samples were taken from sample farms for laboratory analysis.

Tests showed that soils in Kiambu District have a high organic carbon content (3-4%), which reflects high levels of applied organic matter, most likely coupled with low rates of mineralization. Soils are low in N, indicating that more N needs to be added. Phosphorus (P) levels are not severely limiting, which might reflect a build-up of previously applied P.

Analysis of manure showed a wide variability in nutrient quality due to different management systems and probably feed sources. Manure quality is largely determined by decomposition rate, which in turn depends on management and handling.

Farmers were able to identify fertile or infertile areas on their farms, but their perception of manure quality in relation to its potential impact on maize yields was not discernible.

A logistic regression was run to determine which factors significantly influenced adoption of manure and inorganic fertilizer. Extension and off-farm income were found to be significant influences on the adoption of manure. Age of household head, extension, membership in an organization, and off-farm income significantly influenced the use of inorganic fertilizer. The use of both inorganic fertilizer and manure was significantly influenced by extension, membership in an organization, household size, hired labor for manure application, livestock ownership, and off-farm income.

Extension, the most significant factor affecting the use of manure and inorganic fertilizer, should promote adoption by providing advice on improved on-farm manure management as well as fertilizer recommendations, particularly in terms of crop suitability and timing and method of application. Also, the extension service should advise fertilizer dealers to supply the right fertilizer package size to farmers. To further aid adoption, capital (credit) constraints faced by farmers need to be relieved. Improved market information will assist farmers in securing the best prices for their outputs and inputs.

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1.0 Introduction

1.1 Kenya's Agricultural Sector

The agricultural sector is the backbone of Kenya's economy and should therefore be the fastest growing sector. It is the major foreign exchange earner and also provides 80% of national employment. Agriculture provides nearly all of the food requirements and raw materials for the industrial sector, 60% of total export earnings, 45% of government revenue, and accounts for 30% of gross domestic product (GDP). The sector is estimated to have a further indirect contribution of nearly 27% to the GDP through links with manufacturing, distribution, and other service-related sectors. In good years, the sector produces nearly all of the country's food requirements, except wheat, sugar, rice, and edible oils (MOA 1998). Accelerated growth in this sector will increase employment opportunities, enhance foreign exchange earnings, and improve the standard of living (Government of Kenya 1996). Available data show that small-scale agriculture absorbs the largest share of new additions to the labor force; however, employment creation is expected to slow in the future, as the contribution of agriculture to GDP is projected to decline (Government of Kenya 1996). Therefore, policies need to be put in place to ensure the sustainable creation of employment both on and off the farm.

Kenya's arable land area is fixed, yet population is increasing at a rate of 3.34% and is projected to reach around 33.4 million people by the year 2000. More food is required to feed these additional people. The country's requirements can be met through national production or through a combination of national production, imports, and international aid. Although Kenya's food policy emphasizes self-sufficiency, erratic weather has caused food to be imported sometimes, especially maize. These imports must be purchased with foreign exchange, but to raise foreign exchange, more land is planted to export crops at the expense of food crops such as maize, thereby worsening the food situation. This problem could be solved by increasing land productivity for food crops through the increased use of improved seed, more efficient use of fertilizer, improved crop management, better infrastructure, and better food crop processing and storage.

1.2 Soil Fertility

Since 1980, Kenya has experienced unstable growth in the agricultural sector, with negative rates recorded for three consecutive years between 1991 and 1993 (Government of Kenya 1993). Some constraints include:

- inadequate rural infrastructure, including poor roads and transport system;
- high dependence on rainfed agriculture;
- inadequate application of inputs;
- inaccessibility to credit for smallholder farmers, especially women;
- limited application of agricultural research findings owing to inadequate extension activities and support staff;
- low budgetary provision for the agricultural sector;
- cultural constraints relating to gender discrimination in the ownership, transfer, and use of land;
- perceived ethnic exclusion and traditional inheritance practices leading to land fragmentation; and
- poor coordination of major elements of the agricultural sector, such as infrastructure development, water supply, land settlement, and the Ministry of Agriculture (MOA).

Most of these constraints directly or indirectly influence soil fertility and are responsible for negative nutrient balances, characteristic of most agricultural systems in Kenya. Land with high agricultural potential is densely populated and most households have less than one hectare on which to grow crops. Since the arable land area cannot be expanded, land productivity has to be increased.

According to Smaling et al. (1997), soil nutrient depletion and declining crop yields are common in sub-Saharan Africa. An increasing number of African farmers report declining soil fertility to be a major constraint to farming. Kenya, Ethiopia, Rwanda, Malawi, and Lesotho have the highest nutrient depletion rates, i.e., nitrogen (N), phosphate (P), and potassium (K) depletion rates of over 40, 6.6, and 33.2 kg/ha/yr, respectively.

In central Kenya, long-term trials showed a decline in soil carbon (C) from around 20 g/kg to 12 g/kg. The decline is greatest when no inputs are applied and minimized when a combination of inorganic fertilizer and manure is used (Smaling et al. 1997). In Kenya, 70 long-term fertilizer trials were established to test the response of major annual crops to N, P, and farmyard manure in different agroecological zones (AEZs). The results showed that maize responds vigorously to P and manure, with a significant manure-fertilizer interaction (Smaling et al. 1992).

Mugunieri et al. (1997) found that the average amount of fertilizer used by farmers in Kenya is 46 kg/ha; however, much less is used for the production of food crops such as maize, which accounts for 20-28% of annual fertilizer consumption. Studies indicate that the amount of chemical fertilizer used for maize production by most small-scale farmers is below that recommended by research (Ruigu and Schulter 1990). Kenya's average annual fertilizer consumption is about 285,000 million tons (m t), although the country has the potential to use up to 750,000 m t per annum. In the 1990s, fertilizer use was static and affected agricultural productivity accordingly. Farm income in Kenya is often too low for farmers to purchase enough mineral fertilizer and animal manure to compensate for the outflow of nutrients. Since small-scale farmers account for 75% of the country's total agricultural output, decreased agricultural productivity means decreased per capita food production. This leads to reduced rural household income and increased poverty—a vicious circle that is difficult to break.

1.3 Maize in the Kenyan Economy

Maize is the staple food in Kenya. It is grown by 90% of farm households and provides about 40% of the population's requirements (Pearson et al. 1995). About 85% of the country's maize is produced by smallholders from many diverse AEZs. Maize area has stabilized at around 1.4 million hectares (m ha) with limited potential for further expansion. Due to weather fluctuations, production varies, sometimes resulting in serious shortfalls. The average maize yield is about 2 t/ha; however, potential yields of over 6 t/ha are possible through the increased use of improved seed, fertilizer, and crop husbandry practices. Constraints on the growth of the maize subsector include difficulties in selling surplus grain due to weaknesses in the private sector in maize marketing and transport; inadequate credit for farmers to purchase improved seed and fertilizer; and low profitability arising from a combination of low yields and poor marketing strategies.

According to Byerlee et al. (1994) there is sufficient maize technology in sub-Saharan Africa to increase food production; however, an appropriate policy environment coupled with an active technology transfer program is lacking.

1.4 Rationale and Objectives of the Study

Farmers in Kiambu District recognize that soil fertility and erosion are major constraints to crop production. Inorganic fertilizers and manure are widely used, but there are problems with availability, awareness, accessibility, and affordability, especially for inorganic fertilizers. Another constraint is application rate. While there are application guidelines for inorganic fertilizers, soil nutrient depletion is a continuous process that renders such guidelines obsolete with time. As for manure, it is often of low quality and not available in required quantities. According to Jama et al. (1997), farmyard manure has insufficient nutrients to maintain soil fertility and needs to be supplemented with inorganic fertilizers. Jama et al. showed that positive results could be achieved using inorganic fertilizer and manure in western Kenya, but the benefits could vary with location. Palm et al. (1997) also found benefits from combining organic with inorganic fertilizers, but they reported that guidelines are needed for farmers to manage such combinations.

