AN ECONOMIC ANALYSIS OF AGROCHEMICAL USE IN TOMATO PRODUCTION IN KIAMBU DISTRICT

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DEDICATION

THIS THESIS
IS DEDICATED TO MY
PARENTS, MARI R.G AND WANGUI M.G.

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ABBREVIATIONS

Zn = ZINC.

FAO = FOOD AND AGRICULTURE ORGANIZATION

Mn = MANGANESE.

UNEP = UNITED NATIONS ENVIRONMENTAL PROGRAMME

N = NITROGEN.

USDA = UNITED STATES DEPARTMENT OF AGRICULTURE

MD = MAN-DAYS.

CBS = CENTRAL BUREAU OF STATISTICS

K = POTASSIUM.

MFC = MARGINAL FACTOR COST.

W/B = WORLD BANK

ED = ENUMERATION DISTRICT

STD = STANDARD

PSU = PRIMARY SAMPLING UNIT

DEV. = DEVIATION

MAX. = MAXIMUM

MIN. = MINIMUM

KSH. = KENYA SHILLINGS

HA = HECTARE

OLS. = ORDINARY LEAST SQUARE

KG = Kilogram

MOA = MINISTRY OF AGRICULTURE.

L = LITRES

MVP = MARGINAL VALUE PRODUCT

MFC = MARGINAL FACTOR COST

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ABSTRACT

The purpose of this study was to analyze agrochemicals use in pest-disease control in Kiambu district. The broad objective was to study the use and the economics of pesticides in Kiambu district. The specific objectives involved description and determination of profitability of pesticides, description of the pesticide use and the determination of the factors that influence pesticide use in the area of study.

Using a structured questionnaire, data was collected from 89 small scale tomato growers through interviews. The study was done on 1991 short rains tomato crop. The analysis was mainly done through a Cobb-Douglas production Function and cross tabulations. Two hypothesis were conducted to test whether a statistical difference existed between the marginal value product and the marginal factor cost of insecticides and fungicides respectively.

Results indicated that the marginal value product of insecticides and fungicides were statistically different from the respective marginal factor costs. The difference can be attributed to some extent, to the fact that only 14% of the farmers used insecticides within the recommendations and that a proportion of 45% of the farmers applied doses of insecticides which were not effective, thereby getting no increment in yield from their pesticide application. However, 40%, did not deviate significantly from recommendations. Similarly, only 22% of farmers used

Fungicides as recommended, fifty percent used fungicides significantly far above the recommendations. The latter explains the statistical difference in marginal value product and marginal factor cost.

Evaluation of farmers response to the constraining factors against adequate pest/disease control revealed that inability to afford pesticides and lack of access to information on pest/disease control ranked high among the constraints mentioned. From the outcome of this study, it was concluded that future increase in returns to pesticides would come from the ability to devise and implement policies aimed at reducing underuse and overuse of pesticides. Curbing the sale of unpacked or repacked pesticides by middlemen through law enforcement would ensure that the effectiveness of the pesticides is maintained and proper application would therefore increase the returns to pesticides. The rampant deviation of pesticide use from the recommendations and the poor returns from pesticide use can be achieved through a rigorous extension services to fill the farmers knowledge gap.

CHAPTER ONE

1:1 INTRODUCTION.

1:1:1 AGRICULTURE IN KENYA'S ECONOMIC DEVELOPMENT.

Agriculture is the mainstay of the Kenyan economy. Besides provision of food, the sector provides the raw materials required by agro-based industries. Currently it contributes as much as 28.2% of the country's GDP (Republic of Kenya, Economic survey, 1991). Consequently, its importance can not be underestimated especially when the bulk of the country's exports are primarily agricultural commodities.

The goal of the Government has been to stimulate rapid economic growth. However, high input prices have reduced input use especially in sugarcane, maize, beans, rice and wheat. At current prices, value added in agriculture increased by 4.8% in 1991 compared to 6.8% in 1990 but in real terms, value added deteriorated by 1.1% compared with a growth of 3.4% in 1990 (Republic of Kenya, Economic Survey 1992). Taking into account that agriculture contributes about 75% of the employment, either directly or indirectly, then it will continue to play a leading role in such government policies as food self sufficiency, employment generation, foreign exchange earning and income generation especially for the small scale farmers (Republic of Kenya, Development Plan, 1989-93).

Historically, besides tourism, grants and aid, Kenya depends on agriculture to meet its foreign exchange requirements. Thus emphasis on agricultural production has been great as evidenced by development plans since independence. Sessional Paper No 1 of 1986 laid emphasis on increasing the exportable crops by the year 2000.

The horticultural industry was seen by the Government as an area which could play a vital role to achieve this goal. However for the last five years, the performance of the industry has been erratic. Compared to 1990, the horticultural export declined by 10.3% (Republic of Kenya, Economic Survey, 1992). Consequently, horticultural crop production was chosen together with six others, as the principle commodities upon which emphasis should be placed in order to enhance economic development. Table 1:1 presents the six commodities believed to have a high capacity of enhancing economic growth. The seventh commodity, livestock production, was left out.

Table 1.1 OUTPUT PROJECTIONS OF SIX PRINCIPLE COMMODITIES WITH A HIGH CAPACITY OF ENHANCING ECONOMIC GROWTH IN THOUSAND TONES 1989-93.

	1987 ACTUAL	1988 PROJECTED	1993 TARGETED	RATE OF GROWTH (%) (1987-93)
COFFEE	105	123	150	1.04
TEA	156	160	204	1.05
MAIZE	2,583	2,540	3,090	1.04
WHEAT	257	231	255	1.02
MILK	1,503	1,534	1,693	1.02
HORTICULTURE	40	44	70	1.10

SOURCE: Republic of Kenya,Development Plan 1989-93.

From table 1:1, the projected growth rate of 1.1% under horticulture is the highest among the six commodities identified by the Government as having the highest capacity of enhancing economic growth. It is reasonable therefore to expect the production trend in agriculture and horticulture in particular to be in accordance to the emphases placed on them. However,contrary to expectations, production is low. Kenya is still classified by the World's Food Council as a Food Priority Country (FPC). Under this classification, Kenya has a high projected cereal deficit, a high proportion of undernourished population and a low potential for accelerated food production (IADS,1983). Besides inadequate total food production, the food situation is characterized by large fluctuations in supply availability and regional demand for food. Even greater is the regional disparity in resource endowment for accelerated food production. Its the combined goal of intensifying agricultural production and protecting what is and what has been produced that makes agrochemicals to be of paramount importance in agriculture. It is expected that the bulk of the horticultural produce will be produced by relying heavily on agrochemicals to raise production and combat pests and diseases. Fertilizers and pesticides are therefore important inputs in agriculture. Its upon the latter that emphasis will be laid.

1:1:2 CONTRIBUTION OF AGROCHEMICALS TO AGRICULTURE.

Kenya has a land surface area of 569,137 sq.Km. out of which 0% is high potential for arable farming. Out of the total ultivated area, 66% is occupied by small scale farmers (Shenoi, 990). Such farmers occupy plots of 0.2-12 Ha. Its therefore vident that future decisions on raising agricultural output will im at intensive rather than extensive farming. Under intensive cultivation, man is a perpetual competitor with predators on his food source, as table 1:2 shows.

Table 1.2 PRODUCTION AND PEST/DISEASE LOSS FIGURES OF VEGETABLES,FRUITS AND ROOT CROPS IN 1000 TONES.

Vegetables	Production	% Estimated loss
Onions	6,474	16-35
Tomatoes	12,755	5-50
Plantain	18,301	35-100
Cauliflower	916	49
Fruits	Production	% estimated loss
Bananas	36898	20-80
Papaya	931	40-100
Citrus	22,040	20-95
Apples	3677	14
Roots	Production	%estimated loss.
Carrots	557	44
sweet potatoes	17,630	35-95
Yams	20,000	10-60
Cassava	103,486	10-25

Source: FOOD LOSS PREVENTION IN PERISHABLE CROPS, FAO,1981.

From table 1:2 above, 5-50% of tomatoes from developing countries are never harvested. It is estimated that yield losses through pest/diseases is enormous. Jackson et. al., (1965) demonstrated that protection of cotton against jassids increased cotton yields by 50% as compared to unsprayed cotton. In barley economic gains could be achieved by spraying against aphids. Individual losses in horticultural crops, range from 0% to 100% and as indicated above, in less developed countries,about 5% to 50% of the potential tomato harvest is lost in this way (FAO, 1981). Loss in quality and quantity is mainly through the influence of nematodes, fungi, insects, bacterial infection and weeds on the crop. As a result, to achieve the twin objective of crop protection and accelerating agricultural production, agrochemicals will be indispensable.

As an illustration on specific crops, tomato production is chosen. A popular horticultural crop mainly grown in Murang'a, Nyeri, Kirinyaga and Kiambu districts. Tomato is a highly susceptible crop to a wide range of pests, fungal diseases and in a few cases, physiological disorders. The most important pests are the American Bollworm, tobacco whitefly, leafhoppers, thrips, aphids, red spider mite and tomato russet mites (MOA,1985). The major diseases are mainly the early and the late blight. Together with pests, these two diseases may cause partial to total crop failure (FAO, 1981). This in itself is an important indication of the role played by crop protection and by far, the use of chemical pesticides which remains one of the most widely used approach to pest control.

So far, effort to increase small scale farmer's tomato output has not achieved much success and production from such farms continue to decline. Compared to the expected tonnage per hectare, the yields realized over the years 1981-88 was 11.13 (Table 1:3). An extremely low value as compared to the expectation of 90-100 tones/Ha.

Many factors may be responsible for the low yields observed. It could be possible that cash crops have taken the best available land, leaving marginal land for food crops. Prices per ton may be low, however, though the prices of tomatoes were falling from 1986 to 1989, its interesting to note that the hectarage under tomatoes was generally rising. Input use could have been low or inefficient.

The trend is not restricted to tomatoes alone but to most agricultural commodities. Table 1:4 gives an indication of this trend. It presents small scale farmers share of gross marketed production between 1981-89.

The production trend for tomatoes in Kiambu from 1981-88 is presented in table 1:3 below for Kiambu district.

TABLE 1.3 THE VALUE, HECTARAGE AND TONNAGE OF TOMATOES PRODUCED IN KIAMBU DISTRICT FROM 1981-88 IN CURRENT PRICES.

YEAR	HECTARAGE	PRODUCTION IN TONES	TONNAGE/ HECTARE	VALUE IN K£	PRICE / TONNE
1981	258	1,447	5.6	144,700	100.0
1982	438	2,457	5.6	125,700	51.2
1983	621	10,212	16.4	4,657,500	431.3
1984	656.5	10,799	16.4	4,925,315	456.0
1985	432	2,160	5.0	4,320,000	2000.0
1986	472	2,832	6.0	5,805,000	2049.80
1987	1,080	15,211	14.1	5,612,859	369.0
1988	2,000	40,000	20.0	6,000,000	150.0
AVERAGE			11.13*		

SOURCE:REPUBLIC OF KENYA, KIAMBU ANNUAL DISTRICT REPORTS (1981-88)

* Expected yield = 90-100 tones/Ha

Table 1.4 SMALL SCALE FARMERS SHARE OF THE GROSS MARKETED PRODUCTION IN PERCENTAGE (1981-89)

YEAR	PERCENTAGE SHARE	DURATION	AVERAGE SHARE (%)
1981	53.80	1981	53.8
1982	51.70	1981-82	52.75
1983	51.20	1981-83	52.2
1984	51.00	1981-84	51.9
1985	54.20	1981-85	52.4
1986	45.10	1981-86	51.17
1987	47.20	1981-87	50.6
1988	47.10	1981-88	50.6
1989	49.33	1981-89	50.0

SOURCE: REPUBLIC OF KENYA, STATISTICAL ABSTRACT, 1990, PAGE 96.

In table 1:4, small scale farms were defined as those ranging from 0.2-12 Ha. Large scale farms were defined to have at least 700 Ha. The data was obtained through sample surveys involving high sampling errors and should therefore be interpreted with care (Statistical Abstract, 1990). Table 1:4 shows that by 1981, the average small scale farmer's share of the gross marketed production was 53.8%. It dropped steadily to 50.0% by 1989.

When the role played by agriculture in the economy and the scarcity of suitable arable land is considered, economic development is likely to stem from increased agricultural output per unit of land especially in the high potential areas. Raising agricultural output per unit of land largely depends on more and better use of purchased farm inputs combined with better crop husbandry. In particular, provision of appropriate farm implements, use of improved seeds and judicial application of agrochemicals has been documented as one way by which small scale farmers could achieve higher yields in Kenya (World Bank, 1989)

1:1:3 ECONOMICS OF PESTICIDES AND PEST CONTROL.

