ESTIMATING THE MARGINAL PRODUCTIVITY OF PESTICIDES ON PREDOMINANTLY CROP FARMS IN NORTH-EAST KANSAS

by

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The use of pesticides in the U. S. agriculture production system has resulted in intensive crop production by controlling pests that would otherwise cause serious damage. Pesticide use has permitted the production of high quality fruit, vegetables, cotton, and other crops that are very susceptible to insect disease, and other damage. Due to the rapid growth in pest control technology and pesticide use, there is a continuing need for current information on use patterns.
(USDA 1976)

CHAPTER I

INTRODUCTION

Background

Increasing use of pesticides in agriculture is one of the important changes taking place in recent years (Table 1).[20] Pesticides is the common term used to include herbicides (chemicals used to control or kill vegetation), insecticides (chemicals used to control or kill insects), and fungicides (chemicals used to control or kill fungi). The proportion of each in dollars in 1976 are, herbicides 61.5%, insecticides 32.5%, fungicides 6%. Farm use amounts to about 65% of total pesticide use. The remaining 35% is used on public parks, golf courses, and private lawns. [6].

U. S. farmers used 661 million pounds of pesticide in 1976. This was a 38% increase over 1971 (Table 2). Crops accounted for 650 million pounds or 98% of the total farm pesticide used. The remaining 2% was used on livestock. Almost 85% of the pesticide used on crops were applied to 12 major crops. These crops were corn, cotton, wheat, sorghum, rice, other grain, soybeans, tobacco, peanuts, alfalfa, other hay and forage, and pasture and rangeland [6].

Table 1: Pesticide Use on U. S. Farms by year [20]

year	cost in 1960 dollars (in millions)	% of current expense	dollars spent (in millions)	% increase from 1960	cost index (1958 100)	actual % increase
1960	288	1.5	288	--	103	--
1965	476	2.5	528	83.33	111	72.29
1970	566	2.8	758	163.32	134	109.63

Table 2: Pounds of Pesticide Used in U.S. and on Farms in 1976 [6]

type of pesticide	quantity used (lbs. in millions)		farm share %
	domestic	farm	
fungicide	100	43	39
herbicide	555	410	74
insecticide	350	208	59

Recent Surveys of Pesticide Use

The Cooperative Extension Service at Kansas State University, in cooperation with the Kansas Crop and Livestock Reporting Service, conducted a pesticide usage survey on Kansas farms for the 1978 crop year (Table 3).

The survey found the feed grain crops, corn, and grain sorghum to be highly dependent on pesticides.

Table 3: Pesticide Use in Kansas by Crop in 1978 [12]

crop	Total Acres in Kansas (000)	Acres in Survey (000)	Percent of Survey Acres Treated with Herbicides	Percent of Survey Acres Treated with Insecticide
corn	1820	139	86	81
sorghum	4700	309	69	40
soybeans	1480	129	78	2
wheat	11300	495	10	5
alfalfa	1050	69	6	13
pasture and rangeland	21078	793	12	negligible

In addition to the pesticide use reported in Table 3, 35 percent of the wheat seed was treated with fungicide.

In a 1978 survey of pesticide use in Nebraska, it was reported that for several corn herbicides the actual rate of herbicide used was less than the manufacturers recommended rate. The reason was explained as (a) Part of the acreage involved banding rather than total area application which reduces the per-acre requirement (b) Some producers believed the desired degree of weed control could be attained with lower rates of chemical treatment [12].

Kansas Pesticide Law

The Kansas Pesticide Law, which became effective on October 21, 1977, provides that farmers who apply pesticides in agricultural production on their own crops may do so with private applicators certification. Over 20,000 Kansas farmers received their permits in 1977. This certification

ILLEGIBLE DOCUMENT

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THIS IS THE BEST COPY AVAILABLE

P-474

of pesticide applicators was an attempt to insure that farmers who used pesticide had a basic knowledge of pertinent information on pesticide labels, pesticide use safety, environmental considerations, proper storage, use, handling and disposal of pesticide and pesticide containers, and pest problems.

The Role of the Government Concerning Pesticides

The government is responsive to the scientific, economic, social, and cultural needs and interests of the people in trying to promote the improvement of the quality of the environment. Because of this concern by the government, farmers must be informed of the legal aspects of pesticide use or risk punitive action by the courts. In recent years several pesticides have been banned or restricted. Mainly among these are the herbicide 2-4-5-T and the chloronated hydrocarbon insecticides. This restriction has made an economic impact on farmers because some of the chemicals that were banned were the only effective tool against certain pests. An example of this 2-4-5-T which is the only chemical effective in killing large tree-type plants.[3]

The policy of the United States Department of Agriculture (USDA) is to practice and encourage the use of those means of effective pest control which provide the least potential hazard to man, domestic animals, wild life, and the natural environment. For the foreseeable future pesticides will be necessary tools.[3]

The USDA is the principal control agency concerning pesticides. It is responsible for the registration of pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and for enforcement of this act. To be accepted for registration a pesticide must be useful and safe when used according to directions printed on the label. The use of a registered formula may be canceled if it is found to be hazardous, especially to human health.[3]

The Department of Health, Education, and Welfare (HEW) is responsible for establishment and enforcement of pesticide tolerances. Tolerances established are based on a wide margin of safety whenever possible.[3]

State governments also may have regulations in addition to those set by Federal Agencies concerning the licensing of pesticide applicators and registration of pesticides.[3]

There are international concerns about pesticides relating to acceptance of our export products by other countries, and acceptance of products that are imported into the United States. Our concern for the world's health, including our own is shown by our participation in the World Health Organization (WHO). WHO has committees that consider pesticide use and tolerance levels.[3]

Objective of the Study

The objective of this study was to estimate the dollar return for the marginal dollar spent on pesticides on crop farms in North-east Kansas. This was done by using regression analysis and by fitting three types of production function equations to the data. The form of equations tested were linear, Cobb-Douglas, and quadratic. Marginal returns were also computed for fertilizer, depreciation, labor, and feed. Marginal returns were also computed for the number of men per farm, and for inches of rainfall in July. Data for the study were taken from the Farm Management Association records.

Defining the Area in the Study

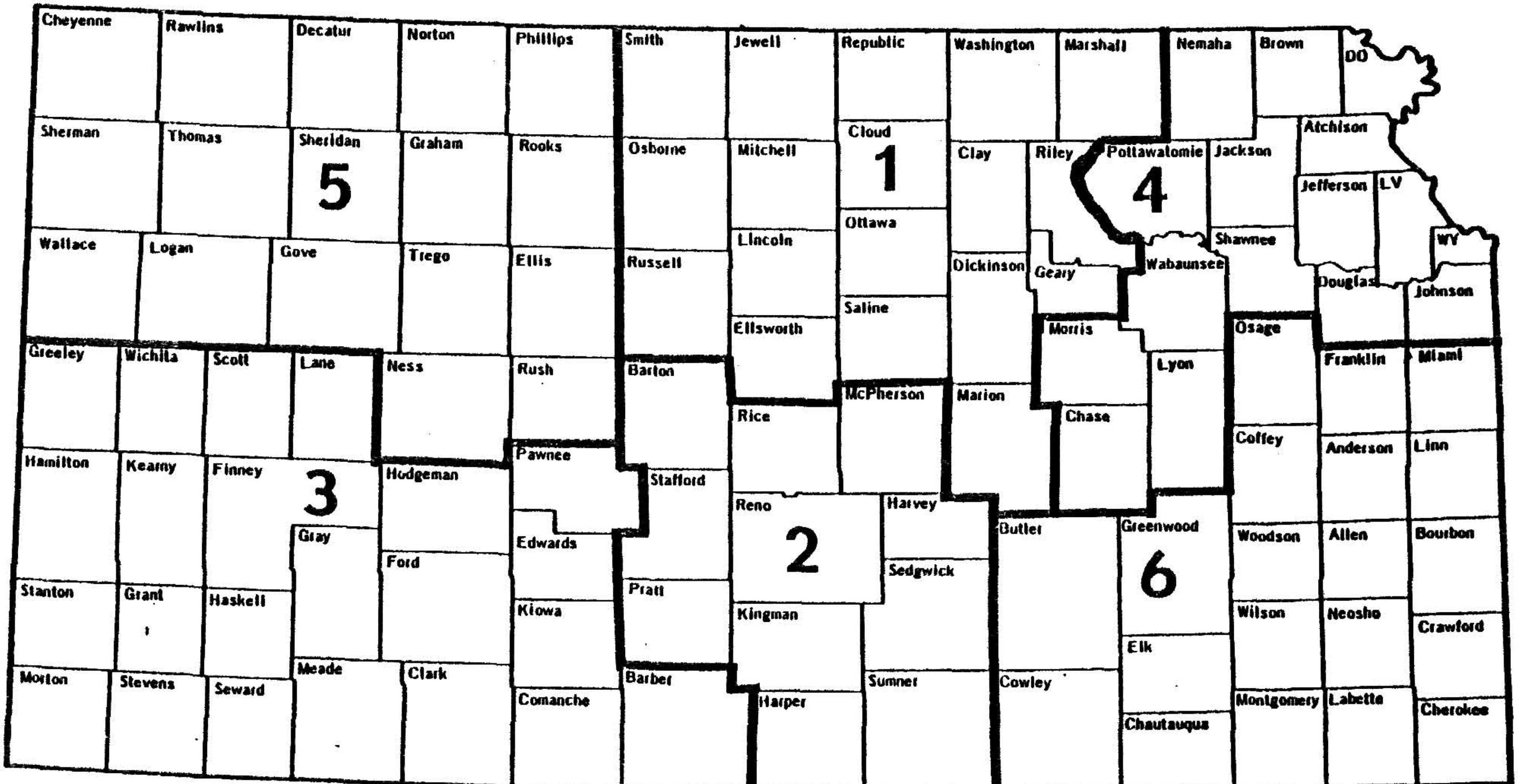
Data for this study are from Farm Management Association number four (FMA # 4). This is a 16 county area in North-East Kansas.(map figure 1). There are 475 farms in FMA # 4. The types of farms include specialized livestock enterprises, mixes of crop and livestock enterprises, and those producing only crops. The types of farm businesses include single proprietors 83%, partnerships 13%, and corportations 4%.

In 1977 the number of crop acres per farm ranged from 20 to 3031. Their main crops are corn, wheat, soy beans, milo, alfalfa, silage, and rangeland or pasture. [14]

Farmers pay a fee to FMA # 4 for assistance in keeping farm business records, preparing taxes, analyzing enterprises and their financial situations. Farms are believed to be larger than average in size as compared to the average farm in North Central Kansas, and higher in gross and net income and expertese of management. This group of farm managers is expected to be better than the average Kansas farm manager in making profitable economic decisions concerning resource use. Profitable decisions would include the expenditures for input items used in this study.

The North-East area of Kansas receives an average precipitation of 34.65 inches per year and compares to 27 inches per year in the Central region, and 20 inches per year in Western Kansas. [17] North-East Kansas is higher in precipitation than other areas of the state and consequently has more problems with insects and weeds. In North-East Kansas the high

Figure 1: Map of Kansas Showing Farm Management Association Areas



* Association Headquarters

○ Satellite Office

value crops are corn and soybeans that have more insect related problems than crops in dryer areas, such as wheat and rangeland. Water is usually the limiting factor for plant growth, so the more rainfall, the more vigorous is the weed growth. Farmers in North-East Kansas area rely more on pesticides than farmers in other parts of the state.

North-East Kansas was selected for this study because farmers use relatively high rates of herbicide and insecticide each year. Farmers need to know as much as possible about maximizing income through the use of pesticides in order to make profitable economic decisions. This study is to provide relevant information to farmers in this area. It is a very specific area, and the computed results are specific to that area.