Landholdings in Kiambu District are small because of the land fragmentation imposed by growing population pressure. Unless land is intensively and more productively used, it is unlikely to provide enough food for consumption and sale. Land productivity could improve if soil fertility is improved, and this study specifically aimed to identify the socioeconomic factors influencing the use of inorganic fertilizers and manure in maize production and to draw implications for research, extension, and policy.

1.5 The Study Area

1.5.1 Location and size. Kiambu is one of seven districts in the Central Province of Kenya. It is located in the south of the province and has a total area of 1,448 km^2. Kiambu borders Nairobi to the south, Murang'a to the north, and Thika District to the east. Table 1 shows the area of Kiambu District by division.

Table 1. Divisions within Kiambu District

Division	Area (km^2)
Kiambaa	191
Githunguri	171
Limuru	286
Kikuyu	232
Lari	568
Total	1,448

Source: District Development Plan (1994-1996).

1.5.2 Topography and geology. Kiambu District is divided into four broad topographic zones: Upper Highland, Lower

Highland, Upper Midland, and Lower Midland. The Upper Highland zone (UH0 and UH1) is found in Lari Division, 1,800 meters above sea level (masl). Soils are highly fertile, very deep, well drained, dark reddish brown to dark brown, strongly calcareous, and, in many places, saline and/or sodic with lava fields present. The upper part of the division is more a forest reserve and water catchment area than an agricultural zone, though farmers raise livestock (sheep), engage in dairying, and grow various crops and temperate fruits. Rainfall is reliable.

The Lower Highland zone (LH1-LH2) is mostly found in Limuru and parts of Githunguri and Kikuyu Divisions at 1,500-1,800 masl. Soils are well drained, shallow, dark reddish brown, and moderately fertile. The main farming system is tea-dairy, though maize, pyrethrum, horticultural crops, fruits, and sheep farming are also found.

The Upper Midland zone (UM2-UM6) is located at altitudes of less than 1,500 masl and occurs in all divisions except Lari. Soils are dark reddish brown, well drained, deep, and have an acidic humic topsoil. Fertility ranges from variable to moderate. Main crops grown include coffee, maize, sorghum, and sunflowers. Farmers commonly keep livestock.

The Lower Midland zone (LH3-LH5) is found in parts of Kikuyu (Karai) and Limuru (Ndeiya) Divisions. Soils are dissected erosional plains and vary from well drained, shallow, and dark red to yellowish red, stony loamy sand to imperfectly drained, very deep, dark brown, and strongly calcareous soils with a sodic clay topsoil. The area is dry since rainfall is low and unreliable. Main crops include maize, sorghum, and millet. Farmers keep livestock.

1.5.3 Climate. The climate in Kiambu District is largely influenced by altitude. Annual rainfall ranges from 750 mm in the lower areas of Ndeiya and Karai to over 1,300 mm in the district's upper regions. Rainfall is bimodal. Long rains occur between April and May, followed by a cool season during July and August, culminating in short rains between October and November. Rainfall distribution is reliable and has largely influenced agricultural activities in the district. Temperatures range from 20.4ºC in March/April to 12.5ºC in July/August in the upland zone.

1.5.4 Administrative units. Kiambu District is divided into five divisions, Githunguri, Kiambaa, Kikuyu, Limuru, and Lari, and has a total of 22 locations and 89 sublocations. Lari and Kikuyu Divisions have more sublocations relative to their size because of their high population density. The district has a well-established network of service centers, which serve as important social and economic facilities for the inhabitants.

1.5.5 Population size and density. Kiambu is the fifth largest district in the Central Province of Kenya and has the highest population (914,000 persons), with a projected growth rate of 3.7% per annum. Kiambu is very densely populated having an average of 373 persons/km^2, ranging from 178 persons/km^2 in Lari to 948 persons/km^2 in Kiambaa (Government of Kenya 1996).

1.5.6 Economic potential. Kiambu District has great economic potential. It is purely an agricultural zone, with climatic conditions favoring major cash crops such as tea, coffee, pyrethrum, and horticultural produce. Farmers also grow food crops and keep livestock. The district has other natural resources including forests, water, and some minerals. Information services and the presence of major supporting development institutions also contribute to the high economic potential of the district.

1.5.7 Land use. Soil types in the district vary in fertility, which influences land use (Table 2).

Table 2. Soil types and agricultural land use in Kiambu District, Kenya

Soil type	Land use
Low fertility	Maize, sorghum, millet, cassava, onions, and tomatoes
Moderate fertility	Citrus, bananas, avocado, onions, lettuces, maize, and beans
High to moderate fertility	Livestock, tea, coffee, and horticulture
High fertility	Forestry, sheep, dairy, pyrethrum, and vegetables

Source: District Agricultural Office, Kiambu.

Farming systems found in each AEZ are:

UH1: Sheep, dairy, and vegetables; permanent cropping possibilities;

UH2: Pyrethrum; long cropping season with a short to medium rainy season;

UH3: Maize-barley zone; medium length cropping season with a short to medium rainy season;

LH1: Tea-dairy zone; permanent cropping possibilities;

LH2: Maize-pyrethrum zone; medium length cropping season with a short to medium rainy season;

LH3: Wheat/maize-barley zone; short to medium cropping season with a short to very short rainy season;

UM1: Coffee-tea zone; long cropping season;

UM2: Main coffee zone; medium to long cropping season;

UM3: Marginal coffee zone; short to very short cropping season with a short to medium rainy season.

2.0 Methodology

2.1 Sampling Procedure

A multistage sampling procedure with simple random sampling was used to select farmers for the survey. Three divisions of Kikuyu, Githunguri, and Kiambaa were randomly selected, and farmers were randomly selected from these divisions, resulting in a sample size of 97. Data were obtained from sample farmers using interviews and structured questionnaires. The farmer survey was undertaken in June/July, 1996, using a single-visit survey approach. Data collected included information on farmers' socioeconomic circumstances and soil fertility management practices.

During farm visits, soil and manure samples were taken for laboratory analysis. Soils were sampled at various plowing depths (0-15 cm) from plots of 0-10 m^2. Ten samples per plot were bulked and mixed thoroughly and a subsample (1 kg) was taken for laboratory analysis. Two composite samples were also taken from each farm, based on the farmer's assessment of fertile (good) and infertile (poor) soils on his or her farm. Samples were air-dried, sieved (2 mm), and analyzed for pH, total organic C, total N, and available P.

Manure samples were collected at each farm from material considered by the farmer to be ready for use for maize production. The main samples collected were cow, goat/sheep (shoat), and poultry (chicken) manure. Samples were analyzed for pH, total ash, organic matter, N, P, postassium (K), calcium (Ca), and magnesium (Mg) as described in Anderson and Ingram (1993).

2.2 Analytical Model

Feder et al. (1985) showed that many models used in adoption studies fail to meet the statistical assumptions necessary to validate the conclusions based on the hypothesis tested, and they advocated the use of qualitative response models. Two models frequently used in adoption studies are the logit and probit. Usually a choice has to be made between logit and probit, but, as Amemiya (1981) has observed, the statistical similarities between the logit and probit models make such a choice difficult. Choice of model may be evaluated *a posteriori* on statistical grounds although, in practice, there will usually not be strong reasons to choose one model over the other. We selected the logit model because the dependent variable is dichotomous and the model is computationally easier. Following Gujarati (1988) the model is specified as:

$$\text{Ln}\ (P_i/(1\text{-}P_i)) = X_t\text{b} + \text{e}_I\ ,$$

where X_t is the index reflecting the combined effect of independent X variables that prevent or promote adoption. The index level can be specified as:

$$X_t = \beta_0 + \beta_1 X_1 + \ldots. + \beta_8 X_8 + \text{e}_I\ ,$$

where:

X_1	=	AGE (age of household head, yr) (+/-);
X_2	=	HHSIZE (household size, no.) (+);
X_3	=	FARMSIZE (farm size, acres) (+);
X_4	=	LSTOCK (number of livestock) (+);
X_5	=	HLAB (use of hired labor for soil fertility practices, dummy variable) (+);
X_6	=	OFFINCOM (availability of off-farm income, dummy variable) (+);
X_7	=	EXTSERV (access to extension services by farmer, dummy variable) (+);
X_8	=	MEMBER (membership of an organization, dummy variable) (+); and
e	=	error term.

