THE DEMAND FOR FERTILIZER IN KOREA

A THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF THE UNIVERSITY OF MINNESOTA

By

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

MARCH 1974

ACKNOWLEDGMENTS

The author would like to thank the Economic Development Center of the University of Minnesota for supporting this research project. The author also wishes to express a deep appreciation to the following people:

To Dr. Dale C. Dahl, major advisor, for his advice, guidance and encouragement throughout graduate program.

To Dr. Young K. Shim for gathering data and his continuous guidance.

To Dr. Martin E. Abel and Dr. Charles Freedman for providing many valuable comments and for serving on the final oral committee.

To Mrs. Kae Perry for her clerical advice and help from the beginning of the manuscript.

To my wife, Rang Hee, and my family for unselfish attitude and constant encouragement enabling me to complete my graduate training.

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CHAPTER I

INTRODUCTION

1. Problem setting

Korea has a mountainous topography. Only 23 percent of the area is arable and a monsoon climate concentrates most of the precipitation in the summer growing season. Agriculture is the basic industry. About one-half of the total population of 31 million is engaged in agriculture and forestry. Their total production accounted for 26.8 percent of the gross national product in 1971.

Agricultural production has not been sufficiently large to provide enough food for the nation. During the 1960's the demand for food crops rose at an annual average of 5 percent, whereas the domestic supply increased at an annual average of 2.5 percent. The supply shortage was met with imported good grains. The shortage is not expected to lessen in the near future.

A larger portion of the population lives on farms. Thus labor inputs relative to land are large. In 1971, the average number of family members per farm was 5.9. They lived on small farms, an average land size of 9.2 danbo (0.9 hectares). The capital input for agricultural production is also a limiting factor. There is severe capital rationing, both internal and external, due to low and unstable yields and the existence of subsistence farming.

For the given resource endowment much of the new technology needed to increase agricultural productivity is embodied in the form

of chemical and/or biological inputs. As a result, the consumption of commercial fertilizer has doubled during the last decade. The development of high yielding varieties of crops which need more fertilizer has been emphasized and will continue to be stressed in the future. Therefore, the demand for fertilizer can be expected to expand. How much and what types of fertilizer will be demanded in the future is a matter of importance to Korean economic planners. Several factors will influence future fertilizer demand in Korea:

1. The consumption and production patterns of agricultural commodities may change. During the last decade, the planted acreage of rice accounted for more than one-third of total plant area. While the rice acreage remained unchanged, acres of such food crops barley, wheat, pulses, potatoes and miscellaneous food crops decreased. The planted area of vegetables, fruits, special crops and mulberry trees substantially increased. These changes in production patterns are expected to continue in the future considering the commercialization of farming and overall economic development. Given that different crops require different combinations of various plant nutrients, fertilizer needs will vary with production patterns.
2. Domestic availability of raw materials for fertilizer production will influence the potential production of fertilizer. The raw materials for urea such as coke, air and water could be supplied domestically but the

phosphate rock and potassium material deposits must be imported. Restraints on the character of the demand for each plant nutrient will affect their import requirements.

3. The demand for fertilizer also varies by region. The production pattern of agricultural crops is different among regions according to regional topography and agro-climatic conditions. And it also varies by production practices in each region. The regional pattern of agricultural production will change as new crops are introduced and as industrial development proceeds.

On the supply side, the location of the fertilizer industry affects the distribution system of fertilizer and fertilizer input prices for farm production. In 1970, more than 70 percent of total fertilizer was produced in the southeastern part of the country. Good harbors in this region can receive imported fertilizer. But a large part of the total fertilizer was consumed in the western part of the country. Firms within the fertilizer industry must constantly make decisions concerning how much to produce and market. Those decisions are now based on "experience and judgment". But systematic techniques in estimating demand will complement these decision-making elements. Correct levels of production and marketing based on the demand relationships of fertilizer are very important in reducing costs and losses from excess storage or shortage.

Several demand questions are of prime interest: What factors affect the increased consumption of fertilizer, totally and by nutrient? What causes differences in the regional demand for fertilizer, if any, and how will these factors change? Why are there any differences between the agronomic needs and actual farm demand for fertilizer? What conditional projections can be made of future consumption of fertilizer totally, by nutrient and by region?

2. Objectives

It is within the framework of the above questions that this study is formulated. The primary objectives of this study is to identify, describe, quantify and analyze the factors affecting the demand for commercial fertilizer. More specific objectives include:

1. To estimate aggregate farm level demand functions for fertilizer, totally and by nutrient.
2. To determine agronomic optimum levels of fertilization.
3. To evaluate the effects of selected economic, physical and behavioral variables on the demand for fertilizer by farm.
4. To forecast consumption of fertilizer at both national and regional levels, totally and by nutrient.

3. Procedures and limitations

Three different approaches are employed to estimate the demand functions for fertilizer using different data. One is a time-series data analysis which estimates the aggregate demand function for

total and individual nutrients of fertilizer. All data are obtained from official reports issued by the Ministry of Agriculture and Forestry and National Agricultural Cooperatives Federation of Korea. Because of lack of regional data it is impossible to estimate the regional demand functions for fertilizer by the time-series method. The national data are available only since 1959 when the official survey data on the farm level was first conducted. This places severe limitations on the degrees of freedom.

Another analytical approach used was an experimental data analysis. The agronomic optimum level of fertilization on various crops is computed by using experimental results obtained from the Crop Experimental Stations in Korea. The fertilizer response functions of various crops are fitted and the optimum levels of each plant nutrient are computed under specific price conditions. These optimum rates of fertilizer are aggregated to arrive at the national and regional "potential use" of fertilizer by total and nutrient. The official estimation of fertilizer demand in Korea has been performed by this method. There can be differences between the agronomic needs and the actual demand because of technical lag and different objective functions between the experiment stations and farm firms but this method provides a base for potential demand for fertilizer if the technological changes in crop production are properly treated.

The third method is a farm survey data analysis. An interview survey of the sample farms was conducted to obtain the economic and demographic variables affecting the purchasing patterns of fertilizer

by farmers. The estimated demand functions for total and individual nutrient fertilizer is summed to quantify a national and regional demand for fertilizer.

The stability of the relations identified determines the predicting powers they possess. The future values of the exogeneous variables are obtained from the related previous studies and from direct estimation of trend values. Based on these projected variables, the expected quantities of fertilizer demanded until 1985 is estimated for total and individual nutrients at national ana regional levels.

4. Organization of the study

Chapter II develops the general economic model for input demand. Different assumptions lead to modifications of the generalized model. Chapter III includes the aggregate demand for total and individual nutrient fertilizer estimated by the time-series data analysis. Chapter IV presents the estimation of the agronomic optimum level of fertilization of various crops from fitted fertilizer response functions using the experimental data.

Chapter V describes the farm demand relationship for fertilizer estimated by the farm survey data. Chapter VI evaluates the three approaches and presents predictions of the future demand for fertilizer in Korea.

Finally, Chapter VII summarizes the study and provides some implications and policy recommendations.

CHAPTER II

GENERAL MODEL OF DEMAND FOR FERTILIZER

1. Introduction

This chapter develops the general model for input demand used in this study. The first section is a discussion of some basic concepts of derived demand for a factor of production in a static environment. This is followed by some consideration of the dynamic aspects of input demand. Later, an investigation into the theoretical framework for the fertilizer supply side of the market is undertaken. Finally, the specific theoretical model for the analyses is presented.

2. Derived demand for input

The demand for commercial fertilizer is derived from the demand for agricultural crops produced by using fertilizer as the limiting input. It is assumed that each farm without any constraints maximizes its profit under perfect competition in the product and input markets. The consequences of relaxation of some of the assumptions will be considered later. Economic theory specifies that the quantity (X_i) of an input demanded for a profit maximizing firm depends on the price of the input (P_i) price of output (P_y) and prices of close substitutes and complements (P_j). The theoretical input demand relationship is:

$$X_i^D = f\ (P_i,\ P_y,\ P_j).$$

The price of input is the variable related to movements along the demand curve. The fertilizer input demand curve is negatively sloped as long as the necessary and sufficient conditions for profit maximization are fulfilled. The price of output is a shifter of the demand curve. In most cases considered by economists, and increase in the quantity of an input will increase the marginal product of the other. Thus, as the price of the product changes the value of marginal product (or marginal value product) proportionally and the quantity of input increases or decreases depending on the direction of change in the output price.

The prices of substitutes and complements are another source of shifters of the demand curve. If the related good is a substitute, then an increase in its price causes an increase in the consumption of fertilizer. Conversely, an increase in the price of a complement cause a decrease in the consumption of fertilizer.

The input demand for the firm with expenditure restriction is also a function of level of capital outlay (C) of the firm. The demand relationship is:

$$X_i^D = g\ (P_i,\ P_y,\ P_j,\ C)$$

It is assumed that for any given expenditures for factors of production farmers tend to maximize profit. Those farmers who have no expenditure restrictions, purchase inputs until the last unit of factor purchased is worth in production just what it costs. But those with an expenditure restriction are unable to purchase inputs to this point.

3. Dynamic considerations in the input demand

i. Price expectation and quantity adjustment.

Economic theory of the competitive firm also introduces additional concepts which aid in determining the use of input by the firm. In the preceding development of factors affecting the quantity of fertilizer demanded by the firm it is assumed that prices of input and output are known with certainty. However, the farm firm must make its decision on the quantity of input to purchase based on expected prices as well as current prices. The expected price is assumed to be a weighted price of the past prices so that expected price is:

$$P_t^e = \beta \sum_{i=0}^{n} (1 - \beta)^t \; P_{t-1} - i,$$

or

$$P_t^e = P_{t-1}^e + \beta (P_{t-1} - P_{t-1}^e)$$

where P_t^e = expected price at time t

P_{t-1} = actual price at time t-1

β = constant and $0 \leq \beta \leq 1$.

This price expectation equation may be incorporated in the demand model if farmers are assumed to make their decision based on price expectation. Not only is there a lag in price expectation of the firm but the full response of the firm to changes in prices of input and output may not be instantaneous. The basic reasons for this lack of an instantaneous response of the quantity of an

input purchased to price changes fall into three broad groups:[1] psychological, technological, and institutional. If farmers are assumed to adjust at constant rate of λ, the quantity adjustment equation will be:

$$Q_t = Q_{t-1} + \lambda(Q_t^* - Q_{t-1})$$

where Q_t^* is desired level of quantity of time t,
and $0 \leq \lambda \leq 1$.

ii. Behavioral adjustment concepts

The preceding discussion has centered around the economic variables. In an aggregate sense when we assume that all firms make their decisions based on only these economic variables, this type of scheme is satisfactory. However, its usefulness in determining the total responsiveness of firm to economic stimuli is somewhat limited if the behavioral characteristics of the management factor of the firm are ignored. And the primary objective of individual firm operator may not be profit maximization, but maximum security for his family. Therefore, a demand relationship for inputs which incorporates the behavioral and psychological characteristics of the entrepreneur is a much broader concept than that specified by the economic theory of the firm. The socioeconomic and demographic variables such as

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[1] Mark Nerlove, Distributed Lags and Demand Analysis, USDA, ERS, Agricultural Handbook, No. 141, 1958.

education, age, experience and family size, are intended to measure how certain messages and predispositions interact with the intervening sociological variable of awareness, attitude, and motivation to produce a purchasing decision by the operator of the firm. These variables are important in a cross-sectional analysis at farm level.

iii. Technological change

There are many other factors which tend to have a gradual influence on the demand for fertilizer. These factors, such as new hybrid seeds, irrigation, and improvement in the quality of the productive resources, are usually lumped into a category called technological change. There are basically two important steps in the process of bringing the effect of technological change to bear on the demand fof fertilizer input. First, a discovery of new production techniques must occur. In the case of fertilizer, many technological changes have occurred both in the manufacture of fertilizer and in the method and form which fertilizer is applied. Such innovations have resulted in a fall in the real price of fertilizer over time. The second step in the process is that adoption of technological innovations concerning fertilizer and other input by the farm must occur. Environmental conditions and knowledge of farmers also will affect adoption. The introduction of adequate variables representing the technological change into the demand models should be undertaken based on different dependent variables and analytical methods.

4. Interdependency of demand and supply relationships

A major problem encountered in developing a model for the fertilizer input sector is the bringing together of the factors affecting supply of fertilizer with these factors which determine the consumption of fertilizer at the farm level. Characteristics of fertilizer input market determine (1)whether factors affecting the quantity of fertilizer clearing the market are best described by a simultaneous system of supply and demand equation, or (2) whether the factor determining the quantity of fertilizer used by the farm can be investigated and demand relationship estimated independently of the supply.

The price formulation policies of the firm in the fertilizer industry are important factors which help determine the interrelationships of the fertilizer market, or determine whether price of fertilizer is exogenous or endogenous. In the study period of time-series data analysis, the price of fertilizer is determined exogenously by government policy. This price was based on the average production and transportation cost but did not reflect them fully. The government tried to supply enough fertilizer by import and domestic production. Also it is possible to assume that price of the fertilizer input is given and thus exogenous in the farm survey data analysis since the action of individual farm would have little influence on the prices of fertilizer. Since the quantity of fertilizer purchased by an individual farm is dependent upon its purchasing costs, but the

purchasing cost is not dependent upon the quantity purchased by the farm, the purchasing costs are thus assumed exogenous and are determined by forces outside the system being examined.

5. Complete models for fertilizer input demand

i. The time series data analysis

Based on the above discussion the demand model for the time-series data analysis is:

$$Q_t^D = f(P_{ft}, P_{yt}, P_{jt}, SC_t, T_t, Q_{t-1})$$

where Q_t^D = quantity demanded in time period of t

P_{ft} = price of fertilizer

P_{yt} = price of output

P_{jt} = price of substitutes and complements

SC_t = scale factor

T_t = technological change

Q_{t-1} = quantity of fertilizer consumed in the previous year

This function is an aggregate relationship at farm level between total nutrients of fertilizer demanded and a weighted average price of nutrients, a weighted average price of agricultural output, the prices of labor and machinery inputs, technological change and/or quantity consumed in the previous year. It is assumed that the weighted average price of fertilizer nutrients is negatively related to the quantity demanded by theory of demand. The price of output is hypothesized to have a positive

relationship with fertilizer nutrients consumed. It is also hypothesized that the coefficient of other input prices (P_j) is positive or negative depending on whether it is a substitute or a complement for the fertilizer input. The technological change variable measured as technological changes in farming is considered as dynamic and is assumed to be positively related to fertilizer consumption. Under the assumption that the quantity demanded is not adjusted instantaneously, the estimated demand function includes the quantity consumed in the previous year. This coefficient tells us how much proportion of the desired quantity demanded is adjusted per unit of time period if other things are constant. From the estimated demand function including the previous year's quantity consumed, we can obtain the long-run coefficients of the variables introduced.

ii. The experimental data analysis

In estimation of fertilizer response function using the experimental data it is assumed that all other factors except fertilizer is constant. But technological change in the experimentation can occur among regions and over time. Thus the derived demand function from the demand for outputs and the response function has a form of:

$$q^D = g(P_f, P_y, T).$$

The optimum level of fertilization for a given crop at a given time is determined by the prices of fertilizer nutrients, price

of the crops and technological change. The prices of other nutrients are incorporated in this model depending upon the form of equation used for the response function. The technological change variable should be included in the fertilizer response function which is estimated by using the data of experimentation over time and across regions.

iii. The farm survey data analysis

Considering differences in adoption rate of new technological innovation, cost constraints, and behavioral and environmental factors among individual farmers and regions, the demand function of farm for fertilizer input has this form:

$$Q_f^D = h(P_f, P_y, P_j, C, T, B, E, R)$$

where Q_f^D = quantity of fertilizer purchased by farm,

P_f, P_y, P_j, and T are the same as those in the previous model,

C = cost constraints,

B = behavioral and demographic factors,

E = environmental factors,

and R = regional factors.

The purchasing pattern of fertilizer by farm is determined not only by economic variables, behavioral and such demographic factors as age, education, and experience of farm manager, but also environmental factors such as total assets, cropping patterns, tenant arrangements and irrigation situations. The regional

differences in farm demand for fertilizer can be attributed by agro-climatic factors. The farmer's response to change in economic and demographic factors in purchasing fertilizer can be different among regions so that regional farm demand function for fertilizer would be separately estimated. The possible effects of these behavioral and demographic, environmental and regional factors to the purchase of fertilizer by farms can be either positive or negative.

iv. Projection model

Based on the demand functions estimated by the three approaches, prediction of future demand for fertilizer is made to show possible ranges of estimate. The variables employed in estimating demand functions are grouped into several categories depending on their characteristics and variabilities during the next ten years when the projection will be made. They are economic (E), sociological (S), financial (F), technological (T), environmental (V) and policy (P) variables. Therefore, the projection model is:

$$Q_F^{FD} = F(E, S, F, T, V, P)$$

The economic variables such as prices or quantities of inputs and outputs are likely to be changed in the near future and is related to price policy. The sociological variables such as age, formal education, experience, and training of farm operator affecting his manageability are expected to be constant during

the short period of time in the aggregate sense of a society except the training variable, but the overall levels of these variables could substantially vary in a longer period of time. The financial variables include the cost constraint, credit arrangement and opportunity of off-farm income. These variables are likely to be changed according to the economic development of a society in either the short or the long run. The technological variables such as improvement of crop varieties and development of new input and output could be change either randomly or with trend, and be influenced by sociological, environmental and policy variables. The environmental variables include agro-climate conditions and regional factors which are steady over time and investment in environmental development such as creation and improvement of infrastructure. The policies regarding prices, production, marketing, income and employment can influence all the variables mentioned above. If the policy emphasizes any aspect of the above variables, there is no difference between policy variables and those variables.

All variables discussed above are related and sometimes identical to each other, but this grouping makes it easier to project future values.

CHAPTER III

AN AGGREGATE DEMAND FOR FERTILIZER - TIME SERIES DATA ANALYSIS -

1. Introduction

This chapter develops an aggregate time series model for estimating the demand for fertilizer in Korea totally and by nutrients. It uses annual aggregate tonnage consumption data for the period 1960-72 which is available by nutrient and in total. The analysis considers the traditional variable suggested by economic theory and also includes some characteristics unique to the Korean fertilizer market.

The historical background of the Korean fertilizer industry and previous studies of the estimation demand for fertilizer, using time series data, are briefly reviewed.

2. Background

Total consumption of commercial fertilizer in 1970 was more than four times that of 1952 and double that of 1960. During the 1960-70 period consumption of nitrogen, phosphate and potash fertilizer increased by 1.5, 2, and 11 times, respectively. During the same period the amount of land cultivated remained almost constant. Therefore, the use of fertilizer per unit area of arable land has also trended upward. Of the total fertilizer consumption the individual nutrients, N, P, and K composed 78, 20, and 2 percent in 1960 and 59, 24, and 18 percent in 1970.

Before 1960, Korean fertilizer mainly was imported from other countries. Domestic production supplied less than 20 percent of total fertilizer consumption until 1966.

After 1968, Korea produced a small surplus of nitrogen fertilizer but a large part of the phosphate and potash fertilizer consumed is still imported. All of the raw materials used in phosphate and potash production are supplied by imports. Table III-1 compares the consumption and production of fertilizer in Korea from 1960-70.

The real price of total fertilizer paid by farmers has decreased, with some fluctuation, during 1959-70. The real price of nitrogen has the same trend as that of total fertilizer but the real price of phosphate and potash increased during the early 1960's and decreased during 1965-70.

Before 1962, fertilizer was distributed by two channels - the government, and the free market. During that period there was a difference between the price of fertilizer distributed by the government and the average price paid by farmers. After 1962 the government distributed all of the fertilizer through farmer cooperatives and the price of fertilizer is now uniform nationwide.

3. Review of literature

There are many studies of the economics of fertilizer use. In general, these studies try to identify the variables that affect fertilizer consumption and to measure their effects.

During the late 1950's Griliches undertook an extensive fertilizer research project testing the hypothesis that the

Table III-1.--Total consumption and production of commercial fertilizer in Korea, 1960-1970.

	Consumption (A)	Proportion of			Domestic production (B)	B/A	Import	Export
	1000 M/T	N	P	K	1000 M/T	Percent	1000 M/T	
		Percent						
1960[1/]	279.4(100)	78	20	2	6.1	2.2	262.0	-
1961[1/]	308.5(110)	68	26	6	29.8	9.6	277.7	-
1962[2/]	59.8	33	67	-	37.4	6.2	52.8	-
1963	307.1(110)	62	31	7	44.9	14.6	285.6	-
1964	364.1(130)	48	42	10	64.0	17.8	341.8	-
1965	393.1(141)	55	32	13	75.4	19.2	442.1	-
1966	423.3(152)	57	29	14	82.5	19.5	486.3	-
1967	486.5(174)	57	27	16	186.5	38.3	483.4	20.0
1968	478.5(171)	60	26	14	478.6	100.0	264.8	25.0
1969	534.7(191)	60	24	16	550.3	102.9	130.6	99.4
1970	562.9(201)	59	24	18	509.6	90.5	6.6	108.9

[1/] Fertilizer year: August 1 - July 31 for years 1960, 1961
January 1 - December 31 from 1963

[2/] Fertilizer year: August 1 - December 31, 1962

Source: Yearbook of Agriculture and Forestry, MAF, Korea.

decline in the real price of fertilizer largely explains the great increase in consumption of fertilizer in the U.S. The model[1/] developed by Griliches argues that fertilizer use per unit of land is a function of the real price of fertilizer, i.e., the price paid for fertilizer relative to the price of crops received by farmers, and that quantity adjustment with respect to changes in price takes place over time. A demand equation relating desired or long-run fertilizer consumption to the real price of fertilizer and an adjustment equation were reduced to the estimating form relating fertilizer consumption in a given year to the real price in the same year and the consumption in the previous year. Assuming adjustments that are not instantaneous, and fitting this model to national data for the years 1911-56, he concluded that it is possible to explain almost all of the variation in fertilizer consumption on the basis of changing relative prices without considering technological change. There are two aspects of technological change involved in this context (a) technological change in fertilizer industry that influences the price of fertilizer, and (b) changes in crop response to fertilizer use and the learning process of farmers in the use of fertilizers. The first is outside the scope of this study, and as for the second, he assumes that the learning process in fertilizer use is a result of changing relative prices,

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1/Zvi Griliches, "The Demand for Fertilizer: An Economic Interpretation of a Technical Change," Journal of Farm Economics, 40, August 1958, pp. 591-606.

technological change here is not exogeneous to the economic forces governing fertilizer use.