General Types of Pesticide Use

Farmers rely on pesticides as a necessary input in their production of agricultural crops. Farmers face several responsibilities when using pesticides. Some of these are personal safety, environmental protection, and the well being of those who in the future might come in contact with the residue of present pesticide use. Farmers also have an economic consideration to increase net income by using pesticides. Some pesticides are very expensive and there may be an alternative method to using chemicals. Pesticide use falls into two use catagories; emergency use situations and preventive use situations. An example of the emergency use situation is a crop infested with a known type of insect that can be controlled with a certain type of insecticide, or a growing crop with a large number of weeds that are known to be susceptable to an available herbicide. If the crop can be saved by using a pesticide and the pesticide cost is less than the value of the crop saved plus the expense of harvesting the crop, it is profitable to use pesticides.

Examples of preventive use are using a pre-plant or pre-emergence herbicide, treating seed with a fungicide, or using a systemic plant treatment for insects. In the preventive use catagory the farmer has more time before the crop will be damaged to weigh the alternatives between pesticide use and other practices such as mechanical cultivation or rotation of crops. Correct management decisions when planning preventive pesticide use will eliminate many of the emergency use situations.

When planning for profitable preventive use of pesticides, one economic consideration is to have a productive crop. To achieve above average profit means using proper fertilization, good quality and variety of seed, timeliness in field operations, and irrigation of possible. The farmer should use the proper mix of these inputs to obtain the most profit. Adding to the expense of producing the crop and reducing any of these factors will reduce yield and/or profit. Pesticides offer the farmer some control of the crop damage caused by controllable pests.

Use or non-use of pesticides by a farmer's neighbors also affect his income. For example, if one farmer uses an insecticide to kill the insects in a crop and has good results, and a near-by field with the same insect infestation is not treated, quite often the insects will move back to the treated field as soon as the effective time period of the insecticide used is over.

The success of a researcher depends a great deal on how well he can build on the work of those that have preceded him.

CHAPTER II

REVIEW OF THE LITERATURE

Accepted theory of production states that maximum profits occur when the value produced by the marginal unit of an input is just equal to the cost of that marginal unit. Managers need to know the increase in output as additional units of inputs of pesticides are applied.

Headley in 1968, estimated the marginal productivity of pesticides and other farm inputs including labor, land and buildings, machinery, fertilizer, and other expenses. He used USDA farm income and expense data for 1963. An average farm for each state comprised the sample. Using three combinations of variables he computed marginal productivity by fitting three Cobb-Douglas functions and one third degree polynomial function. The value marginal product (VMP) ranged from $3.90 to $5.66 for pesticide expense. Headley considered his best equation estimate of marginal productivity of pesticides to be $4.16 in gross income for the marginal dollar spent on pesticides. Table 4 shows Headley's estimates of VMP for other farm inputs.[8]

Headley also estimated marginal rates of substitution of cropland for insecticides. He found that marginal rates of substitution of cropland for insecticide vary substantially among different areas in the United States, from -3.257 in the Southeast region to -.80 in the Lake States region. The marginal rate of substitution represents reduction in ounces of insecticide per one acre increase in cropland. The negative sign indicates that pesticide use substitutes for land use. Likewise the elasticity of substitution varied substantially between different areas, from -326.67 in the Southeast region, to -2.70 in the Appalachian region. The elasticity of substitution is the percentage decrease in insecticide divided by one percent increase in cropland. The negative sign indicates substitutability of the inputs (Table 5).[9]

Table 4: Value of the Marginal Products Computed by Headley

Variables	Regression equation			
	equation 1	equation 2	equation 3	equation 4
total labor	$2.16/day	$1.40/day	$3.81/day	$4.21/day
land and buildings	.06/$1.00	.08/$1.00	.06/$1.00	.08/$1.00
machinery	$2.40/$1.00	--	$2.43/$1.00	.26/$1.00
other	.97/$1.00	--	.97/$1.00	$1.07/$1.00
fertilizer	$4.91/$1.00	$4.20/$1.00	$4.50/$1.00	$3.95/$1.00
pesticides	$5.66/$1.00	$4.23/$1.00	$4.16/$1.00	$3.90/$1.00
machinery plus other	--	$1.16/$1.00	--	--

In 1977, Carlson [4] computed marginal products for insecticides used on cotton in five regional cotton growing areas for the years 1964 to 1969. The data used were collected by personal interviews of cotton growers. He found the expenditure for insecticide relatively constant for the time period, but the marginal productivity fell each year which was attributed to a declining kill function. Insects possibly developed a tolerance to the insecticide. The marginal physical product of the insecticide varied from a low of 48.30 to a high of 1024 pounds of cotton per unit of insecticide. This wide variation was partially due to the range of years and regions in the study.

Table 5: Marginal Rates of Substitution and Elasticity of Substitution of Cropland for Insecticides, by Region, United States, 1964

Region	Marginal rate of substitution of cropland for insecticides 1/	Elasticity of substitution of cropland for insecticides 2/
Appalachian	-33.19	-2.70
Corn Belt	-10.03	-4.35
Delta States	-256.47	-14.89
Lake States	-.80	-8.16
Pacific	-24.06	-6.49
Mountain	-.97	-7.77
Southeast	-3257.00	-326.67
Southern Plains	-547.17	-170.04
United States 3/	-13.24	-6.49

1/ Ounces of insecticide reduced per 1-acre increase in cropland.
2/ Percentage decrease in insecticides per 1-percent increase in cropland.
3/ Does not include Alaska and Hawaii.

> The controversy surrounding the use of agriculture pesticides has resulted in the examination of pest control technology and a need for estimates of the costs and benefits of pesticides. . . . Use of values determined through the market system to estimate benefits are a necessary part of evaluating chemical pest control. . . . Considerably more analysis and information are required to evaluate pesticide technology and to form good national policy in this area.
>
> (J. C. Headley)

CHAPTER III

ECONOMIC CONSIDERATIONS

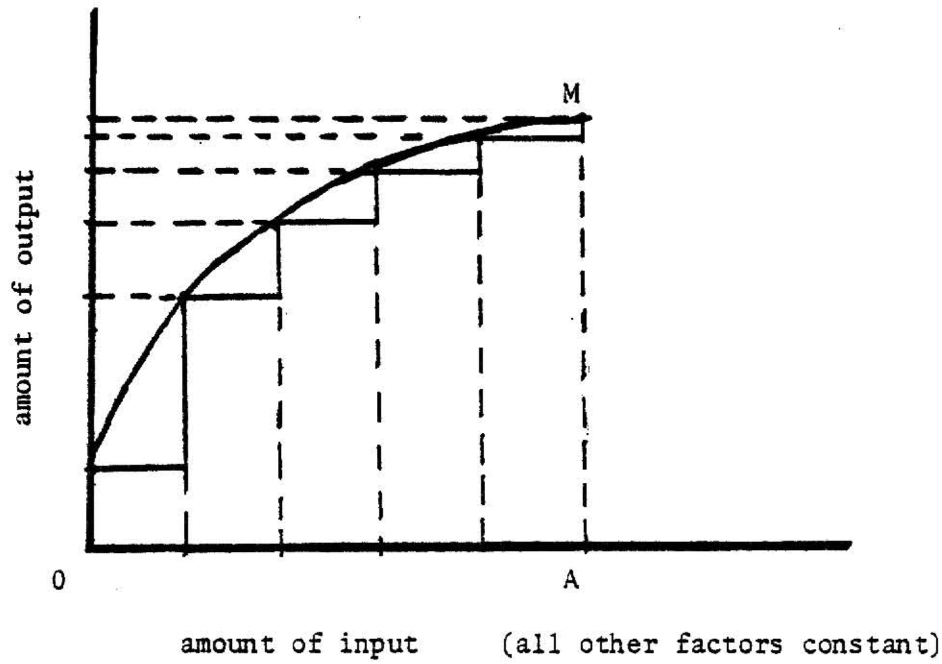
Diminishing Returns

The analysis of the productivity of pesticides is based on an input-output relationship called a production function. It shows the change in output caused by a one unit change in input. A production function shows that using X amount of pesticide results in producing Y bushels of product per acre with other factors being held constant. Usually there are diminishign returns on increasing increments of input.

The law of diminishing returns states that "if increasing amounts of one input are added to a production process while all other inputs are held constant, the amount of output added per unit of variable input will eventually decrease" [5]. Between O and A (Figure 2) output increases at a decreasing rate as successive amounts of inputs are used. At point M there is no further increase in output with added input. Diminishing returns are expected as amounts of pesticide use increase per acre.

A producer must understand the concept of diminishing returns to make profitable decisions concerning the amount of input to use.

Figure 2: Example of Diminishing Returns



to produce a product. Prices of the input and product, and input-output relationships are assumed to be known and constant. The marginal physical product (MPP) can be computed by taking the first derivative of the known production function. The price of product Y (P_y) times the MPP is the value of the marginal product (VMP). The most profitable amount of production is when the VMP is equal to the price of the input (P_x). The equation $P_y * MPP = P_x$ can be expressed as $VMP = P_x$ or $MPP = \frac{P_x}{P_y}$. If VMP is greater than the P_x it would still be profitable to increase the quantity of the input X to produce additional product Y. Diminishing returns mean that the MPP is decreasing, therefore, at some finite amount of X, the condition of $VMP=P_x$ will be met. A linear production function would have a constant VMP. If this VMP were greater than the price of the input, infinite production would be profitable. Part of a non-linear function may have a VMP that is increasing. In this case more input would increase profit at an increasing rate. Usually producers are faced with a VMP that is decreasing. This means that each successive unit of input X will produce a diminishing amount of product Y. If a producer knows the concept of diminishing returns he can make profitable decisions on amounts of inputs to be used [5].

According to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), it is illegal to apply dosages of pesticide greater than the recommended amount [19]. Pesticide manufactures are careful to set the range of recommended use at levels which, under normal conditions, are high enough to be effective and yet low enough not to damage the desired crop or endanger the safety of the applicator. Most of the information available to farmers concerning the amount of pesticide to use is the "recommended volume per acre," or "optimum dosage per unit." This recommended dosage is designed to give a high percent of weed and insect control. This type of information does not specify the effect on yield of limited amounts of pesticide use. Environmental and safety considerations may limit the maximum concentration of pesticide per acre, but most profitable amounts of pesticide use are based on productivity, cost of pesticide, and price of product produced.

Cause and Effect Functions

Some of the data used in this study are pesticide expenditure and farm income. The linkage between pesticide expenditure and income is through a chain of cause and effect relationships. The direct effect of pesticides is to eradicate weeds or insects, $WC = f(P)$. The other links in this chain are: crop yield is a function of weed control, $Y = f(WC)$; income is a function of crop yield, $I = f(Y)$; and then by several substitutions income is a function of pesticide use, $I = f(P)$.

The relationship between pesticide use and weed control is hypothesized to be positive with diminishing returns to additional use. The reason is the younger or weaker weeds are killed with a small dosage of pesticide. Weeds that are increasingly larger and more mature would require an increasing amount of chemical to be effective. This would cause diminishing effectiveness to additional increments of pesticide used.

It is assumed that a positive relation with diminishing returns exists between the amount of weed control and the yield of the crop, Y = f(WC). The reasons for this are: (a) Weeds compete with the crop for moisture, soil nutrients, and sunlight. Many weeds have the vigor and capacity to grow faster and larger than the grain crop. This means that root systems of some weeds are more extensive with high capacity to absorb water and available nutrients necessary for plant growth. When weeds are taller than the planted crop, they shade this crop from sunlight which is also one of the necessary factors needed by plants for growth. (b) The crop is more difficult to harvest. The weeds add to the amount of material that must be handled in harvesting. This slows down harvesting and puts more strain on the harvesting machinery. (c) The quality of the crop is reduced. The grain usually is higher in moisture because of the addition of immature weed seeds and contact during the harvesting operation with the immature weed foliage. This means the grain will probably be more likely to deteriorate if stored for future use. Also there will be more foreign material such as weed seeds and chaff mixed with the grain than if there were no weeds.