The dependent variable is the natural log of the probability of adopting manure, or fertilizer, or both manure and fertilizer (P), divided by the probability of not adopting (1-P). The model was estimated using the maximum likelihood method of the Statistical Package for the Social Sciences (SPSS) software, version 6.1.

Formation of the model was influenced by a number of working hypotheses. It is hypothesized that a farmer's decision to either adopt or reject soil fertility management practices at any time is influenced by the combined effect of a number of factors related to farmers' objectives and constraints (CIMMYT 1993). The variables in the model were hypothesized to influence the adoption of soil fertility management practices positively (+), negatively (-), or both positively and negatively (+/-). Several variables were hypothesized to influence use of the soil fertility methods:

Farmer's age. A farmer's age (X_1) can generate or erode confidence. In other words, with age, a farmer can become more or less risk-averse to new technology. This variable can thus have a positive or negative effect on a farmer's decision to adopt soil fertility management.

Household size. Because large households will be able to provide the labor that might be required to apply fertilizer and manure, household size (X_2) is expected to increase the probability of adopting fertilizer and manure.

Farm size. Farm size (X_3) is an indicator of wealth and perhaps a proxy for social status and influence within a community. It is expected to be positively associated with the decision to use fertilizer and manure.

Livestock ownership. Livestock provide manure, therefore livestock ownership (X_4) is expected to increase the likelihood of using manure.

Hired labor. The use of hired labor (X_5) is hypothesized to be positively related to the use of fertilizer and manure.

Off-farm income. Access to off-farm income (X_6) enables farmers to purchase inputs and is expected to have a positive influence on the adoption of fertilizer and manure.

Extension. Agricultural extension services provided by the Ministry of Agriculture are the major source of agricultural information in the study area. It is hypothesized that contact with extension workers (X_7) will increase farmers' likelihood of using fertilizer and manure.

Member of farmer organization. Members of an organization (farmer groups, non-governmental organizations) are in a privileged position with respect to other farmers, in terms of their access to information on improved maize technologies. Being a member of an organization (X_8) is hypothesized to be positively associated with the use of fertilizer and manure.

3.0 Demographic and Socioeconomic Characteristics

3.1 Demographic Characteristics

Demographic and socioeconomic characteristics of sample farmers are shown in Table 3 for adopters of manure, adopters of fertilizer, and adopters of both manure and fertilizer. On average, farmers using manure were older (55 years) than those using fertilizer (49 years) or manure and fertilizer (54 years). Average farming experience was higher for farmers using both manure and fertilizer (25 years) than those using manure alone (22 years) or fertilizer alone (22 years). Household size was larger for farmers using manure (10 persons) compared to those using fertilizer (6 persons) or both manure and fertilizer (9 persons). There were no significant differences, however, in age of household head, farming experience, and household size between the three groups of farmers. The mean number of males in each family was 2, 2, and 3, while the mean number of females was 3, 2, and 3 for adopters of manure, fertilizer, and both manure and fertilizer, respectively. The average number of children aged below 13 years was 3, 0, and 1 for adopters of manure, fertilizer, or both manure and fertilizer, respectively. This was statistically significant at $p<0.05$.

Adopters of manure had the largest farms (4.7 acres), while adopters of fertilizer or both manure and fertilizer had average farm sizes of 3.7 acres. Similarly, maize area was significantly higher for farmers using manure (2.7 acres; $p<0.5$) than those using just fertilizer (1.2 acres) or both manure and fertilizer (1 acre). Adopters of manure alone had more livestock (5 units) than adopters of fertilizer alone (3 units) or adopters of both manure and fertilizer (4 units). There were no significant differences in farm size and livestock ownership between farmers using manure, fertilizer, or both fertilizer and manure.

Off-farm activities were undertaken by 16.7% of adopters of manure, 12% of adopters of fertilizer, and 42.9% of adopters of both manure and fertilizer. These differences were significant ($\chi^2 = 9.16$; $p<0.05$), indicating that very few farmers were involved in off-farm activities and mainly derived their income from the farm.

Table 3. Demographic and socioeconomic characteristics of adopters of different soil fertility practices, Kiambu District, Kenya

	Use manure		Use fertilizer		Use manure and fertilizer		
Characteristic	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	χ^2
Age of household head (yr)	55.3	10.6	48.8	11.7	53.5	12.5	NS
Farm experience (yr)	22.0	15.7	21.5	12.6	24.7	12.5	NS
Household size (no.)	9.5	8.1	6.2	2.5	9.0	5.0	NS
Farm size (ha)	4.7	3.4	3.7	2.9	3.7	2.2	NS
Maize area (ha)	2.7 a	2.5	1.2 b	0.7	1.0 b	1.0	NS
Livestock (no.)	4.9	6.5	3.2	1.8	3.7	4.4	NS
	Number of farmers	**Percent of farmers**	**Number of farmers**	**Percent of farmers**	**Number of farmers**	**Percent of farmers**	χ^2
Gender of household head							14**
Male	21	61.8	14	56.0	24	70.6	
Female	13	38.2	11	44.0	10	29.4	
Hired labor for fertilizer							NC
No	34	100.0	24	85.7	22	62.9	
Yes	0	0.0	4	14.3	13	37.1	
Hired labor for manure							NC
No	20	58.8	28	100.0	19	54.3	
Yes	14	41.2	0	0.0	16	45.7	
Off-farm income							NC
No	25	83.3	22	88.0	20	57.1	
Yes	5	16.7	3	12.0	15	42.9	
Extension services							NC
No	17	53.1	2	8.3	2	5.7	
Yes	15	46.9	22	91.7	33	94.3	
Credit for fertilizer							NC
No	28	93.3	21	80.8	20	58.8	
Yes	2	6.7	5	19.2	14	41.2	
Member of organization							6.1**
No	15	46.9	11	57.9	8	25.0	
Yes	17	53.1	8	42.1	24	75.0	

Note: NS = not significant; NC = χ^2 not calculated due to insufficient responses in cells; values followed by the same letter are not significantly different at $p<0.05$; ** = significant at $p<0.05$.

3.2 Land Resources

3.2.1 Location. The distribution of landholdings in the study area is shown in Table 4. Adopters of manure were located in UM3 (61.3%), LH5 (25.8%), and LH4 (9.7%); adopters of fertilizer were located in UM3 (54.2%), UM2 (37.5%), and UM1 (4.2%), and adopters of manure and fertilizer were mostly concentrated in UM2 (68.6%), UM1 (14.3%), and UM3 (17.1%). These differences in location were significant ($\chi^2 = 96.67$; $p<0.01$).

Around 33%, 44%, and 37% of farmers using manure, fertilizer, and both manure and fertilizer, respectively, cultivated land away from their homesteads. The average area of this land was 6.7 acres for adopters of manure, 4.7 acres for adopters of fertilizer, and 7.4 acres for adopters of manure and fertilizer; however, there were no significant differences between any two farmer groups. The mean distance of this land from the homestead was 2.31 km for adopters of manure, 3.34 km for adopters of fertilizer, and 14.13 km for adopters of both manure and fertilizer.

3.2.2 Land use pattern. Cropped area in Kiambu is shown in Table 5. Adopters of manure had significantly higher areas under maize (2.82 acres) (F=12.23; $p<0.01$) and beans (2.05 acres) (F=13.73; $p<0.01$) than adopters of fertilizer (0.94 and 0.57, respectively) and both manure and fertilizer (1.01 and 0.53, respectively).

Table 6 shows that maize, beans, and potatoes are grown mainly for subsistence, but coffee is produced solely for sale.