Griliches[2] also fitted this model to regional data for the years 1931-56 utilizing two sets of price data. He found some regional differences (1) the regions with historically more fertilizer experience adjust faster to changes in price than those with less, and (2) the demand for fertilizer is more price elastic, in the long-run, in regions with low fertilizer use.

Heady and Yeh[3] employed numerous algebraic functional forms to estimate the demand for fertilizer. The main forms were linear in logarithms, and fitted to data from 1926-56, omitting 1944-50. Their logarithmic models for total commercial fertilizer, and for consumption of each nutrient included the following independent variables: (1) ratio of current fertilizer price index to the general wholesale price index, (2) average of the crop price index lagged one year relative to the general wholesale price index, (3) all cash receipts from farming lagged one year, (4) cash receipts from crops and government payments lagged one year, (5) total acreage of cropland, (6) time, (7) time squared, and

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2/Zvi Griliches, "Distributed Lags, Disaggregation and Regional Demand Function for Fertilizer," Journal of Farm Economics, 41, February 1959, pp. 90-102.

3/E. O. Heady and M. H. Yeh, "National and Regional Demand Functions for Fertilizer," Journal of Farm Economics, Vol. 41, May 1959, pp. 332-48.

(8) an income fraction, indicating trends in income over the previous years.

Results from the regional models show an elasticity of demand with respect to fertilizer price greater in regions which have increased consumption the most in recent years. They incorporated a time variable to represent the greater technological knowledge which has come from fertilizer experiments, farmers' own findings in fertilizer use and from intensive educational and sales programs by the Extension Services, TVA and commercial firms. This study shows that this technological change and knowledge has been an important factor along with price ratios in causing an increase in the demand for fertilizer in the U.S. They also found cash receipts from farming a significant variable in fertilizer consumption when crop price variable is omitted. But when the latter is included, it turns out to be more significant than cash income.

With the objective of improving predictive models and explaining economic relationship, Brake[4/] disaggregated and concentrated his attention on two historically different regions: The East North Central and the South Atlantic. Predictive variables used in the study can be grouped in five general classes: (1) product price, (2) fertilizer price, (3) price of associated inputs, (4) fertilizer acreage, and (5) capital restriction. Data for the years 1930-58 are used in models of three different forms: linear, first differences and distributed lag.

4/John R. Brake, "Prediction of Fertilizer Consumption in Two Regions of the United States," Unpublished Ph.D. thesis, North Carolina State College, Raleigh, 1959.

Heady and Tweeten[5] update and expand the study reported by Heady and Yeh. Total fertilizer tonnage and total nutrient quantity were estimated separately for the nutrients N, P_2O_5 and and K_2O. Independent variables can be grouped into (1) fertilizer price, (2) index of price for land, (3) cash receipts, (4) acres of cropland, (5) time, and (6) assets on the farm. Deflation was by crop prices. Both linear and logarithmic forms were experimented with but only the logarithmic is reported.

Using a simple logarithmic function, Hayami[6] has sought to explain the three-fold increase in fertilizer input per unit of cultivated land in Japan during 1883-1937, in the dichotomous terms of changes in technology and relative price. He uses the model:

$$g(Q) = \alpha\, g(T) + \beta\, g(P)$$

where α and β are constant parameters, and $\alpha g(T)$ and $\beta g(P)$ are measures of the influence of technical progress and falling prices, respectively, on the growth in fertilizer input g(Q). A simplifying assumption is that technical change in agriculture took place such that the demand function for fertilizer shifted at a constant rate, i. e., $\alpha\, g(T) = \gamma$ = constant. He separates price changes from shifts

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5/E. O. Heady and L. G. Tweeten, Resource Demand and Structure of the Agricultural Industry, Ames, Iowa, Iowa State University Press, 1963.

6/Yujiro Hayami, "Demand for Fertilizer in the Course of Japanese Agricultural Development", Journal of Farm Economics, Vol. 46, November 1964, pp. 766-779.

in the production function and disregards the influence of price change on the location of the production function. His results show that 70 percent of the increase in fertilizer input per unit of cultivated land was explained by technical progress in agriculture which resulted in continuous shift of the fertilizer demand schedule and 30 percent of it was explained by technical progress in fertilizer industry which lowered the price of fertilizer relative to price of farm products.

Reiling[7] analyzed the demand for commercial fertilizer in the United States. He combined time-series data for the period 1950-1964 with cross-sectional data for 48 continental states in a covariance model. The annual quantity of each nutrient applied per acre of land in each of the 48 states was related to the price index of the nutrient, price indices of the most important fertilizer - consuming crops lagged one year, the average net farm income lagged one year, a proxy variable for technological change and farmer's awareness of fertilizer response, and a proxy variable for differences among states in fertilizer productivity and other factors. Reiling concluded that fertilizer nutrient price is an important factor in explaining increased fertilizer consumption. Also, net farm income as an expenditure constraint

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7/E. A. Reiling, Demand Analysis for Commercial Fertilizer in the United States, by States, Unpublished Ph.D. dissertation, Department of Agricultural Economics, Michigan State University, 1966.

was a restrictive factor with respect to fertilizer consumption. Technological change and increased acceptance of fertilizer by farmers were the most important factors in explaining the consumption of nutrients.

Hee[8] developed a demand function for fertilizer in the U.S. in a rather unconventional way with four independent variables, i.e., price of fertilizer, price of the chemical input in an alternative use, consumer income, and level of user technology.

In the model built to test the dynamic process of factor-substitution along a meta-production function in response to long-run trends in relative factor prices, Hayami and Ruttan[9] have determined the extent of variations in factor-proportions, viz., fertilizer land ratio by change in factor prices, i.e., price of fertilizer relative to land price, price of labor relative to land price, and machinery price relative to land price. They assume a linear homogeneous production function which enables them to express the factor proportions in terms of factor price ratio alone without using product prices. Applied to the historical experience of the U.S. and Japan for the period 1880-1960, the Hayami-Ruttan

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8/Olman Hee, "The Farm Revolution and the Demand for Fertilizer," American Institute of Mining, Metallurgical, and Petroleum Engineers, Washington, D. C., U.S. Bureau of Mines (Mimeo), February 1969.

9/Yujiro Hayami and Vernon W. Ruttan, "Factor Prices and Technical Change in Agricultural Development: The United States and Japan, 1880-1960," Journal of Political Economy, September-October 1970.

Model shows that, for both the U.S. and Japan, a fertilizer - land price ratio can explain almost 90 percent of the variations in fertilizer consumed and that wage - land ratio is a significant variable, of which coefficient implies the substitutability between fertilizer and labor contrary to expectation. Over a certain range, fertilizer can be substituted for human care for the plant. A more important factor in Japanese history would be the effect of substitution of commercial fertilizer for the labor allocated to the production of self-supplied fertilizer such as animal and green manure.

Using both traditional and adjusted models to explain changes in fertilizer input N, P, and K separately - per hectare of land used to cultivate paddy in Taiwan during 1950-66, Hsu[10] used independent variables such as the price of each nutrient relative to the price of brown rice and brown rice yield lagged one year as a proxy for farm income - times is used as a proxy of the peasants' increasing familiarity with, and willingness to use chemical fertilizer. He also incorporates the level of nitrogen consumed in the phosphate and the potash model and price ratio between phosphate and nitrogen in phosphate model. His results show that time is a significant variable not in the case of nitrogen but in the case of phosphorous and potash. Almost the

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10/Robert Hsu, "The Demand for Fertilizer in a Developing Country: The Case of Taiwan, 1950-1966," Economic Development and Cultural Change, January 1972.

entire increase in the consumption of nitrogen could be explained by changes in the price of fertilizer relative to that of paddy. He offers the explanation that farmers have been exposed to the use of phosphorous and potash for a shorter period of time than nitrogen and also that the land in Taiwan is relatively more deficient in nitrogen than in the other two nutrients.

In the time-series models for estimation of fertilizer demand covered by this review, they used the following variables: As dependent variables: total quantity of fertilizer consumed, individual components of nutrients, and fertilizer per unit of cropland or arable land. As independent variables: price of fertilizer, price of agricultural products, prices and quantities of other inputs, various ratios of those prices, acreage, farm income, fertilizer used in previous periods, technology and time. The general form of the function is linear and linear in logarithm. Some have used the traditional form while others have used adjustment model, assuming more than one time period to be taken for adjustment in the quantity in response to change in the price. Models have been constructed to study fertilizer demand at national and/or regional levels.

The short-run and long-run price elasticities of demand functions and the variable of technological progress used in various studies are summarized in table III-2.

Table III-2.--Summary of the short-run and long-run price elasticities and technological variables

No,	Author and source	Country and period covered	Price elasticity short-run	Price elasticity long-run	Technological Variables
I	Griliches JFE, 1958	USA 1911-56	-.529	-2.24	Reflect in price
		USA 1911-33	-.777	-2.50	" "
II	Griliches JFE, 1958	USA 1931-56	-.393	-2.14	" "
IV	Heady & Yeh JFE, 1919	USA 1926-53	T -.490	-	Time
			N -.449	-	"
			P -.448	-	"
			K -.403	-	"
		USA 1910-56	t -1.712	-	"
IV	Heady & Tweeten RDSAI	USA 1926-56	-1.4 to -1.5	-2.3 to -2.6	" "
V	Hayami JFE, 1964	Japan 1883-1937	-.43 to -.74		"
VI	Hayami & Ruttan JFE, 1970	USA 1880-1960	-1.101 to -1.952		"
		Japan 1880-1960	-1.173 to -1.437		"
VII	Hsu EDCC 1974	Taiwan 1950-1966	N -2.027	-2.967	"

4. The model used

Two models are estimated using two different assumptions: (1) instantaneous quantity adjustment and (b) lagged quantity adjustment. The first model is a multi-variable model and the second an adjustment model. The multi-variable model assumes that quantity adjusts instantaneously to changes in price -- but the relationship between price and quantity shifts because of changes in other relevant variables.

Under the assumption of instantaneous quantity adjustment, four functions are estimated for total plant nutrient, - nitrogen, phosphate, and potash. The equations fitted are linear and linear in logarithms:

$$Y_k = A_k + \sum_i b_{ik} X_{ik} + \sum_j b_j X_j + e_k, \quad k = 1,2,3,4$$

where k represents total nutrients, nitrogen, phosphate and potash, i represents the specific variable corresponding to each nutrient function, and j represents the common variables to all nutrient functions. In estimating demand functions for each nutrient separately using ordinary least squares method (OLS) the error term e_k is assumed to be independent of the error in the other nutrient demand functions. If the e's are correlated with each other estimation of the demand parameters using generalized least squares will give more efficient estimates than OLS.

In the adjustment model it is assumed that quantity adjustment to change in prices does not take place instantaneously. The demand function determines the desired use and the long-run

equilibrium level of use. Between one period and the next, actual use changes only by some fraction of the difference between the current use and the desired use. The adjustment equation assumes that the farmer moves in the direction of eliminating the disequilibrium but does not necessarily eliminate it all at once. Actually, equilibrium would be attained only if all the independent variables were to remain constant, which they never do. We assume that the change in fertilizer use is a function of the difference between "desired" and current use. In particular, it is assumed that the adjustment equation is linear in the logarithms of desired and actual consumption, hence the implicit adjustment path is nonlinear, slowing down as the difference between the two becomes small.

The basic model expressed as follows:

$$\log Y_t^* = \log b_o + b_1 \log X_{1t} + b_i \log X_{it} + u_t$$

where

Y_t^* = the desired level of fertilizer consumption,

X_1 = the price of fertilizer or relative price,

X_i = other shifting variables (these variables are alternatively added)

u_t = disturbance term

The adjustment equation is:

$$\log Y_t^* = \log Y_{t-1} + r (\log Y_t^* - \log Y_{t-1})$$

or

$$Y_t/Y_{t-1} = (Y_t^*/Y_{t-1})^r$$

where Y_t = the actual consumption of fertilizer during t year.

r = elasticity of adjustment.

Usually we assume that r is greater than 0 and less than 1.[11/] Substituting the basic model into adjustment equation and solving for Y_t we get the estimating equation:

$$\log Y_t = r \log b_o + rb_1 \log X_1 + rb_i \log X_i + (1-r) \log Y_{t-1} + ru_t$$

We can rewrite this equation as the following:

$$\log Y_t = C_0 + C_1 \log X_1 + C_i \log X_i + C_3 \log Y_{t-1} + e_t$$

where:

$C_0 = r \log b_0$, $C_1 = r\, b_i$, $C_2 = r\, b_i$, $C_3 = 1 - r$, and $e_t = ru_t$.

C_1, C_i = short run elasticity, b_1, b_i = long run elasticity.

Hence, $r = 1 - C_3$, $b_1 = C_1/(1 - C_3)$, $b_i = C_i/(1 - C_3)$.

If u_t is asymptotically normally distributed, the e_t also has asymptotically normal distribution with mean 0 and constant variance. The least square estimation method yields consistent and asymptotically efficient estimators in both equations.

11/The other possible cases:

1) If r = 0, then no adjustment occurs over time at all.
2) If r = 1, then instant adjustment occurs.
3) If $1 < r < 2$, the system fluctuates around equilibrium level consequently converges the equilibrium level.
4) If $r > 2$, the system fluctuates around equilibrium level but diverges.
5) If $r < 0$ this system also diverges but can not fluctuate around equilibrium level.

5. Variables and data

The variables used are the following:

As dependent variables:

Y_1 = total nutrients of commercial fertilizer consumed per year (1,000 M/T).

Y_2 = total nutrients of nitrogen consumed (1,000 M/T).

Y_3 = total nutrients of phosphate consumed (1,000 M/T).

Y_4 = total nutrients of potash consumed (1,000 M/T).

As independent variables:

a) own price index:

X_1 = annual average real price index of total fertilizer paid by farm (1965 = 100).

Average real price is obtained by dividing the annual weighted average of price per kg of nutrient of ammonium sulfates, urea, triple super phosphate, and potassium chloride by wholesale price index.

X_2 = Average real price index of nitrogen at farm. Annual weighted price of ammonium sulfate and urea divided by wholesale price index is the average real price of nitrogen.

X_3 = Average real price index of phosphate at farm. The price of triple super phosphate is averaged annually to be the average price of phosphate.

X_4 = Average real price index of potash. The price of potassium chloride is annually averaged out to be the average price of potash.

b) other input prices:

X_5 = real price index of farm wage. Farm wage accounts only for hired labor.

X_6 = real price index of farm machinery. This price is annually weighted average of monthly prices of hoe, shovel, forked rake, weeding hoe, plow, sprayer, thresher, agricultural motor, pumping machine and plow share.

X_7 = price index of land.

c) output price:

X_8 = real index of price received by farm, lagged one year. Annual average weighted price of all crops at farm level is divided by wholesale price index to be real price received by farm.

d) technological change:

X_9 = ratio of well irrigated area to total area.

X_{10} = seed improvement index of rice. The weighted average of proportion of cultivated area of various rice varieties is calculated to make the seed improvement index. The weight is average yield of corresponding variety.

X_{11} = time.

e) other variable:

X_{12} = planting area (1,000 ha.)

All of the data used in this study, except land prices and seed improvement index are derived from official reports of the Ministry of Agriculture and Forestry and the National Agricultural Cooperative Federation.

The change in other input prices relative to fertilizer price affects the use of other inputs which in turn influence the use of fertilizer.

Since all arable land in Korea is fully cultivated the change in land price affects little use of land in production. The intensivity of land use is near capacity regardless of its price because of small subsistence farming at given technological environment. And land price data is not available so this variable is excluded in the models.

Price surveys at the farm level have been conducted since 1959. Data from 1960 to 1972 are used in this study.

The weights used in determining various input price indexes are the proportion of purchasing costs of a specific input to total expenditure for farming and household. The weights of output price are the ratio of value of a specific output to total value of agricultural output produced by the total sample farms. The weights are based on the data obtained from the Sample Survey of the Farm Household Economy and Production Costs of Agricultural Products conducted by the Ministry of Agriculture and Forestry in 1965.

Output price is computed on the basis of the calendar year. However, most of the fertilizer is sold in the first half of the year, whereas the index of price received for crops is much more affected by development in the second half of the year. It is assumed that farmers make decisions for use of fertilizer based on the price of fertilizer relative to the price received for crops last year. Some possible evidence of the lagged response are: (1) market information systems are less developed so that farmers can not predict reasonably the price of crops at harvest time, (2) the government's price stabilization policy will prevent output prices from fluctuating among years. The cropping area is actual acreage of planted area. Land double-cropped is counted twice. This area related the weather conditions and irrigation conditions.

Technological change is regarded as an important factor in shifting the demand function over time. When time is used as a proxy for technical change there are several limitations. First, it assumes that technological progress takes place at a constant rate which is not clear. Second, other variables used in the demand function have a strong trend so that multicollinearity between time and the other variables can cause estimation problems. Finally, since time can be a factor shifting the supply function of fertilizer as well as the demand function, the identification problem arises. Data for the price and quantity of fertilizer consumption represents the equilibrium generated from an intersection of the supply and demand curves. If the demand schedule has shifted more than the supply schedule, the estimated schedule will look like a supply schedule, and vice versa. Therefore, the irrigated land ratio and the seed improvement index will also be used as proxies for technological change. Use of these variables as proxies for technological change also involve bias since they can not include all types of technological progress such as the development of high quality fertilizer and improved knowledge about fertilizer use.

The development of new varieties of a crop is an important factor of technological change affecting the usage of fertilizer. The seed improvement index of rice, which is the most important crop in Korea, was developed to reflect the improvement in the variety of the crop. This index is the average of the proportion of the cultivated acreage of the important varieties of rice

weighted by the average yield of the corresponding varieties. The important thirty-six varieties of rice out of about eighty which have ever been cultivated during 1960-72 period were used to develop this index. The proportion of acreage on which these varieties of rice in question have been planted and the estimated seed improvement index is shown in the following table (table III-3). The computed index is shown not to be so significantly different over time that it is not meaningful to incorporate this index into the fertilizer demand function. Few high yielding varieties of rice have been introduced in Korean agriculture during the period 1960-71. The new high yielding variety of Tongil (IR-667 system) was developed in 1971 but its adoption rate was less than 10 percent in 1972, which was shown in the farm survey. The adoption of new variety of rice by farmers depends not only on its yield but also its taste because the rice is the most important food. The price of Tongil rice was lower than that of the other varieties of rice in rice year of 1972-3. These developments partially reflect the stable seed improvement index over time. Therefore, the use of this index as an alternative proxy of technological change was excluded from this study.

The irrigation ratio as another variable of technological change was also disregarded because the estimated results using the irrigated ratio were not significantly different from that of the model using time variable.

Table III-3.--The seed improvement index, 1960-71, Korea

Year	Proportion of acreage	Seed improvement index	
		Weighted average	Index
	(percent)		
1960	73.57	340.7	103.6
1961	74.46	332.6	100.1
1962	76.58	333.1	103.3
1963	76.58	331.6	99.8
1964	75.95	334.8	100.8
1965	76.71	332.1	100.0
1966	77.25	331.9	99.9
1967	77.78	331.6	99.8
1968	82.44	331.6	99.8
1969	81.84	323.1	97.3
1970	82.33	329.5	99.2
1971	71.11	330.2	99.4

The dependent variables Y_2, Y_3, and Y_4 (consumption of nitrogen, phosphate and potash) are not determined separately but simultaneously. The increase in use of these nutrients will not be explained by completely different variables but will include some common variables. Hence, the assumption that the error terms of the demand functions are independent does not hold and OLS estimation of the demand function will result in inefficient estimates. Therefore, the simultaneous estimation of the parameters using generalized least squares should result in more efficient estimation than OLS.

Because of the small number of observations and because of high correlation between unique variables in the equations ordinary least squares can be used throughout the study.

It is hypothesized that the slope of the demand curve of an input with respect to its own price is negative. The signs of other inputs are either positive or negative depending on whether they are substitutes or complements for commercial fertilizer. It is also hypothesized that output price has a positive effect on the use of fertilizer. Technology is hypothesized to play an important role in explaining the increased use of fertilizer.