Ideally pesticides should be used until the additional money expended will just return the same amount from additional crop revenue (Carlson,1970). To adequately protect their crops, a farmer should have accurate knowledge regarding the value of his crop, the acreage threatened, available control measures, their cost and the possible impact of the pest on quality and quantity of the crop. But reliable statistics on pesticides use in Kenya is meager and too generalized to form a basis of meaningful policy formulation. Perhaps the single most indicative measure of the costs incurred by farmer on pesticides would be an assessment of the total cost of arable hectarage sprayed annually. Unfortunately, such data is not available and its therefore necessary to resort to less adequate information such as the tonnage of pesticide in use at a given time or the total financial outlay on pesticides. Table 1:5 is based on the latter.

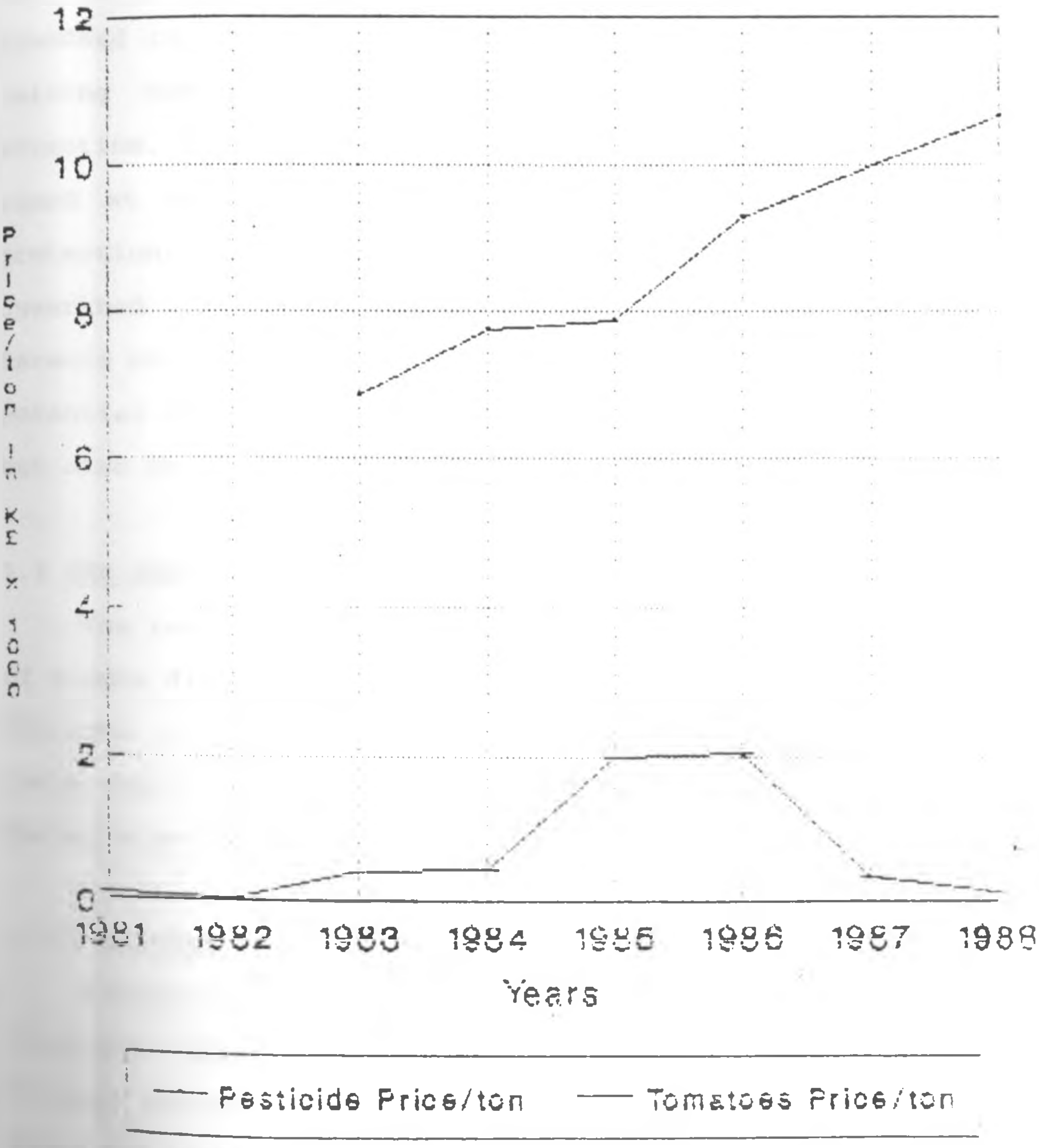
TABLE 1.5 : COST PER TON OF FUNGICIDES AND INSECTICIDES IMPORTED INTO KENYA DURING THE PERIOD 1983-1988 IN KENYA POUNDS,AT CURRENT PRICES.

YEAR	INSECTICIDES	FUNGICIDES	TOTAL	COST/TON
1983	4,470.60	2,385.10	6,855.70	3,427.50
1984	4,831.60	2,915.40	7,747.0	3,873.50
1985	4,823.70	3,073.70	7,897.40	3,948.70
1986	5,954.90	3,325.20	9,280.10	4,640.05
1988	6,881.00	3,783.70	10,664.70	5,332.35

Source: REPUBLIC OF KENYA,STATISTICAL ABSTRACT,1989.

The prices in Table 1:5 are C.I.F prices. Despite the fact that the Custom Duty, port handling and internal transport charges were excluded. The prices of pesticides per Ton in Table 1:5 and those of Tomatoes (per Ton) in Table 1:3 reveals the disparity in price trends in Figure 1 below.

Fig 1: Price trend per ton of pesticide (CIF Prices) and tomatoes between 1981 - 1988 in Kenya Pounds per 1000kgs



It should be noted that the high price of tomatoes per ton in 1984/85/86 was caused by drought.

In view of the rising cost of farm inputs, the Government objective of meeting food self sufficiency and alleviating the standard of living in the rural areas, policies geared towards raising the gains from farm inputs should be given adequate attention. In particular, attention should be given to policies aimed at improving the returns to agrochemicals used in crop protection. Causes of poor returns to farm inputs should be unearthed so that remedies can be identified. In due course, farmers will be able to obtain higher farm output by realizing the potential benefits of improvements not only in agrochemical use but also in other production techniques as well.

1.2 THE AREA OF STUDY

The research was carried out in Kiambu district. Figure No.2 of Kiambu district show the potential land use classification and the area covered during sampling. Kiambu district is one of the three major tomato growing districts in Kenya, the rest being Murang'a and kirinyaga.

1.2.1 GENERAL CHARACTERISTICS OF THE DISTRICT:

Kiambu district occupies an area of 2,448 sq. km. Its divided into seven administrative divisions and twenty seven locations. It borders several districts. To the South is Nairobi city, to the South and south East is Kajiado district. Nakuru district in to the

West. Nyandarua to the North East, Murang'a to the North and Machakos to the East (Fig No. 3).

The district is well placed economically. Market outlets are provided by the adjoining districts, the urban and other trading centres within Kiambu district but by far the largest and most important market outlet is provided by Nairobi City. It is the major market for the district's horticultural products (Jaetzold, R. 1983). The favourable communication network facilitates market accessibility.

The mean annual rainfall varies from 500 mm in the drier areas of Ngoliba and Munyu to 1500 mm towards the North. Rainfall is bimodal, the long rains come in March to may and the short rains from November to December. Tomatoes are mainly grown during the short rains when risk of blight attack is a bit lower. Temperatures are moderate but gets cooler towards the higher areas of Limuru and Githunguri.

The district is dominated by valleys running from North West to South East direction. At the tomato growing areas, the crop is mainly grown along the river valleys while the upper well drained areas are taken by tea or coffee. In some cases, tomatoes are grown on such areas during the long rains. During the short rains, some farmers use irrigation.

Fifty five percent of the district is high potential land. Forty five percent is medium and low potential. The study covered a high potential area in Lari division, receiving 1000 mm of rainfall. This region has red volcanic soils suitable for mixed farming.

The active working group aged twenty to fifty nine year old is approximately 25% of the total population of the district. This group is mainly employed by the agricultural sector (Republic of Kenya, Kiambu District Development Plan, 1984-1988).

Small scale farmers with an average of 1.2 ha are estimated to be 82,000 employing an average of two persons per holding (Republic of Kenya, Economic Survey, 1989). Thus, agriculture is such an important sector that every effort should be put into formulation of ways in which agricultural production and farm incomes can be raised. This is the central theme of this study.

1.3 PROBLEM STATEMENT

Shenoi (1990) estimated that over 85% of the value added in agriculture will come from Kenya's small scale farmers. He noted that this category of farmers cultivate 66% of the total cropped area but obtain yields that are about half of those obtained by large scale farmers.

His conclusion, like that of the Republic of Kenya Development Plan (1989-93), was that this category of farmers will play an important role in the economy owing to their potential of increasing yields, their numerical numbers and the fact that they occupy a large portion of the medium and high potential areas.

At present, tomato yields are low and potential outputs are not realized in the district. This is illustrated by tomato production.

Table 1:3 indicates that only about one tenth of the expected yields are realized. Mukunya et al. , 1978 and the Ministry of Agriculture attributes the observed trend, to a large extent,on the effect of pest and diseases on tomatoes. It is estimated that up to 50% of the tomatoes produced in less developed countries is lost through the influence of pest and diseases and in some cases total crop failure may result (FAO, 1981).

It seems that despite widespread use of pesticides in pest/ disease control, adequate control of the latter is poor and returns to pesticide use, is low.

1.4 OBJECTIVES OF THE STUDY

1.4.1 BROAD OBJECTIVE

To describe the use and the economics of pesticides use in the control of pest and diseases in tomato production in Kiambu district.

1.4.2 Specific objectives

(1) To describe and determine the economic profitability of pesticides use in pest/disease control in tomatoes in Kiambu district.

(2) To describe the use of pesticides in pest/disease control in tomato production in Kiambu district

(3) To determine factors that influence pesticide use in pest/disease control in tomato production in Kiambu.

1.5 HYPOTHESES TESTED

1.5.1 H_o: Insecticide use levels by farmers is not significantly different from recommendations.

1.5.2 H_o: Fungicide use levels by farmers is not significantly different from recommendations.

1.5.3 H_o: Marginal value product of insecticides is equal to Marginal factor cost of insecticides.

1.5.4 H_o: Marginal value product of fungicides is equal to the Marginal factor cost of fungicides.

CHAPTER TWO

2:1 LITERATURE REVIEW

Presented in this Chapter is a brief review of factors which discourage studies on economics of pesticide use in Agriculture. Materials related to these issues are covered under section 2:1 below. Following this section, is a review of relevant studies done in Kenya and elsewhere in the world. Proceeding this section, under section 2:3, is a review of the deficiencies of each of the reviewed studies. Finally, the approach used in this study is highlighted at the end of this section.

2:1:1 ECONOMICS AND DECISION MAKING ON PESTICIDE USE IN AGRICULTURE.

In 1981, FAO/UNEP in joint meeting in Rome noted with concern the apparent lack of economic contribution to decision making process regarding pesticide utilization even though the cost of acquisition and application was rising at unprecedented rate. A task force was put to work, to lay guidelines outlining areas where economics could play a vital role in pest management decisions.

Even after this development, only a handful of studies have been done, chiefly due to certain characteristics possessed by agricultural pesticides as an input in agricultural production. The following are some of the characteristics pointed out.

Ghodake et al,.(1973) noted that economically determined pesticide levels which maximize profits are usually in direct conflict with biologically determined lethal doses. Entomologists urge that pesticide application should always be in terms of discrete levels each comprising of biologically determined lethal dose. One conclusion which can be made from this observation is the fact that though a particular dose may turn out to be profit maximizing, the dose may not be within the prescribed range as given by the manufacturer or the Ministry of agriculture for the purpose of pest/disease control.

Another hinderance was pointed out by Carlson (1971) that unlike other farm inputs, the magnitude of the returns to pesticides hinge upon the ability to assess the economic threshold pest population. The latter being the pest population level that can just be tolerated before an artificial control action is undertaken with the aim of maximizing returns. In practice, determination of the economic threshold pest population is extremely difficult as a result of the following;

(i) Some plants have a tendency to recover from attack and while some pesticides have potential phytotoxic effects on the host, others enhance an upsurge of secondary pests. Still, others have a tendency of killing beneficial insects like bees.

(ii) The concept of economic threshold pest populations is not applicable in prophylactic (preventive) treatments especially those involving control of fungal diseases. Even in insecticides where its applicable, the cost of scouting for pests is expensive both in time and money.

(iii) The farmers literacy and the investment already incurred prior to pest/disease control decisions, play an important role in influencing decisions arrived at (Palti and Ausher, 1986).

Feder (1976) summarized the difficulties encountered by economists in pesticide studies as emanating primarily from difficulties encountered in modelling pest-pesticide-crop interaction.

2:1:2 REVIEW OF RELATED STUDIES

As previously noted, literature in this area is scarce. However, several researchers have ventured into it. Feder (1976) used a pesticide-pest-crop model modified from earlier models by Shoemaker (1973), Talpaz et al.(1974) and Hall et al.(1973). These studies mainly dealt on pesticide use levels that a farmer could choose to maximize profits.