Table 4. Location of landholdings of sample farmers in Kiambu District, Kenya

	Use manure		Use fertilizer		Use manure and fertilizer		
Characteristic	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
AEZ							NC
UM1			1	4.2	5	14.3	
UM2	1	3.2	9	37.5	24	68.6	
UM3			13	54.2	6	17.1	
LH3	19	61.3	1	4.2			
LH4	3	9.7					
LH5	8	25.8					
Cultivated land elsewhere							0.69 (NS)
No	22	66.7	14	6.0	20	62.9	
Yes	11	33.3	11	44.0	15	37.1	9.16*

Note: NS = not significant; NC = χ^2 not calculated due to insufficient responses in cells; * = significant at $p<0.05$.

Table 5. Cropped area of adopters of different soil fertility practices, Kiambu District, Kenya

	Mean area (acres)			
Soil fertilizer practice	Maize	Beans	Potatoes	Coffee
Use manure	2.82 (0.44)	2.05 (0.34)	0.50 (0.12)	
Use fertilizer	0.94 (0.15)	0.57 (0.09)	0.31 (0.04)	2.39 (0.67)
Use manure and fertilizer	1.01 (0.16)	0.53 (0.09)	0.39 (0.06)	2.37 (0.43)

Note: Values in parentheses are standard deviations.

Livestock ownership by farmers in the district is shown in Table 7. Cattle breeds kept by adopters of manure were mainly crossbreeds (38.9%) and Friesians (33.3%), while adopters of fertilizer mainly kept Friesians (50%) and Ayshires (33.3%), and adopters of manure and fertilizer kept Friesians (53.6%) and Ayshires (17.9%). The average number of cattle kept was 4, 2, and 4 for adopters of manure, fertilizer, and manure and fertilizer, respectively. There were no significant

Table 6. Purpose of crops grown under different soil fertility practices, Kiambu District, Kenya

	Use manure		Use fertilizer		Use manure and fertilizer		
Characteristic	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Maize							NC
Subsistence	7	20.6	15	62.5	22	68.8	
Sale	2	5.9	6	25.0	1	3.1	
Both	25	73.5	3	12.5	9	28.1	
Beans							9.30*
Subsistence	20	60.6	15	68.2	24	80.0	
Sale	2	6.1	4	18.2			
Both	11	33.3	3	13.6	6	20.0	
Potatoes							NS
Subsistence	19	67.9	16	88.9	22	78.6	
Sale	2	7.1	1	5.6	2	7.1	
Both	7	25.0	1	5.6	4	14.3	
Coffee							
Sale			9	100	100	100	

Note: NS = not significant; NC = χ^2 not calculated due to insufficient responses in cells; * = significant at $p<0.05$.

Table 7. Livestock ownership by adopters of different soil fertility practices in Kiambu District, Kenya

	Use manure		Use fertilizer		Use manure and fertilizer		
Livestock type and porpose	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Cattle							
Friesian	6	33.3	6	50.0	15	53.3	
Ayshire	3	16.7	4	33.3	5	17.9	
Jersey	1	5.6			1	7.1	
Guernsey			1	8.3	3	10.7	
Crossbred	7	38.9	1	8.3	2	7.1	
Local zebu	1	5.6					
Other breed					1	3.6	
Goats							
Sale	3	33.3					
Subsistence	6	66.7	2	66.7	1	100	
Both			1	33.3			
Sheep							
Sale	2	66.7	1	33.3			
Subsistence	1	33.3	1	33.3	2	66.7	
Both			1	33.3	1	33.7	

differences in the number of cattle kept among the three groups of farmers. Cattle were kept mainly for milk.

The same proportion of adopters of manure and adopters of fertilizer kept goats for subsistence (66.7%) and sale (33.7%). Adopters of both manure and fertilizer kept all of their goats for subsistence (100%). Sheep were reared by all farmers for subsistence and sale (Table 7). Donkeys were kept only by adopters of manure, and solely for transport. Farmers also kept poultry and pigs for sale and subsistence. In general, adopters of manure had a higher average number of livestock (5) than adopters of fertilizer (3) and adopters of manure and fertilizer (4). These differences were not significant.

4.0 Soil Fertility Management

4.1 Nutrient Status of Soils and Manure

Soil pH in the district ranged from 5 to 6 (Table 8). Soils had a high organic carbon (C) content (3-4%), which reflects high levels of applied organic matter, most likely coupled with low rates of mineralization. Soils were low in N (0.2-0.3%), indicating that more N needs to be added. Phosphate levels were variable, ranging from 35 mg/kg to 110 mg/kg, but were not severely limiting, which might reflect a build-up of previously applied P. All soil parameters were lower in magnitude in areas perceived by farmers to be "infertile." Farmers based their assessments on soil color and crop productivity.

Table 8. Characteristics of soils sampled in Kiambu District, Kenya

Parameter	Minimum	Maximum
pH	5.2	6.3
Organic C (%)	3.1	4.5
Total N (%)	0.2	0.3
Total P (mg per kg soil)	35.0	110.0
K (mg per 100 g soil)	80.5	91.4
Mg (mg per 100 g soil)	78.4	138.7

The C levels of manure sampled ranged from 8% to 16%, and N levels ranged from 0.4% to 2.9% (Table 9). The C:N ratio, perhaps the best indicator of manure quality, was lowest for poultry and highest for cattle manure. A low C:N ratio indicates a high quality manure in terms of N release. This explains why farmers ranked poultry manure as the most effective for crop growth. Manure pH ranged from 7 to 9.

Nutrient levels of cattle, shoat, and poultry manure are shown in Table 9. The different manures varied widely in nutrient composition, which reflects different management systems and, probably, feed sources. Decomposition rates, which in turn depend on management and handling, largely determine manure quality.

Table 9. Characteristics of manure sampled in Kiambu District, Kenya

Animal	pH	C (%)	Total N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Cattle	7-9	10-16	0.4-1.8	0.15-0.18	1.9-2.6	0.2-0.3	0.12-0.18
Shoat	7-9	8-12	0.7-2.4	0.12-0.14	3.2-3.6	1.1-1.2	0.12-0.15
Poultry	7-8	10-16	1.5-2.9	0.21-0.24	5.5-6.8	0.7-1.1	0.4-0.6

4.2 Farmers' Soil Fertility Practices

4.2.1 Manure. About 35% of sample farmers used only manure and 36% used a combination of manure and fertilizer. Prior to application, about 57% of adopters of manure heaped the manure to let it decompose, leaving it for about 1-3 months, while 43% heaped it continuously and moved it to the farm as the need arose. Most farmers using both manure and fertilizer (70%) heaped their manure before applying it to the field.

About 70% of adopters of manure and 89% of adopters of both manure and fertilizer applied manure at planting. The application method used by most adopters of manure was banding (81%), while adopters of manure and fertilizer used a number of different methods including banding (45.8%), broadcasting (33.3%), and mixing the manure into the soil (20.8%). About 90% of users of both manure and fertilizer applied manure every season, while 66% of users of manure alone applied it every season, and 34% applied it every other season. Most adopters of manure alone (87.5%) and both manure and fertilizer (90.6%) used manure from their farms.

Details of manure use for different crops are shown in Table 10. For maize production, 87.5% of adopters of manure and 85.2% of adopters of manure and fertilizer used cow manure, and 8.3% of adopters of manure used a combination of cow and shoat manure. Very few farmers used other types of manure (chicken and compost) for maize production. For bean production, 85.7% of adopters of manure and 86.4% of adopters of manure and fertilizer used cow manure. Few farmers applied other types of manure for bean production. For potato production, 96.3% and 80.8% of adopters of manure and adopters of manure and fertilizer, respectively, used cow manure.