6. Results

i. -- Total fertilizer

The results of some of the analysis performed are presented below. Table III-4 shows the regression coefficients and related statistics for total fertilizer demand equations. The equation (I) includes such variables as price of fertilizer, wage, machine price, output price, land, and time in linear. The equation (II) is linear in logarithms for the same variables as in equation (I). Both equations (I) and (II) are the multivariable models under the assumption of instantaneous quantity adjustment. The coefficients of the fertilizer price is negative as expected but are not statistically different from zero. The coefficients of output price are positive and are not statistically significant. The insignificant coefficients of the fertilizer price and output price can be explained by the following

Table III-4.--Regression coefficients and related statistics for total fertilizer demand function, 1960-1972, Korea

	Equations		
	I (Linear)	II (Linear in logarithm)	III
Intercept (a_1)	184.1074 (599.7224)	3.5354 (9.4543)	1.9591 (1.5935)
Price of fertilizer (x_1)	-0.8367 (1.7207)	-0.1655 (0.3603)	-0.1688 (0.1882)
Wage (x_5)	1.4349 (1.5450)	0.3337 (0.4355)	
Price of machinery (x_6)	-1.3651 (4.0715)	-0.3316 (0.8819)	
Price of output (x_8)	0.3966 (1.8736)	0.1218 (0.3614)	
Land (x_{12})	0.0105 (0.1061)	0.2312 (0.8910)	
Time (x_{11})	21.7188+ (11.9274)	0.0592* (0.0285)	
Lagged D.V. (Y_{1t-1})			0.8090** (0.1370)
Coefficient of adjustment (r)			0.191
Long-run elasticity (b_1)			-0.884
R^2	0.969	0.968	0.945
F	63.86**	62.99**	105.85**
D	2.14	2.34	1.84

Figure in ( ) is corresponding standard error
R^2 : coefficient of determination adjusted by degree of freedom
F : F-statistic
D : Durbin-Watson statistic
Significance level ** = 1 percent
* = 5 percent
+ = 10 percent

First, most of the farms produce their output for subsistence. The subsistence farmers may evaluate their output more than market prices. The evaluation of their output also may not be related to market prices. This means that the fertilizer price and the output price may not be an important factor in the farmers' decision to buy fertilizer. Secondly, the market information system is too primitive to provide the price information to farmers to utilize it for buying fertilizer. No services are available about information of expectation of output and prices in advance. Thirdly, the government administrates the supply price of fertilizer based of fertilizer production costs and distribution costs of fertilizer. Therefore, relatively little variation in the prices over time may result in the insignificance. Finally, the underlying fertilizer response schedule may be so steep that price changes have little effect on the use of fertilizer. New introduction of fertilizer in farming and adoption of the high yielding variety may rapidly increase production of the crop concerned.

The demand elasticity with respect to the farm wage rate is about 0.33. This implies that fertilizer is a substitute for farm labor. Over a certain range, fertilizer can be substituted for human care for crops. A more important factor in Korean history would be the effect of substitution of commercial fertilizer for the labor allocation to the production of self-supplied fertilizer such as compost and animal and green manures.

The economic relationship between fertilizer and farm machinery can not be specified with the statistical model.

The coefficients of land in linear equation is very small and is not statistically different from zero. The land coefficient in linear equation says that if the cropping area increases by one hectare the fertilizer consumption increases by 10 kilograms.

The cross-elasticity between fertilizer use and cropping areas is about 0.23.

The consumption of fertilizer appears to have a positive trend over time but it is not statistically significant. The coefficient of time variable in linear equation is 21.7, which means that total fertilizer consumption has been increased by 21.7 thousand tons every year, if the other variables remained constant. The time variable as a proxy for technological change is the most important variable affecting the increase in the use of fertilizer.

The results of estimating the total demand for fertilizer using the adjustment model are presented in equation (III) in table III-4. This equation is linear in logarithm. The estimated coefficient of adjustment is 0.2 indicating that approximately 20 percent quantity adjustment to the price change is completed within one year. This regression implies a substantially higher price elasticity in the long-run than in the short-run. The short-run price elasticity of fertilizer demand is -0.17 but is not statistically significant, wherea the

long-run elasticity is -0.88. Obviously, the fertilizer price is not the only variable affecting the demand for fertilizer, and the omission of some other relevant variables would tend to bias the estimates of these coefficients. Therefore, we might say that this estimate of long-run elasticity is somewhat too high and that the estimate of the adjustment coefficient is somewhat too low. Inclusion of other variables in the adjustment equation results in meaningless coefficients.

The coefficients of determination in all equations are more than 0.94, but all of the coefficients in the multivariable model are not statistically significant except that of time variables. This result comes from fairly high correlation between independent variables and from the small number of observations. But as shown later the individual nutrient demand functions show statistical significant coefficients. The F-statistics are so high that we can say that the regression relationship is very significant. The significance test based on the t and F distribution are no longer valid when the error terms are autocorrelated. Unfortunately, the computed Durbin-Watson statistics (D) with 13 observations can not be compared with the theoretical Durbin-Watson Statistics table. But by extrapolation we may say that there is neither positive nor negative serial correlation at the 5 percent significance level.

ii. -- Nitrogen

The results of the estimated nitrogen demand function are shown in table III-5. The explanation of the equations are the same in the total fertilizer functions. The coefficients of the fertilizer price in the multivariable models are positive but they are not statistically significant. The coefficient of the output price is positive in linear and negative in logarithm, and they are also not statistical / significant. The possible explanation for these perverse results is that the rationing of nitrogen fertilizer in early 1960's when relatively large quantities of nitrogen are consumed compared to other nutrients determined price and quantities demanded of nitrogen. These price and quantity might establish positive schedule for nitrogen. This fact can be proved when the time period is divided into two periods; early 1960's and late 1960's. The coefficients of price of fertilizer and output were reasonable for the late 1960's period when no rations existed. Insignificance of coefficients of price variables was explained in the total fertilizer model.

Farm wages were positively related to the use of nitrogen and its coefficient is statistically significant. The cross-elasticity between the use of nitrogen and the farm wage rate is 0.75. The fact that self-supplied fertilizer contains mostly nitrogen nutrient reflects the high cross-elasticity between the use of commercial nitrogen and the farm wage rate. In other

Table III-5.--Regression coefficients and related statistics for nitrogen fertilizer demand function, 1960-1972, Korea

	Equations		
	I (Linear)	II (Linear in logarithm)	III
Intercept (a_2)	-143.6626 (401.4555)	-3.5828 (10.7689)	-0.4227 (2.7025)
Price of nitrogen (x_2)	0.5649 (0.9159)	0.2104 (0.3300)	0.1190 (0.2930)
Wage (x_5)	1.7230* (0.8360)	0.7514+ (0.4021)	
Price of machinery (x_6)	0.3126 (2.4788)	0.4292 (0.9395)	
Price of output (x_8)	1.0686 (1.1937)	-0.4417 (0.4292)	
Land (x_{12})	0.0571 (0.0712)	0.5482 (0.9457)	
Time (x_{11})	2.9527 (9.8183)	0.0235 (0.0368)	
Lagged D.V. (Y_{2t-1})			0.9933** (0.2753)
Coefficient of adjustment (r)			0.007
Long-run elasticity			(17.000)
R^2	0.954	0.951	0.773
F	42.87**	40.12**	21.49**
D	2.12	1.95	1.65

Significance level = ** 1 percent
* 5 percent
+ 10 percent

words, the commercial nitrogen fertilizer is a good substitute for labor needed to make the self-supplied fertilizer. The other results in the multivariable model is similar with that of the total fertilizer functions.

The results of the adjustment model are shown in equation III in table III-5. The adjustment takes place by one percent within one year but the price elasticity of the nitrogen demand is positive, and it is not statistically significant, therefore, the long-run price elasticity has no meaning.

iii. -- Phosphate

Regression coefficients and related statistics for the phosphate demand function are presented in table III-6. The price elasticity of the phosphate demand is -0.73 and the elasticity with respect to output price is 0.81 in the multivariable models. They are statistically significant at the 10 percent level. The coefficients of the farm wage is negative and is statistically significant at the 5 percent level in the linear equation and 10 percent in the linear logarithm equation. The self-supplied fertilizer contained mostly nitrogen nutrient, and therefore may not be a substitute for phosphate and potash. This implies that phosphate and potash cannot be substituted for labor needed to make compost. More labor may be needed for transportation and application of phosphate and potash. The coefficients of time variable is greater than the previous two functions in both linear and logarithm equations. The possible reason for

Table III-6.--Regression coefficients and related statistics for phosphate demand function, 1960-1972, Korea

	Equations		
	I (Linear)	II (Linear in logarithm)	III
Intercept (a_3)	23.8636 (138.6397)	-2.1442 (10.6752)	2.1782 (1.2668)
Price of phsophate (x_3)	-1.2780* (0.4980)	-0.7299 (0.5048)	-0.2424 (0.2607)
Wage (x_5)	-2.2292* (0.8066)	-1.2262 (0.8305)	
Price of machinery (x_6)	0.9122 (1.1853)	-0.1042 (1.1298)	
Price of output (x_8)	2.1167** (0.6580)	0.8134+ (0.4579)	
Land (x_{12})	0.0071 (0.0284)	1.4498 (1.2586)	
Time (c_{x11})	18.4879** (5.4196)	0.4679** (0.1596)	
Lagged D.V. (Y_{3t-1})			0.7722** (0.1533)
Coefficient of adjustment (r)			.228
Long-run elasticity			-1.063
R^2	0.965	0.960	0.663
F	47.86**	41.27**	12.80**
D	3.18	3.36	2.53

Significance level: ** 1 percent
* 5 percent
+ 10 percent

these results will be explained in the potash function. The adjustment coefficient is 0.22 and the short-run and the long-run price elasticities are -0.24 and -1.063, respectively, but they are not significant.

vi. -- Potash

Table III-7 shows the results of regressed potash demand function. The own price elasticity is about -1.

Cross-elasticities with respect to farm wages and to price of farm machinery appeared to be -1.8 and 1.4, respectively. Some possible reasons why the cross-elasticity with respect to output price is insignificant were explained in the total fertilizer model. The remarkable fact in this model is that the cross-elasticities between consumption of potash and the cropping area, and between use of potash nutrient and time variable were about 2.0 and 1.5, respectively. The former was statistically not different from zero and the latter different at one percent level.

The main reason for this fact seems to be due to an increase in farmers' awareness of the effect of phosphate and potash nutrients on their crops. The Office of Rural Development has demonstrated the advantage of harmonic fertilization of three plant nutrients and conducted the soil test to show the shortage of potash nutrients. Most farmers like the visible effect of fertilization. They use more nitrogen fertilizer because they can see its effect several days after its application as it

Table III-7.--Regression coefficients and related statistics for potash demand function, 1960-1972, Korea

	Equations		
	I (Linear)	II (Linear in logarithm)	III
Intercept (a_4)	8.3362 (92.6227)	-6.6433 (13.6117)	6.9811 (0.9710)
Price of potash (x_4)	-0.3691* (0.1504)	-1.0717* (0.3935)	-0.0507 (0.2123)
Wage (x_5)	-0.7619* (0.3826)	-1.7978* (0.8440)	
Price of machinery (x_6)	0.6367 (0.5438)	1.3988 (1.1794)	
Price of output (x_8)	0.0619 (0.2934)	-0.3847 (0.6663)	
Land (x_{12})	-0.0012 (0.0182)	1.9988 (1.1500)	
Time (x_{11})	14.8320** (3.1775)	1.5514** (0.2900)	
Lagged D.V. (Y_{4t-1})			0.8467** (0.0681)
Coefficient of adjustment (r)			0.153
Long-run elasticity			-.331
R^2	.980	.982	0.928
F	100.83**	113.99**	78.75**
D	3.49	2.96	2.67

Significance level: ** = 1 percent
* = 5 percent
+ = 10 percent

changes the color of the crops. But phosphate and potash do not have this characteristic. This tendency of farmers has been changed by knowing the actual effect of phosphate and potash plant nutrients. The fact that the government has increased the supply of mixed fertilizer and has encouraged farmers to use more potash and phosphates has helped with the development of their crops. By making the farmers more aware of the effectiveness of using phosphate and potash nutrients allows them to make decisions on its use from an economic standpoint.

7. Summary

This study was mainly concerned with the estimation of demand functions for fertilizer under two different assumptions. One is the instantaneous quantity adjustment, and the other is the assumption that the quantity adjustment takes place over time.

It was expected that the small number of observations may result in some inefficient estimating in the demand functions but the results are summarized.

1. The price elasticities of demand with respect to own price and output prices are very low and not significant at the 10 percent level. The possible reasons can be considered by the fact that (a) government administrated the supply price of fertilizer and stabilized output prices, (b) most of the agricultural products have been produced by subsistence,

(c) market information system was less developed, or (d) the underlying production function is so steep that price change has a little effect on use of fertilizer.

2. The small and nonsignificant increase in the use of fertilizer was observed due to an increase in the acreage cropped when other things are constant. But the elasticity of the demand with respect to the cropping area was very high in phosphate and potash models. The expansion of agricultural land came from the net increase of marginal land (reclaimed) offset by using land for the nonagricultural sector in the Korean situation. All the reclaimed land needs a great deal more fertilizer than acres presently under cultivation.
3. The large trend towards increased use of fertilizer was observed under ceteris paribus condition, especially in the phosphate and potash models. Awareness of farmers of the effectiveness of these nutrients as well as the government's encouragement of harmonic fertilization contributed greatly to this trend increase.
4. Fertilizer is a possible substitute for labor. The increase in farm wages induced to substitute the labor needed to make composts and needed to take care of

crops into commercial fertilizer. This substitutability can be observed in nitrogen demand function but not in phosphate and potash functions. The fact that the self-supplied manure contains mostly nitrogen nutrient may explain the results.

5. By using only one independent variable of real price of fertilizer, the quantity adjustment took place about 20 percent in one year. This fact implies that the price elasticity is much higher in the long-run than in the short-run. They are shown as -0.17 and -0.88, respectively, but are not significant. But in individual nutrient function the coefficient of adjustment is less than 9.3 and estimated long-run elasticities are -1.0 phosphate, and -0.33 for potash.

CHAPTER IV

POTENTIAL DEMAND FOR FERTILIZER
- EXPERIMENTAL DATA ANALYSIS -

1. Introduction

The aggregated fertilizer requirements for all crops cultivated during a given period of time provides a "norm potential" for actual total demand for fertilizer. To determine requirements it is necessary to estimate optimum nutrient rates per unit area that will be reasonably consistent with agronomic needs.

The nutrient rate is determined by a fertilizer response function estimated from experimental data for each crop. Estimated nutrient rates are expected to change according to variations in the response functi' . The response function will change due to weather variability and possible technological changes, and also to interaction effects of the two factors over time.

To estimate future requirements it is necessary to determine future optimum nutrient rates for each crop by considering the effects of weather variability and technological change.

Section 2 includes a review of literatures which relate to determination of optimum rate of fertilization, at a given year and over time. Section 3 presents discussion of the static input demand which can be derived from the maximizing condition of profit assuming that both output and input market is perfectly competitive.

The model building for estimation of optimum rates of fertilization over time considering the possible technological changes in the fertilizer response functions is present in Section 4.

Section 5 maintains the empirical results of statistical estimation of the optimum rate of fertilization for various crops over time. Finally, summary of this whole chapter is shown in Section 6.

2. Background

In 1954, Heady and Pesek[1/] published their pioneering article on corn-fertilizer response functions which have demonstrated that simultaneous solution of (1) the optimum rate of fertilization and (2) the optimum combination of nutrients such as N and P is possible from appropriate experimental data. At that time, rather than design experiments that included a wide range of fertilization rates spaced to provide useful estimates of the marginal products, agronomists selected only a few rates of fertilization and replicated them to obtain estimates of experimental error. The fertilization rates included in the experiment were based on a priori judgments by the agronomists; resulting yield differences were judged significant or insignificant depending on the magnitude of the experiment error.

1/E. O. Heady and J. Pesek, "A Fertilizer Production Surface with Specification of Economic Optima for Corn Grown on Calcareous Ida Silt Loam," Journal of Farm Economics, 36, August 1954, pp. 466-82; E. O. Heady, "Hutton and Thorne on Isoclines: A Reply," Journal of Farm Economics, 37, May 1955, pp. 363-368.

As an alternative, Heady and Pesek suggested that fertilization rates be increased, replications reduced, and a production surface be estimated using regression analysis. Economic optima could then be computed from the production surface, rather than selected from those rates stipulated beforehand by the experimenter. They regressed Cobb-Douglas, quadratic, and square root functions with dependent variable of total yield per acre or total yield above check plot levels, and independent variables of pounds of nitrogen and P_2O_5 using the corn experiment conducted on calcareous Ida silt loam in Western Iowa. They then computed the optimum rates for various combinations of prices of corn, N and P_2O_5 from the square root function.

The method of Heady and Pesek was immediately criticized by Hutton and Thorne,[2/] who approved of the original paper as a methodological exercise, but did not believe the method should be adopted for general use because (1) the loss from not using the optima or least cost combination predicted by the regression equation was small and (2) the large experiments were wasteful of observations.

[2/] R. F. Hutton and D. W. Thorne, "Review Notes on the Heady Pesek Fertilizer Production Surface," Journal of Farm Economics, 37, February 1955, pp. 117-119; and R. F. Hutton, "Further Comment on the Heady-Pesek Fertilizer Production Function," JFE, 37, August 1955, pp. 566-568.

In spite of the misgivings of Hutton and Thorne, the methodology of Heady and Pesek continued to be used through the 1950's. Results of such experimentation and elaboration of methodology were reported in two books[3] sponsored by TVA and for Iowa, and in Chapter 14 and 15 of Heady and Dillon.[4] The main contribution of these books can be summarized as follows:

a. Experiment

The normal type of experimental designs used in agronomic-economic research include complete factorials, incomplete factorials, Latin square designs, and double cube and triple cube designs. In each case, however, at least three levels of each nutrient must be included in the experimental design in order to derive fertilizer response function for the nutrient under study. The design must also include treatments which allow for the effects of interactions between nutrients, if analysis of interaction effects is to be possible. Generally, it is desirable that the highest input level be at least that which will result in the maximum physical and/or in decreasing physical yield.

3/E. L. Baum, E. O. Heady, and J. Blackmore, eds., Methodological Procedures in the Economic Analysis of Fertilizer Use Data, Ames, Iowa State College Press, 1956; and E. L. Baum, E. O. Heady, J. T. Pesek, and C. G. Hildreth, eds., Economic and Technical Analysis of Fertilizer Innovations and Resource Use, Ames, Iowa State College Press, 1957.

4/E. O. Heady and J. L. Dillon, Agricultural Production Function, Ames, Iowa State University Press, 1961.

A uniform soil area is required in order that the results can be properly interpreted. With a heterogeneous system the variance will increase and interpretation and extension to other soils will be more complicated. In any area of a given soil type, other natural variations can cause non-uniform conditions. When topography such as depth of topsoil, degree of erosion and the slope changes internal drainage conditions, fertility, rainfall retention, evaporation, insolation, soil temperature, degree of pH and minor nutrients (Zn, Mn, etc.) may also change. All of these variations contribute to errors of measurement. If the soil conditions are uniform within replication and if there is no effect of interactions between the soil conditions and added nutrients, the check plot yields are subtracted from each treatment yield to minimize the errors of measurement coming from the different soil conditions between replications. But usually it is expected that there is some effect of interactions between soil conditions such as moisture, pH, minor nutrients, topography and fertility, and added nutrients. Usually these kind of soil conditions are introduced as variables in production functions.

Uniform weather conditions are required when the experiments are conducted in large areas and if an attempt is made to explain sequential year's data. The weather conditions affect moisture in soil, solar energy and soil temperature, and sometimes result in damage from flood or drought. Alternatively, it is desirable

to add weather conditions such as, rainfall and temperature of growing season as variables in production function in order to minimize the variance which comes from the different weather conditions. Management system is assumed to be the same in the experiment. Differential treatments with respect to liming, fertilizing, manuring, crop removal, drainage, tillage, weeding, seeding, harvesting, terracing, and stripcropping may result in an increase in measurement error. It is also assumed that the damage from insect and disease is too minor to affect the yield.

b. Variables used and estimated functions

Dependent variables are used as total yield of a specific crop per unit area, total yield omitting check plot yield, and total yield above the check plot yield. Use of total yield omitting check plot yield as a dependent variable makes the estimated yield and optima for the different functions agree much more closely.

Independent variables used are fertilization levels of N, P_2O_5, and/or K_2O, plant density, moisture-holding capacity, existing nutrients in soil, and/or percent water solubility of various fertilizer.

The general response function can be of several algebraic forms depending upon the results obtained. The type of design and the type of function fitted influences the results. Thus, careful selection of designs and the use of several types of functions are sometimes necessary in agronomic-economic research.

It cannot be claimed that any of the algebraic functions represent fundamental biological laws of growth. One procedure of choosing the best function is to examine possible applicable functions, and select the one that best fits the data. A useful procedure, where data are being obtained from a replicated experiment, is to examine the size of the lack of fit term as given in the analysis of variance. The function forms used are the Mitcherlich, the Spillman, Cobb-Douglas, quadratic, square root, and quadratic-square root function.

Unfortunately, the results reported in most of these publications were based only on one year's data. In addition many analyses of one year's data of fertility experimentation are conducted based on Heady-Pesek methodology in the 1960's.

In 1962, Tweeten and Heady[5/] derive the static supply function of corn and fertilizer demand functions from the corn-fertilizer response function. They also calculated the demand elasticity and supply elasticity from quadratic, square root and logarithmic production functions. This analysis indicates that static demand function is least elastic where the soil is low in a particular nutrient, but is high in moisture and other nutrients. The implication is that, on the basis of static analysis, a tax or subsidy on fertilizer would result in the

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5/L. G. Tweeten and E. O. Heady, Short-Run Corn Supply and Fertilizer Demand Functions Based on Production Functions Derived from Experimental Data: A Static Analysis, Iowa Agricultural Experiment Station Bulletin 507, June 1962.

greatest percentage change in fertilizer consumption in marginal areas of fertilizer use. It follows that the demand for a fixed ratio of the three elements probably would be less elastic than the demand for any one element. The analysis provides a basis for forming hypothesis of future trends in the demand for fertilizer.

If the price of fertilizer falls relative to the price of corn, the largest proportional increase in fertilizer consumption in the short-run is likely to occur in marginal areas of fertilizer use. The largest total increase would likely be in areas where fertilizer presently is used in large amounts. To the extent that the technological changes substitute for fertilizer, the fertilizer demand elasticity will increase. And to the extent that innovation such as new crop varieties only shift the demand for fertilizer to the right, the fertilizer demand elasticity will decrease.