The model used was a simplification of a highly complex system. It focused on an individual farmer within a region containing similar units, Feder (1976) states that:

> "At any given period, there exists a number of pests in the farm (N). The pest cause damage to the crop such that the damage in dollars (D) is functionally related to the number of the pests in the farm such that;

$$D(N) - \delta N \qquad 2:1$$

where $\dot{U}$ is the damage in dollars by an individual pest. The farmer views the individual pest damage and the total number of pests, N as random variables with mean $\bar{\delta}$ and $\bar{N}$.

The total population of the pest is usually not known and the magnitude of the damage per pest (δ) is under the influenced of plant characteristics such as plant susceptibility, pest biotype and weather conditions. The farmer can alter the total population (hence the damage) of the pest by applying pesticide of volume (x). When a pesticide is applied, a proportion k of the pest population is eliminated. Sometimes non-chemical pest reducing activities are adopted. Such effect lasts over the whole season and therefore their cost can be included in the model as a fixed cost (Co). Consequently the pest population (N) is taken to refer to pest population which remain despite non-chemical control measures undertaken".

The impact of the pesticide on the pest in the model was reflected through a kill function (dosage response function) relating the proportion of the pest killed (k) to the amount of pesticide applied (x) assuming decreasing returns to scale such that $K = k(x)$; $k^1>0$, $k^{11}<0$, $k(0) = 0$, $k(0) = 1$. The kill function was recognized to have a random element arising from the fact that pesticide effectiveness is influenced by weather conditions.

Feder (1976) also recognized the influence of other inputs like fertilizer, irrigation, seed certification and provision of proper farm implements on the productivity of pesticides. To simplify the analysis, he assumed all these inputs to be optimally used. Thus, leading to the maximization of the utility function;

$$\text{Max } E\ u\ \{ (O_0 - C_0) - \sigma N (1 - k(x)) - c\,x \} \text{----} (2:2)$$

Where

$\pi_0 - C_0$ denote profits that would be accrued in absence of pests, N = 0.

N(1-k(x)) is the number of pests surviving after pesticide application. cx is the total cost of pesticide application, c is the cost per unit. The farmer's objective function was to maximize returns by choosing the appropriate level of pesticide to be applied.

The author's analysis and subsequent conclusion revealed that in general, the farmer's tendency was to reduce risk of attack to their crop by reducing the proportion of the pest remaining after pesticide application, 1-k(x). This reaction could be precipitated by uncertainty regarding the degree of damage per pest, the number of pests in the farm and uncertainty regarding the effectiveness of the chemical under use. The author concluded that reduction of uncertainty regarding the risk of attack, the pesticides effectiveness and the magnitude of the loses which may be incurred were important steps in regulating pesticide use and in due course increasing there profitability.

Headley (1963) embarked on a study to estimate the contribution of expenditure on pesticides to agricultural output. From the study he aimed to determine whether the marginal benefit diverged significantly from the marginal cost. In this way, he could determine whether a major policy change was necessary in pest control in U.S. agriculture.

The author utilized a Cobb-Douglas production function using state data from the USDA farm income and expense series for the year 1963. Marginal products were calculated from production elasticities of the inputs. The latter were the independent variables in the Cobb-Douglas production function, the farm output, Y was the dependent variable. Headley specified the equation as given below:

$$Y = Ax_1^{b1}.X_2^{b2}\ .X_3^{b3}.X_4^{b4}.X_5^{b5}.X_6^{b6}.e^{u} \text{ ---------(2:3)}$$

where Y was the farm output, the dependent variables x_1 ..x_5 were total labour, land and buildings, machinery, fertilizers and pesticides. To get these variables, state data were divided by the estimated number of farms in each state to develop input-output data for the average farm. After which the data was divided by the 59 principle crops harvested in each state.

The results indicated that chemical pesticides are highly productive input comparable to commercial fertilizers. Indicating the reason behind the increase in sales of pesticides and fertilizers in U.S. agriculture.

Ziwa (1979) estimated production elasticities of various inputs used in maize and cotton production in Meru and Machakos districts. The author researched on whether marginal productivities of pesticides differ with agro-ecological zones (zone III in Meru and Zone IV in Machakos). Finally the author described and determined the difference in yield/ha between maize sprayed with pesticides and maize not sprayed with pesticides.

He used the Cobb-Douglas production function given below;

$$Y = a\ x_1^{b1}\ .\ X_2^{b2}\ .X_3^{b3}\ .X_4^{b4}\ .e^{u}$$

Where

Y = total output of cotton or maize in kg.

X_1 = Land area in hectares

X_2 = Value of pesticides in Kenya shillings

X_3 = Weeding labour in man-days

x_4 = Other labour in man-days

a = Constant

u = Stochastic error term.

e = Natural log.

Using ordinary least square method on the log linear form of the Cobb-Douglas production function, the analysis lead to acceptance of the hypothesis that marginal value product of pesticide on cotton and maize was positive. On value terms, for every shilling spent in pesticides on cotton at Machakos, Ksh. 1.05 could be obtained per shilling of expenditure on pesticides as compared to Ksh 1.53 at Meru. However, if costs of application of pesticide was included as a component of the value of pesticide in

Ksh, at Machakos, only Ksh 1.25 could be obtained and only Ksh. 1.48 at Meru. On maize, the marginal value product per shilling of expenditure on pesticides was Ksh 3.63 at Meru. Ziwa's subsequent conclusion was that it is profitable to spray cotton and maize with pesticides as both had positive marginal value product.

A test of significance of the difference in yield between maize sprayed with and without pesticide application at Meru revealed that the mean difference in yield was not statistically significant at 5% level of significance although marginal productivity of pesticide on maize was Ksh. 3.63 per shilling of expenditure on pesticides. This was a contradictory finding which the author explained by noting that farmers at Meru did not use recommended dosages of the pesticides. Productivity of pesticides was found to differ with agro-ecological zones revealing the fact that pesticide rates could be profitable in some regions and not in others.

Njiru (1980) and Kitulu (1980) carried out separate studies in Kirinyaga and Machakos district respectively. Their main objectives were similar and were given as follows:

To study the use of nitrogen, copper fungicide and captatol in respect to adherence to official recommendations. The second objective was to study the relationship between expenditure on each agrochemicals to total cost or total variable cost. Finally their last objective was to identify socio-economic variables, which influence agrochemical use.

Various models were used in respect to each objective. In objective one, sample agrochemicals use level (X_1) were compared statistically with the sample recommendation levels (X_2) using the Z statistics. The latter was compared to the tabulated value. In regard to frequencies of application, the sample use level (X_1 were compared to the population average, U. In objective two, linear relationship between expenditure on each agrochemicals and total cost or total variable cost was analyzed by use of least square regression. In objective three, simple correlation was used to test the strength of linear relationship whereupon the selected socio-economic variables were identified and father analyzed using multiple regression analysis.

Finally, the data indicated that farmers in both Machakos and Kirinyaga district deviate substantially from official agrochemical use recommendations. In both locations in regard to captatol and copper fungicide farmers deviated negatively in both areas. Nitrogen was used extravagantly. Thus, in both areas, farmers deviated significantly from official recommendations.
Secondly, after the analysis, the sample data in both locations indicated that proportionate linear relationship existed between the expenditure in each agrochemical on one hand and the total cost or total variable cost on the other hand. Hence it was unlikely that the farmers were using the chemicals according to the pest/disease or physiological requirement of the plant.

On socio-economic variables which influence agrochemical use in small scale coffee farming, few among the selected variables;

wealth, age of farmer, equipment used in coffee enterprise, size of coffee enterprise, net farm family income, net income and managerial earning explained the agrochemicals use for each agrochemical used. However for most agrochemicals, family labour, and proportion of total income contributed by coffee were significant explanatory variables.

2:1:3 DEFICIENCIES OF THE REVIEWED STUDIES

Deficiencies of the preceding studies discussed in this section are those that bear relevance to the present study. In regard to the study done by Feder (1976), the model of maximization of returns is based on the number of pests (N) available in the farm at any given time. However, the concept cannot be utilized when dealing with preventative fungicides like Dithane-M45 because N, the total number of pests, cannot be obtained. The model can only apply to insecticides. However the mobility of some of the insects (eg the tobacco whitefly) from adjacent fields would render N, the number of pests estimated to be very inaccurate if not useless. Besides, time and money are constraining factors. At the same time, pesticide levels which maximize returns may be in direct conflict with the biologically determined lethal doses. And profit maximization is just but one of the farmers objectives.

Feder (1976) also assumed that fertilizers, seed certification and implements used by the farmers, were used optimally. The author had recognized that the way those other inputs were utilized tended to affect the productivity of pesticides. Small scale farmers who have been documented to suffer from scarcity of working capital cannot be assumed to use other inputs optimally in tomato production in Kiambu. Input use by small scale farmers have been documented to be less than optimal (Kitulu, 1979. Njiru, 1980. Shenoi, 1990).

The main problem with Headley study of 1963 was that averaging of state data to get the input output data for the average farm in each state masked the variability of the data. The input output data obtained on this basis could not reflect what happened within an individual farm and the results obtained thereof had little relevance to returns on pesticide to an individual farmer. This is so because the model was designed for policy formulation at the macro rather than micro (farmers) level.

Ziwa (1979) had a problem peculiar to his study, he used secondary input-output data recorded from co-operatives. Primary data was not available and therefore he could not confirm whether the inputs bought were actually used on the enterprises under study. He had no information on the manner in which the inputs were used neither could be ascertain whether all the quantities of the inputs bought were completely used by each farmer. However, the way pesticides are used and the quantities used, affect their productivity.

In regard to studies by Njiru (1980) and Kitulu (1980), comparison of sample agrochemical use levels with the recommended sample averages means that H_o, the null hypothesis, could be accepted even though no single farmer was using recommendations.

Averaging the overusers and the underusers could easily give an average which was within the recommendations. Hence leading to acceptance of H_0 that no difference was detectable.

Studies on returns to pesticides often fail to recognize the influence of underusers optimal users and over users on the profitability of pesticides. This mainly occurs because farmers are not categorized into under, over and optimal users prior to analysis. Rather these three categories of farmers are combined together as a single sample. It is evident that the returns calculated thereof will be highly influenced by the most abundant category of farmers. Thus, despite avoiding the deficiencies of previous studies, categorization of the farmers was done.

CHAPTER THREE

3:1 METHODOLOGY

3.1:1 DATA COLLECTED

Secondary data on tomato production in Kiambu for period 1981-89 were provided by the Ministry of Agriculture. On the other hand, data on imports of insecticides and fungicides were obtained from Central Bureau of Statistics (CBS) under the Ministry of Planning and National Development. Primary data were collected from a sample of eighty nine small scale farmers during the short rains of 1991. The following types of data were collected.

Data on types of pesticides (insecticides and fungicides) used, their unit prices, quantities applied, frequency of application, the interval between successive applications and the cost of application.

Data on gross output of tomatoes and the price for each farmer was recorded. To get an average price, the price before at peak and after peak harvest was recorded. Similarly data on other inputs required for tomato production was also collected. They included the amount of each type of fertilizer applied and their unit prices. The labour input into land preparation, planting, staking, pruning and harvesting was recorded. For each farmer, the cost of hired labour per hour was recorded.

3:1:2 SAMPLING DESIGN

To minimize the cost of sampling and to overcome the limitation of poor communication, multistage sampling procedure was chosen. Kiambu district is divided into seven administrative divisions of which only Kikuyu, Githunguri and Lari division are important commercial producers of tomatoes. Because of the nature of the climatic conditions at the time of sampling, the crop in Githunguri and Kikuyu divisions were affected by scarcity of rainfall. Hence, only Lari division was chosen for data collection.

Lari division is divided into 5 locations. The locations formed the primary sampling units (PSU). Two of these PSU, Gatamayu and Kijabe were chosen randomly. The location chosen were further divided into sub-locations which formed the enumeration districts (ED). Six Enumeration Districts (EDs) were chosen randomly from a total of 10 in the two Primary sampling units (PSU). Each sub-location (ED) was dominated by ridges running in the North West to South East direction. They formed the villages or the ultimate sampling units (USU).

At each village or USU, a list of farmers growing tomatoes commercially was prepared by the local extension officer. From the list a random sample of farmers was selected for an interview. Table 3.1 gives the number of farmers interviewed in each sub-location (ED).

TABLE 3.1: NUMBER OF FARMERS INTERVIEWED IN EACH SUB-LOCATION.

Sub-location (ED)	Number chosen for interview	Farmers interviewed	Number remaining after discarding half filled questionnaires
Gatamayu	20	16	16
Kagwe	20	20	20
Kamuchege	20	18	17
Kagaa	20	18	17
Gachoiri	20	15	10
Mbauini	20	12	9
TOTAL	120	99	89

The difference between farmers chosen for interview and those actually interviewed is made up of farmers who were not available for the interview for one reason or another. The half filled questionnaires were discarded. They comprised of farmers who were unable to recall the amounts of inputs used in their plots.