The next function is that income is a positive function of crop yield, I = f(Y), is assumed to be a linear function because the price farmers receive is not affected by their individual actions, therefore income would be directly proportional with crop yield.

Finally there is a positive relationship with diminishing returns between pesticide use and income, I = f(P). This conclusion was reached through the following chain of reasoning. Weed control is a positive function with diminishing returns to pesticide use. It was explained why yield is a positive function of weed control, and that income is a positive function of yield. Through this chain of linked positive functions it is hypothesized that income is a positive function of pesticide use with diminishing returns for dollars spent for additional units of pesticide.

Factors Affecting Effectiveness of Pesticides

The way pesticides work is very complex because of the many variable factors involved. For herbicides, many factors determine its effectiveness. Some of these are: kind of weeds, rate applied, uniformity of application, retention of leaves, loss of herbicide due to sunlight, stage and rate of growth of weeds, spray additives, and volatility of herbicide. Three other more important factors are ; soil, temperature, and moisture [18].

Herbicides are most effective in a loam soil. The clay soils with smaller particles need a higher concentration of herbicide to be effective because the many particles have a large surface area which adsorbs the molecules of herbicide. Adsorption is the process whereby ions and molecules are retained in the soil due to electrical attraction between themselves and the soil particles. Soils with higher organic matter content also require a higher herbicide application because of adsorption. Sandy soils need a high concentration of herbicide application because of leaching. Leaching occurs when the molecules of herbicide which are attached to the particles of moisture wash too deeply into the soil to be effective [1].

Herbicides are most effective in killing weeds when the weeds are growing rapidly which is when the soil temperature is 80 to 90 degrees Fahrenheit. This temperature range also causes fastest herbicide breakdown from microbial action.

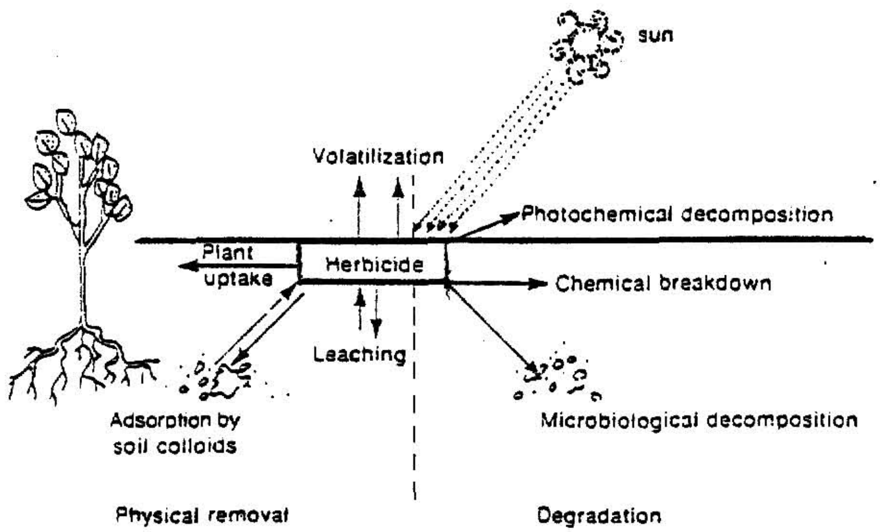
Soil moisture is needed to carry the chemical herbicide from the soil up into the weed. If the soil moisture is inadequate the chemical is not as effective and so fewer weeds are killed. If there is excess soil moisture the chemical is diluted, washed away, or leached too deeply into the soil where it may cause damage to the germination of the planted crop while germination of weeds near the surface may be unaffected.

Because of these factors, soil composition, temperature, and moisture, the amount of weed control in response to pesticide use varies from year to year. Figure 3 illustrates these factors.

Financial Risk of Using Pesticides

A major factor concerning pesticide use is the uncertainty of the benefits that will be received from the use of pesticides. Chemical use may dramatically increase the yield of a crop, or may have essentially no effect. Either way there is a substantially added cost to the production of that crop.

Figure 3: Process by which Herbicides may be Inactivated [1]



An example of risk is in the 1978 report of crop yields in Kansas. On an experimental test of corn in Rossville, the plot that was hand weeded yielded 174.3 bushels per acre, while the plot with absolutely no weed treatment of any kind yielded 158.3 bushels per acre [16]. This was not a statistically significant difference.

On a yield test of grain sorghum at Manhattan the hand weeded plot yielded 128.4 bushels per acre, while the no treatment plot produced only 63.4 bushels per acre. On this yield test area the herbicide treated plot yielded approximately the same as the hand weeded plot [16].

These two examples illustrate the yield variability and therefore the financial uncertainty involved in the decision to use pesticides.

Theory is valuable because it reduces the need to learn everything through experience.

CHAPTER IV

THE MODEL

Regression Analysis [11]

The marginal productivity of pesticides was estimated by using regression analysis. Regression analysis is a process where a functional relationship is determined by minimizing the squared deviations between sample data points of the dependent and the estimated function. It involves a comparison between two or more variables. A simple regression equation of one dependent and one independent variable is:

$$Y = A + BX + e$$

where Y = the dependent variable

A = a constant

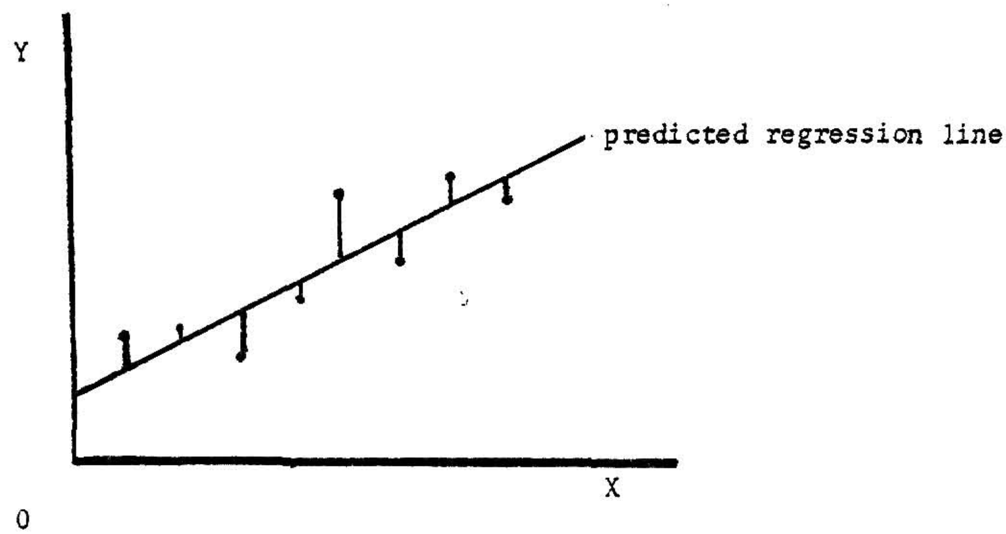
B = a parameter which shows how many units of change in one variable (Y), are associated with one unit of change in another variable (X). The B coefficient is used in determining the value of the marginal product of an input.

X = the independent variable

e = the error term

The independent variable is the one thought of as varying independently and being the cause of change in the dependent variable. Values for parameters A and B in the equation are estimated by using the minimized sum of the squared deviations between the known Y value and the predicted regression line. This regression line is the estimated values of Y for all values of X. In Figure 4 the points are the actual values of Y.

Figure 4: Example of a Linear Regression Line

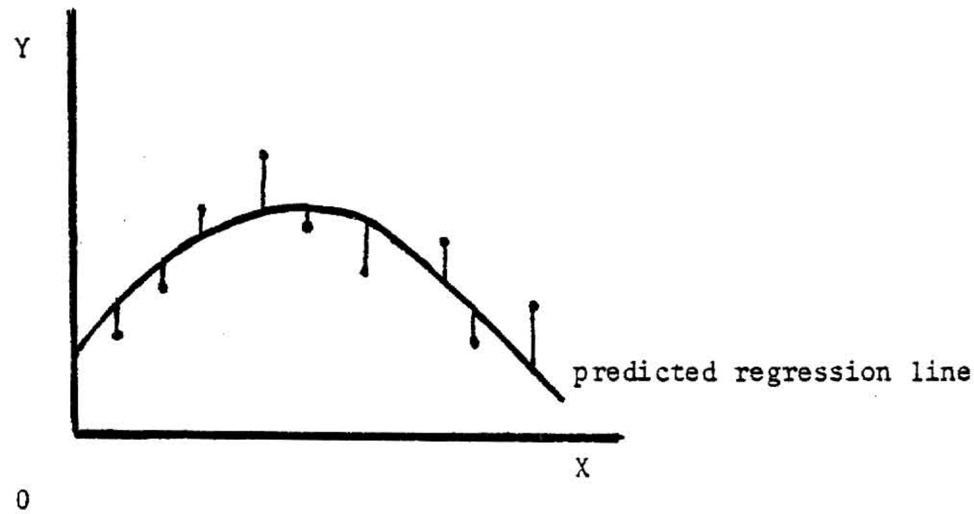


The correctness of fit is shown by the R^2 statistic, which is the coefficient of determination and measures the percentage of the variance of Y determined by X. Multiple regression is a more complex form where more than one independent variable is used to predict the dependent variable.

Figure 5 illustrates a non-linear regression line fitted to data points. In some cases a non-linear function may provide a better fit.

The regression was done using a Statistical Package for the Social Sciences (SPSS) computer program with stepwise inclusion of independent variables [15]. This means that variables are brought into the equation one at a time with the independent variable that has the largest squared partial correlation with the dependent variable being first. Other independent variables are then selected to enter the

Figure 5: Example of a Non-linear Regression Line



equation by the qualification of being the variable that explains the greatest amount of variance unexplained by the variables already in the equation. This process is then continued until either all of the independent variables are in the equation, or the variable has a F statistic less than .01 which is considered a tolerance level insufficient for computation. At each step in the analysis, F ratios are computed for variables not yet in the equation. The F ratio for a given variable is the value that would be obtained if that variable were brought in on the very next step. The F statistic is a ratio of the mean square of the regression divided by the mean square of the residual, and indicates the significance of the variable. A rule of thumb is the F statistic is significant at the 95 percent confidence level if it is greater than two. This means that if an independent variable has an F statistic greater than two, there is only a 5 percent chance of the variable being wrongly chosen. The F statistic varies with the number of degrees of freedom. The number of degrees of freedom is the sample size minus the number of independent variables. With a high number of degrees of freedom the F statistic can be lower and yet still be significant.

Collection of Data

Data from FMA #4 were used as the source of farmers expense for income, pesticides, fertilizer, depreciation, feed, labor hired, interest, cash rent, and machinery. In FMA #4 data, the expense category, pesticides, is the total dollars spent for all types of pesticides which include herbicides, insecticides, and fungicides (Table 6).

This study uses a relatively small area, North-East Kansas, as its data source, and individual farms as sample elements. The average farming operation in FMA #4 in 1978 was capital managed $600,522, gross income $122,786, and net income $38,124. A large percentage of the cropland is dryland with only 2.42 percent of the crop acres being irrigated.