In 1966, Hoffmar and Johnson[6/] compared analyses of typical experiment, controlled-survey experiment and the farm survey data. They concluded that the controlled-survey technique provides a possible means by which both research and extension may jointly approach a problem, that its application could prove to be the optimum way to allocate limited research and extension

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6/B. R. Hoffmar and G. L. Johnson, Summary and Evaluation of the Cooperative Agronomic-Economic Experimentation at Michigan State University, 1955-1963, Michigan State University, Agricultural Experiment Station Research Bulletin 11, 1966.

funds, especially in developing countries. It could also provide much reliable and applicable input-output information needed by farm planners, budgeters, and linear programmers.

Estimation of single production function and corresponding economic optima from data over a series of years has been attempted in several articles. Brown and Oveson[7] estimated the average function of N from experimental data of continuous spring wheat over a ten-year period at the Pendelton Branch Experiment Station, Oregon, incorporating the probability of occurrence of response functions. This average function would be the relevant function to use in determining economic optimum inputs when the deviation of particular responses from the average cannot be predicted in advance.

Using the seven-year experiment data with corn conducted at three sites in north and central Missouri, Doll[8] computed the average optima and average profit from average profit function obtained by averaging the seven annual profit functions which were formed by multiplying the estimated production function by the price of corn and subtracting the cost of nitrogen and plant population. He compared the average optima with annual optima

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[7] W. G. Brown and M. M. Oveson, "Production Functions from Data Over a Series of Years," JFE, 40, May 1958, pp. 451-57.

[8] J. P. Doll, "A Comparison of Annual Versus Average Optima for Fertilizer Experiments," Amer. Journal of Agricultural Economics, 54, May 1972, pp. 226-233.

and concluded that the annual optimal fertilizer varied significantly from year-to-year, but resulting expected profits did not. He argued that the large experiments needed to estimate the production surfaces were not necessary.

Agronomists and economists have also attempted to explain variation in yield between years as a function of weather in agronomic experiments where the same treatments have been applied over a number of years.

Based on 19 experiment years data from a nitrogen-irrigation experiment on Starr Millet conducted at the Middle Tennessee Experiment Station during 1957-61, Smith and Parks[9] incorporated the number of drought days in the growing season into a response function and computed the economic optima of nitrogen simulating the expected profit at each level of nitrogen fertilizer.

Montana and Barker[10] obtained the optimum economic level of nitrogen by incorporating the probability of solar energy during 45 days before harvesting the crop. They used the data obtained from monthly planting experiments conducted by the Department of Agronomy, IRRI during May 1968 to April 1970.

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[9] W. G. Smith and W. L. Parks, "A Method for Incorporating Probability into Fertilizer Recommendation," Journal of Farm Economics, 49, No. 5, December 1967, pp. 1511-15.

[10] C. B. Montana and R. Barker, The Economic Significance of the Relationship Between Rice Yield, Nitrogen Input and Solar Energy, Unpublished IRRI Saturday Seminar Paper, 1971.

These two papers introduced the simulation procedure for computing the optimum rate of fertilizer using only one nutrient.

Barker, Cordova and Raumasset[11] used the safety-first models which consider the acceptable probability level of disaster under yield uncertainty situation over time to compute the optimum level of nitrogen using IRRI nitrogen response data of promising line experiment during 1966-1971. They revised the Pearson system of probability density function which is used to convert uncertainty into risk and derived the inverse of the cumulative frequency distribution of yield and estimated profit at the acceptable probability level of disaster (0.10) using the sample moment as estimates of the moments of the parent population and generating the frequency distribution. The inverse of the cumulative distribution function of estimated profit is maximized to obtain the optimum nitrogen.

Smith and Engelstad[12] projected fertilizer need for Korea from 1967-1971 based on agronomic requirements for the important crops. The principle sources of experimental data were the various publications by staff members of the Institute of Plant

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11/R. Barker, V. Cordova, and J. Raumasset, The Economic Analysis of Experimental Results in Nitrogen Response of Rice, A paper prepared for Conference on Economics of Fertilizer Use, Asian and Pacific Council, Food and Fertilizer Technology Center, Taipei, Taiwan. June 5-15, 1972.

12/W. G. Smith and O. P. Englestad, Projected Fertilizer Need for Korea, 1967-1971, TVA Fertilizer Consultant Team, Muscle Shoals, Alabama, June 30, 1965.

Environment, Office of Rural Development at Suwon, the United Nations (FAO) Soil Fertility Project, the Association for Potash Research, and the Concentrated Phosphate Export Association, Inc. These data for the most part were obtained from experiments conducted on farmer's fields and therefore are typical of average fertility conditions.

The quadratic form of yield response function with respect to rate of N, P, and K was fitted to arrive at estimates of nutrient for rice and barley. Estimates of agronomic needs for other crops were derived through consultation with research and guidance personnel of the Office of Rural Development of Korea specifically associated with each crop. These agronomic needs are multiplied by the projected cultivating area of corresponding crops and added up to arrive at aggregated need for fertilizer.

3. Derived demand function

Short-run factor demand may be defined as the various quantity which farmers will purchase at all possible prices of the particular factor. Prices of other inputs and of the products from which the factor demand is derived are assumed constant. This definition of short-run factor demand with the added assumptions of profit maximization and knowledge of input-output and price relationships by farmers is referred to as static demand.

To understand the logic relating the production function and static demand, it is useful to consider the marginal value product which is equal to the marginal physical product

multiplied by the product price. A farmer maximizing profits in the absence of capital restrictions would use a resource in a quantity such that the marginal value product from the resource equals its marginal cost.

In agriculture the marginal cost is the factor price. Thus, marginal value product and static demand would be equivalent under the assumptions of a representative production function, complete knowledge, profit maximization and absence of capital and institutional restrictions.

Static demand estimated from controlled experimental data may differ from static demand on farms because of above-average experimental conditions, failure to include residual response and to specify other relevant input and other reasons. With a given soil fertility level, ignoring residual response from fertilizer applied in the current year reduces demand for nutrients and causes over-estimation of actual static demand elasticity assuming the slope remains unchanged. Failure to specify all relevant short-run inputs may result in under-estimation of static demand elasticity on farms.

The net influence on demand estimates because of differences between farms and experimental conditions is not apparent from a priori logic. The static demand estimated in the controlled experimental condition may parallel those found on farms to the extent that the experimental conditions are similar to those found on farms and the tendencies for over-estimation and under-estimation offset each other.

Comparing the static demand elasticities in this study with actual factor demand elasticity as might be expressed by a farmer in the market, farmers are probably less responsive to input price changes than is indicated by static demand elasticities because of conditions broadly associated with uncertainty and adjustment lags, such as motive other than profits, capital limitations, and inadequate knowledge of price and the production function.

Static demand with respect to a product price is called static-cross demand which is a function of input-output price ratio, assuming that the price of other outputs and of related inputs in production processing are fixed.

Static cross-demand shows that the demand quantity of fertilizer may change because of relative change in product price to input price. Cross-demand has its role in explaining the relationship among static supply, static factor demand[13/]

13/Consider a production function:

(a) $Y = f(X_1, X_2, \ldots X_n)$
where output, Y, is a function of factors $(X_1, X_2, \ldots X_n)$. The total derivative of (a) with respect to the product price Py is:

(b) $$\frac{dY}{dPy} = \frac{\partial Y}{\partial X_1}\frac{dX_1}{dPy} + \ldots + \frac{\partial Y}{\partial X_n}\frac{dX_n}{dPy}$$
multiply (b) by Py/Y and obtain

(c) $$\frac{dY}{dPy}\cdot\frac{Py}{Y} = \frac{\partial Y}{\partial X_1}\frac{X_1}{Y}\frac{dX_1}{dPy}\frac{Py}{X_1} + \ldots \frac{\partial Y}{\partial X_n}\frac{X_n}{Y}\frac{dX_n}{dPy}\frac{Py}{X_n}$$

and technology in farming. At a given fertilizer price it is possible to find the change in demand for fertilizer of variou products according to the change in product prices under assumptions that experiment of fertilizer for each product is conducted at the same time and under reasonable conditions for each crop.

This relative change in fertilizer demand among products may indicate "substitution in use of fertilizer input" among products when fertilizer is not the only input. Whe: fertilizer is the only one input in producing outputs it is the measurement of marginal transformation rate among products.

Derivation and characteristics of the algebraic demand function are presented in Appendix A-2.

4. Optimum level of fertilizer over time

There are many factors which influence yield response and hence the optimum level of fertilizer input over time. These variables can be classified into categories based upon the degree to which they could be controlled or predicted by the farmer.

13/(continued)
The elasticity of supply (Es), the elasticity of production (Ep_i) and elasticity of static cross-demand for fact X_i (Ecd_i) are:

$$Es = \frac{dY}{dPy}\,\frac{Py}{Y} \qquad Ep_i = \frac{\partial Y}{\partial X_i} \cdot \frac{X_i}{Y} \quad \text{and} \quad Ecd_i = \frac{dX_i}{dPy} \cdot \frac{Py}{X_i}$$

Hence, (c) may be written as $Es = \sum_{i=1}^{n} Ep_i\ Ecd_i$.

(1) factors which can be controlled or manipulated - time of planting, density of plant, level of weed control, level of plant protection against pests and disease, choice of variety, level of other inputs, and level of nutrients.

(2) factors which can not be controlled but for which occurrence can be predicted - rainfall, level of solar energy, farm price.

(3) factors which are largely unpredictable - floods, drought, typhoons, pest and disease attack.

The yield response to fertilizer can vary widely depending upon the particular combination of factors present. If the optimal level of fertilizer input were estimated by using the particular year's experiment result, the effects of uncontrollable factors could not be estimated. To catch the effects of uncontrollable factors, a series of experiment data over time should be obtained at given seasons. Under uncertainty due to the uncontrollable factors we should incorporate this uncertainty into computing the optimum economic level of fertilizer inputs.

Furthermore, it is expected that some technological changes take place over time. For example, it is meaningless to choose old varieties in an experiment when a new variety of a crop has been developed. And the controllable factors present above are considered within a given situation of knowledge and

technique. The knowledge level will be improved so that the cultivating technique will be changed.

In the prediction of future fertilizer requirements, it is desirable to use the optimum levels of fertilizer in which technological changes are taken into account rather than that of the given level of technology.

The main difference between the weather variable and technological changes is that the farmer is randomly determined while the latter has some trend over time. The occurrence of both variables is not known a priori so that they have some a priori probability distribution. If it were assumed that farmers maximize the expected profit, we could compute the optimum level of fertilizer input under conditions of given prices of output and fertilizer. Weather variability models are presented in Appendix A-3.

Technological progress implies the increased output can be obtained from given resources. There might be a shift up in the response functions. In controlled experiments, all of the controllable factors can be changed over time and have displayed different effects on the response function. The most possible changes in technology can be regarded as follows:

(1) Improvement of crop variety: this is the most important factor to shift the response function.

(2) Improvement of nutrients in fertilizer: the effect of nitrogen contained in urea will be different from that contained

in ammonium sulfate. It is also possible to consider that there will be a change in solubility and absorbability of nutrients toward more favorable conditions for plant.

(3) Improvement of cultivating technique: it is meaningless to conduct an experiment by using traditional cultivating techniques when new methods of cultivating have been adopted. This kind of improvement includes development of new combinations of three nutrients, adequate density of plant for new variety. It also includes changes in the use of other inputs, new development of fertilizer application method, such as, change in proportion of basal dressing and top dressing, change in drainage, irrigation, tillage, weeding and harvesting methods, and new practices of plant protection against disease and insects.

The technological changes will shift the response function as shown in figure IV-1. This relationship may be drawn as U_0 and U_1 in figure IV-1 which represent the fertilizer response curve of traditional technology and improved technology. For farmers facing U_0, a decline in fertilizer price relative to product price from P_0 to P_1 would not be expected to create much increase in fertilizer application in the yield. The benefit of a decline in the fertilizer price can only be fully exploited if U_1 is made available to farmers through the adoption of new technology. Conceptually it is possible to draw a curve such as U on figure IV-1, which is the envelope

of many such response curves, each representing a level of technology of different degrees of fertilizer responsiveness. It may be called an innovation frontier curve or a meta-production function representing the potential inherent in nature. It is hypothesized that the adaptation of crop production to new opportunities in the form of lower relative prices of fertilizer inputs involves an adjustment to a new optimum along this meta-production function:

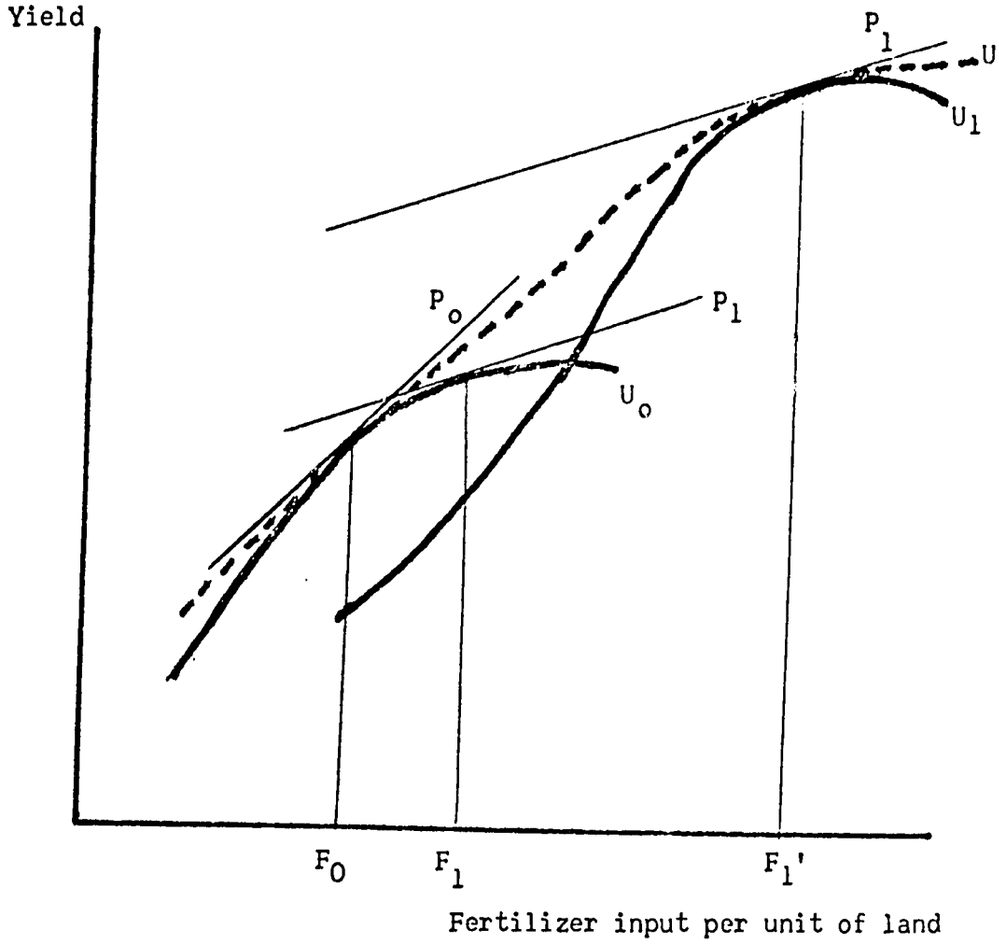

Figure IV-1. Meta-production curve

In fact it is very difficult to separate the effect of technological change from the effect of weather variability on response function. Variation in yields of fertilizer experiments between years can be explained by combination of weather conditions and changes in technology.

The probability of occurrence of weather conditions and technological advance are not known a priori but the advance in technology would have some trend over time. The combination effect of these two conditions can be assumed to have some trend over time.

If a proxy variable which represents all the actual effect of weather conditions and changes in technology can be found, the meta-production function might be estimated by incorporating this variable into response function which is regressed by using the data over series of time periods.

The actual average yield per unit land of farm of the corresponding crops at given locations and given seasons is introduced as the proxy variable. This variable could represent the effect of the combination of weather conditions and technological changes. This variable can reflect the supply of a crop which is a base for estimation of fertilizer requirements. It has also the advantage of easiness of collecting data and predicting future value.

In contrast this variable has some limitations to utilize as a variable representing two conditions - weather and technology.

First, the experiment did not cover all of the varieties cultivated by farm at a given year. If the most popular varieties among the farmers at given regions were chosen as experimental varieties, the variance from this limitation could be reduced.

Second, there would be some technological lag between farm field and experiment station. This lag is expected to be reduced by extension service and mass media. It is very difficult to estimate the lag over time. Suppose the lag is one year. One year lagged value of the proxy can be used.

Third, the cultivating area of each crop shouldn't fluctuate too much year-by-year. Steady increases or decreases in the cultivating area implies that the actual average yield (= total production/total cultivating area) would vary according to weather conditions and technological changes. If there exists some fallow land and rotation from existing land to fallow land, the yield variation comes partly from productivity of fallow land. It is desirable to apply this variable to data of a country where all arable lands are fully utilized and crops cultivated in paddy and upland are different. The production function incorporating this proxy variable will be

$$Y = f(N, P, K, A) \qquad (1)$$

where Y = experimental yield per unit land (Kg/10a)
N = nitrogen (Kg/10a)
P = P_2O_5 (Kg/10a)
K = K_2O (Kg/10a)
A = average actual yield per unit of land at given region and given season. Time-series data (Kg/10a). This is independent of N, P, and K.

The variables A and P_n/Py (output-fertilizer price ratios) are exogeneous and have some trend over time.

Hence, $A = g(T)$

$P_n/Py = h_n(T)$

$P_p/Py = h_p(T)$

$P_k/Py = h_k(T)$, where Py is price of output, P_n, P_p and P_k are price of N, P, and K, respectively, and T is time.

The optimum level of fertilizer nutrients at a given time can be estimated by the following equations.

$$\begin{bmatrix} N \\ P \\ K \end{bmatrix} = D^{-1} \begin{bmatrix} h_n(T) - f_n - f_{NA}\, g(T) \\ h_p(T) - f_p - f_{PA}\, g(T) \\ h_k(T) - f_k - f_{KA}\, g(T) \end{bmatrix}$$

Where $D = \begin{bmatrix} f_{NN} & f_{NP} & f_{NK} & f_{NA} \\ f_{PN} & f_{PP} & f_{PK} & f_{PA} \\ f_{KN} & f_{KP} & f_{KK} & f_{KA} \\ f_{AN} & f_{AP} & f_{AK} & f_{AA} \end{bmatrix}$

The optimum level of fertilization over time will be computed by putting in the value of year variable T.

5. Estimated results from experimental data

i. Data and designs of experiments

a. Rice

The fertility experiments for rice which is the most important crop in the Korean economy were conducted on the farm by the Office of Rural Development (ORD) and U.N. Special Fund Korean Soil Fertilizer project from 1964 until 1969. And then ORD has conducted its own experiments since. The data of 4,301 experiments are obtained from 1964 until 1972 and are averaged for each province in each year. Therefore, average of experimental results of 72 are used for this analysis. The detail soil test was completed before the experiment is conducted. In each province the most common variety is selected for the experiment. The 3^3 complete factorial design was used during 1964 - 1966 and 1970 - 1972 and the incomplete factorial design during 1967 - 1969. The application levels of fertilizer and numbers of experiments are presented in table IV-1.

b. Other crops

This experiment was conducted by U.N. Korean Soil Fertility Project on farmer's farms. Considering weather conditions and farming patterns, each province is divided into several regions in which the types of soil are randomly selected, and in turn the experimental farms are randomly selected from the random sample of soil type.

The sample farms of the fertility experiment for barley and wheat were selected from every province, those for corn from Kangwon, Kyong-buk and Kyong-nam, those for soybeans from every province except Kangwon and Jeon-buk, those for sweet potatoes from every province except Kangwon, and those for white potatoes from only Kangwon province.

Table IV-2 shows the number of experiments and the application levels of three nutrients by crop.

ii. Estimated results for rice

The estimated quadratic fertilizer response functions for rice with proxy of technological change using time-series and cross-provincial experiment data are shown in table IV-3. Equation (1) includes linear and square terms of each variable and all interaction terms among variables. Equation (II) includes linear and square terms and interaction terms between each nutrient and proxy of technological variables. Only linear and square terms are included in equation (III). In all three equations the coefficients of determination and F-value are substantially increased compared with the average response function without the proxy variable of equation (IV). The coefficients of all interaction terms except those of the proxy of technological change are not statistically inefficient. The derivation of the static demand functions from equation (II) and (III) are presented in table IV-4.

The optimum rates of fertilization for years of 1972, 1975, 1980 and 1985 are computed as shown in table IV-5. The optimum rates of nitrogen are computed from the demand equation (i) in table IV-4. But those of phosphate and potash are calculated from equation (ii) because of insignificant coefficients of interaction terms between the proxy of technological change and phosphate and potash. The price ratio of each nutrient relative to price of rice is shown in table IV-5 and are estimated by linear trend projection of prices of fertilizer nutrients and rice during 1960 to 1972. The yield projection is made by trend estimation of 1955-1972 data.

Price elasticities of demand for N, P, and K at the optimum rates for 1972 are: -0.04, -0.25, and -0.24, respectively.

The cross-elasticity of demand for nitrogen with respect to actual yield at optimum rate for 1972 is 1.1, implying the diminishing marginal product of rice.

iii. Estimated results for other crops

The estimated quadratic fertilizer response functions for barley are shown in table IV-6. No coefficients of interaction terms are statistically significant but the coefficients of determination in the functions with the actual yield of barley as a proxy of technological change is substantially increased compared with that without the proxy of technological change. Coefficients of the technological variable are statistically significant in every function.

The fertilizer response functions for wheat, corn, white potatoes, sweet potatoes and soybeans estimated by using 1967 experimental data are presented in table IV-7. The coefficients of interaction terms between nutrients are statistically insignificant as shown in Appendix A-1. The interesting thing is that all of the coefficients of linear terms are positive and those of the square terms are negative as expected even if some of them are not statistically significant. This means the diminishing return to variable factors can be observed.

The derived demand functions of N, P, and K from the response function without interaction terms are linear and independent with prices of other nutrients shown in table IV-8 and IV-9. In general, the slopes of the P and K demand function are greater than that of N.