3:1:3 QUESTIONNAIRE DESIGN

The questionnaire used in this study was compiled in accordance with the objectives of the study. Several sources of information were helpful; Examples and guidelines on questionnaire design for collecting reliable information on pesticide use (FAO,1984),extensive modifications were done using questionnaires previously used by Njiru (1980) and Kitulu (1980) in their studies on divergences of agrochemical use from recommendations in Kirinyaga and Machakos districts respectively. Ziwa's (1979) questionnaire proved a good source of information for modification purposes.

Pretesting the questionnaire with 15 farmers at Lower Kabete was done in order to check the suitability of the information collected. It lead to the final modification of the questionnaire which was made to cater for the pest situation, the pesticides in use, the crop under study and the farmers circumstances.

3:1:4 DATA TRANSFORMATIONS

All variables excluding the dummy in the regression equation were converted into per hectare basis. As a result of 'such a standardization, contribution of land manifests itself in the intercept as land is included implicitly in the regression equation. Hence its contribution is not lost.

3.2.1 ANALYTICAL FRAMEWORK

Data analysis was done using two main approaches; Production function analysis where the dependent variable, yield in Kilogram and the factors of production were fitted to a Cobb-Douglas production function. The rest of the analysis was done using cross-tabulations.

Cross-tabulations involved calculation of statistical variables, frequencies, means, percentages and standard deviations of the samples involved. Statistical variables thus generated were used to test hypotheses.

3:2:2 PRODUCTION FUNCTION ANALYSIS

Introduction

In agricultural production, variation in yield occur from farm to farm. To explain the variation, researchers recognize the fact that yield depends on the level of inputs used. Such inputs include fertilizers, labour, seeds, pesticides and a host of several other factors such as the status of the soil, the weather conditions and the management capabilities of the farmer. In practice, it is impossible to list all the factors responsible for the yield observed. Consequently, a simplification is usually done such that the yield observed is taken to be a response of the more important factors. The physical relationship between the input variables and the output of a farm is generally termed as a production function.

The production function analysis is based on three assumptions;

(i) That a continuous casual relationship exist between each of the inputs and the output. Implying that the first derivative of the response equation does exist.

(ii) That diminishing returns prevail in relation to each input. Thus a negative second derivative of the response equation exists.

(iii) Decreasing returns to scale is exhibited such that an equal proportionate increase in all inputs result in less than proportionate increase in output (Dillon.J.L, 1977).

In most applications, production functions based on power type equations have been used to estimate marginal value products for mean inputs based on farm samples. The marginal value products can then be compared with the marginal factor costs.

3:2:3 CHOICE OF THE MODEL

No single form of production function is available for characterization of agricultural production under all environmental conditions. As a result, one of the main difficulties in production function estimation is to select an algebraic form which is consistent with the system being investigated.

Kleinbaum and Kupper (1978) suggested three approaches from which the best analytical model can be obtained. The first approach "the forward strategy" begins with a simple structural model (mostly linear) from which complexity is added in successive steps. The second strategy, "the backward method" begins with a complex structural model from which unnecessary terms are eliminated successively.

The third and the last strategy uses a model suggested from experience and or theory. Allowance is made for increasing or decreasing the complexity of the model as the data may dictate. Several algebraic forms of production function are in common use. They include the linear production function, the square root, the quadratic and finally the power function, the Cobb-Douglas production function is an example of the latter.

Based on the last strategy, a Cobb-Douglas production function was used in this study. The function was used to relate the output of tomatoes in kilogram per hectare to the independent variables, Labour, Insecticides, Fungicides, Nitrogen, Phosphorous Potassium and a Dummy variable for seed certification. Land was included implicitly by converting all the variables into per hectare basis through division of every variable by land in hectares. Section 3:3:0 contains descriptive materials related to each of these independent variables and the dependent variable.

In mathematical terms, the Cobb-Douglas production function can be expressed as

$Y = f\ (X_1, X_2, ---, Xn)$ and specified as

$$Y = A \sum \prod_{(i=1)}^{n} X_i^{b_i} e^{u} \qquad (3,1)$$

Where Y is the dependent variable, n is the sample size, b_is are the elasticities of production of the factor represented by X_i and u is a stochastic error term.

The function has been used widely for analyzing agricultural production systems. Several basic properties of the function has been responsible for this. The Cobb-Douglas production function immediately releases the elasticities of production which are independent of the units of measurement. The function also permits increasing or decreasing returns to scale without taking up many degrees of freedom as compared to other equally applicable functions, like the quadratic function (Heady and Dillon, 1960).

Logarithmic transformation maintains the assumption of independently distributed error terms with a finite variance. The normality assumption makes it convenient to evaluate statistical significance of the relationship between coefficients of statistical parameters relating to regressors and regressants.

Despite its obvious advantages, the Cobb-Douglas production function is unsatisfactory under certain circumstances. An example is where ranges of increasing and decreasing marginal productivities exist or where both positive and negative marginal products exists, in such a case, the function is unsuitable. Again, unless the economic optimum amount is defined over a very small magnitude of the input, the function overestimates the input which equates marginal revenue to marginal cost. Finally, the function assumes unit elasticity of substitution between input variables (Heady and Dillon, 1960).

3:2:4 ORDINARY LEAST SQUARE (OLS) APPROACH

The causal relationship between the yield (Y_i) and the factors of production used, X_i, may be expressed as follows;

$$Y_i = \alpha + \beta x_i + - - - - - - + e$$

Where e is the unexplained variation. Normally, during estimation, not all the factors are included. Exclusion of some of the factors of lesser importance has two justification;

(i) They make the analysis of the relationships between the yield and factors manageable.

(ii The more the variables, the larger is the number of observations needed to estimate the equations (Koutsoyiannis, 1977). Under certain assumptions[1], Ordinary Least Squares (OLS) can be used to unearth the casual relationships between the regressant and the regressor. Data on yield (Y_1) and the input levels (X_i) for each farmer is utilized. Thus, OLS estimates of α and β of the estimated regression line can be obtained. This feat is accomplished by obtaining estimates of α and β that minimizes the sum of squares of the vertical segment drawn from the observed data point (Yi) to

the fitted value Y_i. Hence, ordinary least square involves minimization of error sum of squares.

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[1] For more details, consult Koutsoyiannis (1977).

$$=\sum_{i=1}^{i=n} (Y_i - \hat{Y})^2 \qquad (3.3)$$

(Wonnacott and Wonnacott, 1978)

The OLS estimates are the best linear unbiased estimators[2]. Given any other estimate of Ó and ß depicted by $Ó_o$ and $ß_{o1}$, the OLS estimators always yields the minimum total square error as illustrated below.

$$(y_i - \hat{\alpha} - \hat{\beta}_1 X_i)^2 \leq (y_i - \hat{\alpha}_o - \hat{\beta}_{o1} X_i)^2 \qquad 3:4$$

(Klaubaum and Kupper, 1978).

To judge the "goodness" of the parameter estimates, tests are done. One of the two tests widely used, is the square of the correlation coefficient (R^2). It shows the proportion of the total variation of the dependent variable that can be explained by the independent variables (Koutsoyiannis, 1977). Normally R^2 is adjusted for degrees of freedom. Its then referred as adjusted R^2. The latter only increases when any added variable helps in explaining the variation in the dependent variable.

To verify the validity of the Ordinary Least Squares estimates of Ó and ß, the standard error is used. If the standard error of beta is equal to or smaller than half the numerical value of the parameter estimate, we conclude that the estimate was statistically significant (Koutsoyiannis, 1977).

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[2] Gause Markov theorem, Wonnacott and Wonnnacott (1978).

3:3:0 DEFINITION OF VARIABLES IN THE REGRESSION

3:3:1 Gross output of tomatoes in kilogram

Potential harvest, at any given time, is the crop which matures in the field whether harvested or not. Its the maximum output that can be harvested from that given farm for that particular crop. But the farmer is never able to get the potential harvest, some is attacked by pests, the rest is lost through diseases and only a fraction of the potential output is realized. The amount realized is referred as the actual output. The actual output prior to consumption and marketing is taken as the gross output in this study. The ease of measuring this variable rose from the fact that tomatoes were harvested in standard boxes shown in appendix A.

To improve the accuracy of the estimation, the harvesting period was divided into three stages, the period before peak harvest and its duration for every farmer, the peak harvest and its duration for each farmer and the period after the peak harvest and its duration. The period before and after peak harvest was taken as three weeks unless stated by the farmer. The duration of the peak harvest depended on how long the harvesting period was for each farmer. Hence, the total yield (Yi) in kilogram for each farmer was given by

$$Yi = \bar{Y}_{BP} W_{BP} + \bar{Y}_{P} W_{P} + \bar{Y}_{AP} W_{AP} \quad --- \quad 3:2$$

Where

Y_i Was the tomato yield in Kg/Ha

$\bar{Y}_{BP}$ Was the weekly average number of boxes harvested before peak harvest.

W_{BP} Was the duration of harvesting before peak harvest.

$\bar{Y}_{P}$ Was the weekly average number of boxes harvested during peak harvest.

W_{P} Was the duration in weeks during peak harvest.

$\bar{Y}_{AP}$ Was the weekly average yield in boxes harvested after the peak harvest.

W_{AP} Was the duration of harvesting in weeks after peak harvest.

It should be noted that some farmers only experienced two periods, the period before and at peak period. This happened for farmers whose crop was severely attacked by Red spider mite and tomato russet mites. These two pests were found to be serious at Kagwe and Mbauini Sub-location.

The yield for each farmer was converted into kilograms using the average weights of the standard boxes in Appendix A. The gross output was entered in the model as the dependent variable in kilograms per hectare.

3:3:2 Kilograms of Phosphorus (P_2O_5) applied.

Almost every farmer uses some inorganic fertilizer to improve the natural soil fertility. The extent to which the applied phosphorus influences yield depends on the natural level of phosphorus in the soil. The latter was difficulty to measure and because of this reason, the level of natural phosphorus was assumed to be the same for all farmers.

The amount of P_2O_5 was calculated by using the percentage of P_2O_5 in any given inorganic fertilizer. For example D.A.P. has 18% N, 46% P_2O_5 and 0% K. Hence the amount of P_2O_5 in kilogram = $\%P_2O_5$ multiplied by kilogram of inorganic fertilizer used. Phosphorous was entered in the model as kilogram of P_2O_5 per hectare. Phosphorous influences tomato yield positively. It is responsible for synthesis of chlorophyll in the leaves and therefore influences carbohydrate metabolism. It is expected that it's coefficient in the regression equation will be positive unless too much is used in which case it becomes deleterious to the crop. In the later case, the coefficient will be negative.

3:3:3 Kilograms of Nitrogen (N) applied

The amount of Nitrogen in kilogram is calculated in a similar manner to that of P_2O_5 above. The regressant was entered in the model as kilograms of Nitrogen per hectare under similar assumption that the natural fertility of the soil was the same for every farmer. Nitrogen is required for growth metabolism and its regression coefficient will be positive or negative.A negative coefficient will be witnessed under excessive use.

3:3:4 Amount of Insecticide Applied in Litres

Most farmers used Ambush-cy to control pests. The remainder, used such diverse chemicals as Dedevap, Sumicidin, Rogor, Karate, Brigade, Kelthane, Thiodan, Diazinon and Kilpest. If a chemical had the same pest range as Ambush-cy, the dosages applied were converted into Ambush-cy equivalent. The pest range was checked against a pest chart provided by Twiga Chemical industries. Thiodan, sumicidin karate and diazinon were treated this way. In total, only six farmers were affected.

Different insecticides are made from many different chemical compounds. On the basis of this reason, conversion of dosages into Ambush equivalent could not be based on the active ingredient as different chemicals had different active ingredients from Ambush-cy. To overcome this difficulty, if two units of Ambush-cy were recommended for the same pest range in tomatoes as one unit of another pesticide B, then 2 units of Ambush-cy was taken to be equivalent to one unit of pesticide B. It was assumed that differences in the effectiveness of the pesticides would not affect the results significantly, mainly because of the small number of farmers affected.

Farmers had no standard measure of pesticide dosages. Dosage were measured using containers of different sizes. A measuring cylinder had to be used to estimate the dosage per knapsack.

Multiplication of the latter with the total number of knapsack applied, gave the dosage per single application. The latter was multiplied by the frequency of application to give the total quantity applied over the growing season. It should be noted that less chemical is used per application before the crop matures at 3.5-4 months. Similarly it should also be noted that beyond four months the tips of the tomatoes are still rising and the chemical applied at this stage may be more than at 3.5-4 months stage. However the variables were taken at the 3.5-4 months stage and any discrepancy resulting from this approach was assumed to be low. The independent variable was entered in the model as litres of Ambush-cy per hectare. The regression coefficient is expected to be positive unless its phytotoxic to the crop beyond certain levels of concentrations in which case it may become negative.

3:3:5 Amount of Fungicides Applied in Kilograms.