Table 6: Total Farm Expenses for Farming Operations in FMA #4 in 1978 [7]

Expenses	Average	Percent of Total Farm Expense
feed	$18,164	22.64%
depreciation	$9,929	11.73%
fertilizer	$8,143	9.62%
labor hired	$3,845	4.54%
pesticides	$3,497	4.13%

Farm Record Data

The collection of data in an agricultural study presents the researcher two choices. One choice is to study a very small but carefully controlled sample. This method enables the researcher to hold constant all variables except the one being studied, and this variable can be measured to an accurate degree. This type of research is done in small plots or greenhouses where most of the processes are done by hand. The results of the experiment can usually be compared to a controlled sample in which the measured variable is not present. The controlled sample method of research is expensive and the findings may be distorted when used in the large commercial environment. This type of research is most relevant for agronomy or animal science research.

The other choice is to study records of the commercial operations. The collection of the data is relatively inexpensive but there is less control of external factors which affect the variable to be measured. The results are not as exact as when a precise control experiment is used. Nevertheless non-controlled data is often the only method available for many studies. This is the case in studying the productivity of pesticides as used on the commercial farm [10].

To estimate the marginal productivity of pesticides, as many as possible of the external factors affecting the variables were held constant. Important among these were the major type of product of the farm, the general area where the farms were located, the approximate size in crop acres, the differences in farming practices, and the relationship of dollar value between different years.

It is important to control the non-measured variables to obtain more reliable estimates of productivity of the measured variables. Some variables must be controlled to show diminishing returns to others.

A problem that might be encountered in using data from farms with a large variation in the number of acres was that the variation in income was more closely related to number of acres than to the expenditures in pesticides. In this case the relationship between income and pesticides would be distorted, and the model would not pick up diminishing returns due to pesticide expense. To control the influence of crop acres on productivity, farms of size 500 to 700 acres of cropland were used. This size of farm included the average of FMA #4 in 1977 and eliminates both the extremely small and large farming acreage.

Farms were chosen which received 70 percent or more of their gross income from crops. The main crops grown on these farms located in North-East Kansas, were primarily corn and soybeans with little irrigation used. Farms specializing in livestock production tend to use smaller proportions of pesticide. In 1978 the average cash crop farm in FMA #4 spent $4,593 on pesticides, 6.34 percent of total farm expense, while those farmers in FMA #4 that specialized in hog production, spent $892, 1.28 percent of total farm expense.[7]

This study used a combination of cross-section and time series data. The advantage of time series data in this study was it used the same farms and operators in consecutive years. This caused less variation between the individual sample farms in soil type, management ability, and farming practices. Farmers were likely to have the same enterprises year after year.

With cross-section data the variation from year to year of crop yield and effectiveness of pesticide due to weather was reduced. Another advantage of cross-section data was that prices paid and received were more nearly the same among farmers.

To overcome the effect of price differences between years all dollar values of inputs and gross income were deflated with 1967 being the base year, equal to an index of 100. All dollar variables were deflated each year.(Table 7).

Table 7: Price Indexes Used as Deflation Factors for Dollar Variables 1974-1978 [20]

Variables	1974	1975	1976	1977	1978
gross income	192	185	186	183	210
pesticide expense	119	160	174	157	147
labor expense	178	192	210	226	242
interest expense	223	262	299	339	396
fertilizer expense	167	217	185	181	180
feed expense	194	187	191	186	183
cash rent	166	199	214	235	245
machinery expense	161	195	217	238	259
depreciation expense	161	195	217	238	259

The variable gross income was deflated using the index of all farm production. Pesticide expense was deflated using the index of agricultural chemicals. Labor expense was deflated using the index of wage rate. Interest expense was deflated using the index of interest. Fertilizer expense was deflated using the index of fertilizer. Feed expense was deflated using the index of feed. Cash rent was deflated using the index of farm services and cash rent. Machinery expense and depreciation expense was deflated using the index of tractors and other machinery.

The Sample

Farms in the sample were chosen that in 1977 had between 500 and 700 crop acres, and greater than 70 percent of their gross income derived from a combination of grain, hay and forages, cash crops, and government payments. Of the 475 cooperators of FMA #4 in 1977, twenty-two farms met the qualifications(the first year for which data was examined).

To obtain sample farms from years 1974-1978 the initial 22 farms chosen from 1977 data were used if they were members of FMA #4 during those years. Only 18 of the 22 farms that met the qualifications in 1977, were FMA #4 members in 1974 and 1975. In 1976 there were 21, and in 1978 there were 20 farms that were FMA #4 members of those original 22. This gives a sample size of 99. There are not the same number of farms for each year because some of the 22 farms that met the qualifications in 1977 were not FMA #4 members in the other years.

The total acres of major crops in 1977 of these 22 farms were corn 4469, wheat 2950, soybeans 2639, milo 2398, alfalfa 156, other hay 457, silage 110, and other grain 72.

The Independent Variables

Independent variables other than pesticides help explain variance in gross income, the dependent variable. The independent variables included in the study along with their computer code lettering were:

(a) Pesticide expense deflated, PESTD

(b) Labor hired expense deflated, LABRD

(c) Interest expense deflated, INTRD

(d) Fertilizer expense deflated, LABRD

(e) Feed expense deflated, FEEDD

(f) Cash rent expense deflated, RENTD

(g) Machinery expense deflated, MACCD (this was a sum of machinery repairs, machinery hired, and fuel expense)

(h) Depreciation expense deflated, DEPD (this was a sum of depreciation of machinery equipment and depreciation of motor vehicles)

(i) Workers per farm, NMEN

(j) Man work units per farm, PMWU

(k) Palmer drought index, for North-East Kansas, PDI

(l) Rainfall during July, for North-East Kansas, JLR

Variables one through ten were taken from the individual farm records of FMA #4.[14] Variables one through eight were reported in dollar amounts. Variables 11 and 12 were provided by Merle Brown, Research Associate, Department of Physics, Kansas State University.

Labor Variables

There were three labor measuring variables in this study. These were labor hired expense, workers per farm, and man work units per farm. Since these variables measured some of the same factors, only one was used in any one equation.

Workers per farm is an estimate of number of workers for a farm based on months of operator's labor, months of unpaid family labor, and months of hired labor. The total months is divided by 12 to calculate workers per farm, thus the effort of hired workers is included in two variables, the labor expense variable and the workers per farm variable. One unit of workers per farm is one man working full time for one year.

Man work units per farm is an estimate of the number of days required for the acreage of specified crops and for the number of livestock of each type. A man work day is defined as a ten-hour day. Man work units arecalculated by multiplying crop labor standards times number of acres in each crop enterprise, plus livestock labor standards times number of head in each livestock enterprise.

Labor hired expense is the dollar amount of wages paid for work done on that farm.

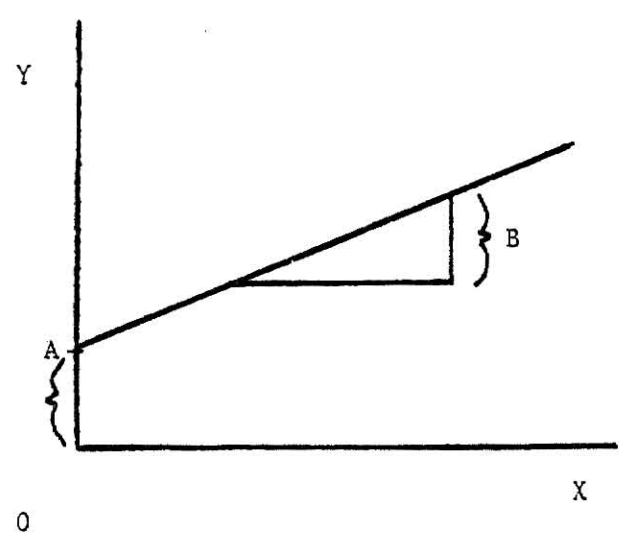
Weather Variables

Rainfall has a great influence on crop yield and therefore the gross income of the farmer. Two rainfall related variables were used in the study to estimate their effect on income in different; the Palmer drought indes, and rainfall in July. These independent variables measure some of the same facots, both variables are not included in the same equation.

The Palmer drought index is a monthly factor formulated by using precipitation, temperature, soil moisture, and other related weather factors.

The rainfall in July variable is an average number of inches of rain in July from 25 precipitation measuring stations in North-East Kansas. Average rainfall in July was calculated for each of the five years used in the study. Since corn is the predominant crop in this area, July rain has much effect on its yield on non-irrigated cropland.

Figure 6: Linear Function



Forms of Production Functions [10][11]

Three different types of production functions were fitted to the data: linear, Cobb-Douglas, and quadratic.

The linear production function is of the form:

$$Y = A + B_1X_1 + B_2X_2 + \ldots B_nX_n$$

where Y = gross income, the dependent variable

A = the Y intercept, or the constant

$B_1, B_2, B_3 \ldots$ are the X coefficients representing a relationship between the respective X variable, and the Y variable.

$X_1, X_2, X_3 \ldots$ are the independent variables.

The linear equation shows an increase in Y that is proportional with an increase in X as measured by the B coefficient.

The Cobb-Douglas function is of the form:

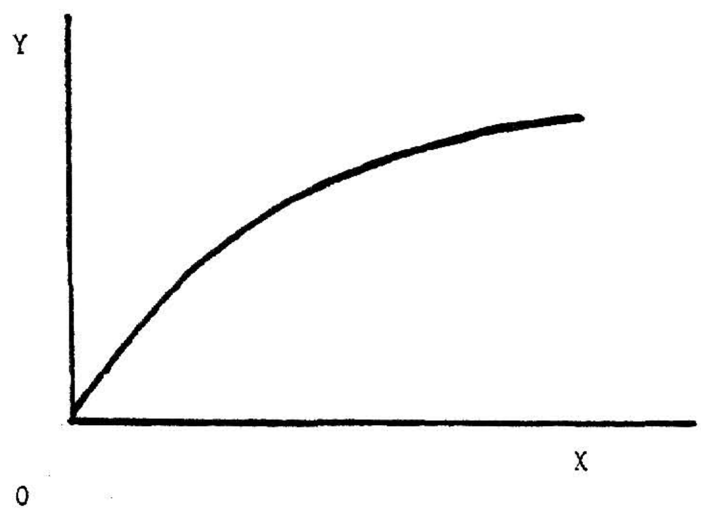
$$Y = AX_1^{B_1} \; X_2^{B_2} \ldots X_n^{B_n}$$

In the Cobb-Douglas equation the B coefficient represents the constant elasticity of production. Constant elasticity of production means that each percent increase in input adds the same percent amount to output.

Cobb-Douglas functions are frequently used in farm input analysis. The reason for this is that the algebraic model provides (a) adequate fit of the data, (b) computation feasibility, (c) sufficient degrees of freedom unused to allow for statistical testing when the sample size is small, and (d) it is an easy way to fit non-linear data.

The Cobb-Douglas function implies that at least some quantity of each input must be used if the output is to be nonzero. In reality this condition does not necessarily hold true as one or more inputs may be at zero level. To overcome this problem the zero observation can be replaced by some figure of arbitrary small. The function can not be used where there are ranges of both increasing and decreasing returns to marginal productivity. It is most often used showing decreasing returns to inputs asymptotically approaching maximum production.