From the demand functions, it is useful to calculate the optimum rate of each nutrient. They are shown in table IV-10. The price ratios of these crops to three nutrients are estimated by trend projection of 1960-1972 data. The yield projection of barley is made by trend values for 1955-1971. Care should be taken to explain the optimum rates which exceeds the original highest rate of application in the experiment.

As shown in table IV-10, the optimum rate of P for white potatoes, and that of K for corn are examples. This kind of result might come from the misuse of equation forms which require the maximum yield while the application rates of

Table IV-1.--Numbers of experiments and application levels of three nutrients for rice, 1964-1972, Korea

Year	Numbers of experiment	Application levels									
		N				P			K		
		1	2	3	4	1	2	3	1	2	3
		(Kg/10a)									
1964	555	0	5	10		0	3	6	0	3	6
1965	309	8	10	12		0	3	6	0	4	8
1966	1,398	8	10	12		0	3	6	0	4	8
1967	780	8	10	12	14	0	3	6	0	4	8
1968	798	8	10	12	14	0	3	6	0	4	8
1969	336	8	10	12	14	0	3	6	0	4	8
1970	31	8	10	12		0	3	6	0	4	8
1971	62	8	11	14		0	3	6	0	4	8
1972	32	8	11	14		0	5	10	0	5	10

Table IV-2.--Numbers of experiments and application levels of three nutrients for various crops 1965-1969, Korea

Year	Crop	Numbers of Experiments	Application level											
			N				P				K			
			1	2	3	4	1	2	3	4	1	2	3	4
			(Kg/10a)											
1965	Barley	153	6	9	12		5	10			5	10		
1966	Barley	576	3	6	9	12	2	4	6	8	2	4	6	8
1967	Barley	198	6	8	12	14	4	8	12	16	2.5	5	7.5	10
	Wheat	42	6	8	12	14	4	8	12	16	2.5	5	7.5	10
	Corn	16	8	12	16		8	16			8	16		
	S.potato	82	4	7.9	10		4.5	9			10	20		
	W.potato	8	6	7.9	12		4.5	9			5	20		
	Soybean	214	4				4	8			3	6		
1968	Barley	314	7	10	13		5	7.5	10		4	6	8	
1969	Barley	144	7	10	13		5	7.5	10		4	6	8	

Table IV-3.--Fertilizer response functions of rice, 1964-1972, Korea

	I	II	III	IV
Intercept	547.2638	549.9204	409.1095	3.8886
	(95.3874)	(95.1256)	(83.6798)	(10.5996)
N	-0.6163	-0.6184	17.3646**	13.3569**
	(5.3111)	(5.2779)	(1.4113)	(2.5131)
P	4.7924	3.1504	2.6309	3.2325
	(6.2849)	(6.0113)	(2.0700)	(3.6976)
K	6.5374	6.7564	1.2087	1.7624
	(4.7227)	(4.5119)	(1.558	(2.7833)
A	-1.7670**	-1.7670**	-1.494[illegible]**	
	(0.4199)	(0.4191)	(0.4250)	
N^2	-0.5280**	-0.5548**	-0.5267**	-0.2260
	(0.0977)	(0.0352)	(0.2856)	(0.1522)
P^2	-0.0827	-0.0961	-0.0931	-0,2111
	(0.3302)	(0.3293)	(0.3322)	(0.5934)
K^2	-0.0491	-0.0474	-0.0444	-0.1456
	(0.1871)	(0.1865)	(0.1882)	(0.3361)
A^2	0.0031**	0.0031**	0.0032**	
	(0.0005)	(0.0005)	(0.0005)	
NP	-0.1618			
	(0.2070)			
NK	0.03570			
	(0.1612)			
NA	0.04064**	0.0411**		
	(0.01170)	(0.0161)		
PK	-0.0618			
	(0.1723)			
PA	-0.0006	-0.0012		
	(0.01277)	(0.0127)		
KA	-0.0125	-0.0125		
	(0.0093)	(0.0095)		
R^2	.761	.762	.757	.226
F	134.56**	171.74**	230.37**	29.66**

Note: ** significant at the 1 percent level.
* significant at the 5 percent level.
+ significant at the 10 percent level.

Table IV-4. -- The derived demand function from the response functions of rice, 1964-1972, Korea
$D = a + bA + cPr$, (Pr = Price ratio)

Equation	Nutrients	Coefficient a	b	c
i	N	-.5573	.0370	-.9012
(from II)	P	16.3912	-.0062	-5.2029
	K	71.2700	-.1318	-10.9485
ii	N	16.4843		-.9493
(from III)	P	14.1364		-5.3734
	K	13.6114		-11.2612

Table IV-5. -- Projected price ratios, yield and optimum rates of fertilization for rice, 1972, 1975, 1980 and 1985, Korea.

	Price ratio			Yield (unhulled rice)1/	Optimum rate		
	N	P	K		N	P	K
				----------(Kg/10a)			----------
1972	0.7512	0.5323	0.2368	466	15.81	11.26	10.95
1975	0.6791	0.5136	0.2273	485	16.17	11.38	11.06
1980	0.6332	0.6332	0.2199	516	17.85	11.66	11.15
1985	0.600.	0.4529	0.2131	546	19.11	11.70	11.23

1/ Estimated by the linear trend of 1955-1971.

Table IV-6.--Fertilizer response functions of barley, 1965 - 1969, Korea

	I	II	III	IV
Intercept	144.2659	146.3566	132.9470	162.7077
	(42.4244)	(42.1854)	(32.2172)	(125.0487)
N	13.8177*	12.6677*	14.3754**	11.1186*
	(6.2284)	(5.7028)	(3.6748)	(4.8703)
P	7.0927	7.6845	8.3546**	11.4403**
	(6.4422)	(5.5132)	(3.0310)	(4.01537)
K	5.8229	6.4561	5.6760	8.6352+
	(7.6012)	(6.0823)	(3.9903)	(5.2953)
A	-0.5590	-0.6035	-0.5292	
	(0.3874)	(0.3836)	(0.3523)	
N^2	-0.6981*	-0.4359+	-0.4398+	-0.2768
	(0.3186)	(0.2357)	(0.2327)	(0.3090)
P^2	-0.5314*	-0.4077*	-0.4135+	-0.6549*
	(0.2303)	(0.2049)	(0.1999)	(0.2644)
K^2	-0.3991	-0.2663	-0.2590	-0.4834
	(0.3559)	(0.3351)	(0.3311)	(0.4382)
A^2	0.0034**	0.0035**	0.0035**	
	(0.0009)	(0.0009)	(0.0009)	
NP	0.3166			
	(0.4214)			
NK	0.3109			
	(0.4393)			
NA	0.0062	0.0088		
	(0.0217)	(0.0215)		
PK	-0.0850			
	(0.4355)			
PA	0.0043	0.0035		
	(0.0226)	(0.0224)		
KA	-0.0031	-0.0038		
	(0.0233)	(0.0232)		
R^2	0.663	0.665	0.670	0.416
F	28.13**	35.93**	50.09**	24.00**

Note: ** significant at the 1 percent level.
* significant at the 5 percent level.
+ significant at the 10 percent level.

Table IV-7.--Fertilizer response functions of various crops, 1967, Korea

	Wheat	Corn	White potatoes	Sweet potatoes	Soybeans
Intercept	154.244	131.371	351.075	1,397.224	101.856
	(7.931)	(20.697)	(74.719)	(33.647)	(1.923)
N	19.8658**	32.7894**	25.9667	55.3460**	
	(2.4697)	(4.1909)	(19.8898)	(12.4231)	
P	5.9344**	15.7369**	103.4102**	19.9712**	2.2738+
	(1.7184)	(2.2832)	(14.4102)	(6.9853)	(1.1397)
K	1.9451	2.2045	16.2669+	13.9315**	2.4206
	(2.7495)	(2.6107)	(9.3685)	(3.1434)	(1.5197)
N^2	-0.7054**	-0.9558**	-1.7147	-2.7745**	
	(0.1457)	(0.1958)	(1.2138)	(0.9699)	
P^2	-0.2561*	-0.4890**	-4.5022**	-1.3586+	-0.1339
	(0.1046)	(0.1372)	(1.5499)	(0.7469)	(0.1396)
K^2	-0.0442	-0.0370	-0.6886	-0.3484*	-0.1825
	(0.2676)	(0.1836)	(0.4353)	(0.1512)	(0.2483)
R^2	.980	.956	.940	.912	.867
SE	7.985	21.525	76.923	37.587	3.218
F	75.37**	77.84**	55.20**	27.05**	8.18**

Note: Figures in parentheses are the corresponding standard errors.

R^2's are coefficients of determination.

SE is estimation error.

** significant at the 1 percent level.
* significant at the 5 percent level.
+ significant at the 10 percent level.

Table IV-8.--The derived demand functions for the response function of barley, 1965-1969, Korea.
$D = a + bA + cPr$ (Pr = price ratio)

Equation	Nutrients	Coefficient a	b	c
i	N	14.5305	0.0100	-1.1470
(from II)*	P	9.4242	0.0042	-1.2263
	K	12.1195	-0.0071	-1.8772
ii	N	16.3477		-1.1368
(from III)*	P	10.1550		-1.2155
	K	10.9575		-1.9305

* Table IV-6.

Table IV-9.--Derived demand functions for individual nutrients of fertilizer by crops from the response functions without interaction terms, 1967, Korea
$D = a - bPr$ where P_r = fertilizer-output price ratio

Crop	Demand for N a	b	Demand for P a	b	Demand for K a	b
Wheat	14.08	.71	11.58	1.95	11.93	6.13
Corn	17.15	.52	15.72	1.02	29.79	13.51
White potatoes	7.57	.29	12.03	.11	11.81	.73
Sweet potatoes	9.97	.18	7.34	.37	19.99	1.73
Soybeans	4.00	---	8.49	3.73	6.63	2.74

Table IV-10.--Projected price ratios and optimum rates of fertilization for other crops, 1967, 1975, 1980, and 1985, Korea

	Price ratio			Yield	Optimum rate		
	N	P	K		N	P	K
					(Kg/10a)		
Barley							
1967	2.6773	1.8135	0.8967	185	13.31	8.09	9.12
1975	2.2221	1.5686	0.6680	212	14.10	8.38	9.36
1980	2.1983	1.6176	0.6797	232	14.23	8.41	9.20
1985	2.1686	1.6466	0.6877	251	14.55	8.45	9.04
Wheat							
1967	2.3789	1.6114	0.7986		12.39	8.44	7.04
1975	2.9689	2.0916	0.8967		11.96	7.51	6.48
1980	3.0640	2.2544	0.9503		11.89	7.20	6.11
1985	3.1378	2.3817	0.9973		11.39	6.94	6.00
Corn							
1967	2.6251	1.7782	0.8812		15.27	13.80	17.88
1975	2.5593	1.7791	0.7666		15.83	13.81	19.44
1980	2.4098	1.7746	0.7481		15.91	13.82	19.68
1985	2.3206	1.7622	0.7376		15.95	13.83	19.83
White potatoes							
1967	2.5791	1.7470	0.8658		6.82	11.82	11.20
1975	3.0717	2.2134	0.9411		6.68	11.79	11.12
1980	3.1955	2.3515	0.9896		6.65	11.78	11.09
1985	3.2342	2.4545	1.0277		6.63	11.76	11.07
Sweet potatoes							
1967	5.8067	3.9333	1.9493		8.95	5.89	16.62
1975	6.7570	4.491	2.0292		8.76	5.68	16.48
1980	6.2422	4.594	1.9337		8.85	5.65	16.77
1985	6.4512	4.5460	2.0468		8.81	5.67	16.45
Soybeans							
1967	1.5750	1.0669	0.1282		4.00	4.52	5.18
1975	1.4002	1.0552	0.4483		4.00	4.56	5.40
1980	1.4632	1.0775	0.4531		4.00	4.47	5.39
1985	1.4333	1.0776	0.4594		4.00	4.47	5.39
Other grain[1/]					10.90	8.30	9.10
Fruit[1/]					13.60	16.50	12.00
Vegetables[1/]					25.50	16.50	21.90
Mulberry[1/]					25.00	13.00	17.00
Tobacco[1/]					10.00	15.00	20.00
Industrial crop[1/]					6.30	4.60	4.40

1/The experiment data can not be obtained and the recommendation of fertilization for these crops in 1972 are obtained from Office of Rural Development in Korea.

fertilizer for maximum yields in the experiment are not considered and other errors.

It is of interest to know how much the demand changes due to the change in price of fertilizer with constant output price and due to the change in output price with constant fertilizer price. The direct price elasticity and the cross-elasticity with respect to output price have alternative signs and the same magnitude for the derived demand functions from the response function without interaction terms, as shown in the previous chapter.

The estimated elasticities at the optimum rate are shown in table IV-11. The magnitude of this elasticity depends upon the coefficient of production function, fertilizer-output price ratio and the optimum rate of fertilizer.

These elasticities can be explained by the two different ways: price elasticity and cross-elasticity with respect to output price. At a given output price the demand for N used for barley, wheat and corn production will increase by 0.8, 1.3, and 0.8 percent, respectively, as price of N increases by 10 percent. In another way, at a given price of fertilizer the demand for N, P, and K used for barley production will increase by 0.8, 1.5, and 2.0 percent, respectively, as the price of barley increases by 10 percent. Change in demand for fertilizer used for other crop productions can be explained as above, as price of output increases at a given fertilizer price.

Table IV-11.--The estimated price elasticities of demand for three nutrients at the optimum rate, 1967, Korea

Crops	Demand elasticity with respect to its own price of		
	N	P	K
Barley	-.08	-.15	-.20
Wheat	-.13	-.37	-.69
Corn	-.08	-.13	-.66
White potatoes	-.11	-.02	-.06
Sweet potatoes	-.11	-.25	-.20
Soybeans	--	-.88	-.03

The derived demand functions from the response functions which have positive interaction terms as assumptions are estimated for corn, wheat, and white potatoes in table IV-12. Its functions have the form of:

$$D_N = a + b\frac{P_n}{Py} + c\frac{P_p}{Py} + d\frac{P_k}{Py}$$

where D_N is demand for N .

We can expect that $b < 0$, c and d are either positive and negative depending on the interaction term to be negative or positive if the second order conditions for profit maximizations are satisfied.

Table IV-12.--The derived demand functions from response functions which have the positive interaction term, 1967, Korea

		Corn	Wheat	White potato
N	a	17.9049	15.0815	11.3861
	b	-.4686	-.5895	-.1745
	c	-.1023	-.3254	-.0392
	d	-.6358	-.4341	-.0806
optimum		15.93	12.79	10.06
P	a	18.3912	14.5411	12.8138
	b	-.1023	-.3254	-.0392
	c	-1.0473	-1.8281	-.1203
	d	-.7514	-.5246	-.0437
optimum		15.96	10.40	12.02
K	a	42.4603	23.9057	17.6768
	b	-.8358	-.4341	-.0806
	c	-.7514	-.5246	-.0437
	d	-13.7932	-6.3931	-1.0423
optimum		27.30	16.90	15.00

These demand functions have the similar slope and different intercept terms compared with the demand functions derived from the response functions which have no interaction terms.

6. Summary and conclusions

To provide a norm potential for actual total demand for fertilizer, the recommendable rates of each nutrient per unit area that will be reasonably consistent with agronomic need are estimated by experiment fertilizer response function on farmer's farm. Taking account of possible technological changes in the future which affect the optimum level of fertilization, actual yield of a crop on farmer's farm at a given region as proxy of the combination of technological changes and weather conditions might be incorporated into the fertilizer response function of the corresponding crop. Some limitations of this proxy variable will be lack of uniformity of variety of experiment with that of actual farming, technical lag, and yield effect of fallow land, which can be removed or alleviated by collection of adequate data and selection of the right variety in experiment.

The maximum and optimum rates of each nutrient depends on the agro-climate conditions of each region which influence the yield of a crop and the adoption of new variety of a crop. Therefore, it is important to determine the optimum rates of fertilization for each crop in every region. Whether the recommendable rates of fertilization are based on the maximum

rates or on the optimum rates depends upon many factors as follows:

a. The output-fertilizer price ratio

If the price of fertilizer is very low relative to price of output, there is a little difference between the optimum and maximum rates.

b. The purpose of production of a crop

The imputed price of output for home consumption might be different from the market price. In subsistence farming, farmers tend to maximize output within their capacity to meet their consumption so that price situation might little influence their production decision-making. Farmers who produce cash crops are expected to be very sensitive to profitability.

c. Economic situations of a country

If there is deficiency in food crops in a developing country, they try to maximize output by any efforts such as subsidy to fertilizer price and/or output price support due to limited foreign currency. The upward fluctuation in output price within crop year may result in more profitable output at more than optimum level of fertilization.

d. Composition of fertilizer cost in total expenditures and substitutability of fertilizer for the other input

In experimentation, other input except fertilizer is assumed to be constant. But if the same relative expensive factors are substituted for fertilizer, the greater quantity

of fertilizer than the optimum level can be actually applied to cultivation of a crop.

CHAPTER V

FARM DEMAND FOR FERTILIZER ANALYSIS OF FARM SURVEY DATA

1. Introduction

The total demand for fertilizer is a simple sum of individual demands for it in a given area during a given period of time. To determine the quantity of fertilizer purchased by individual farms, it is necessary to collect the relevant data from the farmers themselves. The farmer's purchasing patterns differ according to individual controllable and environmental factors. It is the main purpose of this chapter to estimate the farm demand relationship for fertilizer at a point in time.

A major survey was made in Korea to determine the important factors affecting the fertilizer purchasing behavior of farmers and to examine the effects of those factors on their demand for fertilizer. If the relationships between these factors and the quantity of fertilizer purchased by a farm are established, and if the expected future levels of these factors can be predicted and their respective effects with respect to time are stable, then we can estimate the future demand for fertilizer. Estimates of the future demand for fertilizer are presented in Chapter VI of this thesis.

To obtain the relevant data for this analysis questionnaires were developed to include the items regarded a priori as factors

related to the demand fof fertilizer. The survey involved 300 farms from 30 villages reflecting those dominant cropping systems. A cropping system can be defined in many ways but clearly a basic dichotomy exists in Korea between upland and paddy cropping patterns. Further, climatic transitions along the peninsula give rise to an important subclassification of paddy cropping patterns according to the feasibility of growing a second crop with rice in a given year. This difference gives rise to single cropping paddies and double cropping paddies. Since all data are recorded by political/geographical subdivision--province, Gun (county), Myun (sub-county)--it is useful to group political/geographical subdivisions according to cropping system: an upland cropping region (Northeast), a single cropping paddy region (Northwest), a western double cropping region (Southwest), and an eastern double cropping region (Southeast). The upland cropping region includes Kangwon, Chung-buk and Jeju provinces and is characterized by single cropping pattern and high ratio of upland relative to total arable land. Kyongg' and Chung-nam provinces are included in the single cropping region which have characteristics of single cropping per year and high ratio of paddy field. The western double cropping region includes Jeon-buk and Jeon-nam provinces where most of land are planted twice a year and paddy ratio is high due to plain topography. The eastern double cropping region includes Kyong-buk and Kyong-nam provinces and

is characterized by double cropping pattern, and most of fertilizer industries are located in this region where paddy ratio is lower than that in the western double cropping region. Sample villages were randomly chosen in proportion to the number of farms in each region. Three villages were randomly selected from the upland region, seven villages from the single cropping paddy region, nine villages from the western double cropping region and eleven villages from the eastern double cropping region. Ten sample farms were also chosen from each village to total 300 sample farms. The places where the field survey was conducted are shown in table V-1 and figure V-1.

The field survey was conducted under the supervision of Dr. Young Kun Shim, Professor of Agricultural Economics at Seoul National University. Interviewers were selected from the students of the Department of Agricultural Economics, College of Agriculture, Seoul National University, Korea. The students selected as interviewers were trained appropriately before beginning the survey. A pretest survey was conducted prior to the main survey.