Mixing of different fungicides presented the biggest handicap in estimating this variable. Seventy two farmers, used Dithane-M45, fifteen farmers used Antracol. The latter has the same active ingredient (Zinc and Magnesium) as Dithane-M45. It was converted into Dithane-M45 equivalent on the basis of the percentage active ingredient. These two fungicides were used individually or in form of mixture. Nine farmers mixed kocide 101 and Antracol or Dithane-M45. The kocide was converted into Dithane-M45 equivalent. Any farmer using Ridomil, Benomyl or Benlate were not included in the analysis as the chemicals are systemic.

Calculation of the total quantity of fungicide used was similar to that of Ambush-cy except that most farmers used a recommended container for measuring the dosages. Where this was not the case, farmers used tablespoons. A table spoonful was estimated to be 20 grams of Dithane-M45.

The independent variable was entered in the model as kilograms of Dithane-M45 per hectare. The regression coefficient is expected to be positive or negative as in the case of insecticides above.

3:3:6 Labour in man-days

Labour[3] used in tomato production was classified according to the farm operations; land preparation, planting, weeding, pruning, staking, fungicide application and harvesting.

The hours worked per day, the number of days worked and the number of people involved were used to get the total hours used in each operation. In doing so, female and male labour was weighted equally. A Man day for children below 15 years old, was taken to be equivalent to a third of that of adults. One of the limitation in labour as a variable was that a Man-day used in one operation was taken to be equivalent to a Man-day used in any other operation. Similarly the rate of doing work varies from one individual to another. The work accomplished by a man day from one individual may be different from that of another individual. Despite these shortcomings the variable was recorded and entered in the model as

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[3] Labour for insecticide application was excluded because, in all cases, insecticides were mixed with fungicides prior to application.

Man-days per hectare. Its regression coefficient is expected to be positive.

3:3:7 Organic Manure in Bags

Organic manure (cattle manure) is an important input in production of tomatoes. All cultivators used manure. Simpson (1986) in his book "fertilizers and manures" points out that different crops respond differently to manures but the highest increase in yield occur in potatoes, sugar beet, marigolds turnips and vegetables. Tomato is a vegetable and in the same genus as potatoes.

Cattle manure contains 1.5-2.5% nitrogen and 2.0-5.0% of P_2O_5. Chicken manure contains 15-25%N and 12-15% Phosphorous. Of these two elements, only 1/3 of Nitrogen and 1/2 of P_2O_5 is released to the first crop (compiled from data obtained from several sources: Simpson, 1986, page 89). Given that 290 Kg of fresh cattle dropping give 1.3 Kg dry matter (ILEIA,1992) and assuming 70% water loss by the time the manure is applied in the farm, then 87 Kg (30% of 290 Kg), will contain 1.3 kg of manure on dry matter basis. Using the percentage content of Nitrogen and Phosphorous above, 87 Kg of manure on average contains 0.026 Kg of Nitrogen of which only 1/3 is available during the first crop. Thus 87 Kg of manure (equivalent to 2 bags) provides 1/3(0.026)Kg N. Similarly, 87 Kg of manure contain 0.0445 Kg of phosphorous of which only half is available during the first crop, equivalent to 1/2(0.0445) Kg of P_2O_5. Decomposed cattle manure was bought in bags from middlemen operating from Narok district. The amount of nitrogen and phosphorous contained in the manure was calculated and added to the inorganic nitrogen. Similarly, the phosphorous was added to inorganic phosphorous. Thus manure was not treated as a variable by itself.

3:3:8 Kilogram of Potassium Applied in Kilograms.

In regard to the farmers who used 20:10:10 the amount of potassium was calculated from the percentage of potassium in the inorganic fertilizer applied. The regressant was entered in the model as kilogram of potassium. A positive or negative regression coefficient is expected.

3:3:9 The Dummy Variable (Seed Certification).

All farmers who planted uncertified seeds were given a value of unity while all other farmers were given a value of zero. The variable was entered in the model as unity for farmers using uncertified seeds and zero elsewhere.

Uncertified seeds have low genetic potential in terms of yield expectations. At the same time their response to external inputs such as inorganic fertilizers is usually low and they may be more susceptible to pests and diseases. Because of these and many other reasons, the regression coefficient is expected to be negative.
A stepwise regression was done to eliminate unnecessary variables.

3:4:0 ANALYSIS OF PROFITABILITY OF PESTICIDES.

The productivity of pesticides is measured by the marginal product of pesticide. The marginal value product is equivalent to the marginal product multiplied by the unit price of the product. In 1966, Massell and Johnson observed that given;

(i) A crop i,

(ii) A factor of production (k) of that crop.

(iii) The elasticity of production E_{ki} of factor k on the crop i,

(iv) The amount of the factor (k) used on that crop, X_{ki},

(v) The yield observed Yi, then, the marginal product f_{ki} is given by:

$$f_{ki} = E_{ki} \frac{\overline{Y}_i}{\overline{X}_{ki}} \qquad 3:7$$

When evaluated at the geometric means of the yield and the amount of the factor, the marginal product obtained relate to that of the average farm.

The principle behind the use of resources for crop protection, as indicated before, is that resources should be used until the additional money expended just returns the same amount from additional crop revenue (Carlson, 1970). Thus in objective one, if the marginal value product is positive then its profitable to use additional pesticides but profits will only be maximized if marginal revenue is equal to the marginal cost. At this point, the regression coefficient which equates marginal value product to marginal factor cost is obtained by equating the right hand side of equation 3:7 to the marginal factor cost, p_x, and solving for the required coefficient. At the profit maximizing point,

$$MVP = \left(E_{ki}\frac{\bar{Y}_i}{\bar{X}_{ki}}\right)P_y$$

And

$$MVP = P_x$$

Therefore

$$\left(B_c\frac{\bar{Y}_i}{\bar{X}_{ki}}\right)P_y = P_x$$

$$B_c = \frac{\bar{X}_{ki}}{\bar{Y}_i}\frac{P_x}{P_y} \quad \dots\dots\dots\dots \quad 3\,7b$$

where β_c = regression coefficient which equates MVP to MFC.

x bar = geometrical mean of input.

y bar = geometrical mean of output.

p_x = marginal factor cost of resource.

p_y = price per unit of the product.

The calculated regression coefficient is tested for statistical difference from the regression coefficient using a t statistic.

3:4:1 DESCRIPTIVE ANALYSIS

To analyze objective two and three, cross tabulations were employed.

3:4:2 DEFINITION OF UNDER AND OVERDOSE OF PESTICIDES.

Pesticide application rates are blanket recommendations with a lower and a higher limit. Farmers applying pesticides within the range are said to apply the pesticides optimally. Any amount applied below the lower limit is taken not to influence pest/diseases appreciably. Similarly any amount applied over and above the upper limit is considered as going to waste.

Under normal farming conditions, some farmers apply pesticides below the lower limit (underdose) others apply within the recommended range while the rest apply higher than the recommended dose (overdose).

3:4:3 ANALYSIS OF OVER AND UNDERDOSE.

Prior to analysis, all farmers in the sample were grouped according to whether they use underdose, overdose or whether they apply the chemicals within the recommendations.

3:4:3:1 Analysis of overdose.

The amount of pesticide in kilogram or litres applied as overdose is given by the actual dosage applied per hectare less the upper limit recommended. The percentage of the farmers in the sample, the amount applied, the mean of the overdose, the mode, maximum and minimum value is evaluated for each category of farmers.

To analyze the amounts of pesticide involved for the whole growing season, the amount of overdose applied is multiplied by the frequency of application. As before, the percentage of the farmers involved, the amounts involved, the mode, mean, maximum, minimum and standard deviation is evaluated.

The statistical variables derived above were used to test the significance of the deviation of the pesticide applications from those applied by farmers who follow recommendations. The extent of the deviations was analyzed by comparing the calculated t statistic against the tabulated value at 95% confidence level. The calculated t statistic was given by:

$$t=\frac{[\overline{X}_1-\overline{X}_2]}{\sqrt{\frac{S^2{}_1}{n_1}+\frac{S^2{}_2}{n_2}}} \qquad 3:8$$

where X_1 bar and X_2 bar are the means of the respective samples. S^2_1 and S^2_2 are the sample variance of the samples involved. n_1 and n_2 are the number of individuals in the respective samples. In the case of Fungicides, farmers applying fungicides within the recommended range were taken to have zero deviations from recommendations.

Consequently, the calculated t statistic becomes;

$$t=\frac{\overline{X_1}}{[S_1/\sqrt{n_1}]} \qquad 3:8\ b$$

The null hypothesis is rejected if the calculated t value exceeds the critical value at the respective degrees of freedom.

3:4:3:2 Analysis of underdose

Except for minor modifications the analysis of underdose was similar to that of overdose. As noted before any amount applied below the lower limit of the recommendations was considered as an underdose. To analyze the amounts used as underdose over the whole growing season, the amount used per single application was multiplied by the frequency of application. The farmers involved, ounts applied, the mean, maximum, minimum and standard deviation as evaluated. Equation 3:8 was used to test the significance of he difference between doses applied by underusers of insecticides nd those that follow the recommendations.

:5:0 FACTORS INFLUENCING PESTICIDE USE IN PEST/DISEASE CONTROL IN TOMATO PRODUCTION IN KIAMBU.

Farmers were asked to respond to the question of what curtails adequate pest/disease control. The responses were tabulated in percentages. Similarly, among the alternatives;

(i) Directions from the packages.

(ii) Guidelines from extension workers.

(iii) Guidelines from salesmen.

(iv) Farmer's past experimentation with the pesticides.

Farmers were asked to respond to what influenced the rates and timing of the applications most. The answers were tabulated in percentages.

CHAPTER FOUR

EMPIRICAL FINDINGS

Presented in chapter four are the main analytical findings. The first section covers the results of the descriptive analysis. Proceeding this section are the results based on production function and multiple regression analysis. The last section presents results on factors which curtails adequate pest/disease control in Kiambu district.

4:1 RESULTS OF DESCRIPTIVE ANALYSIS ON UNDER AND OVERUSE OF PESTICIDES.

The following Tables; table 4.1, 4.2, 4.3 and table 4.4 presents the results on use of under and overdose of pesticides. table 4.1 and 4.3 were constructed on the basis of a single application as opposed to Table 4.2 and 4.4. The latter were based on the total number of applications over the whole growing season. In table 4.1 and 4.3 the optimal users (those within the recommended range) were also included.

4:1:1 ANALYSIS OF INSECTICIDES

Table 4.1 APPLICATION OF UNDERDOSE,OPTIMAL AND OVERDOSE OF INSECTICIDES PER SINGLE APPLICATION IN L/HA.

	INSECTICIDES:AMBUSH-CY			
	Underdose (<1.0 L/Ha)	Overdose >1.5 L/Ha)	Rec. users (1.0 L/Ha-1.5 L/Ha)	Sample Figures
No. of farmers	38	37	14	89
Percentage of Farmers	44.83	40.23	13.79	100.00
Mean amount	0.534	1.934	1.221	1.815
Std.deviation	2.721	8.821	0.094	7.063
Maximum	0.988	5.087	1.480	6.587
Minimum	0.098	0.037	1.097	0.098
Total Amount	20.830	67.667	14.653	157.895
Value (Ksh)	6,209.40	20,171.50	4368.00	192,116.50

Source:Sample Data.

Analysis of underdose revealed that 44.83% of the farmers used less than the recommended rate of 1 L/Ha of Ambush-CY. On average these farmers used 0.534 L/ha. Assuming the application does not affect the pests appreciably due to the low dosage used, such farmers stood to lose Ksh 159.20 for every application executed. This being the value of 0.534 L of Ambush-cy at the prevailing average price of Ksh 298.10 per litre. At the prevailing market prices in Appendix B and the average price of Ksh 4.40 / Kg of tomatoes, equation 3.7 gives the economic optimal amount of insecticides and fungicide over the growing season as 138.24 litres and 323.43 Kg/Ha respectively. However, farmers used between 0.96 and 36 litres of insecticides per hectare which is far below the economically optimal amount. Results show that 86.21% of the farmers do not use the insecticides as they should. Its therefore no wonder that the effectiveness of insecticides is low, giving rise to high incidence of pest/diseases and low outputs per hectare.

4:1:2 HYPOTHESES TESTING

4:1:2:1 Underuse of insecticides

Equation 3:8 was used to test the null hypothesis that insecticide use levels by farmers was not significantly different from recommendations. Using Equation 3:8, to test hypothesis one, the calculated t statistic was given by:

$$t=\frac{\overline{X}_1-\overline{X}_2}{\sqrt{\frac{S^2_1}{n_1}+\frac{S^2_2}{n_2}}} \qquad 3:8 \text{ (repeated)}$$

$$t=\frac{0.534-1.221}{\sqrt{\frac{0.261^2}{39}+\frac{0.094^2}{12}}}$$

$t = -13.74$

From the equation above and the data in table 4:1,Clearly, enough grounds exist to reject the null hypothesis in favour of the alternative hypothesis because the critical $t_{0.05,49}$ value of -1.68 is exceeded. Acceptance of the alternative hypothesis means that at 95% level of confidence, 44.83 % of the farmers underuse insecticides to such an extent that they may not be effective in combating pests, leading to crop loses and reduction in profits. Available evidence as deduced from Table 4:1 seem to indicate that more effort should be laid on availing evidence to the farmers on the importance of discouraging use of low and ineffective doses as well as curbing overuse.