Table 11 shows the timing and method of manure application for crop production in the study area. About 70% of adopters of manure and 89% of adopters of manure and fertilizer applied manure during planting for maize production. Sixty-seven percent of adopters of manure and 85% of adopters of manure and fertilizer applied manure during planting for bean production. About 64% of adopters of manure and 86% of adopters of both manure and fertilizer applied manure during planting for potato production. Significantly more farmers applied manure every season ($\chi^2 = 11.32$; $p<0.01$). Banding was the application method most significantly used for all crop production ($\chi^2 = 11.25$; $p<0.05$).

According to adopters of manure, the main constraints on using manure were its high labor requirement for application

Table 10. Types of manure used for crop production, Kiambu District, Kenya

Crop and manure type	Use manure		Use manure and fertilizer	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Maize production				
Cow	21	87.5	23	85.2
Cow and shoat	2	8.3		
Cow and chicken	1	4.2	1	3.7
All			2	7.4
Compost			1	3.7
Bean production				
Cow	12	85.7	19	86.4
Chicken			1	4.5
Cow and shoat	2	14.3		
All				
Potato production				
Cow	26	96.3	21	80.8
Chicken			2	7.7
Cow and shoat	1	3.7		
All			2	7.7
Compost			1	3.8

Table 11. Timing and method of manure application in Kiambu District, Kenya

	Use manure		Use manure and fertilizer	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Timing of application				
Maize				
At planting	16	69.6	23	88.5
After planting	1	4.3		
Before planting	6	26.1	3	11.5
Beans				
At planting	6	66.7	17	85.0
After planting	0	0.0	0	0.0
Before planting	3	33.3	3	15.0
Potatoes				
At planting	18	64.3	19	86.4
After planting	0	0.0	0	0.0
Before planting	10	35.7	3	13.6
Method of application				
Maize				
Banding	17	81.0	11	45.8
Broadcasting	1	4.8	8	33.3
Incorporation	1	4.5	5	20.8
Ringing	2	9.5		
Beans				
Banding	6	66.7	16	94.1
Broadcasting	3	33.3		
Incorporation			1	5.9
Potatoes				
Banding	21	91.3	19	95.0
Broadcasting	0	0.0		
Incorporation	2	8.7	1	5.0
Frequency of manure application				
Skip one season	21	65.6	28	90.3
Every season	11	34.4	1	3.2
Skip two seasons			2	6.5

(57.4%), unavailability (14.9%), and high cost (17%). For users of both manure and fertilizer, the main constraints on using manure were its high labor requirement (44.4%), unavailability (19.4%), and untimely delivery (19.4%). Studies have shown that farmers have rejected manure because of its high labor demands and the variable quality of the product (Mwangi 1997). The main advantages of manure, according to adopters, were soil improvement (31.3%), its lasting residual effect (29.7%), and good water retention capacity (20.3%). For adopters of manure and fertilizer, the advantages given were its lasting residual effect (32.4%), soil improvement (29.4%), and good water retention capacity (14.7%).

4.2.2 Fertilizer. About 29% of sample farmers used only fertilizer. Almost all farmers applied fertilizer at planting. Around 53% of adopters of fertilizer alone and 78% of adopters of both manure and fertilizer applied fertilizer by mixing it into the soil, while 47.1% and 22%, respectively, used banding. This difference was significant ($\chi^2 = 3.0$; $p<0.01$). All farmers using fertilizer only and 94% of farmers using both manure and fertilizer applied fertilizer every season.

Different types of fertilizers were preferred for different crops (Table 12). Of farmers using fertilizer only, 90.5% preferred DAP, 4.8% preferred NPK, and 4.8% preferred diammonium phispate (DAP) and calcium ammonium nitrate (CAN) for maize production, while adopters of both manure and fertilizer used DAP (94%) and NPK (5.9%). The main fertilizer applied for bean production was DAP for all adopters of fertilizer and 96.8% of adopters of manure and fertilizer. Similarly for potato production, DAP was used by 100% of adopters of fertilizer and 92.6% of adopters of fertilizer and manure. For coffee production, adopters of fertilizer used DAP (23.1%), NPK (30.8%), CAN (23.1%), DAP and CAN (15.4%), and other fertilizers (7.7%), while adopters of manure and fertilizer preferred DAP (14.3%), NPK (42.9%), and CAN (42.9%).

Table 12. Farmers' fertilizer preferences for crop production in Kiambu District, Kenya

	Use manure		Use manure and fertilizer	
Fertilizer	**Number of farmers**	**Percent of farmers**	**Number of farmers**	**Percent of farmers**
Maize production				
DAP	19	90.5	32	94.0
NPK	1	4.8	2	5.9
DAP and CAN	1	4.8		
Bean production				
DAP	19	100.0	30	96.8
NPK			1	3.2
Potato production				
DAP	14	100.0	25	92.6
NPK			1	3.7
CAN			1	3.7
Coffee production				
DAP	3	23.1	1	14.3
NPK	4	30.8	3	42.9
CAN	3	23.1	3	42.9
DAP and CAN	2	15.4	0	0.0
Other	1	7.7	0	0.0

Fertilizer rates for crop production are shown in Table 13. The DAP rate used for bean production was significantly higher for farmers using fertilizer alone than for farmers using fertilizer and manure ($t=1.97$; $p<0.05$). The DAP rates used on other crops did not significantly differ between the two farmer groups**.**

The timing and method of fertilizer application for different crops are shown in Table 14. Most farmers applied DAP at planting, except for maize, which received CAN after planting. For all crops, the main methods of fertilizer application were banding and incorporation. For maize production, 52.9% of adopters of fertilizer and 77.8% of adopters of manure and fertilizer used the incorporation method. For bean and potato production, banding was used more than incorporation, but this was not statistically significant. Calcium ammonium nitrate was broadcasted for maize production, while NPK was applied by banding and incorporation. Most fertilizer users applied it every season. Significantly more farmers did not hire labor for fertilizer application ($\chi^2 = 4.12$; $p<0.05$).

4.2.3 Manure and fertilizer. Details of combined manure and fertilizer use are shown in Table 15. About 91% of farmers mixed manure and fertilizer; 71% of these mixed DAP with manure. About 77% of the farmers using only fertilizer preferred the use of fertilizer to improve crop production, while about 20% of the farmers using only manure would rather use fertilizer. About 43% of the

Table 13. Fertilizer rates for crop production in Kiambu District, Kenya

Fertilizer type and crop	Number of farmers	Fertilizer rate (kg / ha)	Standard error	t
DAP				
Maize				-0.35 (NS)
Fertilizer users	18	51.1	4.9	
Manure and fertilizer users	26	53.5	4.7	
Beans				1.97*
Fertilizer users	17	266.72	78.1	
Manure and fertilizer users	27	124.84	29.3	
Potatoes				0.77 (NS)
Fertilizer users	12	143.87	51.61	
Manure and fertilizer users	22	100.16	31.21	
Coffee				
Fertilizer users	2	58	11.31	
Manure and fertilizer users	1	180		
CAN				
Coffee				
Fertilizer users	1	100		
Manure and fertilizer users	1	180		
NPK				
Coffee				0.86 (NS)
Fertilizer users	2	150	100.00	
Manure and fertilizer users	3	83	16.67	

Note: NS = not significant; * = significant at p<0.05.

farmers using manure and fertilizer prefer fertilizer for improving crop production. These differences were significant ($\chi2 = 12.61$; $p<0.01$).

Advantages of using fertilizer, given by adopters of fertilizer, were its lower labor requirement compared with manure (40.7%) and improved yields (37%). The advantages of using fertilizer, given by adopters of manure and fertilizer, were increased yields (47.1%), lower labor requirement (11.8%), and ease of availability compared with manure (11.8%). Adopters of fertilizer obtained it from stockists (64.1%), the local market (23.1%), or the cooperative society (12.8%). Adopters of manure and fertilizer obtained their fertilizer from stockists (55.3%), the cooperative society (25.5%), or the local market (19.1%). Major constraints on fertilizer use faced by adopters of fertilizer were its high price (44.6%), lack of the right fertilizer package size (17.9%), and lack of credit (17.9%), while constraints for adopters of manure and fertilizer were high price (38%), lack of credit (21.1%), and lack of the right fertilizer package size (14.1%).