2. Backgrounds of sample farms

Of a total of 25 million farms in Korea, 300 were selected to be analyzed in this study. The average size farm in the survey was 14.5 tanbo (3.6 acres) of which paddy fields account for 56 percent. The average size in this survey is greater than the national average size of farm of 9.3 tanbo (2.5 acres) reported by the Ministry of Agriculture and Fisheries, but the paddy ratio

Table V-1.--The Places Where the Field Survey was Conducted

No.	Province	County (Gun)	Myun	Village
1	Kyonggi	Kanghwa	Hajean	Mangwol
2	Kyonggi	Ansung	Ansung	Bongnam
3	Kyonggi	Yangpyung	Yangdong	Kosong
4	Kangwon	Cmke	Buk	Hankyea
5	Chung-buk	Jungwon	Sangmo	Wontong
6	Chung-buk	Boeun	Naebuk	Sosung
7	Chung-nam	Asan	Sunjang	Daehueng
8	Chung-nam	Susan	Nam	Dalsan
9	Chung-nam	Buyeo	Imcheon	Chilsan
10	Chung-nam	Kumsan	Jinsan	Jihang
11	Jeon-buk	Kimjae	Wolchon	Yeonjung
12	Jeon-buk	Oggu	Oggu	Ikog
13	Jeon-buk	Kochang	Asan	Hakjeon
14	Jeon-buk	Sunchang	Kurim	Kumchang
15	Jeon-nam	Kwangsan	Imkog	Kwangsan
16	Jeon-nam	Naju	Dasi	Dongkog
17	Jeon-nam	Seongju	Woldung	Wolyong
18	Jeon-nam	Hwasun	Hancheon	Jungu
19	Jeon-nam	Haenam	Masan	Yeongu
20	Kgung-buk	Youngyang	Cheonggi	Kumae
21	Kgung-buk	Andong	Pungsan	Sosan
22	Kgung-buk	Kumeung	Nongso	Sinchon
23	Kgung-buk	Sungju	Daega	Daechon
24	Kgung-buk	Youngcheon	Imgo	Dukyeon
25	Kyung-buk	Wolsung	Kyunkog	Kajung
26	Kyung-buk	Chungdo	Kumcheon	Sajeon
27	Kyung-nam	Milyang	Muan	Ungdong
28	Kyung-nam	Haman	Kaya	Kaya
29	Kyung-nam	Hapcheon	Daebyung	Hakum
30	Kyung-nam	Hadong	Okjong	Daekog

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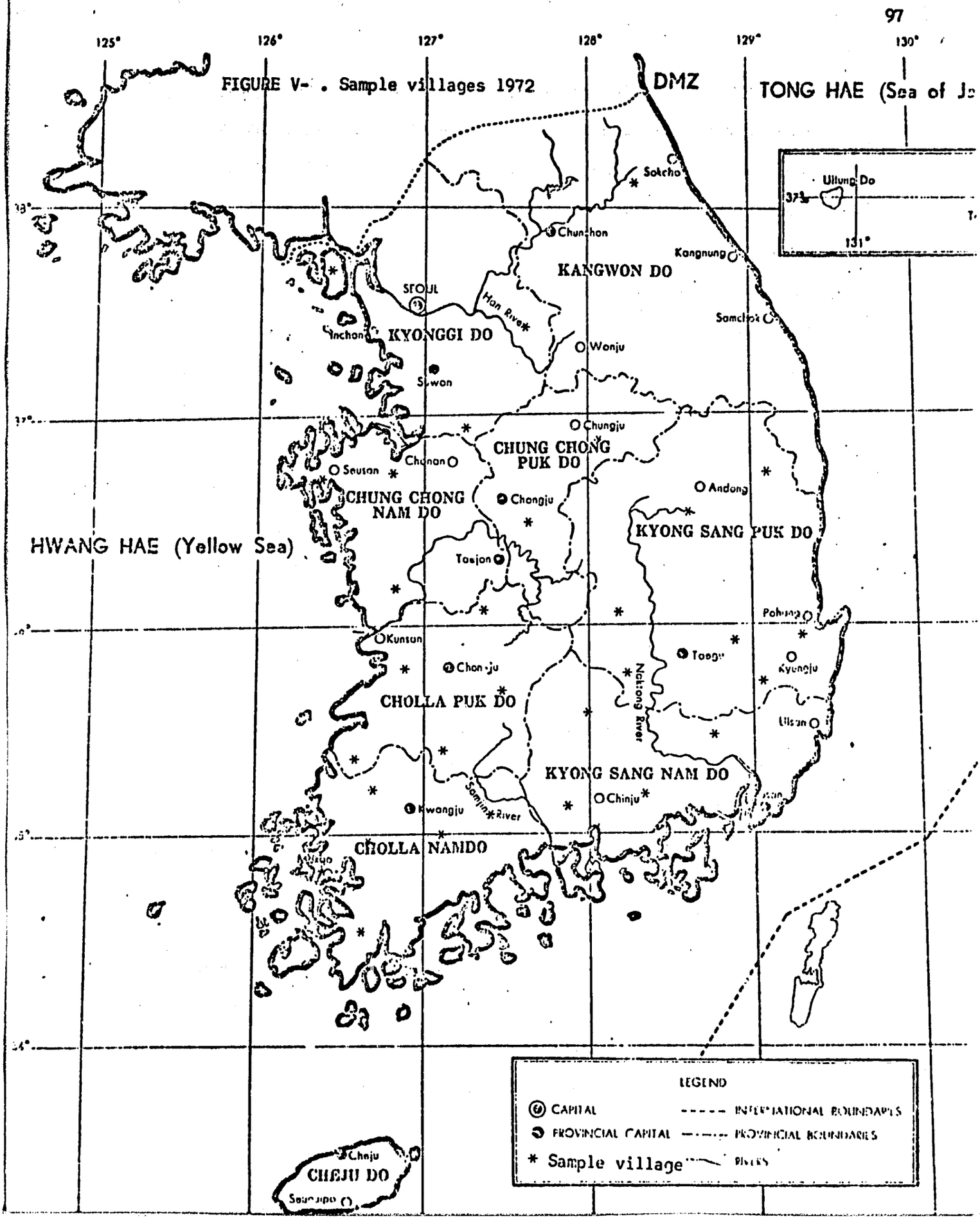

FIGURE V- . Sample villages 1972

is almost the same in the survey and the official report. Farm size in the upland region appears to be slightly larger than in the other regions. The ratio of tenant land to total land is about 13 percent but tenant farming is not officially permitted in Korea. The ratio of double cropping paddy to total paddy is low in the upland and single cropping regions but high in the double cropping region as can be expected. The proportion of irrigated paddy is averaged to be about 70 percent. These characteristics of land resource are reflected in the division of the survey area into the four regions and are shown in table V-2.

The number of family members are 7.0 and there is no difference in size of family among the regions. Half of total family is children, implying that a laborer supports more than one older aged family member. The annual family farming days in adult man-equivalent units are 436.8. This means then an average of 27 man-days are required to farm one tanbo. This is a little greater than the official report of 24 man-days per tanbo in 1969. The hired labor forces will appear later in this discussion of cash expenditures and receipts.

In addition to manpower, animals are also an important power source in Korean farming. The average unit of livestock in hog equivalent units is 6 (or one cow per farm). The average unit of livestock is higher in the upland and east double cropping region than it is in the single cropping and the west double cropping region. This fact partly implies that feed is the limiting factor in raising draft cattle because farms in the

Table V-2.--Farming resources of the sample farms 1972, Korea

	REGION				
	Upland	Single cropping	West double cropping	East double cropping	National average
Total land (10a)	17.3	13.0	14.4	14.8	14.5
Paddy ratio (%)	40	72	70	55	56
Ratio of tenant land (%)	13	13	24	5	13
Ratio of double cropping paddy (%)	7.6	3.9	45.2	60.9	26.9
Ratio of irrigated paddy (%)	49	77	73	73	69
Number of family	6.7	6.9	7.3	7.3	7.0
Number of children	3.8	3.5	3.6	3.7	3.5
Annual family labor (adult man equivalent unit)(days)	474.4	357.1	425.9	489.7	436.8
Livestock (hog equivalent unit) (head)	6.95	4.24	5.81	7.06	6.01
Fertilizer input per farm (Kg)	265.3	261.3	289.4	319.8	291.3
per tanbo (10a)	15.3	20.1	20.1	21.5	20.1
Compost used (Kg)	2,650	790	1,936	1,045	1,605

western plain in Korea are hard to find with grazing land such as the mountain side during nonfarming summer time.

The sample farm used commercial fertilizer of 290 kg in nutrient per farm or 20 kg per tanbo. This figure is close to the official report published in 1971.[1/] The issue and related problems of commercial fertilizer is our main concern in this study and will be discussed in detail later. The farms in the analysis used an average of 1.6 M/T of compost during the survey period. These resource characteristics of the sample farm are shown in table V-2.

Managerial service is important in agriculture because it involves decision-making in each state of cultivation practices from seeding to marketing activities. The farmers' managership seems to be established by farming experience rather than by official education and technical training. Table V-3 shows the percentage distribution of age, farm experience, education and technical training of farm managers in the various regions. Experience of farmers is closely related to their age and they have an average of 22 years farming experience. One quarter of the total sample farmers never attended any school and more than half of them have finished elementary school. College graduates among the sampled farmers were negligible. During the past two years the farmers who have received no technical training or who have never attended an agricultural workshop at all account for 77 percent.

[1/] Ministry of Agriculture and Forestry, Korea, Year-book of Agriculture and Forestry, 1972.

Table V-3.--Background of farm manager, 300 sample farms, 1972, Korea.

	Upland	Single cropping	West double cropping	East double cropping	National average
	(percentage distribution)				
1. Age					
Less than 20	-----	-----	-----	0.9	0.3
21 - 30	-----	2.9	4.4	1.8	2.7
31 - 40	30.0	38.6	26.7	28.2	30.3
41 - 50	33.3	30.0	30.0	31.8	31.0
51 - 60	30.0	18.6	24.4	21.4	27.3
Over 60	3.3	10.0	14.0	10.0	10.7
No answer	3.3	------	-----	1.8	1.0
2. Farm experience					
Less than 10 yrs.	23.3	20.0	13.3	14.5	16.3
11 - 20	37.7	52.8	34.4	30.9	37.7
21 - 30	26.6	12.9	24.5	28.2	26.3
31 - 40	6.7	11.4	21.1	18.2	16.3
Over 40	6.7	2.9	6.7	8.2	6.3
Average (years)	21.2	19.7	24.1	25.3	22.3
3. Education level					
No school	36.7	20.0	25.6	25.4	25.3
Elementary sch.	40.0	51.4	54.4	50.9	51.0
Junior high	20.0	21.4	13.3	12.7	15.6
Senior high	3.3	4.3	6.7	10.0	7.0
College	---	2.9	---	0.9	1.0
4. Days of training or workshop attended (1970-1971)					
No training	76.7	75.7	71.1	83.6	77.3
1 - 5 days	13.3	11.4	8.9	6.4	9.0
6 - 10	10.0	8.6	7.8	3.6	6.7
11 - 20	---	---	7.8	5.6	4.3
20 - 30	---	2.8	4.5	0.9	2.3
Over 30	---	0.5	---	---	0.3
Average (days)	1.0	6.2	3.4	1.3	3.0

This fact implies that technical training or the agricultural workshop was concentrated to leading farmers or village leaders, and that it is inversely related to illiteracy. There is little difference in the background of farm managers among regions.

It is hard to get net income data from the survey but the cash income position of the sample farm is shown in table V-4. Most of the gross cash income comes from crop sales and its composition is 74 percent of crop sales, 13 percent of livestock and livestock products and 13 percent of off-farm income. The farmer in the east double cropping region has higher crop sales, livestock and its products sales and off-farm income than the farms in the other region do on the average. Cash expenditures on hired labor and fertilizer input are the most important items among total cash expenditures. There is little difference in total cash expenditures among regions. Therefore, average net cash income of farms in the east double cropping region is higher than that of the other regions. These facts can be partly explained by development of industrial complexes including the fertilizer industry in that region, which might expand markets for agricultural products and opportunity for off-farm jobs.

Average gross cash income of about 230,000 won minus average cash expenditures of 93,500 won makes average net cash income of 136,000 won. The farms in the analysis have an average debt of 38,000 won. These figures are a little greater than the corresponding national average of farms in the 1.5 - 2.0 ha. size in 1971.

Table V-4.--The cash income and expenditures, 300 sample farms, 1972, Korea.

	Region				
	Upland	Single cropping	West double cropping	East double cropping	National average
	(1,000 won)				
Cash income					
Crop sale	180.96	158.40	148.45	179.63	166.86
Livestock and its product	31.96	20.20	20.84	53.38	31.60
Off farm income	18.66	13.20	41.50	52.62	31.50
Total gross cash income	231.58	191.85	210.79	295.63	229.96
Cash expenditure					
Building	13.40	4.71	3.41	10.60	9.28
Machine	6.33	11.57	4.16	16.00	9.51
Seed	6.36	1.75	1.74	2.72	3.14
Ag chemicals	5.23	8.62	9.10	8.09	7.76
Fertilizer	14.43	13.07	15.32	16.90	14.93
Materials	6.33	2.68	3.17	4.60	4.19
Feed	2.20	2.28	3.35	6.31	3.53
Hired labor	17.23	17.34	21.28	15.80	17.91
Tax and charges	8.73	7.55	15.17	5.20	9.16
Interest	10.00	5.42	2.98	6.28	7.67
Others	0.73	7.81	8.10	8.16	6.20
Total expenditures	90.97	82.80	99.32	100.87	93.49
Net cash income	140.61	109.04	111.67	194.76	136.47
Debt	48.16	44.12	26.19	34.44	38.22

3. Review of Literature

Variation in use of fertilizer between regions or between farms has been explained by cross-sectional analysis. Using regional data from the 1954 Census of Agriculture, Griliches[2/] developed a cross-sectional model. Fertilizer use per unit of land was viewed as a function of fertilizer price relative to prices received by farm. But in addition, the price of fertilizer relative to labor, land, and the average percent content of nitrogen in soil contributed to the explanation. The form of the equation is linear in logarithm of the variables. The results show labor as a complement and land as a substitute for fertilizer. This model explained between 75 and 90 percent of the interstate variation in the use of fertilizer.

Combining actual fertilizer purchase data of 900 farmers in Illinois collected by the Farm Research Institute, Urbana, Illinois during 1950-60, monthly data of Illinois Cooperative Crop Reporting Service and U.S. Census data, Daniel[3/] developed fertilizer demand models. These were divided into several individual models such as total fertilizer, all nitrogen, all phosphate, all potash, straight nitrogen, straight phosphate, straight potash model. Each model is applied to spring and

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[2/] Zvi, Griliches, "The Demand for Fertilizer in 1954: An Inter-State Study," Journal of the American Statistical Association, 54, (June 1959), pp. 377-84.

[3/] R. Daniel, An Economic Analysis of the Farmer Demand for Fertilizer Nutrients. Unpublished Ph.D. Thesis, Purdue University, 1970.

fall data. The dependent variables include total quantitative or nutrient quantities of all fertilizer and individual fertilizer. The independent variables are price of fertilizer, price of farm products, price of land, price of labor, total acres in the farm, quantity of fertilizer applied to previous crop, weather, technology (time), major source of income, gross farm sales, tenure arrangement, form of fertilizer input (bag, bulk, etc.), services purchased with the fertilizer, education of the operator, age of the operator, family size (operator), membership in farm organizations by operator and location of farm within the state. The equation form is linear in logarithm.

The results of this study implied that:

1. prices of fertilizer are quite important to the farmer in his purchase of fertilizer except potash fertilizer,
2. price elasticity of demand varies substantially between spring and fall except for potash, more elastic in spring,
3. crop prices appeared to influence only the fall fertilizer purchase,
4. farmers are responsive to increased convenience and advantages associated with bulk fertilizer and prefer delivery and custom application services,
5. farmers located in certain areas of the states do tend to purchase different fertilizers of the three basic nutrients,

6. demographic characteristics of the operator such as education, age, residence and ownership were not consistently related to purchase of all fertilizer nutrients, and
7. due to the high proportion of unexplained variation associated with these farmer-fertilizer demand relationships, their use for prediction is limited.

Using the survey data of 174 sample farms in the Ribeirao Preto, Brazil, Nelson[4/] derived the demand for fertilizer from estimated production function of various crops such as cotton, rice, corn, soybeans and all crops. Yield of each crop is viewed as a function of quantity of fertilizer used, quantity of other variable inputs such as labor, machinery and seed, land and management. He used the Cobb-Douglas function and quadratic function which is reported. The actual farm's use of fertilizer might be explained by the relationship, $U = p\,R + (1-p)\,E$, where

U = level of fertilizer use

p = probability that the recommendations are correct

R = recommendation level

E = optimum use level based on experience

1-p = probability that farmer's experience is correct.

4/W. C. Nelson, An Economic Analysis of Fertilizer Utilization in Brazil, unpublished Ph.D. thesis, Ohio State University, 1971.

This relationship is derived by comparing the actual use of fertilizer, optimum level obtained from estimated production function and recommendation level.

4. The Statistical Model

The first step in analyzing the demand for fertilizer was to set up a theoretical model describing how the market for fertilizer works. This was done in Chapter II. The next step becomes one of putting the relevent factors and relationships into a form that can be estimated with statistical methods. In this section, the statistical model which includes the economic and behavioral factors affecting the demand for fertilizer of a farm are presented first, followed by a discussion of the statistical methods used in evaluating and testing these models. The form chosen for the farm fertilizer demand relationship, in this study, is a linear function. This function gives us varying elasticity of demand for fertilizer with respect to various independent variables and makes it easy to predict the future demand. In order to understand the factors involved in the farm fertilizer demand model, the following relationships are considered:

a. Demand function of the individual farm for all fertilizer and for each nutrient, N, P, and K contained in the straight and mixed forms of fertilizer.
b. Demand function of the individual farm for all forms, straight and mixed.

These relationships represent eight different demand functions--total fertilizer, all nitrogen, all phosphate, all potash, straight nitrogen, straight phosphate, straight potash, and mixed fertilizer. All of these dependent variables are measured in plant nutrients basis--which explains the individual farm's behavioral relationships in its purchases of these fertilizers.

The reason why the mixed and straight fertilizer models are included is that farmers make decisions on purchasing mixed fertilizer based not only on the nutrients contained therein but also on the proportion of the nutrients in the mixes. Mixed fertilizers with different proportion of each nutrient are applied to different crops and to the same crops at different stages of growth. These models may give us some information about farmer's preferences between straight and mixed forms, but the availability of the different forms of fertilizer a given economy will use will be an important limitation to these models.

In estimating the farm fertilizer demand relationship, two different functions are fitted for each model. The first is a demand function for fertilizer per farm and the second a demand function for fertilizer per acre. Regional demand functions are also estimated to understand regional differences in the effects of various variables.

The functions used were:

$$Q_i = b_{0i} + b_{1i} P_i + b_{2i} P_j + b_{3i} AG + b_{4i} LB + b_{5i} EX + b_{6i} ED + b_{7i} TR + b_{8i} PA + b_{9i} LD + b_{10i} RE + b_{11i} IR + b_{12i} CP + b_{13i} OM + b_{14i} VA + b_{15i} SA + b_{16i} OI + b_{17i} DT + b_{18i} CP + U_i$$

where

i represents total fertilizer, all nitrogen, all phosphate, all potash, straight nitrogen, straight phosphate, straight potash and mixed fertilizer ($i = 1, \ldots, 8$).

Alternative values of the dependent variables are therefore defined as follows:

Q_1 = Total purchase of all fertilizer by farmers per year in kilograms in actual plant nutrients.

Q_2 = Total purchase of all nitrogen nutrients by farmers per year in kilograms.

Q_3 = Total purchase of all phosphate nutrients per year in kilograms.

Q_4 = Total purchase of all potash nutrients per year in kilograms.

Q_5 = Actual N purchased as straight nitrogen fertilizer in kilograms.

Q_6 = Actual P_2O_5 purchased as straight phosphate fertilizer in kilograms.

Q_7 = Actual K_2O purchased as straight potash fertilizer in kilograms.

Q_8 = Actual amount of N, P_2O_5 and K_2O purchased in mixed fertilizer in kilograms.

The exogenous variables are defined as follows:

P_i = Purchasing costs per kg of plant nutrient (10 won/kg). The purchasing cost of total fertilizer is calculated by the following formula:

$$P_1 = \frac{\sum_j (\text{price payment + transportation costs + credit cost + leakage})}{\sum_j \text{Quantity purchased i nutrients}}$$

j represents straight nitrogen, phosphate, and potash and mixed fertilizer.

The purchasing costs of straight nitrogen (P_5), straight phosphate (P_6), straight potash (P_7) and mixed fertilizer (P_8) are calculated by dividing total purchasing costs by corresponding nutrient.

The purchasing cost of all nitrogen is a weighted average of the purchasing cost of straight nitrogen and the purchasing costs of nitrogen nutrients contained in various mixed fertilizers. The weights are the quantity purchased.

$$P_2 = \frac{P_5 Q_5 + \sum_h r_{2h} C_h}{Q_5 + \sum_h q_h M_h}$$

where H represents various mixed fertilizers such as: 22-22-11, 18-18-18, 14-37-12, etc.

r_{2h} = value proportion of nitrogen contained in h mixed fertilizers

C_h = total purchasing costs of h mixed fertilizers

q_h = quantity proportion of nitrogen contained in h mixed fertilizers

M_h = total quantity of nutrients contained in h mixed fertilizers.

The purchasing costs of all phosphate and all potash are estimated by the same method as in the case for all nitrogen.

To get r_{ik} it is assumed that prices of three important mixed fertilizers are determined on the basis that each nutrient has the same value in different mixed fertilizers and that materials other than the plant nutrients have no value. This implies that the value of each nutrient can be obtained by solving the following equations simultaneously

$$\begin{bmatrix} q_{11} & q_{12} & q_{13} \\ q_{21} & q_{22} & q_{23} \\ q_{31} & q_{32} & q_{33} \end{bmatrix} \begin{bmatrix} P_N \\ P_P \\ P_K \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} \quad \text{or } AP = V$$

where q_{ij} = quantity proportion of i nutrients in j mixed fertilizer, P_N P_P and P_K are the values of N, P_2O_5 and K_2O per kilogram, respectively, and V_1, V_2 and V_3 are the prices

of 22-22-11, 18-18-18, and 14-37-12 per kilogram, respectively.

Therefore,

$$P = A^{-1} V.$$

The value proportion of nitrogen contained in 22-22-11 will be

$$r_{21} = \frac{q_{11} P_N}{V_1}$$

The same method can be used to obtain the value proportion of other nutrients in each mixed fertilizer. The following results are used in this study:

Mixed fertilizer	Quantity proportion			Value proportion		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
22-22-11	.40	.40	.20	.47	.40	.13
18-18-18	.33	.33	.33	.42	.35	.23
14-37-12	.22	.59	.19	.27	.60	.13

P_j = purchasing costs of other nutrients (10 won/kg)
This variable is included in straight nutrient model.

AG = family labor input per year in adult male equivalent days, including yearly employed labor

EX = years of farming experience of farm manager

ED = formal education level of farm manager

TR = days of training or workshop attended during the last two years

PA = paddy acres (100 pyung)

LD = total acres in the farm (100 pyung)

RE = rental acres (100 pyung)

IR = well irrigated paddy acre (100 pyung)

CR = cropping acre (100 pyung)

OM = acres of orchard and mulberry land (1,000 pyung)

VA = cultivated acres of new rice variety (IR-667) (100 pyung)

SA = gross farm sale (1,000 won)

OI = off-farm income (1,000 won)

DT = debts (1,000 won), excluding credit purchase of fertilizer

CP = compost used (100 kg)

U_i = disturbance terms

b_is = parameters to be estimated.