4:1:2:2 Overuse of insecticides

Taking the population deviation of the farmers following recommendations to be zero, then, the calculated t statistic for deviations resulting from overuse of insecticides was given by (equation 3:8b);

$$t_{0.05,36}=\frac{1.934-0}{8.821\sqrt{37}}$$

$$t_{0.05,36}=0.036$$

The critical $t_{0.05,36}$ is 1.68. Hence, the null hypothesis that farmers overusing insecticides do not deviate significantly from recommendations was accepted. By so doing, it means that 40.23% of the farmers who overuse insecticides do not deviate significantly from recommendations. Consequently, underuse of insecticides is the major handicap to pest/disease control.

As noted before, the total loss from under and overuse of pesticides is reflected by the number of applications made. The total amounts of over and underuse of insecticide was obtained from values of single applications (presented in table 4.1) multiplied by the frequency of application. The values thus obtained are presented in table 4.2

Table 4.2 TOTAL AMOUNTS OF OVER AND UNDERUSE OF INSECTICIDES APPLIED IN L/HA, DURING THE CROP CYCLE

	INSECTICIDES;AMBUSH-CY	
	Total <1 L/HA	Total>1.5 L/HA
Number of farmers	38	37
% of farmers	44.83	40.23
Mean Amount	4.147	11.777
Max. Amount	11.125	26.45
Standard deviation	2.721	8.281
Min. Amount	0.118	0.444
Total Amount	157.571	435.733
Value (Ksh)	47,696.70	131,896.40

Source: Sample Data.

From table 4.2, during the growing season, farmers lost on average Ksh 1,236.20 through underdose. This being the value of 4.147 Litres of Ambush-cy per Ha. Those using overdose lose an equivalent of Ksh 3,510.70 on average. More than anything else table 4.2 illustrates the possible quantities of insecticides lost through the growing season. The fact that total underuse ranges from 0.118 to 11.125 L/Ha and total overuse from o.444 L/Ha to 26.45 L/Ha gives evidence of the erratic manner in which insecticides are used. To curb this trend, studies on factors responsible for erratic usage should be given prominence.

From the outset, the prices of pesticides were shown to increase at a higher rate than those of the produce. Coupled with the loses observed in table 4.2 above, it is evident that utilization of agrochemicals in this manner leads to reduction in profit arising primarily from ineffective or wasteful pest control measures.

4:1:3 ANALYSIS OF FUNGICIDES

Analysis of underuse, the use of recommended doses and overuse of fungicides is presented in table 4.3 below.

TABLE 4.3: APPLICATION OF UNDER,OVER AND OPTIMAL DOSES OF FUNGICIDES IN KG/HA (RECOMMENDED RANGE IS 1.5-2.5 KG/HA.)

	FUNGICIDES:DITHANE-M45. underdose (<1.5 Kg/Ha)	overdose (>2.0 Kg/Ha)	rec. doses (1.5-2.0 Kg/Ha)	Sample Figures
Number of farmers.	25	44	19	88
% of farmers	28.41	50.0	21.59	100.0
Mean Amount	0.866	2.518	2.026	23.825
Standard. deviates	6.438	19.02	.290	21.639
Max. Amount	1.482	6.481	2.470	132.95
Min. Amount	0.079	0.110	1.581	4.3 ,
Total.Amount	21.654	110.784	38.497	2,096.582
Value (Ksh)	4,829.90	24,710.40	8,586.8	467,642.60

Source: Sample Data.

$$t=\frac{\bar{X}_f}{[S_f/\sqrt{n}]}$$

where X_f is the mean over dose of fungicide used.

S_f is the standard deviation and n is the number of farmers.

$$t=\frac{2.518}{[1.757/\sqrt{44}]}$$

$$t=9.51$$

If the calculated t value exceeds the critical $t_{0.05,43}$ value of 1.68, then, the null hypothesis is rejected in favour of the alternative hypothesis. Thus at a confidence level of 95%,the null hypothesis can be rejected in favour of the alternative hypothesis. Consequently, 50% of the farmers use significant amounts of fungicides, over and above the recommendations. Such farmers incur loses through the additional cost of fungicides which under practical considerations, can be said to be going to waste. Thus to reduce overuse, one important consideration is to relate fungicide use to the risk of disease attack thereby decreasing the frequencies of application and advocating the use of the lower limits of the recommendations during periods of low risk.

4:1:4:2 Underuse of fungicides.

Using equation 3:8 and data on table 4;3, a null hypothesis that farmers underusing fungicides do not deviate significantly from recommended rates was tested. The calculated t statistic is given by;

$$t_{0.05,23}=\frac{0.866-2.026}{\sqrt{\frac{6.438^2}{25}+\frac{0.29^2}{19}}}$$

$$t_{0.05,42}=1.658$$

The tabulated t statistic of 1.68 is more than the calculated t statistic and hence the null hypothesis was accepted.

TABLE 4.4: TOTAL AMOUNT OF FUNGICIDE APPLIED AS OVER AND UNDERDOSE. (RECOMMENDED RANGE IS 1.5 -2.5 KG/HA).

	FUNGICIDES:DITHANE-M45	
	Total<1.5 Kg/Ha	Total>2.5 Kg/Ha
% of farmers	26.14	50.0
Mean Amount.	10.298	27.591
Std.deviation	6.438	19.052
Max.Amount.	25.935	66.950
Minimum Amount	0.730	0.828
Total Amount.	236.859	1214.002
Value (Ksh)	52,831.40	270,738.20

Source: Sample Data.

From Table 4.4 above, as much as 76.14% of the farmers do not use fungicides as they should, either losing through under or overuse. In fungicides, overuse was more pronounced than underuse.

As noted above, this reflects the fact that fungicide are applied as an insurance against fungal diseases and not necessarily when treatment is required. Its therefore evident that ensuring that pesticides are used as they should would be the first goal in trying to arrest the recurring pest/disease problems experienced in Kiambu.

4:2 RESULTS OF REGRESSION ANALYSIS.

Below, in Table 4.5, are the variables in the Cobb-Douglas Production Function. The Sum, mean, maximum, minimum and standard deviation of the variables are given.

TABLE 4.5: STATISTICAL PARAMETERS OF THE VARIABLES IN THE REGRESSION EQUATION.

Variable/Ha	Sum	Mean	Maximum	Minimum	Std. dev.	Geometrical mean
Yield (Kg)	513,284.5	5,767.2	19,440	508	3,494.9	8.475
Labour(MD)	4,548.9	51.1	131.6	6.1	25.6	3.814
Fertilizer(Kg)	2997.7	33.5	265.1	0.1	33.7	2.274
Fungicide(Kg)	2096.6	23.8	133	4.3	21.6	2.843
Insecticides(L)	644.5	7.2	36	0.96	7.1	1.624

Source:Sample Data.

In table 4.5, Nitrogen in Kg/Ha, Phosphorous in Kg/Ha and Potassium in Kg/Ha was aggregated together as N.P.K fertilizer. The three variables, calculated from inorganic and organic fertilizer, were correlated such that it was difficult to decipher the individual influence of each variable on the dependent variable. PindycK and Rubinfeld (1986) states that;

"---------If two variables are highly correlated, its possible to obtain least square coefficients though interpretation becomes difficult. Partial regression coefficients are interpreted to measure the change in dependent variable due to a change of the variable in question other variables held constant--------". Varying one of the related variable without varying one of the related variable become impossible so that such coefficients become difficult to interpret.

The yield as observed in table 4:5 show a wide range of variation from 508Kg/Ha to 19,440Kg/Ha. The mean yield of tomatoes was 5,767.2 Kg/Ha. When compared with the expected yield of 100,000 Kg/Ha, it gives 5.8% of the expected yield. The fact that the maximum yield recorded was 19,440 Kg/Ha reveals the fact that production per hectare can be improved.

Tomato production is labour intensive though variation in labour allocated to tomato production was great. The maximum being 131.6 Man days and the lowest being 6.1 Man days, on average 51.1 Man days were utilized.

Consumption of fertilizers was widespread. Where application of inorganic fertilizer was low, manure application was used for supplementation. On average, farmers used 33.7 Kg of N.P.K comprising an average of 17.37 Kg of Nitrogen 11.19 Kg of P_2O_5 with the remainder taken by potassium. The figures however do not reflect the fertility status of the soil prior to application, a factor which may distort the observed coefficient of N.P.K fertilizer.

Pesticide use was erratic. Application ranged from 0.96 L/Ha to 36 L/Ha of insecticide and 4.3 Kg/Ha to 133 Kg/Ha of the fungicide over the growing season. On average, 7.2 L/Ha of insecticide and 23.8 Kg/Ha of fungicide were used. The wide ranges observed were attributed to differences in frequencies and rates of application per hectare. Pesticides were therefore thought to be used irrationally and could account for some of the difference between the observed and the expected yield.

4:2:1 REGRESSION COEFFICIENTS OF THE ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION.

The estimated Cobb-Douglas production function for cross-section data on small scale tomato growers in Kiambu is of the form

$Y = A.X_1^{b1} . X_2^{b2} . X_3^{b3} . X_4^{b4}$ --------Cited as equation 3:1

Where

Y = Gross output of tomatoes in Kilogram per hectare.

X_1 = Litres of Insecticide (Ambush-cy) applied on tomatoes per hectare from transplanting to harvesting.

X_2 = Kilograms of Fungicide (Dithane-M45) applied on tomatoes per hectare from transplanting to harvesting.

X_3 = Labour in Man days used for land preparation, planting, weeding, pruning, staking, and pesticide application per hectare.

X_4 = N.P.K fertilizer in Kg per hectare.

r_1 = Dummy variable for seed certification.

b_i = The estimated regression coefficients.

A = A constant.

Using ordinary least square, the equation was estimated in its log. linear form.

$\ln Y = \ln A + \beta_1 \ln X_1 + \beta_2 \ln x_2 + \beta_3 \ln_3 x_3 + \ldots\ldots\ldots$ 4:1

The coefficients obtained are presented below. All variables except insecticides had significant t-values. Table 4:6 presents the coefficients obtained from the analysis.

TABLE 4.6 MULTIPLE REGRESSION COEFFICIENTS: DEPENDENTS VARIABLE IS TOMATOES IN KILOGRAM PER HECTARE.

Independent Variable (X_i/ha)	ß	SE ß	T value	Sig.T
Dummy (R)	-0.56194	0.11663	-4.818	0.0000
Insecticide (l/ha)	0.06133	0.06029	1.017	0.3120
Fungicide (kg/ha)	0.19776	0.06553	3.018	0.0034
Labour (MD/ha)	0.37015	0.09589	3.860	0.0002
Fertilizer (NPK kg/ha)	0.12376	0.03687	3.357	0.0012
Constant	6.15745	0.37366	16.479	0.0000

Multiple R = 0.75493

R^2 = 0.56991

Adjusted R^2 = 0.54369

SOURCE: ESTIMATED COBB-DOUGLAS PRODUCTION FUNCTION FROM SAMPLE DATA.

All the regression coefficients have the appropriate signs. The negative coefficient of the Dummy variable imply that uncertified seeds have a negative influence on yield, either due to their low genetic potential, low resistance to pests/diseases or due to low ability of responding to production inputs. The results show that several explanatory variables were significant above 99%.

However insecticides were only significant at 69%. As a result they do not explain variation in yield of Tomatoes appreciably. Given the fact that only 13.79% use insecticides as they should (table 4.1), this is hardly surprising. The 44.83%of farmers who use an average of 0.534 L/ha may be contributing nothing to yield by so doing. As opposed to fungicides, a higher proportion of farmers underuse insecticides.

4:2:2 THE GOODNESS OF FIT

The explanatory variables explains 54% of the variation in the tomato yield. The rest 46% is unexplained. Adjusted R squared for cross-section data should be in the range of 60%. Low R^2 is, believed to have resulted from the following considerations;

(i) Variables may be omitted from the regression equation either because they are unknown to the researcher or because, even when known, they may be elusive to statistical quantification. Some variables are omitted because, individually they have little influence on the dependent variable and adequate observations may not be available for analysis.

(ii) Low R^2 may result from mispecification of the model.

(iii) Aggregation of data over time, spatial or cross_sectional adds together data influenced by factors which are different to some degree, thus introducing errors of aggregation.

(iv) Deviation of observed values from fitted regression line may result from errors of measurement during collection and processing of data. The stochastic error term is introduced in the model to accounts for the unexplained variation.

4:2:3 PROFITABILITY OF PESTICIDES

The prices of tomatoes in Kilogram fluctuated from Ksh 1.0 per to Ksh 7.50/Kg. For each farmer, the price was obtained by averaging the price at, before and at peak harvest. On average, the price of tomatoes per kilogram was Ksh 4.40. On the other hand, the actual retail value of pesticides was distorted. The distortion was caused by three factors;

(a) Sale of unpacked pesticides

These were pesticides either bought from stockists and sold in small quantities at a profit or pesticides smuggled from across the border (as claimed by farmers).