Figure 7: Cobb-Douglas Function

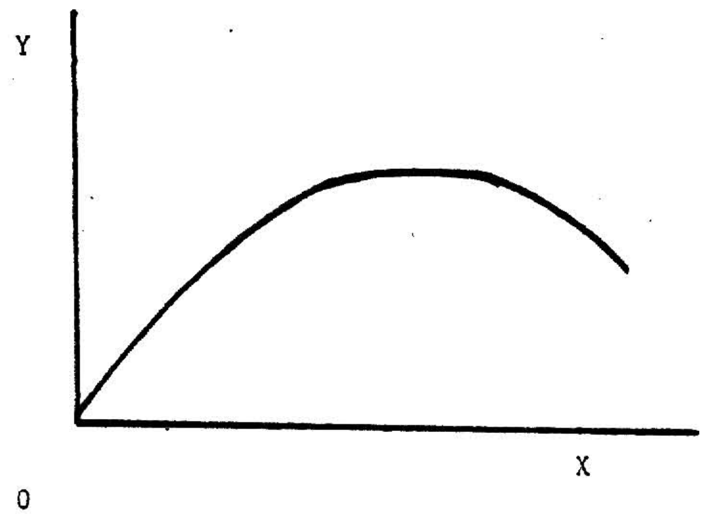


The quadratic function is in the form of:

$$Y = A + B_1X_1 + C_1X_1^2 + B_2X_2 + C_2X_2^2 + \ldots + B_nX_n + C_nX_n^2$$

In this function B_1 is the coefficient for the linear term, and C_1 is the coefficient to the squared term of the input. If the C coefficient is negative, then the equation denotes diminishing marginal returns as the input increases. The quadratic function has greater flexibility than either the linear or Cobb-Douglass functions. It assumes neither constant elasticities between input and output nor constant increases in output to an increase in input. Also, a quadratic function shows output increasing at a decreasing rate, reaching a maximum, and then decreasing as input increases.

Figure 8: Quadratic Function



CHAPTER V

RESULTS AND ANALYSIS

Different combinations of independent variables were used to explain the variance in the dependant variable, gross income. Some regressions equations included only the deflated expense variables but results were considered unsatisfactory. The "Palmer drought index" and "July rainfall" variables were added to estimate the influence of weather on the year-to-year variability in gross income.

Variable Set 1

The regression equation with the best combination of independent variables was:

gross income	(Y)
pesticide expense	(X_1)
depreciation expense	(X_2)
fertilizer expense	(X_3)
number of men	(X_4)
July rainfall	(X_5)
feed expense	(X_6)

The X terms represent the variables in the following equations.

The linear equation was estimated as: (F statistic in parenthesis)

$$Y = 2531.65 + \underset{(16.72)}{2.41X_1} + \underset{(11.09)}{1.81X_2} + \underset{(11.84)}{1.41X_3} + \underset{(5.97)}{6382.77X_4} + \underset{(2.34)}{1489.57X_5} + \underset{(2.21)}{1.28X_6}$$

$R^2 = .65$

The F statistic (in parenthesis beneath the coefficient) shows all variables statistically significant at the 5 percent level.

The value of the marginal product (VMP) of pesticide is computed by taking the partial derivative of the X_1 term with respect to Y.

$$\frac{dY}{dX_1} = 2.41$$

The value of 2.41 means that each dollar increase in pesticides returns $2.41 in gross income since both dependent and independent variables

The value of the marginal product is the change in value of output due to the addition of one unit of input. The first derivative of a production function is the marginal physical product (MPP) when X and Y are in terms of physical quantities of input and product. The VMP is then the MPP times the price of Y. In this study the change in output in dollars is compared to the change in input in dollars. The resulting derivative will be called the VMP. The critical point is where $\frac{PY^*}{PX^*} \frac{Y}{X} = 1$. A figure greater than one indicates a profit for the expense item while a figure less than one indicates a loss.

The estimate for the VMP of pesticides shows a high return to pesticides but more troublesome, the linear equation implies a $2.41 return regardless of how much pesticides are used. To test a more reasonable relationship the Cobb-Douglas and quadratic equations with the same set of variables was tested.

The Cobb-Douglas equation using the same variables was:

$$Y = 206.16 \underset{(9.18)}{X_1^{.05685}} \; \underset{(32.05)}{X_2^{.43015}} \; \underset{(7.67)}{X_3^{.08343}} \; \underset{(7.07)}{X_4^{.30413}} \; \underset{(8.71)}{X_5^{.21162}} \; \underset{(6.07)}{X_6^{.03459}}$$

$R^2 = .55$

The F statistic (in parenthesis beneath the coefficient) shows all variables highly statistically significant.

The value marginal product for the Cobb-Douglas equation is

$B_1 * \frac{\overline{Y}}{\overline{X}_1}$ where B_1 is the exponent of the X_1 term, $\overline{Y}$ is the geometric mean of Y, and $\overline{X}$ is the geometric mean of X, the geometric mean is found by computing the n<u>th</u> root of the product of n factors.

The VMP for pesticides in the Cobb-Douglas equation is $.05685 * \frac{34895}{1316} = 1.51$ where: the geometric mean of gross income (Y) is 34895, and the geometric mean of pesticides (X_1) is 1316.

The estimated VMP of $1.51 is the return per dollar expenditure at the mean. Farmers spending less than $1316 would receive higher returns per dollar, and those spending more than $1316 receive less than $1.51. Thus some farmers could profitably use more pesticides while others might be receiving less than $1 return per dollar expenditure on pesticides.

The Cobb-Douglas function shows diminishing returns to each input because every B_i is less than 1. The function shows increasing returns to scale because the sum of the B_i coefficients is greater than 1. With the elasticity sums being more than 1, gross income will increase by a greater percentage than inputs. Increasing returns to scale are not considered very likely, therefore the Cobb-Douglas function may not provide a reasonably reliable description of the input-output relationship.

The quadratic equation using the same variables is estimated as: (F statistic in parenthesis)

$$Y = -13{,}352.52 + \underset{(6.38)}{3.228X_1} - \underset{(.32)}{.00007558X_1^2} + \underset{(8.30)}{4.727X_2} - \underset{(3.44)}{.0002424X_2^2} +$$

$$\underset{(3.03)}{1.997X_3} - \underset{(.21)}{.00003545X_3^2} + \underset{(6.23)}{7087.228X_4} + \underset{(.74)}{5532.485X_5} - \underset{(.41)}{714.045X_5^2} +$$

$$\underset{(1.99)}{2.825X_6} - \underset{(1.28)}{.0004896X_6^2}$$

$$R^2 = .67$$

Linear terms of all variables except July rainfall were statistically significant at the 5 percent level (F statistic in parenthesis beneath each coefficient). However most of the squared terms were statistically insignificant and for the variable number of men was not brought into the equation because of too low statistical insignificance.

The VMP is found by taking a partial derivative of each Y term with respect to X $\frac{dy}{dX_1} = B_1 + 2C_1\overline{X}$ where B_1 is the coefficient of the X term representing pesticides, C_1 is the coefficient for the squared term, and $\overline{X}$ is the arithmetic mean of the pesticide variable.

The VMP for pesticides in the quadratic equation is computed as:

$$\frac{dY}{dX_1} = 3.228 - 2(.00007558)\ (2781.35) = 2.81$$

where 2781.35 is the arithmatic mean of pesticide expenditure.

When the X^2 term is negative it means a production function curve with diminishing returns to pesticides. As the amount of input increases, output will increase, reach a maximum, and then decrease.

The quadratic function estimates the productivity of pesticides of $2.81 per dollar expenditure on pesticides; this value is calculated at the arithmatic mean of pesticide expenditure. The value suggests North-East Kansas farmers received a very high return per dollar spent on pesticides. Very likely, some farmers could have increased their income by using more pesticides to control weeds and insects.

The value marginal product of other independent variables in the preceding equations is shown in Table 8.

The value marginal product for the expenses of pesticide, depreciation, fertilizer, and feed indicate the amount of gross income received for the marginal dollar, at the mean, spent on those inputs. For number of men it represents the amount of gross income received for

Table 8: Value of the Marginal Products for Variable Set 1 for Three Equations Tested

Variables	Equations		
	linear	Cobb-Douglas	quadratic
pesticide expense	$2.41/$1.00	$1.51/$1.00	$2.81/$1.00
depreciation expense	$1.81/$1.00	$3.23/$1.00	$2.18/$1.00
fertilizer expense	$1.41/$1.00	$ .85/$1.00	$1.66/$1.00
number of men	$6382.77/man	$7885.70/man	$7087.29/man
July rainfall	$1489.57/in.	$3823.96/in.	$2404.08/in.
feed expense	$1.28/$1.00	$6.25/$1.00	$2.18/$1.00
R^2	.65	.55	.67

the marginal unit of labor measured at the mean. The value marginal product for July rainfall estimates the additional gross income received for the marginal inch of rainfall received in July measured at the mean.

In comparing the three types of equations tested in this study, the quadratic is the most meaningful. The quadratic equations show diminishing returns to increasing amounts of input and had the highest R^2 of the equations used. The VMP's are reasonable. In Table 8 in the quadratic equation, expense inputs; pesticide, depreciation, fertilizer, and feed, all show a profit for their marginal use.

The Cobb-Douglas equation also shows diminishing returns, but the VMP's (Table 8) are less reasonable. It shows a marginal productivity for fertilizer (.85) to be losing money, while the productivity for feed expense (6.25) seems unrealisticly high. The Cobb-Douglas had the lowest R^2 of the three equations.

This study limited the sample farms to less than 30 percent of gross income received from livestock. Even so, feed expense for livestock was significant as an explanatory variable for gross income. This indicates that most predominantly crop farms in this part of the state have some livestock enterprises. This is the reason "feed expense" was included in the equation.

This group of farms were efficient at the mean, and one dollar spent on pesticide would return \$2.81. When pesticide expense has a profitable return the reasons why farmers may not spend more are: (1) they do not know the profitability of pesticides, (2) they were too cautious when faced with a risky expense, or (3) they killed all the weeds and/or insects with the treatment used and there was no need to use more pesticide.

The simple correlations for the variables in the preceding equations are shown in Table 9 .

Table 9 : Simple Correlations Among Variables in Variable Set 1

	GROID	PESTD	DEPD	FERTD	NMEN	JULR	FEEDD
GROID	1.000	.6740	.4626	.6159	.2264	.5440	.1397
PESTD		1.000	.3502	.5676	.2532	.3586	.1051
DEPD			1.000	.2023	.0259	.4047	.1281
FERTD				1.000	.1228	.4226	.0129
NMEN					1.000	-.0069	.0948
JULR						1.000	-.1139
FEEDD							1.000

The degree of association between two independent variables is called correlation. This varies between + 1 for perfect correlation, to - 1 which is perfect negative correlation. The correlation between pesticides expense and other independent variables for this model varied from .1051 to .5676.

Variable Set 2

A second set of variables used expense inputs only as its four independent variables. These variables were:

pesticide expense (X_1)

depreciation expense (X_2)

fertilizer expense (X_3)

labor hired expense (X_4)

The X terms represent the respective variables in the following equations. The equation for the linear function was (F statistic in parenthesis):

$$Y = 14{,}303 + \underset{(22.64)}{2.78X_1} + \underset{(9.38)}{1.67X_2} + \underset{(10.00)}{1.32X_3} + \underset{(4.98)}{1.51X_4}$$

$$R^2 = .62$$

All variables included were highly statistically significant.

The Cobb-Douglas function using the variables identified above was:

$$Y = \underset{(14.88)}{369.98X_1^{.07741}} \; \underset{(24.83)}{X_2^{.38449}} \; \underset{(5.14)}{X_3^{.07381}} \; \underset{(2.20)}{X_4^{.02627}}$$

$$R^2 = .45$$

All variables were statistically significant at the 5 percent level. The equation shows diminishing returns because the elasticity sum is less than 1.

The quadratic function was estimated as:

$$Y = 2047.41 + \underset{(9.81)}{3.805X_1} - \underset{(.61)}{.00009876X_1^2} + \underset{(6.54)}{4.145X_2} - \underset{(3.32)}{.0002319X_2^2} +$$

$$\underset{(7.05)}{2.794X_3} - \underset{(2.10)}{.0001018X_3^2} + \underset{(9.42)}{5.229X_4} - \underset{(4.81)}{.0004896X_4^2}$$

$$R^2 = .66$$

All linear and squared terms of variables in the equation are statistically significant at the 5 percent level except the squared term for pesticides. All square terms have negative coefficients and all linear terms have positive coefficients indicating diminishing returns to all inputs.