Advantages of using manure, given by adopters of manure, were its on-farm availability (31.3%) , its residual effect (29.7%), and increased water retention (20.3%). The advantages of using manure, given by adopters of manure and fertilizer, were its residual effect (32.4%) and soil improvement (29.4%). More than 90% of the adopters of manure obtained it from their own fields. Major constraints on manure use faced by adopters of manure were its expensive labor requirements (55.1%), its high price (16.3%), and unavailability of manure (14.3%). Main constraints for adopters of manure and fertilizer were its expensive labor requirements (42.1%), untimely delivery (18.4%), and unavailability of manure (18.4%).

Table 14. Timing and method of fertilizer application by farmers in Kiambu District, Kenya

	Use manure		Use manure and fertilizer		
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Timing of application					
DAP					
Maize					
At planting	22	95.7	32	100.0	
Before planting	1	4.3			
Beans					
At planting	19	95.0	31	100.0	
Before planting	1	5.0			
Potatoes					
At planting	14	100.0	27	100.0	
CAN					
Maize					
After planting	2	100.0			
NPK					
Maize					
At planting	1	50.0			
After planting	1	50.0			
Coffee					
After planting	1	100.0	1	100.0	
Method of application					
DAP					
Maize					2.96 (NS)
Banding	8	47.1	6	22.2	
Incorporation	9	52.9	21	77.8	
Beans					1.71 (NS)
Banding	12	80.0	15	60.0	
Incorporation	3	20.0	10	40.0	
Potatoes					0.05 (NS)
Banding	9	75.0	15	71.4	
Incorporation	3	25.0	6	28.6	
CAN					
Maize					NC
Broadcasting	1	100.0			
NPK					
Maize					NC
Banding	1	100.0	1	100.0	
Incorporation					
Frequency of application					NC
Every season			33	94.3	
Skip one season	26	100.0	1	2.9	
Once every season			1	2.9	
Hired labor					4.12*
No	24	85.7	22	62.9	
Yes	4	14.3	13	37.1	

Note: NS = not significant; NC = χ^2 not calculated due to insufficient responses in cells; * = significant at $p<0.05$.

Table 15. Manure and fertilizer use by farmers in Kiambu District, Kenya

Characteristic	Use manure		Use fertilizer		Use manure and fertilizer		χ^2
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	
Manure mixed with fertilizer							48.62**
No	25	96.2	8	88.9	3	9.4	
Yes	1	3.8	1	11.2	29	90.6	
Type of fertilizer mixed with manure							
DAP			1	100.0	15	71.4	
Other					3	14.3	
Any					3	14.3	
Prefer fertilizer							12.61**
No	12	80.0	5	22.7	20	57.1	
Yes	3	20.0	17	77.3	15	42.9	
Why fertilizer is preferred							
Better yields	1	33.3	10	37.0	8	47.1	
Less labor required	2	66.7	11	40.7	2	11.8	
Lack of manure	0	0.0	2	7.4	2	11.8	
Others	0	0.0	4	14.8	5	29.4	
Manure advantages							
Residual effect	19	29.7	2	13.3	11	32.4	
Water retention	13	20.3	6	40.0	5	14.7	
Higher yields	4	6.3	1	6.7	1	2.9	
Soil improvement	20	31.3	5	33.3	10	29.4	
On-farm resource	8	12.5	1	6.7	5	14.7	
All of the above	0	0.0			2	25.9	
Marketing problems							14.13**
No	2	10.0	4	33.3	14	66.7	
Yes	18	90.0	8	66.7	7	33.3	
Type of marketing problems							23.91**
High transport			4	50.0			
Poor infrastructure	10	56.0	2	25.0	3	42.9	
Far market center	8	44.4	1	12.5	1	14.3	
No demand			1	12.5	3	42.9	

Note: NS = not significant; ** = significant at p<0.01.

5.0 Credit Availability

Most (81%) adopters of fertilizer and adopters of manure and fertilizer (59%) did not have access to credit (Table 16). Three sources of credit were available in the study area, with the most popular being cooperatives. About 84% of farmers who obtained credit from cooperatives used it for fertilizer. Farmers rarely used commercial banks to access credit. About 89% required collateral for their credit, usually in the form of future production. Very few adopters of manure alone obtained credit. Of these farmers, 3.1% obtained credit from cooperatives more than four years ago. About 56% of all farmers indicated that they faced problems in accessing credit.

The most common constraint on access to credit was its high interest rate, according to 28.6%, 40.0%, and 36.4% of adopters of manure, fertilizer, and manure and fertilizer, respectively. Two other major problems were unavailability of loans and inflexible repayment terms (Table 17).

Table 16. Farmers' access to credit for fertilizer in Kiambu District, Kenya

	Use manure		Use manure and fertilizer		
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Credit for fertilizer					33.28 (NS)
No	21	80.8	20	58.8	
Yes	5	19.2	14	41.2	
Credit source					3.18 (NS)
Commercial bank	2	40.0	1	7.1	
AFC	3	60.0	1	7.1	
Cooperatives			12	85.7	
When was credit obtained					2.71 (NS)
This year	1	25.0	6	46.2	
One year ago			2	15.4	
2-3 years ago			1	7.7	
4 years ago	3	75.0	4	30.8	
Collateral required					1.0 (NS)
No	1	25.0	1	7.1	
Yes	3	75.0	13	92.9	
Type of collateral					
Land	1	20.0	2	11.1	
Future income	0	0.0	3	16.7	
Future production	2	40.0	9	50.0	
Group guarantee	1	20.0	3	16.7	
Other	1	20.0	1	5.6	

Note: NS = not significant.

Table 17. Constraints on the use of credit for farmers in Kiambu District, Kenya

Constraint	Use manure		Use fertilizer		Use manure and fertilizer	
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers
Unavailability of loans	2	28.6	0	0.0	7	31.8
No collateral	1	14.3	1	20.0	0	0.0
Inflexible repayment terms	1	14.3	1	20.0	7	31.8
High interest rates	2	28.6	2	40.0	8	36.4
Lack of knowledge	1	14.3	1	20.0	0	0.0

6.0 Extension and Membership in Organizations

6.1 Extension

Extension visits were received mostly by adopters of both manure and fertilizer (94.3%), followed by adopters of fertilizer (91.7%) and adopters of manure (46.9%) (Table 18). These differences were significant ($\chi^2 = 25.15$; $p<0.01$). Two extension visits per month were most common among farmers using fertilizer and manure (38.7%) and those using fertilizer (50.0%). This difference was significant ($\chi^2 = 18.28$; $p<0.05$). Farmers were visited individually, as a group, or both, although it was more common for individuals to be visited.

For adopters of manure, extension messages focused on land use practices (30.6%), manure use (19.4%), and improved seed (19.4%). For adopters of fertilizer, extension emphasized fertilizer use (26.2%), while for adopters of manure and fertilizer the emphasis was on fertilizer use (22.3%).

Around 80%, 58.8%, and 40% of farmers using manure, fertilizer, and manure and fertilizer, respectively, experienced problems with the extension service. Problems cited by adopters of manure were that the extension message was unclear (38.5%) and the service was not available (30.8%). Adopters of fertilizer said that visits were infrequent (44.4%), the service was unavailable, and that messages were unclear (22.2%). Adopters of manure and fertilizer said that the service was not timely (36.4%) and visits were infrequent (36.4%).

6.2 Membership in Organizations

More adopters of manure (53.1%) and manure and fertilizer (75%) were members of farmer organizations compared to adopters of fertilizer (42.1%). This difference was significant ($\chi^2 = 6.08$; $p<0.05$) (Table 19). The main farmer organizations in the study area were cooperative societies and farmer groups. Of farmers using manure, about 56%, 31%, and 13% were members of cooperative societies, farmer groups, or both, respectively. About 88% and 13% of farmers using fertilizer were members of cooperative societies or both cooperative societies and farmer groups, respectively.