(b) High price of small packages.

All prices were converted into per Litre (insecticides) or per kilogram (fungicides) basis. Since small packages are relatively costly, the resultant price per litre or per Kilogram was higher.

(c) Conversion of different insecticide into Dithane-M45 equivalent and different insecticides into Ambush-cy equivalent.

The above conversion resulted in harmonization of pesticides of different prices. Consequently,the prices of Ambush-Cy and Dithane-M45 used, was given by the average price quotations in appendix B.

Given that profits are maximized at the point where marginal value products equals marginal factor cost, then at that point the ratio of marginal value to marginal factor cost is unity. Any significant difference from unity imply that profit can be improved either by using more or less input. To compare MVP and MFC, the regression coefficient (β_c) which equates marginal value product to marginal factor cost is evaluated using equation 3.7b and compared with the sample regression coefficient. The statistical basis of comparison was facilitated by use of t statistical given by

$$t = \frac{\beta - \beta_c}{s\beta}$$

where $s\beta$ is the standard error of the sample regression coefficient. β_c is the coefficient which equates MVP to MFC. Analysis of the data indicated the following.

Table 4:7 HYPOTHESES TESTING ON MARGINAL VALUE PRODUCTS AND MARGINAL FACTOR COSTS.

VARIABLE	H_o	Geometrical mean	regression coeff.	Calculated coeff.	t value	t critical	H_o Status.
Fungicide	MVP=MFC	2.843	0.19776	0.7052	10.68	2.0	Rejected
Insecticide	MVP=MFC	1.624	0.06133	1.1808	15.00	2.0	Rejected
Yield	-	8.475	-	-		-	-

Source: Sample Data.

Table 4.7 gives the tests of hypotheses on marginal value products and the marginal factor cost. From table 4.7 the, hypothesis that MVP = MFC is rejected in favour of the alternative hypothesis. Similarly H_o for fungicide is rejected in favour of the alternative hypothesis. As a result, small scale farmers growing tomatoes in Kiambu use pesticides (fungicides or insecticides) in unprofitable manner in the sence that profits can be improved. However no general statement regarding the cause can be arrived at on the basis of these two tests.

However for every additional kilogram of fungicide used, 0.19776 Kg of tomatoes are obtained equivalent in value to Ksh 2.60 and for every litre of insecticide used 0.06133 Kg of tomatoes are obtained equivalent in value to Ksh 1.40. From the results above and those noted earlier under descriptive analysis (pg 52), 44.83% used very low amounts of insecticides averaging 0.534 L/Ha. Such farmers should increase the quantities of insecticides applied in order to reduce the gap between the marginal value product and the marginal factor cost. On the other hand, 40.23% of the farmers used the insecticide in rates which were over and above the requirements. To make insecticide use more profitable such farmers should be encouraged to reduce excessive use of insecticides. Similarly, on the question of fungicides (Pg 57), 26.14% under use fungicides and they can make fungicide use more profitable by increasing the quantities of fungicides that they use, thereby approaching the point at which marginal revenue is equal to the marginal cost. But the majority 50% over use fungicides, their remedy on raising the profitability of fungicide use, lies on their ability to follow fungicide recommendations and thereby reducing the overuse. The implication of the above results was that farmer's pesticide use was not profit maximizing.

4:3:0 FACTORS RESTRICTING ADEQUATE PEST /DISEASE CONTROL.

In the effort of trying to control pest and diseases, farmers were faced by various problems. Table 4.8 below presents the response to the question of what curtails adequate pest/disease control in tomatoes in Kiambu. The responses were tabulated in percentages. The constraints ranged from inability to afford the inputs, lack of access to advice to low effectiveness of the pesticides. However, it should be noted that claims of low effectiveness should not be construed to mean poor efficacy of the chemicals. The cause could have resulted from poor application techniques to adulteration of the chemicals sold in unpacked form by middlemen.

Table 4.8 FACTORS RESTRICTING ADEQUATE PEST/DISEASE CONTROL IN TOMATOES IN KIAMBU.

Factor	Percentage of respondents with a similar complaint.
Inability to afford adequate amounts	62.9
Lack of access to advice	33.7
Low effectiveness of unpacked insecticides.	22.5
Poor effectiveness of unpacked fungicides.	21.3

SOURCE: Sample data.

From table 4.8, majority of the farmers (62.9%), seem not to be able to purchase adequate pesticides to be able to comply with the recommendations of pesticides in question. On advice, 33.7% claim not to have access to advice when required. A possible consequence of the communication difficulties in the area and the high ratio of farmers to extension officers. Complaints against poor effectiveness of the chemicals was mainly levelled against middlemen in the region who buy, unpack and sell pesticides in small quantities. Such chemicals have questionable quality as a result of possibilities of adulteration. Repacking is against the law.

Besides economic factors, five other factors are important. They influence the rates and timing of pesticide applications, they include the use of directions on the package, guidelines from extension workers, guidelines from salesmen and experimentation by farmers themselves. The influence of each was presented in Table 4:9 below.

TABLE 4.9: FACTORS INFLUENCING RATES AND TIMING OF APPLICATIONS.

Factor	Percentage of respondents claiming the factor to have the greatest impact on the amounts and timing of application
Extension workers	29.2
Directions on the package	23.6
Interfarmer communication	22.5
salesmen	19.1
farmers own experimentation	41.5

Source: Sample data.

Table 4.9 gives evidence on the fact that extension services need to be improved on pesticide use. Out of 100%, only 29.2% of the farmers claim that extension service has the greatest influence on the rates and timing of applications. Noting that interfarmer communication accounts for 22.5%, tendency towards group demonstrations of pest control should be encouraged. Salesmen should be conversant with pest control as their influence affects 19.1% out of 100% of the farmers.

CHAPTER FIVE

SUMMARY AND CONCLUSION

Chapter five presents the summary of the study. The conclusions arrived at and finally the possible options available to remedy the situation.

5.1 SUMMARY

As the cost of pesticides per unit continue to rise while that of tomatoes remain constant or declines, further loss is being inccured through reduction in quality and quantity of the produce by pest/diseases. Loss in tomatoes is estimated to be 5% to 50% in less developed countries (F.A.O., 1981). Available evidence show that though virtually all farmers use pesticides, the use has not eliminated the heavy losses incurred through quality and quantity reductions caused by pests/diseases. Neither does there seem to be a marked increase in efficiency of pesticide use.

The study, done in Kiambu district, was an attempt to analyze use and the economics of agrochemical use in tomato production. The study employed primary data collected from a random sample of eighty nine small scale farmers commercially producing tomatoes in Kiambu district. Data on output of tomatoes in kilograms was fitted to inputs using a Cobb-Douglas production function selected apriori. The choice of the latter was based on its advantages over other functional forms of production functions.

Several difficulties, encountered in this study require emphasis. Not all input variables could be included in the regression equation due to estimation difficulties which discourage such endeavor. The accuracy of the data influences the conclusions made thereof but the study relied mainly on the farmers ability to recall the inputs used and their inclination to tell the truth. Lack of suitable approach to quantify the management input and lack of a suitable denominator under which different fungicides and insecticides could be combined together as one variable presented a setback. Some variables were difficulty to quantify. The quality of labour from one person to another could not be quantified. Labour for different operations was weighted equally. Similarly female and male labour was also weighted equally but that of children below fifteen years was taken to be a third of that of the adults for every Man day worked. Even after all these setbacks many of the observations and conclusions derived from this study have important policy implications and suggestions.

The broad objective was to study the use and the economics of agrochemicals used in tomato production in Kiambu district. The specific objectives included the following;

To describe and determine the economic profitability of pesticides used in tomato production in Kiambu district. After analysis, ·the data indicated that, the deviation between marginal value product and marginal factor cost was significant. For every litre of insecticide used, 0.06133 Kg of tomatoes were obtained, equivalent to Ksh 1.40. The gain was very low but understandable considering that 44.83% of the farmers underuse insecticides while 40.23%

overuse it. Insecticides did not feature as a significant explanatory variable to variation in yield.

Similarly, on economic profitability of fungicides used in tomato production in Kiambu district. Results indicated that ,as in the case of insecticides, marginal value products was significantly different from marginal factor cost. For every Kilogram of fungicide used, 0.19776 Kg of tomatoes are obtained, equivalent in value to Ksh 2.60. The gain was very low,as in the case of insecticides, only 21.59% used fungicides according to recommendations.

The second objective was to describe pesticide use in pest/disease control in tomato production in Kiambu district. As noted from above, only 13.79% of the farmers use insecticides within the recommended range. A fact that is thought to have a big impact on the pest/disease status in the district. The null hypothesis that insecticide applications by farmers underusing insecticides is statistically equal to that of farmers following recommendations was tested and discarded in favour of the alternative hypothesis. Consequently, farmers encounter pest problems as the insecticide applied may not affect the pests appreciably. Additional expenditure was incurred by those who overused the insecticides though they were found not to deviate significantly from those who follow recommendations.

Analysis of fungicides revealed that majority of the farmers, 50% overused fungicides. Only 28.41% underused it. This group of farmers was found not to deviate significantly from those following recommendations. Similarly under objective two, the null hypothesis that fungicide applications by farmers overusing fungicides was statistically equal to that of farmers following recommendations was tested. The alternative hypothesis was accepted. Hence, such farmers suffered additional cost of production resulting from excessive use of fungicides.

The final objective was to determine the factors that influence pesticide use in pest/disease control in tomato production in Kiambu. Inability to afford pesticides ranked highest with 62.9% of the respondents. Lack of advice from extension staff accounted for 33.7%. Out of the total number of farmers, 22.5% complained against efficacy of insecticides, bought and repacked by middlemen in the region and then sold to the farmers. A similar complaint was raised against fungicides by 21.3% of the farmers.

5.2 CONCLUSION

Pesticides are inputs of paramount importance in agriculture. In some enterprises, more so in tomatoes, they govern the extent of the gap between yields achieved and yields achievable. When not used judiciously, agriculture in general and horticulture in particular, may be drastically affected through the influence of pests and diseases.

In conclusion, the study has revealed the plight of farmers in regard to crop protection. The profitability of pesticides used in crop protection in tomatoes can be improved. A lot of underuse and overuse of pesticides exist, leading to a big gap between marginal value product and marginal factor cost. A factor that contributes negatively in the effort of combating pest/diseases.

Insecticide utilization was rather poor. The majority of farmers, 44.83%, underused while 40.23% overused the insecticide, only a mere 13.79% followed the recommendations. A similar problem was noted in fungicides, where only 21.79% followed recommendations. Fifty percent overused while 28.41 underused fungicides, as a result, use of unrecommended pesticide rates is a big problem in this area. Thus returns to pesticide use will continue to be low unless corrective measures on how to use them is undertaken.

5:3 RECOMMENDATIONS

To tackle the problem of pest/disease menace in tomato production in Kiambu, the following recommendations were advanced;

(i) Profits accrued from pest/disease control can and should be raised by increasing the efficiency of pesticide use in such a way as to reduce the use of very low and very high doses. Rampant misuse of pesticides should be curbed through a rigorous extension service. Non Governmental Organizations should be encouraged to contribute towards effective and safe use of pesticides.

(ii) Research need to focussed on raising the efficiency of pesticide use.

(iii) Evaluation of agricultural extension service in a view of making it more responsive to problems of pests/diseases in the region is necessary.

(iv) Standards of pesticides sold in the region should be maintained through law enforcement against selling unpacked or repacked pesticides. Such pesticides reduces the effectiveness of pest/disease control because they are prone to adulteration.

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APPENDIX A

WEIGHTS OF STANDARD BOXES USED DURING HARVESTING OF TOMATOES IN KIAMBU DISTRICT.

STANDARD BOXES	WEIGHT
SMALL	30 KG
MEDIUM	45 KG
LARGE	60 KG

Source Sample data.

APPENDIX B:

AVERAGE PRICE OF AMBUSH-CY AND DITHANE-M45 FROM PRICE QUOTATIONS

	CHEMICAL	SOURCE	PRICE QUOTED
1.	AMBUSH-CY	E.A. SEED COMPANY	KSH. 293.50
2.	AMBUSH-CY	SIMPSON AND WHITELAW LTD	KSH. 302.70
	AVERAGE PRICE QUOTATION		KSH. 298.10

CHEMICAL	SOURCE	PRICE QUOTED
DITHANE-M45	E.A. SEED COMPANY LTD.	KSH.223.05
DITHANE-M45	SIMPSON AND WHITELAW LTD.	KSH. 223.05
AVERAGE PRICE QUOTATION		KSH. 223.05

QUESTIONNAIRE ON AGROCHEMICALS

Name of the interviewer ______________________

Name of the farmer ______________________

Sub-location ______________________

Date ______________________

A: BACKGROUND INFORMATION

(1) What is the area under tomatoes in your farm?....(specify the units)

(2) Which type of tomato seeds did you plant? (Tick the correct entry)

(a) Certified.