The price of fertilizer is uniformly established by government at unit crop pick-up points but the variation in purchasing cost among farms and among regions comes from the difference in transportation costs, credit costs, and leakage.

The purchasing costs (P_i) are assumed to be negatively related to purchase of fertilizer. The purchasing costs of other nutrients (P_j) are incorporated into the straight nutrient model.

If nutrients in straight fertilizer are regarded as the same nutrients in mixed fertilizer these nutrients can be substitutes. The self-supplied fertilizer (compost) can be regarded as a good substitute for commercial fertilizer, especially for nitrogen nutrients. Its quantity variable (CP) is incorporated in the demand model because valuation or pricing of compost is very difficult. The quantity of compost used may be closely related to labor input. In the sense, labor input is a substitute for commercial fertilizer. Family labor is the most important labor source in farming in Korea but the price of family labor is hard to impute considering wages of hired labor so that the equalized family labor (LB) is incorporated in the model. The total effect of labor input to the purchase of commercial fertilizer may not be assumed to be negative or positive because more labor input will be needed to cultivate and harvest the crops on which more fertilizer was used.

The price of output is an important factor affecting the demand for inputs but its difference among farms and regions cannot be found. Farm gross cash sales is incorporated into the models to reflect commercialization and size of the farm. Another variable which will reflect the size of the farms is total acreage. Acres of orchard and mulberry land is another variable of commercialization. Therefore, the farm's gross cash sales (AS), total acreage (LD) and acres of orchard and

mulberry land (OM) are assumed to be positively related to the purchase of fertilizer.

In an aggregate sense, when we assume that all farms use only these economic variables in their decisionmaking processes, the demand for fertilizer could be estimated and shown to be a function of the above economic variables. Its usefulness in determining the total responsiveness of farms to economic stimuli is somewhat limited if the behavioral characteristics of the management factor of the firm are ignored. For example, the primary objective of individual farm operators may hot be profit maximization, but maximum security for their families. The socioeconomic and demographic variables which are intended to measure how certain messages and predispositions interact with the intervening sociological variables of awareness, attitude, and motivation to make a purchasing decision by the operator of the farm are measured as education, experience, training, age, family size and tennant position. Therefore, education (ED), experience (EX), training (TR), age (AG), rental acreage (RE) are incorporated in the fertilizer demand model in an attempt to measure the influence of behavioral awareness, attitude, and motivation of the farm operator in his decision as to the quantiy of fertilizer to purchase. Since education and experience of the operator is an attempt to determine the operator's awareness of new technological innovations and his ability to operate a farm it is thus hypothesized that farmers with higher level education and more experience will be more

aware of different innovations and thus use more fertilizer. The age is an attempt to reflect habit and resistance to change by the operator in the demand model so that it will have a negative influence on the quality of fertilizer used. The effect of tennant acreage ratio on the purchase of fertilizer will be different according to tenant arrangement.

There are other factors which tend to have more of a gradual influence on the demand for fertilizer. These factors such as new hybrid seeds, irrigation, and improvement in the quality of productive factors are usually lumped into a category called technological change. The well irrigated acre (IR) and the cultivated acres of new variety (VA) as technological change variables are incorporated into the demand model. The adoption of new variety is not only related to behavioral characteristics of farm operators but also depends on the soil condition, weather conditions and water availability, and characteristics of a new variety with regard to taste and home consumption preference. In the latter sense, the new variety variable can be regarded as exogeneous. These technological variables are assumed to have positive influence on the purchase of commercial fertilizer. Cropping acre (CP) reflects the difference in weather conditions among regions and size of farm.

Since the purchase of commercial fertilizer is a cash expenditure, a cash income source outside of the farm such as off-farm income and debt level are expected to affect the

purchase of fertilizer as expenditure constraints. A priori, the direction of their influence can not be hypothesized until the source of off-farm income and purpose of debt are specified. Though the intensity of fertilizer use on upland and paddy depend on the crops cultivated and soil conditions, the paddy acre (PA) is introduced to examine the general trend of fertilizer use among regions.

The second function is same as the first except that all variables but purchasing cost, age, experience, education and training variables are divided by total land--making per acre variables. Therefore, in the second function, the variable of LA is labor input per acre, CR, cropping ratio, PA, paddy ratio, OM, orchard ratio, IR, irrigated ratio, RE, rental ratio, VA, ratio of new variety acre, and SA, OE, DI and CP are sale per acre, off farm income per acre, debt per acre and composted used per acre, respectively. Total acre variable is incorporated in the second function reflecting scale factor but excluded from the first function because of multicollinearity with cropping acre in the upland and single cropping regions.

The specification of the assumption concerning the error is the essential difference between the economic and the statistical model. The following assumptions are made about the error terms:

(1) the error term is a random real value

(2) the error term has an expected value of zero

(3) the variance of the error term is assumed to be constant over the sample

(4) the error term is normally distributed

(5) the error terms associated with each set of observations are independent of each other

(6) the error term is not correlated with any predetermined variable.

This set of assumptions insures the attainment of maximum likelihood estimators of the parameters of the equations in the above fertilizer models.

Since the total fertilizer model is a one equation model with only one endogeneous variable, the application of ordinary least squares to this model will obtain maximum likelihood estimates of the coefficients in the model. But since each of the three nutrients is sold through the same outlets and to some extent their individual use by the farmer is for the same purpose it is conceivable that there are additional common factors which affect demand for all three nutrients quite apart from the explanatory variables used in these nutrient models. Since these factors are neglected in the individual nutrient equations, their influence upon the farmer's purchases of fertilizer nutrients must be analyzed with respect to the disturbance terms in individual nutrient models. The application of ordinary least squares, independent of each individual nutrient equation, would thus be inefficient due to the contemporaneous correlation of the three error terms. To avoid

this inefficiency the application of the generalized least squares approach to the whole system of equations simultaneously was discussed in Chapter III. There are, however, too many variables to be incorporated into the three individual models for computer programming to allow an estimate of the parameters simultaneously. Therefore, the ordinary least squares method was used to estimate the individual nutrient demand equations.

5. Statistical results

The estimated results of the demand for straight nitrogen is almost the same as that for all nitrogen. The regressed demand function for other straight fertilizers is not statistically significant. The results of the demand for straight fertilizers, therefore, are not presented here.

i. Total fertilizer model

The results of the demand relationships for total fertilizer per farm and per acre are presented in table V-5 and table V-6, respectively. They show national and regional demand functions both per farm and per acre. The coefficients of determination adjusted for degree of freedom have a range of .60 to .87 for the "per farm" demand functions and .30 to .60 for the "per acre" demand functions for all regions. The estimated F-values show that the regressions fitted are statistically significant at a 1 percent level except the per acre demand function in the upland region is significant only at 5 percent

Table V-5.--Estimated statistics of the demand relationships for total nutrients per farm, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	264.1034	115.1713	506.9189	428.002	220.6317	248.3983
	(74.7928)	(209.7293)	(126.5076)	(93.1062)	(164.8624)	(99.8391)
Purchasing cost	-51.9106**	-55.4770	-83.0734**	-76.7110**	-46.7930*	-49.3103**
	(11.2297)	(42.0056)	(20.6664)	(15.0167)	(23.2028)	(14.3250)
Labor	0.0138	0.1087	0.0326	0.0918+	0.0210	0.0075
	(0.0261)	(0.0980)	(0.0576)	(0.0553)	(0.0457)	(0.0328)
Age	0.8421	31.2791	02.9468	-1.9619	5.4779	-0.0958
	(8.8969)	(23.7070)	(12.3367)	(10.5630)	(19.9893)	(12.6420)
Experience	0.9814	-1.3768	-0.4102	-0.0500	1.0219	1.1128
	(0.8987)	(3.3404)	(1.1304)	(1.1118)	(2.2882)	(1.3603)
Education	8.4992	41.0981+	-18.7125	-7.1897	30.5723	12.5280
	(10.0911)	(27.1911)	(12.0535)	(12.8148)	(26.0879)	(15.7840)
Training	-0.577	-8.0699	-0.2215	3.1236*	-2.6165	1.7643
	(0.3940)	(10.2529)	(0.2888)	(1.2790)	(5.1437)	(2.0742)
Cropping area	4.1514**	2.7481+	6.2246**	3.0975**	3.7501**	3.9678**
	(0.4278)	(1.4431)	(1.2222)	(0.4244)	(1.0234)	(0.5601)
Paddy	0.4123	-2.6630	-1.7884	2.3815**	0.2667	0.7733
	(0.6011)	(2.8209)	(1.4943)	(0.8046)	(1.6583)	(0.9171)
Orchard	-3.4639**	-2.3465	-18.2422**	-0.2695	-3.1395**	-3.3239**
	(0.4449)	(2.1444)	(8.0427)	(1.1541)	(1.0228)	(0.5710)
Irrigated acre	0.3806	3.8288	0.1799	-0.0095	0.4154	0.3437
	(0.3874)	(2.4542)	(0.2912)	(0.7074)	(2.0740)	(0.9535)
Rental acre	-0.2037	6.1841**	-0.9592	-2.3264))	0.3546	-0.6365
	(0.6189)	(2.3366)	(1.2752)	(0.8098)	(2.5943)	(0.9296)
Farm sale	0.1366**	0.1249	0.1848*	0.0930	0.1009	0.1333*
	(0.0493)	(0.2274)	(0.0812)	(0.0196)	(0.0923)	(0.0627)
Off-farm income	-0.0698	-1.8477**	0.0855	0.0690	-0.1485	-0.0542
	(0.0793)	(0.4558)	(0.4137)	(0.0856)	(0.1469)	(0.0946)
Debt	0.3741**	0.2689	0.0445	-0.0704	1.0289**	0.5429**
	(0.1135)	(0.3988)	(0.2562)	(0.1496)	(0.2670)	(0.1497)
Compost	-0.1631	0.3303	0.1082	0.6327*	-1.0440	-6.2116
	(0.2966)	(0.7886)	(0.5842)	(0.2993)	(0.8258)	(0.4166)
Variety	-1.3123	7.8041+	-5.8872	0.8105	-5.2484	-1.5667
	(1.3824)	(4.1222)	(3.9865)	(1.2520)	(3.9239)	(1.9274)
$\bar{R}^2$	0.6553	0.8035	0.7015	0.8723	0.6014	0.6567
F	36.5372**	8.4157**	11.1392**	39.0268**	11.2824**	24.7949**

Note: ** significant at 1 percent; * significant at 5 percent; + significant at 10 percent; R^2 coefficient of determination adjusted for degree of freedom; figures in parenthesis standard error.

Table V-6.--Estimated statistics of the demand relationships for total nutrients per acre, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	8.8185	10.1052	12.2643	14.1029	11.4104	9.4293
	(1.6230)	(5.3991)	(5.6799)	(2.4627)	(2.2125)	(1.7305)
Purchasing cost	-1.0815**	-1.1172	-2.5924**	-2.6679**	-0.6641*	-0.8499**
	(0.2340)	(0.9524)	(0.8072)	(0.4283)	(0.2861)	(0.2307)
Labor/acre	0.0073	0.0238	0.0362	0.0070	0.0018	0.0027
	(0.0139)	(0.0619)	(0.0683)	(0.0209)	(0.0157)	(0.0132)
Age	-0.1129	0.5311	-0.3684	0.2468	-0.0644	-0.1840
	(0.1852)	(0.5164)	(0.4215)	(0.3040)	(0.2467)	(0.2061)
Experience	-0.0169	-0.0295	-0.0116	-0.0360	-0.0068	0.0069
	(0.0184)	(0.0551)	(0.0391)	(0.0324)	(0.0270)	(0.0216)
Education	0.0310	0.8071	-0.3906	-0.3245	0.0763	-0.0675
	(0.2074)	(0.4965)	(0.4204)	(0.3257)	(0.3122)	(0.2482)
Training	-0.0038	0.1723	-0.0032	0.0567+	-0.0804	-0.0276
	(0.0081)	(0.3035)	(0.0096)	(0.0315)	(0.0583)	(0.0315)
Total land	-0.0074**	-0.0112	0.0121	-0.0072+	-0.0042	-0.0061*
	(0.0029)	(0.0198)	(0.0243)	(0.0038)	(0.0032)	(0.0026)
Cropping ratio	3.2328**	2.7190	9.9023**	3.8187**	1.5695**	2.1716**
	(0.4458)	(2.4088)	(2.2979)	(0.7233)	(0.5663)	(0.4691)
Paddy ratio	0.2115	-4.0343	-1.6054	4.6983**	-3.0686*	0.7535
	(2.8848)	(2.8704)	(2.2975)	(1.2619)	(1.4210)	(1.0549)
Orchard ratio	-0.4072	-10.0930+	11.6481	2.3703	-5.7816**	-1.6473
	(1.7509)	(6.0988)	(10.9247)	(2.4201)	(2.1140)	(1.7013)
Irrigation ratio	0.4782	3.0086	0.2902	-1.0712	1.2848	0.3654
	(0.4186)	(2.0883)	(0.5595)	(0.7131)	(0.9747)	(0.6404)
Rental ratio	-0.2136	5.6962**	-1.5662	-0.2013	-5.661	-0.2419
	(0.7217)	(1.7317)	(1.8236)	(0.8361)	(1.4325)	(0.8141)
Farm sale/ acre	-0.0415	0.1483	0.0279	-0.0069	0.0562	0.5000+
	(0.0320)	(0.1499)	(0.1114)	(0.0476)	(0.0370)	(0.031)
Off-farm income	-0.0047	-2.0527**	0.5448	0.0785+	-0.0407+	-0.0048
	(0.0253)	(0.5849)	(0.4721)	(0.0479)	(0.0232)	(0.0224)
Debt/acre	0.3248**	0.7058	-0.5094	0.1668	1.0159**	0.4602**
	(0.0953)	(2.5676)	(0.3651)	(0.1025)	(0.1723)	(0.0934)
Compost/acre	0.2839	0.0369	-0.8298	0.4464+	0.3391	0.4595**
	(0.1758)	(0.6692)	(0.6043)	(0.2573)	(0.2245)	(0.1749)
Variety/ acre	0.0244	3.6825	-7.5747	0.1110	-0.5319	0.2774
	(1.0768)	(4.8409)	(5.3247)	(1.2018)	(1.5760)	(1.0661)
R^2	0.3001	0.5265	0.4351	0.6082	0.3976	0.3373
F	8.1423**	2.8973**	4.1270**	9.1290**	5.2332**	6.9601**

Note: **significant at 1 percent; *significant at 5 percent; + significant at 10 percent; ( ) standard error.

level. It is expected that the coefficients of per farm demand functions differ from that of per acre demand functions because several variables can not be transformed into variables per acre. The direction of exogeneous variables effects on the purchase of fertilizer is same for both per farm and per acre demand functions except that of statistically insignificant variables.

The purchasing costs measured in actual wons per kilogram of fertilizer nutrients by farmer at farmgate have a significant negative effect on the total quantity of fertilizer purchased both per farm and per acre. The coefficients of the purchasing costs of -51.9 per farm and -1.1 per acre implies that a ten won increase in purchasing costs will decrease the individual's purchase of all fertilizer by 51.9 kilograms per farm and 1.1 kilograms per acre if other variables remain constant. The elasticities of demand for total and individual nutrient per farm and per acre with respect to purchasing costs as well as some of the other variables, will be presented later. Negative effect of the purchasing costs on purchase of fertilizer is true for all regional demand functions per farm and per acre, but that of the upland region is statistically not significant.

The family labor input measured as the adult male-equivalent days including yearly employed labor have a nonsignificant positive effect on the individual farm's purchase of total fertilizer. This is also true for all regions, and the same results are obtained as per acre demand function in all regions. Most of

the coefficients of the family labor are positive, indicating that farm with large family labor purchases large quantity of fertilizer both per farm and per acre.

The cropping acre and ratio has a significant positive influence on the purchase of total fertilizer by individual farm and per acre. The coefficient of 4.1 says that 100 pyung increase in cropping acre results in increase in total fertilizer by 4.1 kilograms (123 kg/ha), being other conditions constant. The coefficient of 3.2 in the per acre demand function for total nutrients implies that ten percent increase in ratio of cropping acre to total land results in increase in purchase of total fertilizer by 0.32 kilograms per 100 pyung (9.6 kilograms per hectare). The positive effect of cropping acre and ratio on the purchase of total fertilizer per farm and per acre appears in all regions but that of the upland region is statistically insignificant. Negative coefficient of total land in the per acre function means that the larger farm uses fertilizer less intensively.

There is a national trend that farmers use more fertilizer in paddy field and less fertilizer in orchard and mulberry land. Significant positive coefficient of paddy variable can be found only in the west double cropping region where rice cultivation is the most important farming, but significant negative coefficients of orchard and mulberry variable appear in all regions except the west double cropping region. Significant positive

coefficient of paddy ratio and significant negative orchard ratio of the per acre demand function in the east double cropping region are partly from the fact that upland is used more intensively--usually three times per year--and that cash crops are cultivated on upland by taking advantage of urban market development in that region.

Irrigated acre and ratio have positive coefficients in the total demand function per farm and per acre as expected but they are not statistically significant. These results are true in all regions. Rental acre and ratio are expected to have either negative or positive effect on use of fertilizer per farm and per acre according to tenant arrangement. Fixed proportion tenants make decisions on the use of fertilizer based on his share of total production, while fixed amount tenant makes decisions based on total production. The former uses less fertilizer per acre and the latter uses more fertilizer per acre if production costs are shared between tenant and landlord. The coefficients of rental acre and ratio are significantly positive in the upland region and insignificantly negative in the other region.

Farm sales regarded as cost constraints have statistically significant positive effect on purchase of total fertilizer by farm. This is true in the single and double cropping region and not significant in other regions and in the per acre functions.

Off-farm income can have either positive or negative effect on use of fertilizer. The large cash off-farm income can release cost constraints which poor farms have to have income outside farming by offering their labor. The coefficient of off-farm income is negative in the upland and the east double cropping regions and positive in the single and west double cropping regions to both the per farm and per acre functions.

Debt can also have either negative and positive effect on purchase of fertilizer. The negative effect comes from the facts that debt enforces the cost constant, that the poor farms have to bear debt for their living and that larger farms can operate their farms with their own cash. The positive effect may be the result of the belief that poor farms have no ability for credit while large farms have the ability to carry debt needed to operate their farms. The estimated coefficients of debt per farm and per acre are positive and statistically significant for national demand functions. In regional demand functions, the east double cropping region has significant positive coefficients in both per farm and per acre functions.

Compost used is a possible substitute for commercial fertilizer so that it is expected to have negative coefficient. The estimated results show no significant coefficients except that the west double cropping region has significant positive one implying that dominant rice farming with large family labor can make compost. The significant positive effect of family labor on purchase of fertilizer supports this result.

The coefficients of variety variable, measured as cultivated acre of new variety of rice (IR-667) which reflect the different conditions for adoption of technological change are not significant in both the per farm and per acre functions in all regions (except the upland region which has a significant positive value as expected).

The socio-demographic variables such as age, experience, education and training of farm operator have insignificant effect on purchase of fertilizer but they have positive coefficients. The coefficients of education in the upland region and of training in the west double cropping region are statistically significant and positive.

ii. Nitrogen model.

The estimated coefficients and related statistics of the demand functions for all nitrogen per farm and per acre are presented in table V-7 and table V-8, respectively. The results obtained in the nitrogen model are similar to those of the total fertilizer model in terms of statistical significance and signs of the coefficients. In national demand function for nitrogen per farm, statistically significant variables are purchasing costs with negative coefficient, cropping acre with a positive value, orchard and mulberry acre (negatively), irrigated acre (positive), and farm sale (positive), as expected.

In nation demand function for nitrogen per acre, family labor input per acre has a significant positive effect and

Table V-7.--Estimated statistics of the demand relationships for nitrogen per farm, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	37.7226	-86.6642	55.1559	147.2905	34.1358	52.7692
	(45.7570)	(175.8684	(92.4058)	(37.8934)	(115.3727)	(58.2663)
Purchasing cost	-8.4040+	-1.8264	-2.7485	-22.6026**	-12.2666	-12.7224+
	(5.8278)	(29.6844)	(15.0437)	(5.4659)	(16.5116)	(8.2983)
Labor	0.0079	0.0823+	-0.0042	0.0391*	0.0061	0.0025
	(0.0107)	(0.0418)	(0.0240)	(0.0194)	(0.0194)	(0.0133)
Age	2.5744	2.0998	-1.6910	-2.0760	6.1890**	4.3028
	(3.6538)	(10.7490)	(5.0773)	(3.8485)	(8.4962)	(5.1568)
Experience	0.5123	0.2050	0.1207	0.2048	0.6716	0.5595
	(0.3688)	(1.3042)	(0.4886)	(0.4077)	(0.9604)	(0.5156)
Education	5.7420	19.4031	8.4311+	-0.2974	17.6196	10.6943+
	(4.1464)	(11.1025)	(4.9129)	(4.6827)	(11.0713)	(6.4416)
Training	-0.0417	-0.7221	-0.1057	0.7699+	-1.0247	0.2218
	(0.1619)	(4.0036)	(0.1058)	(0.4576)	(2.1573)	(0.8460)
Cropping acre	2.3276**	1.7812**	2.4060**	2.0741**	2.1980**	2.3026**
	(0.1759)	(0.5931)	(0.5056)	(0.1572)	(0.4226)	(0.2277)
Paddy	0.3415	-0.0803	0.2867	0.9214**	-0.1394	0.2040
	(0.2461)	(1.0844)	(6.6151)	(0.2931)	(0.7068)	(0.3733)
Orchard	-1.9878**	-1.8884*	-9.3572**	-1.0327*	-1.8723**	-1.9758**
	(0.1847)	(0.8796)	(3.3050)	(0.4201)	(0.4230)	(0.2341)
Irrigated acre	0.3866*	0.6386	0.2367+	0.1479	1.4366	0.9039*
	(0.1589)	(0.9691)	(0.1223)	(0.2576)	(0.9096)	(0.3887)
Rental acre	-0.2915*	2.3676*	-0.4983	-0.9169**	0.4107	-0.1697
	(0.2533)	(0.9485)	(0.5366)	(0.2947)	(1.0994)	(0.3783)
Farm sale	0.0435**	0.0642	0.0890**	0.0753**	0.0141	0.0272
	(0.0194)	(0.0826)	(0.0331)	(0.0254)	(0.0393)	(0.0257)
Off-farm income	-0.0427	-0.8129**	0.0754	0.0303	-0.0709	-0.0448
	(0.0325)	(0.1876)	(0.1717)	(0.0312)	(0.0621)	(0.0384)
Debt	0.0530	0.1809	0.0956	-0.0258	0.1817	0.0642
	(0.0466)	(0.1440)	(0.1082)	(0.0254)	(0.1120)	(0.0610)
Compost	0.0016	0.1943	0.1062	0.1744	-0.3194	-0.1020
	(0.1218)	(0.2876)	(0.2400)	(0.1088)	(0.3505)	(0.1699)
Variety	-0.2765	2.7862+	-1.0029	-0.1370	-1.9587	-0.6358
	(0.5676)	(1.4355)	(1.6422)	(6.4557)	(1.6684)	(0.7861)
$\bar{R}^2$	0.7429	0.8788	0.7957	0.9434	0.6293	0.7405
F	55.0123**	14.1535*	17.8058**	93.7558**	12.5665*	36.5007**

Notes: ** significant at 1 percent; * significant at 5 percent; + significant at 10 percent; ( ) standard error.