The VMP of pesticides, depreciation, fertilizer, and labor hired expenses in the preceding equations are shown in Table 10.

Table 10: Value of the Marginal Products for Variables in Set 2 for Three Equations Tested.

Variable	Equations		
	linear	Cobb-Douglas	quadratic
pesticide expense	\$2.78/\$1.00	\$2.05/\$1.00	\$3.26/\$1.00
depreciation expense	\$1.67/\$1.00	\$2.89/\$1.00	\$1.71/\$1.00
fertilizer expense	\$1.32/\$1.00	\$ .75/\$1.00	\$1.82.\$1.00
labor hired expense	\$1.51/\$1.00	\$3.22/\$1.00	\$4.01/\$1.00
R^2	.62	.45	.66

The quadratic equation is considered better than the Cobb-Douglas because it explains more of the variance in gross income and the VMP's of variable seem more reasonable. This equation uses the labor hired expense which does not include the operators labor. It is assumed that on a crop farm labor is hired only when most needed. The VMP for labor hired expense was 4.01, indicating a return of \$4.01 for one dollar spent for hiring additional labor. One reason this may be high is the value of getting farm work done at the right time. The VMP of \$4.01 shows how important timeliness is in the busy season of the year when labor is often scarce.

Another possibility for the high return per dollar spent on hired labor may be that it is related to the size of farm. A larger farm may hire more labor and consequently have a higher gross income.

The equation indicates the marginal productivity to be .55 higher for pesticide expense, .47 lower for depreciation expense, and .16 higher for fertilizer expense when compared to variable set 1.

The simple correlations for variables in set 2 are shown in Table 11.

Table 11: Simple Correlations among Variables in Variable Set 2

	GROID	PESTD	LABRD	FERTD	DEPD
GROID	1.000	.6739	.4774	.6159	.5440
PESTD		1.000	.3821	.5676	.3586
LABRD			1.000	.2786	.4208
FERTD				1.000	.4226
DEPD					1.000

Other Equations Tested

Other groups of independent variables were tested in the three functional forms. Since quadratic equations show diminishing returns to increasing amounts of input, and had the highest R^2, the results are given with the quadratic function only.

The equation tested in Table 12 uses man work units per farm for the labor variable rather than labor hired or number of men. The VMP for this variable was -3.35. This would indicate that most farms in this study were getting a negative return on labor used. The VMP equation shows that returns to a man work day is positive if less than 212 work days are employed. The estimate of 212 work days seems unrealistically low.

Table 12: Coefficients of Variable, F Statistic, and the VMP for the Equation Tested with Variable Set 3 for the Quadratic Equation

Variable	B coefficients	F statistic for B term	C coefficients	F statistic for C term	VMP
pesticide expense	2.84	4.62	-.0000229	.03	2.96
depreciation expense	4.48	6.59	-.0001699	1.59	2.70
fertilizer expense	2.43	4.02	-.0000784	.99	1.68
July rain	7071	1.14	-962.4301	.70	2854.35
feed expense	4.01	3.63	-.0005237	3.01	3.07
PMWU	30.90	.21	-.070518	.47	-3.35
R^2 = .65					

The linear terms are statistically significant for all variables except the July rainfall and man work day units; Only the square term of the variable feed expense is statistically significant.

Another equation tested used eight expense inputs as the independent variables (Table 13).

Table 13: Coefficients of Variables, Their F Statistic, and VMP for Equation Tested with Variable Set 4 for Quadratic Equation

	B coefficients	F statistic for B term	C coefficients	F statistic for C term
pesticide expense	2.98	5.11	-.0000554	.18
depreciation expense	6.60	9.79	-.0004571	6.68
fertilizer expense	3.57	7.43	-.0001712	3.96
labor hired expense	3.68	3.49	-.0003624	2.14
machinery expense	-3.78	1.73	.0003827	2.94
interest expense			.0001094	1.17
feed expense	2.93	1.84	-.0004231	1.95
cash rent expense			-.0000111	.03
R^2 = .69				

This equation uses only dollar value expense inputs. The B coefficients for the variables "interest" and "cash rent expense" did not enter the equation because the F statistic was less than .01 showing very little significance. The B coefficient for "machinery expense" was negative, while the C coefficient was positive. This would show decreasing income for additional dollars spent at relatively low amounts spent but as more was spent the return would increase at an increasing rate. This is just opposite of a normal quadratic production function. Because of this it is not considered realistic. Interest expense also had a positive C coefficient causing income to increase at an increasing rate for additional expenditures.

The simple correlations for this equation are shown in Table 14.

Multicollinearity is a phenomenon that occurs in a regression model when two or more independent variables tend to move together in the same pattern because of a high correlation between each other. When the variables are highly correlated it is difficult to separate their respective effects on the dependent variable. This is the problem that caused some of the unrealistic coefficients in the eight variable equation. All of the expense inputs would logically contribute to the explanation of gross income, but when used in combination with each other the results are illogical because of multicollinearity. One variable is partially explaining the effects of another, and when the second variable is also on the equation the results are distorted. This is probably the reason why the machinery expense coefficients were unrealistic and also the most likely reason why interest expense is insignificant (Table 14).

Table 14: Simple Correlations among Variables in Variable Set 4

	GROID	PESTD	LABRD	INTRD	FERTD	FEEDD	RENTD	MACCD	DEPD
GROID	1.0000	.67396	.47738	.37484	.61589	.22640	.26359	.54144	.54401
PESTD		1.0000	.38208	.48817	.56761	.25320	.28132	.45663	.35857
LABRD			1.0000	.36430	.27859	.03829	-.11096	.49739	.42026
INTRD				1.0000	.28149	-.12776	-.06377	.52834	.31902
FERTD					1.0000	.12278	.41587	.51221	.42258
FEEDD						1.0000	.28075	.03345	-.00685
RENTD							1.0000	-.03895	.11464
MACCD								1.0000	.56444
DEPD									1.0000

Other Results

Three of the deflated expense variables consistantly showed the highest correlation with the dependent variable, and had very significant F values. These three variables were: deflated pesticide expense, deflated depreciation espense, and deflated fertilizer expense. Using only these three independent variables in a linear equation form produced an R^2 of .60. The .60 compares to an R^2 of .69 which was obtained using 16 independent variables which included eight variables and their squared terms in a quadratic equation. The .69 was the highest R^2 obtained for any equation in the study but was not considered the most useful equation because of the insignificance of many of the variables.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Findings

The increasing use of pesticides in recent years show that farmers believe that pesticides are a more productive way of combating pests than any alternative method. The objective of this study was to estimate the marginal productivity of pesticides for farmers in North-East Kansas. The model used a combination of time series and cross sectional data from Farm Management Association #4 farms for the years 1974 through 1978 that were predominantly crop farms, and were between 500 and 700 crop acres in size. Pesticide expense was the total farmer expenditure for herbicides, insecticides, and fungicides.

Regression analysis was used with gross income being the dependent variable, and pesticides being the independent variable of prime concern. Other independent variables used were: depreciation expense, fertilizer expense, feed expense, a labor measure, and rainfall in July. Three types of production functions--linear, Cobb-Douglas, and quadratic--were fitted to the model data.

The productivity was computed in dollars of gross income received for the marginal dollar spent of pesticides measured at the mean. The estimated value of the marginal product ranged from $1.51 using a Cobb-Douglas equation with six independent variables, to $3.26 using a quadratic equation with four independent variables. From the results of this study it is believed that the quadratic equation form is the most meaningful because of the statistical fit, statistical significance of variables, and the sign and magnitude of the variables.

Using a quadratic equation with six explanatory variables, the marginal productivity of pesticide was estimated as $2.81. This indicates an increase of gross income of $2.81 for the marginal dollar spent for pesticides.

This study also estimated the marginal productivity of other farm inputs from FMA #4 members in North-East Kansas. These were:

(a) Depreciation expense, An increase in gross income of $2.18 for the marginal dollar of depreciation expense.

(b) Fertilizer expense, An increase in gross income of $1.66 for the marginal dollar of fertilizer expense.

(c) Number of men, An increase in gross income of $7087.29 for the marginal full time worker on the farm.

(d) July rain, An increase of $2408.08 for the marginal inch of rain in July.

(e) Feed expense, An increase of $2.18 for the marginal dollar spent on livestock feed.

Evaluation

This study estimates that farmers are receiving, in benefits from using pesticides, more than the cost of the chemicals. It would indicate farmers' use of pesticides, even in uncertain and financially risky situations, are finding it a profitable practice.

Limitations of the Study

Limitations of this study are:

(a) The data used in this study are from a specific area and a specific time frame (North-East Kansas, and the years 1974-1978). The marginal productivity values computed are estimates which may not be true for other farming areas or other years.

(b) The farms used as the sample are not average farms and are not randomly selected, but are a specific group of Farm Management Association #4 members. FMA members, which are expected to be better than average in management ability, may have marginal productivity higher than average.

(c) Due to multicollinearity between independent variables, a function of one variable may show partial effects of other variables not in the equation. This means that even though independent variables may be omitted, some of the effects of those variables remain. If this is the case the VMP of an independent variable may be distorted.

(d) The study assumes that the farmers used pesticides according to normal, generally accepted practices.

Possibilities of Future Studies

Each farming region is unique in its amount and timing of precipitation, severity of winter, elevation, and types of soil. These differences cause differing mixes of crops and livestock enterprises. An estimated marginal productivity of pesticides in one area would not necessarily hold true for another area. Because of this there is opportunity for study in other regions.

More data are needed concerning the expenditures on certain types of pesticides on a single crop, such as herbicides in grain sorghum. More data are also needed concerning the degree of weed control and plant damage with differing concentrations of a specific herbicide on a specific crop. These studies would determine the economic impact of using a particular kind of pesticide in varying amounts.

REFERENCES

1. Anderson, Wood Powell. Weed Science Principles. LaCruces, New Mexico: New Mexico State University. West Publishing Co. (1977) 171-189

2. Brown, Merle. Record of "Palmer Drought Index" and "July Rainfall" for North-East Kansas for 1974-5-6-7-8. Manhattan, Kansas. Research Associate. Department of Physics. (1979)

3. Byerly, T. C. "The Role of the Government in the Pesticide Controversy," Economic Research on Pesticides for Policy Making. Washington, D. C. U. S. Department of Agriculture. Proceedings of a Symposium. April 1970. 3-13

4. Carlson, Gerald A. "Long Run Productivity of Insecticides," American Journal of Agricultural Economics, 59 (August 1977), 543-548.

5. Doll, John P. and Orazem, Frank. Production Economics Theory with Applications. Columbus, Ohio: Grid Inc. (1978) 53-64

6. Eicher, Theodore R.; Andrilenas, Paul A.; and Anderson, Thelma W. Farmers Use of Pesticide in 1976. Washington, D. C. U. S. Department of Agriculture. Economics, Statistic and Cooperative Service. Agricultural Economics Report No. 418. December 1978.

7. Hackler, Raymond F.; Dickson, William M.; Parker, Leonard C.; Gerlaff, Delton, C.; Petty, Daryl K. Farm Management, Summary and Analysis Report, Kansas 1978, Association No. 4. Manhattan, Kansas. Kansas State University. Department of Economics. Cooperative Extension Service.

8. Headley, J. C. "Estimating the Productivity of Agricultural Pesticides," American Journal of Agricultural Economics, 50 (February 1968), 13-25.

9. Headley, J. C. "Productivity of Agricultural Pesticides," Economic Research on Pesticides for Policy Decision Making. Washington, D. C. U. S. Department of Agriculture. Proceedings of a Symposium. April 1970. 80-88

10. Heady, Earl O. and Dillon, John L. Agricultural Production Functions. Ames, Iowa. Iowa State University Press. (1961) 142-194

11. Hu, Teh-wei. Econometrics, An Introductory Analysis. Pennsylvania State University: University Park Press. (1973) 35-59

12. Johnson, Bruce, and Byers, Thomas. Agriculture Crop Pesticide Use in Nebraska, 1978. Lincoln, Nebraska. University of Nebraska. The Agricultural Experiment Station. Report No. 100. October 1979.