Table 18. Details of extension services accessed by farmers in Kiambu District, Kenya

	Use manure		Use fertilizer		Use manure and fertilizer		
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	χ^2
Extension							25.16*
No	17	53.1	2	8.3	2	5.7	
Yes	15	46.9	22	91.7	33	94.3	
Frequency of extension contact							18.28*
Once every 3 months			3	13.6	1	3.2	
Once per month	3	20.0	5	22.7	9	29.0	
2 times per month	10	66.7	11	50.0	12	38.7	
3 times per month			1	4.5	3	97.0	
5 times per month	2	13.3	2	11.0	6	19.4	
Type of visit							11.79*
Individual	12	80.0	16	84.2	10	47.6	
Group			3	15.8	3	14.3	
Both	3	20.0			8	38.1	
Extension topic							
Fertilizer use	5	13.9	17	26.2	27	22.3	
Manure	7	19.7	12	18.5	23	19.0	
Insecticides	6	16.7	13	20.0	24	19.8	
Improved seed	7	19.4	12	18.5	24	19.8	
Land use practice	11	30.6	11	16.9	23	19.0	
Extension problem							7.25*
No	3	20.0	7	41.2	18	62.1	
Yes	12	80.0	10	58.8	11	37.9	
Nature of extension problem							11.01 (NS)
Service not available	4	30.8	2	22.2	1	9.1	
Service not timely	1	7.7	1	11.1	4	36.4	
Infrequent visit	1	7.7	4	44.4	4	36.4	
Unclear messages	5	38.5	2	22.2	1	9.1	
Other	2	15.4	3	1.0	1	9.1	

Note: NS = not significant, * = significant at $p<0.05$.

Farmers using manure and fertilizer were members of cooperative societies (91.7%) or of both cooperatives and farmer groups (8.3%). This difference was significant ($\chi^2 = 11.8$; $p<0.05$).

About 91% of adopters of manure and fertilizer and 88% of adopters of manure paid for the services rendered by cooperatives and farmer groups.

Most adopters of manure (88%) and manure and fertilizer (55%) experienced problems with cooperatives and farmer groups. Farmers using manure and fertilizer felt that the organizations had no interest in serving farmers (33.3%), charged high membership fees (26.7%), and delayed paying farmers (20%). Farmers using manure reported that the organizations delayed payment (84.6%) and charged high membership fees (7.7%). For farmers using fertilizer, problems cited were delayed payment (33.3%) and high membership fees (22.2%).

The main service provided by organizations in the study area was marketing of farmers' produce, which was used by 37% of adopters of manure, 47.1% of adopters of fertilizer, and 44% of adopters of fertilizer and manure. Other services included fertilizer, credit, animal manure, and labor exchange.

Table 19. Membership in organizations by farmers in Kiambu District, Kenya

Characteristic	Use manure		Use fertilizer		Use manure and fertilizer		χ^2
	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	Number of farmers	Percent of farmers	
Member of organization							6.08*
No	15	46.9	11	57.9	8	25.0	
Yes	17	53.1	8	42.1	24	75.0	
Type of organization							11.8*
Cooperative society	9	56.3	7	87.5	22	91.7	
Farmer group	5	31.3					
Both	2	12.5	1	12.5	2	8.3	
Payment required							0.94 (NS)
No	2	12.5			2	9.1	
Yes	14	87.5	7	100.0	20	90.9	
Problem experienced							8.63*
No	2	12.5			10	45.5	
Yes	14	87.5			12	54.5	
Type of problem							
No interest	0	0.0	0	0.0	5	33.3	
High membership fee	1	7.7	2	22.2	4	26.7	
Payment delay	11	84.6	3	33.3	3	20.0	
Other	1	7.7	4	44.4	3	20.0	
Service provided							
Marketing	10	37.0	8	47.1	22	44.0	
Fertilizer	0	0.0	5	29.4	15	30.0	
Credit	7	25.9	5	23.5	11	22.0	
Animal manure	3	11.1	0	0.0	0	0.0	
Labor exchange	7	25.9	0	0.0	2	4.0	

Note: NS = not significant; * = significant at $p<0.05$.

7.0 Factors Affecting the Adoption of Soil Fertility Practices

Table 20 indicates that the logistic model accounted for 75% of the total variation in the adoption of manure. The chi-square statistic shows that the parameters included in the model were significantly different from zero at the 1% level for adoption of manure. The maximum likelihood estimates of the logistic regression are shown in the table. Extension contact and off-farm income were factors significantly influencing the adoption of manure. The odds in favor of adopting manure decreased by a factor of 0.03 for farmers who had access to extension services. This was because extension services in the area had been discouraging farmers from using only manure. The odds in favor of adopting manure decreased by a factor of 0.11 for farmers who had off-farm income, indicating that farmers were not willing to invest in manure only.

Table 20. Parameter estimates for factors affecting adoption of manure

Explanatory variables	Parameter estimates (β)	Wald statistic	Exp. (β)
Intercept	0.2552	0.03	
Age of household head (yr)	0.0328	0.85	1.03
Extension service	-3.6174***	14.53	0.03
Member of organization	0.2700	0.15	1.31
Farm size (acre)	0.0989	0.82	1.10
Household size (no.)	-0.0332	0.24	0.97
Hired labor to apply manure	0.1942	0.08	1.21
Livestock ownership (no.)	0.0783	1.20	1.08
Off-farm income	-2.1691*	5.30	0.11
Model chi-square	34.45***		
Overall cases correctly predicted	75.3%		
Sample size	97.0		

Note: * = significant at p<0.1; ** = significant at p<0.05; *** = significant at p<0.01.

As shown in Table 21, the logistic model explained 83% of the total variation in the adoption of fertilizer. The chi-square statistic shows that the parameters included in the model were significantly different from zero at the 1% level for adoption of fertilizer. The maximum likelihood estimates of logistic regression are also shown in the table. Farmer's age, extension contact, membership in an organization, and off-farm income significantly influenced the adoption of fertilizer. The odds in favor of adopting fertilizer decreased by a factor of 0.94 for older farmers, possibly because older farmers are less receptive to improved soil fertility technologies. Access to extension services significantly and positively influenced the likelihood of adopting fertilizer by a factor of 6.7 at the 1% level. Extension services inform farmers of the benefits of fertilizer. Contrary to expectation, the odds of adopting fertilizer decreased by a factor of 0.31 for farmers who were members of an organization. Similarly, the likelihood of adopting fertilizer decreased by a factor of 0.26 for farmers who had off-farm income.

The logistic model explained 83% of the total variation in the adoption of both manure and fertilizer (Table 22). The chi-square statistic indicates that the parameters included in the model were significantly different from zero at the 1% level for adoption of manure and fertilizer (Table 22). The maximum likelihood estimates of logistic regression are also shown in the table. Extension contact, household size, membership of a farmer organization, off-farm income, livestock ownership, and hired labor for manure application significantly influenced the adoption of both manure and fertilizer. The odds in favor of adopting manure and fertilizer increased by a factor of 16.35 for farmers who had access to extension services. Extension services informed farmers of the benefits of using both manure and fertilizer. Household size had a significant impact on the use of manure and fertilizer, increasing the likelihood of adoption by 1.16 at the 5% level. Larger households are able to provide the labor required for manure application. The odds in favor of adopting manure and fertilizer increased by a factor of 3.99 for farmers who were members of an organization. Off-farm income significantly increased the likelihood of adoption of manure and fertilizer by a factor of 9.32 at the 1% level. Farmers with off-farm income had the cash to purchase fertilizer and hire labor for manure application. Contrary to expectation, the odds in favor of adopting manure and fertilizer decreased by a factor of 0.84 for farmers who owned more livestock. The odds in favor of adopting manure and fertilizer increased by a factor of 7.21 for farmers who hired labor for manure application.