(b) Uncertified.

B: INFORMATION ON YIELD

(1) By considering the time duration before peak Tomato harvest (taken as three weeks unless otherwise stated by the farmer), fill the relevant information below.

Size of the harvesting box	Average number of boxes per week	Duration in weeks	Price per box
(a) Small size	__________	________	________
(b) Medium size	__________	________	________
(c) Large size	__________	________	________

(2) Similarly, fill the average number of boxes, the duration and the price per box regarding the peak harvest.

Size of the harvesting box	Average number of boxes per week	Duration in weeks	price per box
(a) Small size	____________	________	_______
(b) Medium size	____________	________	_______
(c) Large size	____________	________	_______

(3) Finally, fill the average number of boxes, the duration and the price regarding after peak harvest (taken as three weeks unless otherwise stated by the farmer).

Size of the harvesting box	Average number of boxes per week	Duration In weeks	Price per box
(a) Small size	______________	_________	________
(b) Medium size	______________	_________	________
(c) Large size	______________	_________	________

(C)INFORMATION ON INSECTICIDES.

(1) In regard to the insecticide used, indicate the dosage per sprayer (knapsack) the size of the later and how many Knapsacks required per the area under tomatoes per single application of the mature crop(about 3.5 months)

insecticide	Sprayer size (L)	Dosage per sprayer	Sprayers per area given.
(a)__________	______	______	_______
(b)__________	______	______	_______
(c)__________	______	______	_______

(2) Basing your answers on the mature tomato crop ,fill the table below regarding the insecticide(s) applied on your tomato crop since the initial application.

Name of insecticide(s) applied.	Frequency of application	Dosage (Kg or L)per area given	Cost per unit	Transport cost from retail
(a) ________	__________	_______	______	_______
(b) ________	__________	_______	______	_______
(c) ________	__________	_______	______	_______

(3) What is the cost of hiring labour per day per person?.....How many hours does the labourer work per day?...

(4) For every single round of insecticide spray, indicate the following

Number of people required.	Number less 15 years old	Hours worked per day	Total number of days worked
----------	----------	---------	----------
----------	----------	----------	----------
-----------	----------	-----------	-----------

(D) <u>INFORMATION ON FUNGICIDES</u>

(1) For every round of fungicide application, indicate the fungicide used, the size of sprayer, the number of sprayers (knapsacks) required and the dosage per sprayer, base your answers on mature crop (3.5-4 months)

Fungicide	Sprayer size (L)	Dosage per sprayer	Number of sprayers
(a)_______	_______	_______	_______
(b)_______	_______	_______	_______
(c)_______	_______	_______	_______

(2) Basing your answers on the mature Tomato crop and starting with your earliest fungicidal application, fill the information regarding frequency, dosage,cost of acquisition and transport.

Name of fungicide applied	frequency of application	Dosage per area given	Cost per unit (Kg/L)	Transport cost from retail
(a)________	___________	________	_____________	________
(b)________	___________	________	_____________	________
(c)________	___________	________	_____________	________

(3) Consider a single round of fungicide application on mature tomato crop and fill the relevant information below

Number of people required	Number less 15 years old	Hours worked per day	Number of days worked
(a)_________	__________	_________	________
(b) _________	__________	_________	_________
(c)_________	__________	_________	_________

(E) INFORMATION ON FERTILIZERS

(1) In the effort of trying to increase your tomato yields, fill the information regarding the fertilizers used, indicate the quantities and the costs involved for both organic and inorganic fertilizers.

Name of fertilizer	Quantity used	Cost per unit
(a)__________	__________	__________
(b)__________	__________	__________
(c)__________	__________	__________

(D) INFORMATION ON LABOUR REQUIREMENT

(1) Below are the husbandry practices under tomatoes. Under each, fill the required information in the Table below.

Task	Number of people required	Number less 15 years old	hours worked per day	Days worked
Land preparation	______	______	______	______
Planting	______	______	______	______
Weeding	______	______	______	______
Staking	______	______	______	______
Pruning	______	______	______	______

(F) ADDITIONAL INFORMATION

(1) In your bid to control pests and diseases,what is your major constraint? Rank

(a)..

(b)..

(c)..

(d)..

(2) Which ones,among the alternatives below, do you consider as having the greatest influence on your present application rates and timing of application ?

(a) Directions on the package

(b) Extension worker's guidelines

(c) Quidelines from salesmen

(d) Farmers previous experimentation.

KIAMBU DISTRICT

FIG.2

POTENTIAL LAND USE CLASSIFICATION AND SAMPLING AREA

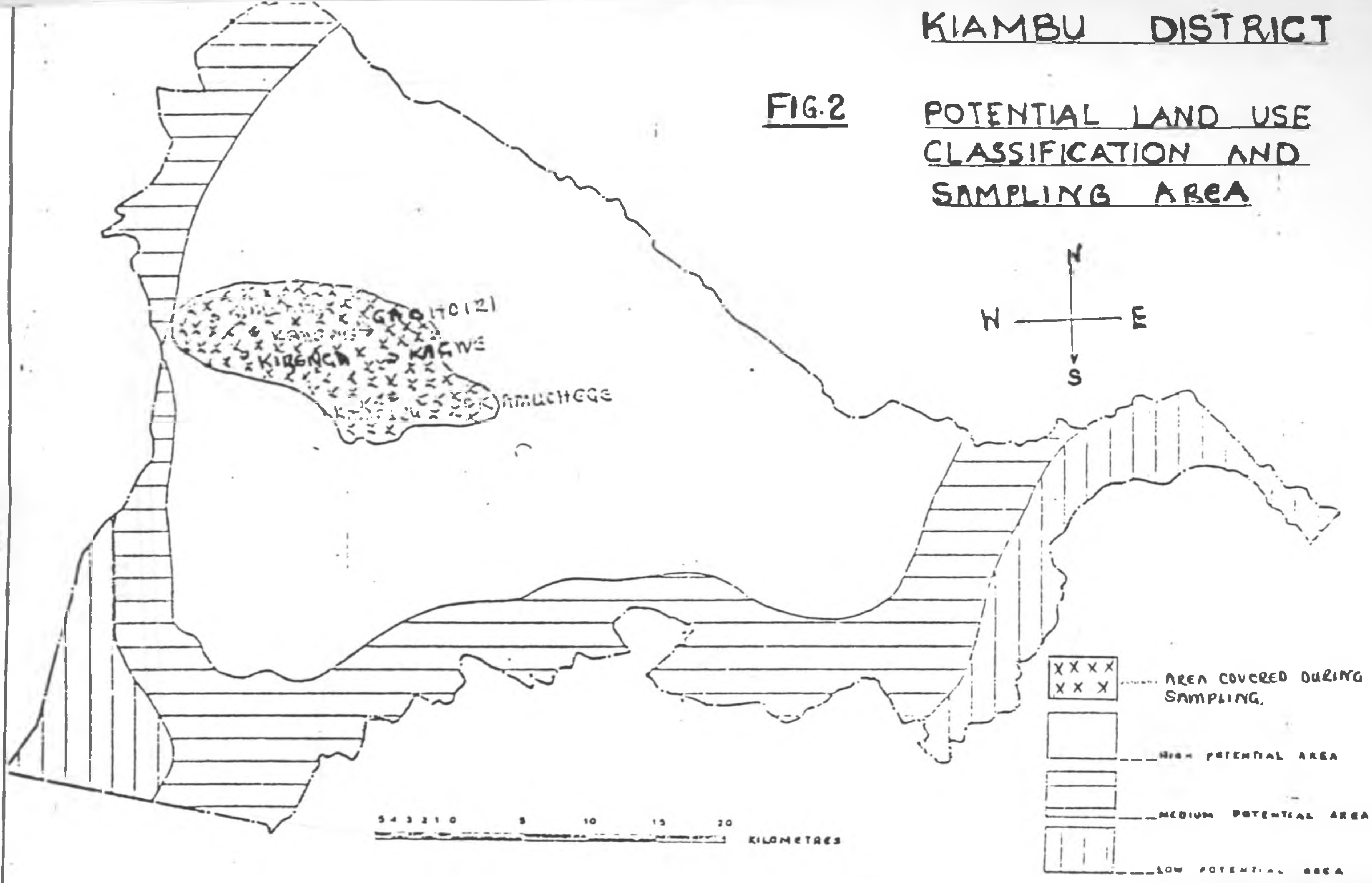
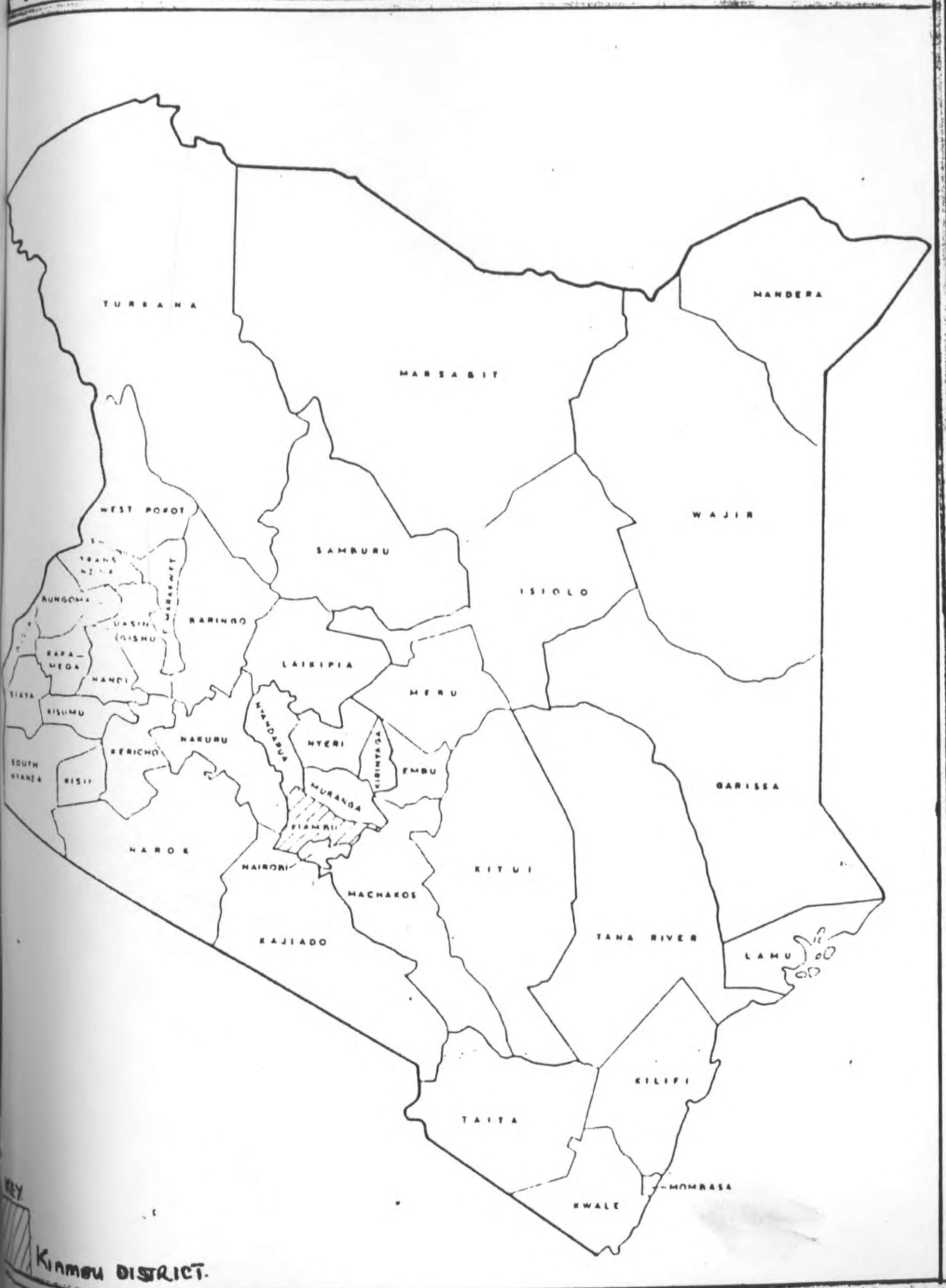


FIG. Nº 3.


TURKANA
MARSABIT
MANDERA
WEST POKOT
WAJIR
SAMBURU
TRANS NZOIA
MARAKWET
ISIOLO
BUNGOMA
UASIN GISHU
BARINGO
KAKA-MEGA
LAIKIPIA
NANDI
MERU
SIAYA
KISUMU
NYANDARUA
NAKURU
NYERI
KIRINYAGA
EMBU
KERICHO
SOUTH NYANZA
KISII
MURANGA
GARISSA
KIAMBU
NAROK
NAIROBI
KITUI
MACHAKOS
TANA RIVER
KAJIADO
LAMU
KILIFI
TAITA
MOMBASA
KWALE
KEY
Kiambu DISTRICT.