13. Johnson, M. E. 1978 Pesticide Survey. Topeka, Kansas. Kansas Crop and Livestock Reporting Service. July 1979.

14. Langemeier, Larry N. The K-Mar-105 Whole Farm and Enterprise Data Bank and Retrieval System. Manhattan, Kansas. Kansas State University. Department of Economics Extension.

15. Nie, Norman H.; Hull, C. Hadlai; Jenkins, Jean G.; Steinbrenner, Karin; Bent, Dale H. Statistical Package for the Social Sciences, Second Edition. McGraw-Hill Inc. (1975) 320-367, 293-300

16. Russ, Oliver G. Report of 1978 Herbicide Data. Manhattan, Kansas. Kansas State University. Agriculture Experiment Station. Contribution No. 79-253-E. (1979) 9, 25

17. Sixty-first Annual Report and Farm Facts. Topeka, Kansas. Kansas State Board of Agriculture. (1977)

18. Smith, F. W. Chemical Weed Control in Field Crops. Manhattan, Kansas. Kansas State University. Agriculture Experiment Station. Report of Progress No. 346. January 1979. 3-5

19. U. S. Congress. The Federal Insecticide, Fungicide, and Rodenticide Act. Environmental Protection Agency. P. L. 92-516 (1972). Amended 94-140 (1975), 95-396 (1978)

20. U. S. Department of Agriculture. Agricultural Statistics 1978. Washington, D. C. Economic Research Service. (1978) 416-457

21. U. S. Department of Agriculture. Farm Cost Situation. Washington, D. C. Economic Research Service. (1975)

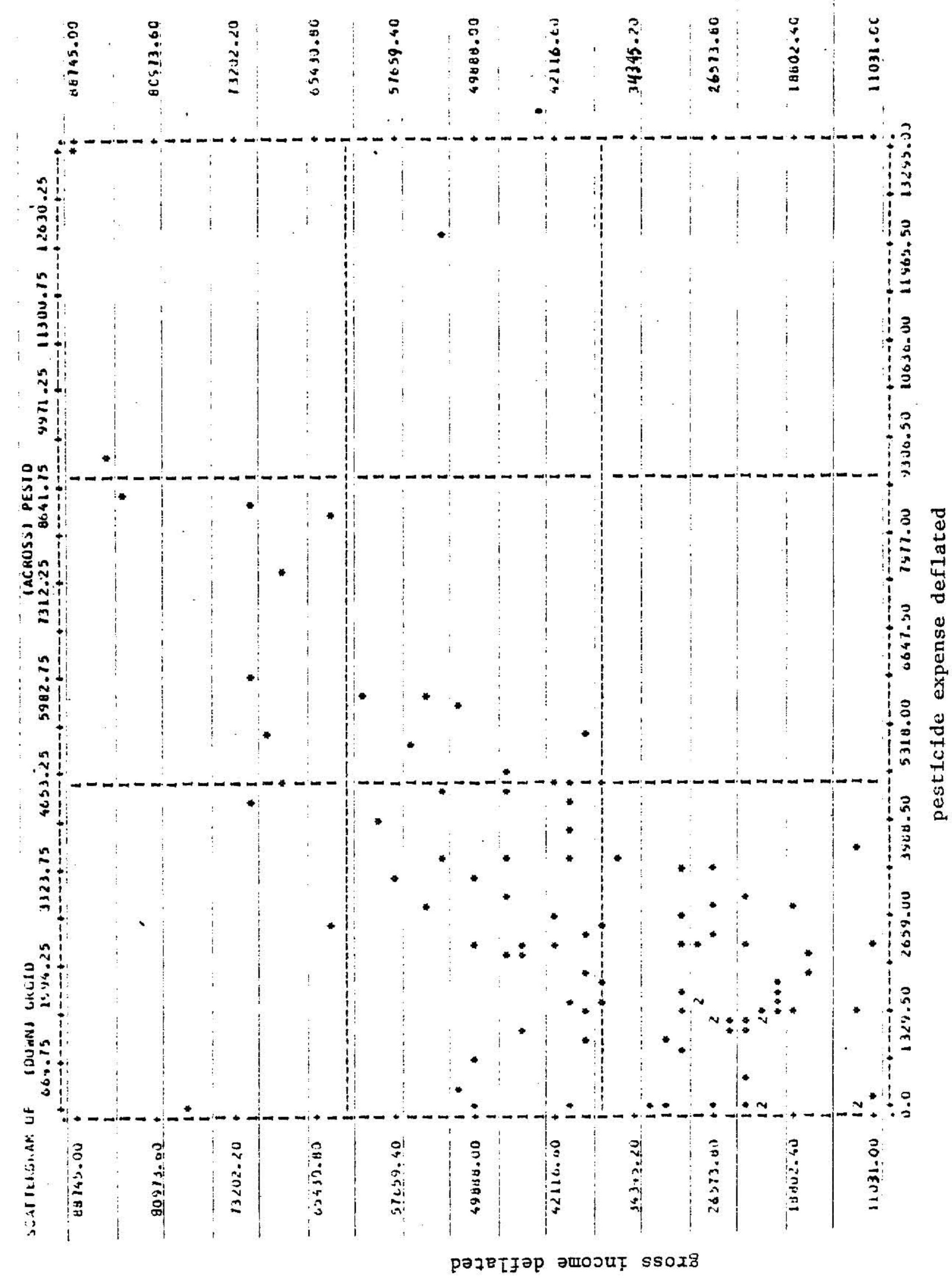
APPENDIX

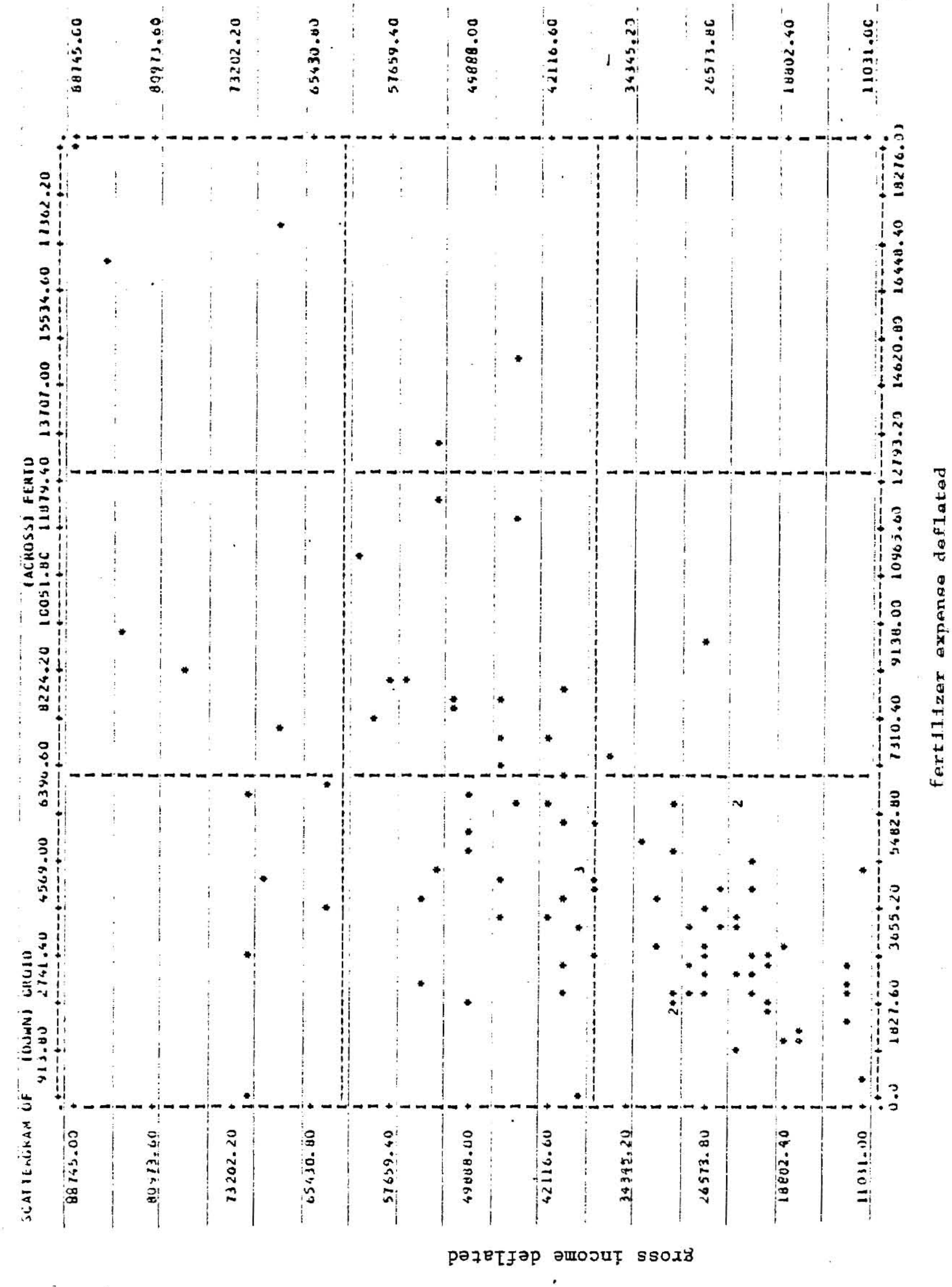
Scattergrams Showing Relationship Between Gross Income and Pesticide, Fertilizer, Depreciation, Labor, and Feed Expense