Table 21. Parameter estimates for factors affecting adoption of inorganic fertilizer

Explanatory variables	Parameter estimates (β)	Wald statistic	Exp. (β)
Intercept	2.5619	2.30	
Age of household head (yr)	-0.0667*	3.40	0.94
Extension service	1.9012*	3.52	6.70
Member of organization	-1.1657**	2.94	0.31
Farm size (acre)	0.0879	0.47	1.09
Household size (no.)	-0.1634	2.05	0.85
Hired labor to apply fertilizer	0.3607	0.19	1.43
Livestock ownership (no.)	-0.0854	0.40	0.92
Off-farm income	-1.3565*	2.76	0.26
Model chi-square	21.78**		
Overall cases correctly predicted	82.7%		
Sample size	97.0		

Note: * = significant at p<0.1; ** = significant at p<0.05.

Table 22. Parameter estimates for factors affecting adoption of both manure and fertilizer

Explanatory variables	Parameter estimates (β)	Wald statistic	Exp. (β)
Intercept	-5.4893***	7.53	
Age of household head (yr)	0.0150	0.18	1.02
Extension service	2.7940***	6.44	16.35
Member of organization	1.3829*	3.63	3.99
Farm size (acre)	-0.2593	2.72	0.77
Household size (no.)	0.1461**	3.82	1.16
Hired labor to apply fertilizer	1.3856	2.00	4.00
Hired labor to apply manure	1.9748**	6.28	7.21
Livestock ownership (no.)	-0.1700*	3.15	0.84
Off-farm income	2.2318***	7.32	9.32
Model chi-square	42.261***		
Overall cases correctly predicted	82.7%		
Sample size	97.0		

Note: * = significant at p<0.1; ** = significant at p<0.05; *** = significant at p<0.01.

8.0 Conclusions and Implications

The study showed that about 35% of sample farmers used manure alone, 29% used fertilizer alone, and 36% used both manure and fertilizer. Cow manure was the most widely used manure. The average amount of manure used for maize production was 6.2 t/acre for users of manure and 2.7 t/acre for users of both manure and fertilizer. The main constraints on using manure for adopters of manure alone were the high cost of labor to apply it (55.1%), unavailability (14.3%), and high cost (16.3%). For users of both manure and fertilizer, constraints on using manure were the high cost of labor to apply it (42.1%), unavailability (18.4%), and untimely delivery (18.4%). The main constraints on using fertilizer for adopters of fertilizer alone were its high price (44.6%), unavailability of the recommended fertilizer package size. (17.9%), and lack of credit (17.9%), while for adopters of both manure and fertilizer, constraints were its high price (38%), untimely delivery (21.1%), and unavailability of the recommended fertilizer package size (14.1%).

The logistic regression showed that extension contact and off-farm income were significant factors influencing the adoption of manure. Age of household head, extension contact, membership in an organization, and off-farm income significantly influenced the use of inorganic fertilizer. The use of both manure and inorganic fertilizer was significantly influenced by extension contact, membership in an organization, household size, hired labor for manure application, livestock ownership, and off-farm income.

Land productivity needs to be emphasized in Kiambu District because of increasing population pressure, and this can be achieved through the use of manure and inorganic fertilizer. This study has shown that several factors influence the use of manure and inorganic fertilizer. Extension, the most significant factor, should promote adoption by providing advice on improved on-farm manure management and fertilizer recommendations, particularly in terms of crop suitability, and timing and method of application. Extension officers should also advise fertilizer dealers to supply the right fertilizer package size demanded by farmers. Also, solutions need to be found to relieve capital (credit) constraints faced by farmers using manure and fertilizer. Improved market information will assist farmers in securing the best prices for their inputs and outputs.

References

Amemiya, T. 1981. Qualitative response models. *A Survey Journal of Economic Literature* 19:1483-1536.

Anderson, J.M., and J.S. Ingram. 1993. *Tropical Soil Biology and Fertility: A Handbook of Methods*. Wallingford, UK: CAB International.

Byerlee, D., P. Anandajayasekeram, A. Diallo, Bantayu Gelaw, P.W. Heisey, M. Lopez-Pereira, W. Mwangi, M. Smale, R. Tripp, and S. Waddington. 1994. *Maize Research in Sub-Saharan Africa: An Overview of Past Impacts and Future Prospects*. CIMMYT Economics Working Paper 94-03. Mexico, D.F.: CIMMYT.

CIMMYT. 1993. *The Adoption of Agricultural Technology: A Guide for Survey Design.* Mexico, D.F.: CIMMYT.

District Agricultural Office in Kiambu. 1993. *District Development Plan (1994-1996).* Nairobi, Kenya: Government of Kenya

Government of Kenya. 1993. *National Development Plan, 1994-1996.* Nairobi, Kenya: Government of Kenya.

Government of Kenya. 1996. *National Development Plan, 1997-2001.* Government of Kenya.

Gujarati, D.N. 1988. *Basic Econometrics*. 2nd edition. New York, New York: McGraw-Hill.

Hassan, R.M., F. Muriithi, and G. Kamau. 1998. Determinants of fertilizer use and the gap between farmers' maize yield and potential yields in Kenya. In R.M. Hassan (ed.), *Maize Technology Development and Transfer: A GIS Application for Research Planning in Kenya*. Wallingford, UK: CAB International.

Heisey, P., and W. Mwangi. 1996. *Fertilizer Use and Maize Production in Sub-Saharan Africa*. CIMMYT Economics Working Paper 96-01. Mexico, D.F.: CIMMYT.

Ikombo, B.M., A.O. Esilaba, and A.M. Kilewe. 1994. *A Diagnostic Survey of the Farming Systems in Kiambu District*. KARI-NARC, Muguga. Unpublished.

Jama, B., R.A. Swinkels, and R.J. Buresh. 1997. Agronomic and economic evaluation of organic fertilizer. Mimeo.

Ministry of Agriculture. 1998. *Agricultural Sector Investment Programme (ASIP).* Agricultural Sector Development Strategy. Nairobi, Kenya: Kilimo House.

Mugunieri, G.L, H.O Nyangito, and L.O. Mose. 1997. Agronomic and socioeconomic factors determining maize yield response to fertilizers in western Kenya. In E. Adipala, J.S. Tenywa, and M.W. Ogenga-Latigo (eds.), *African Crop Science Conference Proceedings*. Pretoria, 13-17 January 1997. Pp. 1465-1471.

Mwangi, W.M. 1997. Low use of fertilizers and low productivity in sub-Saharan Africa. *Nutrient Cycling in Agroecosystems* 47: 135-147.

Palm, C.A., R.J.K. Myers, and S.M. Nandwa. 1997. Combined use of organic and inorganic sources for soil fertility maintenance and replenishment. In *Replenishing Soil Fertility in Africa*. Special Publication No. 5. Madison, Wisconsin: American Society of Agronomy and Soil Science Society of America.

Ruigu, G.M., and M. Schulter. 1990. *Fertilizer and Seeds Requirements in Kenya from 1981/83 to 1990/91.* World Bank Working Paper. World Bank, Washington D.C. .

Pearson, S., E. Monke, G. Argwings-Kodhek, F. Avillez, M. Mukumbu, S. Pagiola, D. Sellen, and A. Winter-Nelson. 1995. *Agricultural Policy in Kenya: Applications of the Policy Analysis Matrix*. Ithaca, New York: Cornell University.

Smaling, E.M.A., S.M. Nandwa, and B.H. Janssen. 1997. Soil fertility is at stake. In *Replenishing Soil fertility in Africa*. Special Publication No. 51. Madison, Wisconsin: American Society of Agronomy and Soil Science Society of America.

Smaling, E.M.A., S.M. Nandwa, H. Prestele, R. Roetter, and F.N. Muchena. 1992. *Yield Response of Maize to Fertilizers and Manure under Different Agro-ecological Conditions in Kenya*. Dordrecht, the Netherlands: Elsevier Science Publishers B.V.