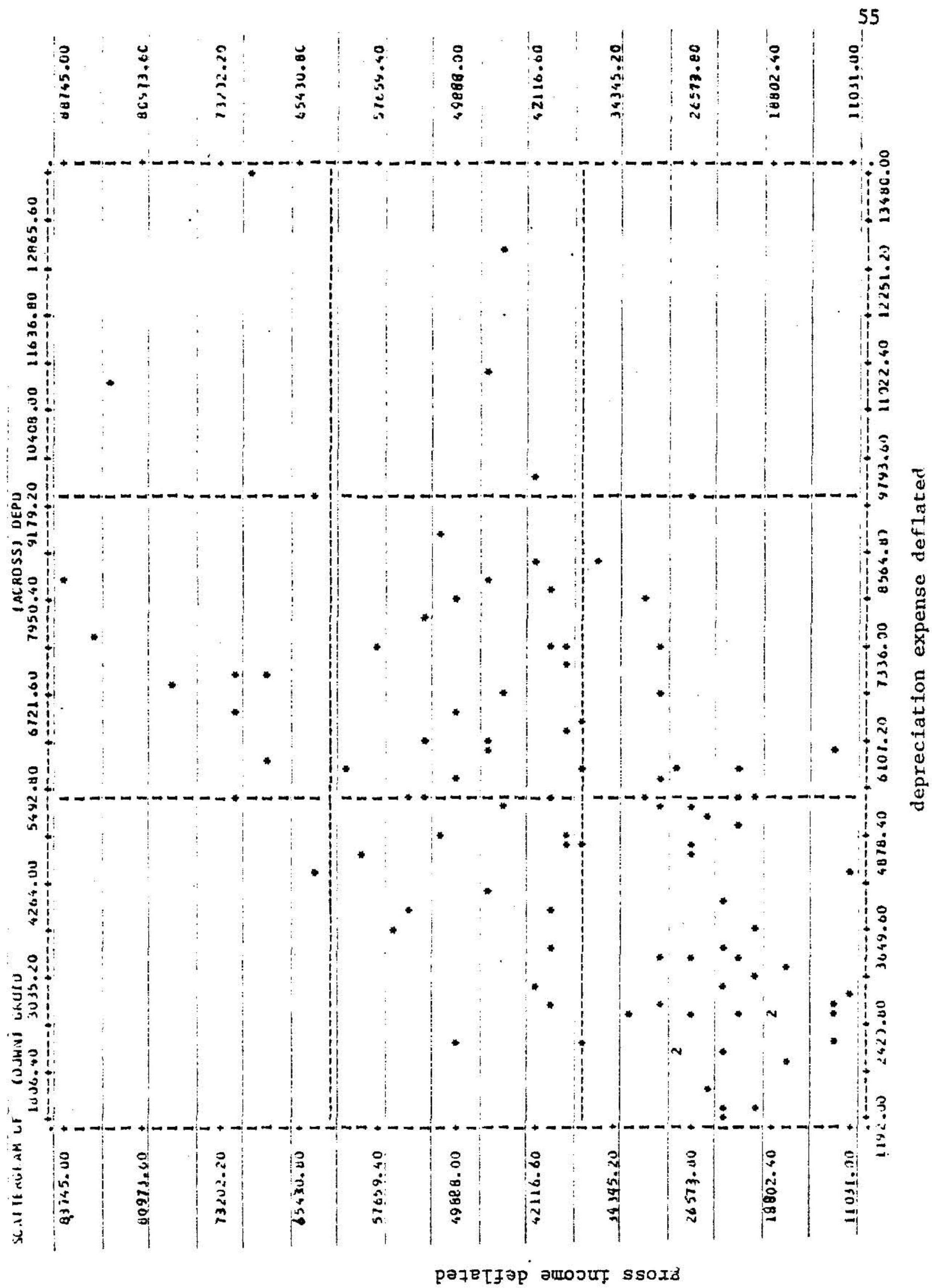
ILLEGIBLE DOCUMENT

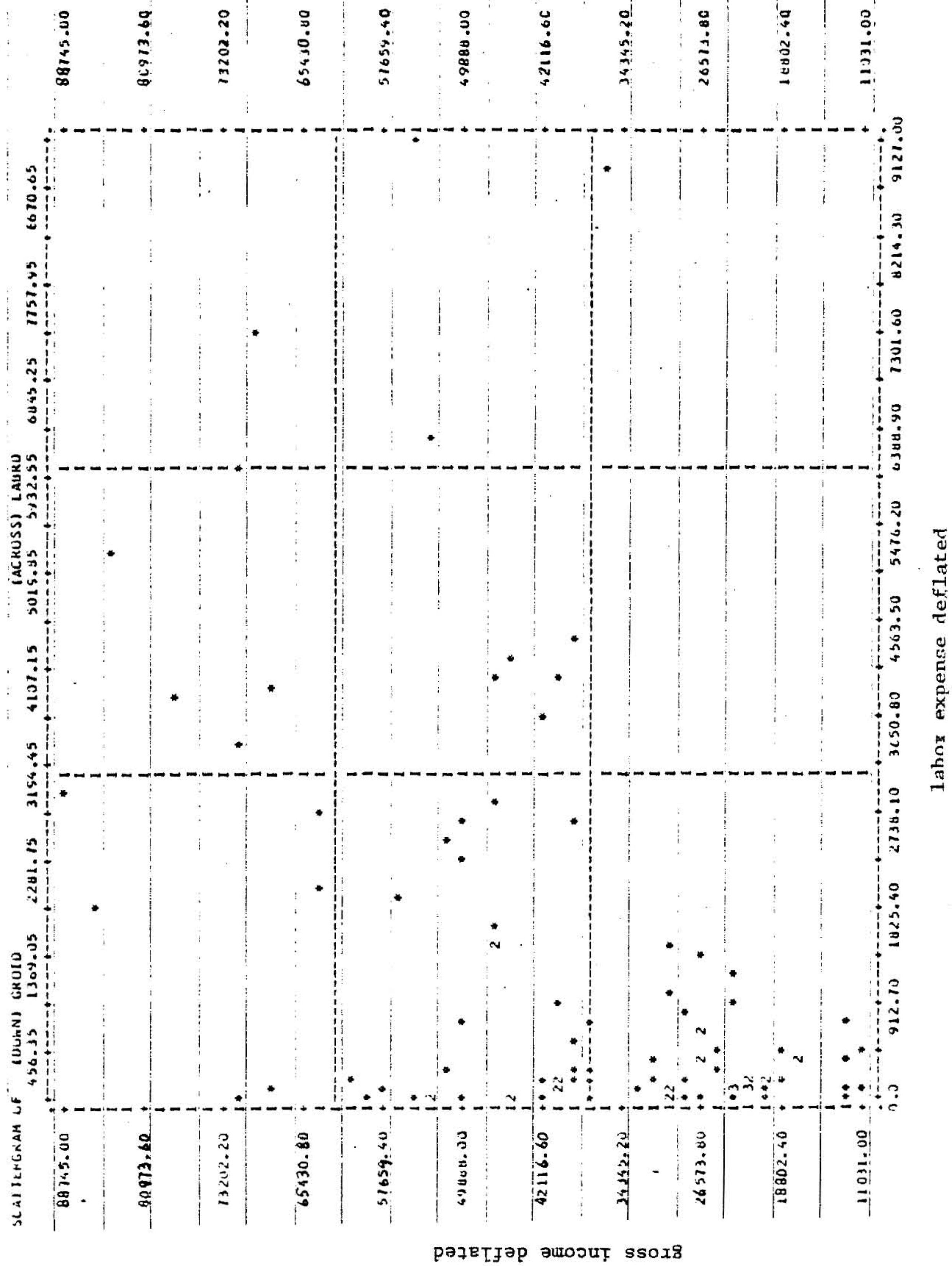
THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

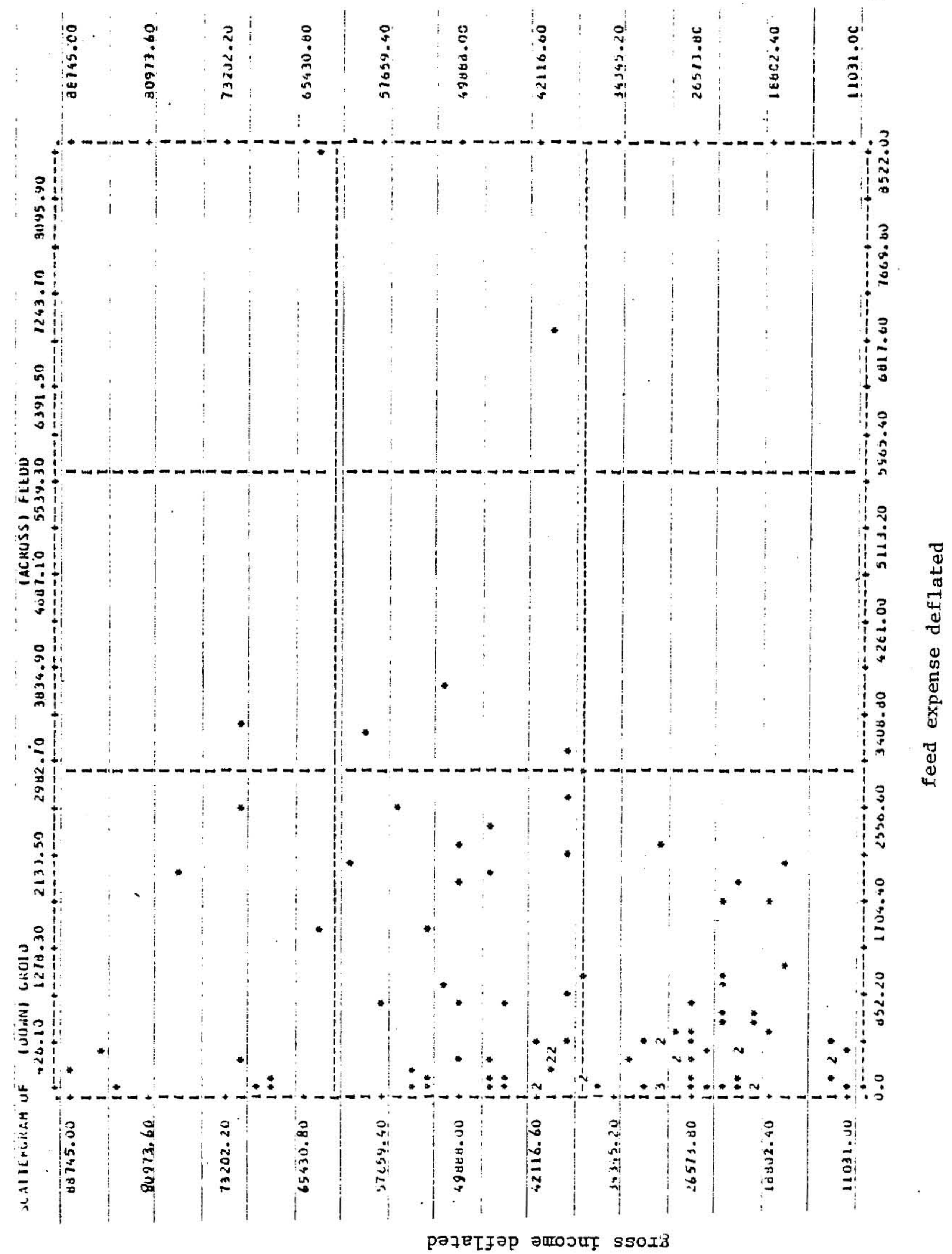
THIS IS THE BEST COPY AVAILABLE


pesticide expense deflated
gross income deflated


SCATTERGRAM OF (DOWN) GROID (ACROSS) FERTD
gross income deflated
fertilizer expense deflated


SCATTERGRAM OF (DOWN) GROID (ACROSS) DEPD
depreciation expense deflated
gross income deflated


SCATTERGRAM OF (DOWN) GROID (ACROSS) LABRD
labor expense deflated
gross income deflated


gross income deflated
feed expense deflated

ESTIMATING THE MARGINAL PRODUCTIVITY OF PESTICIDES ON PREDOMINANTLY CROP FARMS IN NORTH-EAST KANSAS

by

ALLEN W. JANKE

B. S., Kansas State University, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Economics

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Increasing use of pesticides in agriculture has been one of the important changes to have taken place in recent years. Farmers rely on pesticides as a necessary input in their production of agricultural crops. Pesticide is the common term used to include herbicides, insecticides, and fungicides.

The objective of this study was to estimate the dollar return for the marginal dollar spent on pesticides on crop farms in North-East Kansas. This was done by using regression analysis and fitting three types of production functions to the data. The forms of the functions were linear, Cobb-Douglas, and quadratic.

Data were taken from Farm Management Association #4 for the years 1974 through 1978. These farms are believed to be larger than average in size, and higher in gross and net income and expertise of management. The North-East area of Kansas was used in the study because it has a higher rate of precipitation than other areas of Kansas and because of this there are more problems with weeds and insects. This in turn results in relatively high rates of herbicide and insecticide use by farmers. The data used were the gross income and the actual expenses for pesticides and other production inputs from individual farms. Farms used in the study were between 500 and 700 crop acres in size and received 70 percent or more of their gross income from crops. The model used a combination of time series and cross-sectional data with a sample size of 99.

The study showed the use of pesticides to be a profitable input in farm production. Productivity of pesticides was computed in dollars of gross income received for the marginal dollar spent on pesticides. The results of this study estimated the value of the marginal product for pesticides at $2.81 using a quadratic equation.

Also included in the study were estimates of marginal benefits from expenditures on fertilizer, depreciation, labor, and feed. Benefits in dollars for the marginal inch of July rainfall were also estimated.