Table V-8.--Estimated statistics of the demand relationships for nitrogen per acre, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	2.3824	4.7415	-2.6857	5.9932	3.0655	3.9301
	(0.8295)	(4.5414)	(2.7080)	(1.2391)	(1.3128)	(0.8817)
Purchasing cost	-0.2710*	-0.6186	0.2296	-0.8510**	-0.0508	-0.3170*
	(0.1243)	(0.6983)	(0.4156)	(0.2028)	(0.1790)	(0.1255)
Labor/acre	0.0127*	0.0291	0.0133	0.0153	0.0030	0.0067
	(0.0050)	(0.0310)	(0.0212)	(0.0938)	(0.0063)	(0.0050)
Age	-0.0044	0.1412	-0.0520	0.1029	0.383	-0.0019
	(0.0665)	(0.2660)	(0.1379)	(0.1373)	(0.0990)	(0.0787)
Experience	0.0105	0.0106	0.0056	-0.0161	0.0053	0.0035
	(0.0066)	(0.0262)	(0.0127)	(0.0146)	(0.0108)	(0.0082)
Education	0.0139	0.3157	-0.1878	-0.0430	0.0257	0.0346
	(0.0744)	(0.2145)	(0.1375)	(0.1466)	(0.1257)	(0.0951)
Training	-0.0025	0.1722	-0.0023	0.0167	-0.0259	0.0003
	(0.0029)	(0.1393)	(0.0031)	(0.0140)	(0.0234)	(0.0120)
Total land	-0.0037**	0.0057	-0.0016	-0.0048**	-0.0030*	-0.0042**
	(0.0010)	(0.0096)	(0.0079)	(0.0017)	(0.0014)	(0.0010)
Cropping ratio	1.8969**	0.1949	4.0121**	1.7913**	1.1706**	1.3721**
	(0.1618)	(1.1862)	(0.7456)	(0.3409)	(0.2266)	(0.1811)
Paddy ratio	0.9773**	-0.8499	0.9975	2.4224**	-0.2706	0.9613*
	(0.3159)	(1.2619)	(0.7414)	(0.5717)	(0.5681)	(0.4011)
Orchard ratio	-0.2620	-5.0581+	-3.1342	-0.4193	-1.5539+	-0.7743
	(0.6328)	(2.9289)	(3.5217)	(1.1184)	(0.8577)	(0.6552)
Irrigation ratio	0.2163	0.7509	0.2435	-0.4285	0.7737+	0.1777
	(0.1505)	(0.9793)	(0.1866)	(0.3241)	(0.3969)	(0.2446)
Rental ratio	0.0031	2.4929**	-0.4414	-0.0519	-0.3176	0.0075
	(0.2586)	(0.8668)	(0.6076)	(0.3759)	(0.5800)	(0.3073)
Farm sale/ acre	0.0221+	0.0493	0.0590+	-0.0092	0.0168	0.0144
	(0.0115)	(0.0642)	(0.0364)	(0.0214)	(0.0149)	(0.0118)
Off-farm income	-0.0076	-1.0137**	-0.0939	0.0284	-0.0228*	-0.0103
	(0.0091)	(0.2913)	(0.1529)	(0.0214)	(0.0093)	(0.0085)
Debt/acre	0.0226	0.5005+	0.0515	0.0507	0.0125	0.0401
	(0.0342)	(0.2637)	(0.1206)	(0.0444)	(0.0651)	(0.0355)
Compost/ acre	0.0838	-0.1196	-0.0381	0.1219	0.1819*	0.1405*
	(0.0631)	(0.3028)	(0.1953)	(0.1158)	(0.0901)	(0.0668)
Variety/ acre	-0.5245	0.2065	-1.2923	0.8757	-0.5679	-0.6906+
	(0.3875)	(1.9375)	(1.7347)	(0.5420)	(0.6303)	(0.4073)
$\bar{R}^2$	0.5205	0.4581	0.4824	0.6181	0.4833	0.5008
F	20.0942**	2.4422	4.7833**	9.4764**	6.9981**	12.7450**

Note: **significant at 1 percent; *significant at 5 percent; + significant at 10 percent; ( ) standard error.

irrigated ratio has an insignificant positive effect on the purchase of nitrogen, while the former is insignificant and the latter is significant in national demand for nitrogen per farm. Significant positive coefficient of paddy ratio in the per acre function implies that much nitrogen fertilizer mostly purchased in the form of urea is applied to the cultivation of rice, the most common crop grown on paddy fields.

In the upland region, the demand function for nitrogen per farm has a significant positive coefficient of family labor, a significant negative coefficient of cropping acre, a significant negative coefficient of orchard and mulberry acre, a significant positive coefficient of rental acre, a significant negative coefficient of off-farm income and a significant positive coefficient for variety. Significant positive coefficient of rental acre and negative one of off-farm income imply that landlords share production costs with poor peasants in this region. The landlords do possibly require their peasants to cultivate new variety with support of production costs so that variety variable has significant positive coefficient only in this region. In the demand function for nitrogen per acre in the upland region, cropping ratio has insignificant effect on use of nitrogen implying that there is little difference in cropping ratio between farms because single cropping pattern prevails in this region.

In the single cropping region, education, cropping acre, orchard, irrigated acre, rental acre and farm sale have a significant effect on the use of nitrogen per farm while

cropping ratio and farm sale per acre influence significantly the use of nitrogen per acre.

In the west double cropping region, purchasing cost, family labor, training of manager, cropping acre, paddy acre, orchard and mulberry acre, rental acre and farm sale have significant coefficients with reasonable signs. Significant positive coefficient of paddy shows that fertilizer use is concentrated on paddy fields in this region. But family labor, training of manager, rental ratio and farm sale do not significantly influence the use of nitrogen per acre.

In the west double cropping region, cropping acre and ratio, total land, orchard acre and ratio, irrigated ratio, off-farm income per acre, and compost per acre appear to have significant coefficients in either the per farm or per acre function. Less intensive use of land by large farms is observed in the double cropping regions. Positive coefficients of paddy acre and ratio in the single and west double cropping regions imply that paddy crops are dominant ones in these regions, while negative coefficients of paddy acre and ratio in the upland and east double cropping regions say that upland is a dominant cropping pattern in the upland region and more intensive use of upland in the east double cropping region supports this result.

Age and experience of farm operator never appear to be significant in the nitrogen model. The results are the same as in the total fertilizer model and are not given. For

explanations the reader is referred to the discussion of the total fertilizer model.

iii. Phosphate model.

The computed results of the demand relationships for all phosphate per farm and per acre are shown in table V-9 and table V-10, respectively. The purchasing cost at the farmgate does not significantly influence the purchase of phosphate per farm and per acre but also has positive coefficients. The sample farms purchase an average 15 kilograms of straight phosphate out of 78 kilograms of all phosphate. More than 80 percent of phosphates are purchased in the form of mixed fertilizer so that farmers' response in purchasing phosphate to change in purchasing cost can be explained by farmers purchasing pattern of mixed fertilizer, which is examined in the mixed fertilizer model. Two different results from those of the nitrogen model are observed. One is significant negative effect of paddy ratio on use of phosphate. Phosphate is said to be mostly used for crops grown upland such as barley and wheat. The other is significant positive coefficients of compost used per acre. Compost is composed of nitrogen so that complementary relationship between plant nutrients. Regional demand functions also have similar results for other variables except those mentioned above as those of nitrogen functions. The estimated F-value of per acre function in upland region show insignificant regression.

Table V-9.--Estimated statistics of the demand relationships for phosphate per farm, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	2.4359	-128.9349	17.0062	7.9720	29.0870	20.3193
	(22.3613)	(79.6685)	(51.9148)	(34.4163)	(42.5193)	(29.2424)
Purchasing cost	0.8370	14.8942	2.5246	0.5698	-3.5790	-1.5616
	(2.8855)	(9.6301)	(7.8228)	(5.0314)	(4.6226)	(3.4190)
Labor	0.0045	0.0618	-0.0032	0.0178	0.0062	0.0030
	(0.0103)	(2.0422)	(0.0271)	(0.0291)	(0.0151)	(0.0123)
Age	-2.3358	2.1011	-0.5257	1.4628	-2.1222	-3.8944
	(3.5362)	(9.3298)	(5.8508)	(5.8717)	(6.6848)	(4.7819)
Experience	0.1360	0.4482	-0.5307	-0.3651	0.0396	0.1821
	(0.3580)	(1.7494)	(0.5320)	(0.6149)	(0.7608)	(0.5144)
Education	-1.0516	19.1395	9.3846+	-6.8948	3.4830	-3.0081
	(4.0110)	(12.9522)	(5.6168)	(7.1337)	(8.7342)	(5.9822)
Training	0.0568	-4.4874	-0.0192	2.0478**	-0.0724	1.3212+
	(0.1566)	(4.4937)	(0.1203)	(0.6925)	(1.6999)	(0.7846)
Cropping acre	1.2431**	1.0048	2.9155**	0.4023+	1.2909**	1.1338**
	(0.1713)	(0.7059)	(0.5766)	(0.2323)	(0.3408)	(0.2127)
Paddy	-0.0008	-1.8947	-1.8487**	1.1443*	0.5569	0.4863
	(0.2393)	(1.2936)	(0.7005)	(0.4446)	(0.5525)	(0.3463)
Orchard	-0.9888**	-0.4110	-7.7428*	0.7742	-1.0785**	-0.9169**
	(0.1781)	(0.9080)	(3.7633)	(0.6490)	(0.3424)	(0.2172)
Irrigated acre	-0.0621	2.1107+	0.0742	-0.1190	-1.5135*	-0.7275*
	(0.1540)	(1.1705)	(0.1369)	(0.3895)	(0.6710)	(0.3613)
Rental acre	0.0625	1.7850	-0.5740	-1.1074*	0.0007	-0.4154
	(0.2460)	(1.1007)	(0.5970)	(0.4476)	(0.8564)	(0.3508)
Farm sale	0.0749**	0.0055	0.0443	0.0422	0.0758*	0.0945**
	(0.0189)	(0.1034)	(0.0396)	(0.0384)	(0.0308)	(0.0236)
Off-farm income	-0.0209	-0.4000+	-0.0685	0.0030	-0.0340	-0.0073
	(0.0315)	(0.2106)	(0.1948)	(0.0471)	(0.0490)	(0.0356)
Debt	0.1707**	-0.0653	6.0902	0.0785	0.4604**	0.2715**
	(0.0453)	(0.1703)	(0.1202)	(0.0795)	(0.0916)	(0.0570)**
Compost	-0.0358	-0.0164	1.4563	0.4871**	-0.4227	0.0607
	(0.1180)	(0.3770)	(0.2741)	(0.1655)	(0.2758)	(0.1575)
Variety	-0.7541	1.8229	-2.3869	0.9057	-2.2094+	-0.6012
	(0.5503)	(1.8925)	(1.8804)	(0.6949)	(1.3127)	(0.7318)
$\bar{R}^2$	0.5358	0.4869	0.4094	0.6347	0.6461	0.5945
F	22.5763**	2.7199*	3.9897**	10.6646**	13.4372**	19.2360**

Notes: ** significant at 1 percent; * significant at 5 percent; + significant at 10 percent; ( ) standard error.

Table V-10.--Estimated statistics of the demand relationships for phosphate per acre, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	0.1907	0.2409	-1.6476	-0.0995	3.1418	0.9822
	(0.5690)	(2.0385)	(2.1834)	(0.9604)	(1.0260)	(0.7031)
Purchasing cost	0.2934	0.2826	0.4212	0.1156	0.0900	0.2339
	(0.6560)	(0.2020)	(0.2508)	(0.1241)	(0.1026)	(0.1713)
Labor/acre	-0.0029	0.0084	-0.0276	-0.0100	-0.0030	-0.0040
	(0.0060)	(0.0253)	(0.0271)	(0.0104)	(0.0084)	(0.0064)
Age	-0.0548	0.0363	-0.0921	0.2129	-0.0794	-0.0957
	(0.0797)	(0.1908)	(0.1677)	(0.1541)	(0.1330)	(0.0995)
Experience	0.0002	-0.0061	-0.0145	-0.0280+	-0.0040	0.0014
	(0.0079)	(0.0234)	(0.0155)	(0.0163)	(0.0145)	(0.0104)
Education	-0.0101	0.3059+	-0.2364	-0.1920	0.0663	-0.0186
	(0.0888)	(0.1755)	(0.1667)	(0.1640)	(0.1687)	(0.1197)
Training	0.0015	-0.0065	0.0004	0.0416**	0.0090	0.0326
	(0.0035)	(0.1146)	(0.0038)	(0.0157)	(0.0315)	(0.0152)
Total land	-0.0009	0.0064	0.0027	-0.0022	0.0003	-0.0006
	(0.0012)	(0.0080)	(0.0094)	(0.0019)	(0.0019)	(0.0012)
Cropping ratio	0.7885**	0.9565	3.6000**	0.5943+	0.0997	0.4433+
	(0.1923)	(1.1077)	(0.8897)	(0.3335)	(0.3057)	(0.2268)
Paddy ratio	-0.8513*	-1.8966+	-1.5776+	0.9886	1.9153*	-0.6618
	(0.3780)	(1.0990)	(0.9034)	(0.6673)	(0.7642)	(0.5041)
Orchard ratio	-0.9097	-3.2240	2.9343	1.1174	-3.3355**	-1.1994
	(0.7547)	(2.4952)	(4.2524)	(1.2414)	(1.1407)	(0.8228)
Irrigation ratio	0.1128	1.5537	0.1304	-0.2084	0.0664	-0.0693
	(0.1803)	(0.9967)	(0.2220)	(0.3546)	(0.5219)	(0.3089)
Rental ratio	-0.1971	1.6249*	-0.6860	-0.2777	-0.6391	-0.3896
	(0.3113)	(0.7690)	(0.7136)	(0.4217)	(0.7528)	(0.3898)
Farm sale/ acre	0.0160	0.0369	-0.0080	0.0034	0.0261	0.0242*
	(0.0137)	(0.0562)	(0.0446)	(0.0239)	(0.0499)	(0.0149)
Off-farm income	0.0007	-0.5091*	0.1642	0.0174	-0.0070	0.0025
	(0.0109)	(0.2414)	(0.1808)	(0.0241)	(0.0125)	(0.0108)
Debt/acre	0.1037*	0.1020	-0.1284	0.1454**	0.4269**	0.1649**
	(0.0417)	(0.2154)	(0.1462)	(0.0494)	(0.1053)	(0.0461)
Compost/ acre	0.1764*	0.0936	-0.2803	0.3281	0.1852	0.2763**
	(0.0759)	(0.2604)	(0.2388)	(0.1302)	(0.1212)	(0.0846)
Variety/ acre	0.0564	1.2071	-2.0465	0.8158	-0.8454	0.1531
	(0.4644)	(1.6029)	(2.1075)	(0.6112)	(0.8474)	(0.5161)
$\bar{R}^2$	0.1648	0.2176	0.3130	0.2728	0.2828	0.2044
F	4.4722**	1.4744	2.8495**	2.9646**	3.5293**	4.5089**

Note: **significant at 1 percent; *significant at 5 percent; + significant at 10 percent; ( ) standard error.

iv. Potash model.

The estimated results of the demand relationships for potash nutrients, per farm and per acre, at national and regional level are almost similar with those of nitrogen nutrient in terms of significance and sign of coefficients except negative coefficients of paddy acre and ratio which are explained in phosphate model shown in table V-11 and table V-12. For an explanation of these results refer to those of the nitrogen model.

v. Mixed fertilizer model.

Farmers make decisions on the purchase of mixed fertilizers on the basis of not only individual nutrients contained therein but also combination of them considering their crops in nutrient requirements. Their decision will also be restricted by the availability of various types of mixed fertilizer. Table V-13 and table V-14 show the computed statistics related to the demand relationships for mixed fertilizer per farm and per acre.

The coefficients of purchasing cost of mixed fertilizer are positive and insignificant in the per farm function and statistically significant in the per acre function. But the coefficients of the purchasing cost of straight nitrogen are negative and statistically significant. This means that the straight nitrogen is a complement to mixed fertilizer as an important source of phosphate and potash nutrients. These results of purchasing costs of mixed fertilizer and straight nitrogen can be partly explained by the national policy which emphasize

Table V-11.--Estimated statistics of the demand relationships for potash per farm, sample farms 1972, Korea.

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	-3.4853	-22.4688	105.9494	59.8976	58.1242	54.8398
	(17.2302)	(45.6197)	(42.2680)	(27.9294)	(52.4247)	(30.3887)
Purchasing cost	-0.8177	-0.2720	-32.0872**	-19.7940**	-17.2212	-18.7352**
	(0.7215)	(0.7037)	(8.8719)	(6.7119)	(11.6576)	(6.8151)
Labor	0.0092	-0.0038	0.0015	0.0089	0.0132	0.0101
	(0.0099)	(0.0378)	(0.0269)	(0.0228)	(0.0162)	(0.0118)
Age	-0.5130	8.8891	-0.8856	-0.1170	0.8035	-0.8110
	(3.3878)	(8.3045)	(5.8428)	(4.5782)	(7.0906)	(4.5563)
Experience	0.1150	-1.4904	-0.2000	-0.0231	-0.1939	0.0354
	(0.3421)	(1.4165)	(0.5360)	(0.4809)	(0.8050)	(0.4891)
Education	5.7680	15.9014	3.3098	-1.2751	7.7621	3.4081
	(3.8591)	(10.9771)	(5.6857)	(5.5537)	(9.2450)	(5.6895)
Training	-0.0237	-5.2434	-0.0705	1.2663*	-2.4831	0.1034
	(0.1499)	(3.9462)	(0.1211)	(0.5465)	(1.8406)	(0.7474)
Cropping acre	0.7218**	0.6912	1.1953**	0.4573*	0.5841+	0.6727**
	(0.1625)	(0.5814)	(0.5808)	(0.1816)	(0.3182)	(0.2021)
Paddy	-0.1592	-2.6790*	-0.8700	0.2378	0.0597	-0.0327
	(0.2282)	(1.0917)	(0.7118)	(0.3482)	(0.5858)	(0.3311)
Orchard	-0.5943**	-1.3723+	-0.1732	0.0308	-0.4671	-0.5296*
	(0.1692)	(0.7840)	(3.8011)	(0.5033)	(0.3630)	(0.2071)
Irrigated acre	-0.0166	0.8735	-0.0579	0.1640	-0.2512	0.0345
	(0.1476)	(1.0883)	(0.1393)	(0.3049)	(0.7139)	(0.3431)
Rental acre	0.2184	2.6243*	-0.1523	-0.2126	0.3782	0.0700
	(0.2349)	(0.9765)	(0.6014)	(0.3504)	(0.9246)	(0.3360)
Farm sale	0.0401*	0.1007	0.0912*	-0.0030	0.0129	0.0245
	(0.0179)	(0.0903)	(0.0380)	(0.0301)	(0.0327)	(0.0225)
Off-farm income	0.0131	-0.8125**	0.0529	0.0732+	-0.0192	0.0273
	(0.0301)	(0.1837)	(0.1955)	(0.0372)	(0.0578)	(0.0339)
Debt	0.1264**	0.0761	-0.0827	0.0421	0.3475*	0.1922**
	(0.0432)	(0.1492)	(0.1207)	(0.0631)	(0.0947)	(0.0539)
Compost	-0.1316	0.2810	-0.2837	0.0679	-0.2896	-0.1552
	(0.1130)	(0.3164)	(0.2757)	(0.1293)	(0.2956)	(0.1501)
Variety	-0.5921	4.8921**	-2.8593	-0.0584	-0.8359	-0.3516
	(0.5256)	(1.5014)	(1.8835)	(0.5422)	(1.3916)	(0.6962)
$\bar{R}^2$	0.2819	0.6339	0.3240	0.4543	0.3060	0.3203
F	8.3361**	4.1387**	3.0675*	5.6324**	4.0049**	6.8625**

Note: ** significant at 1 percent; * significant at 5 percent; + significant at 10 percent; ( ) standard error.

Table V-12.--Estimated statistics of the demand relationships for potash per acre, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	0.8886	1.7422	5.8207	2.1726	3.2265	2.6915
	(0.6125)	(1.2957)	(2.8644)	(1.0110)	(1.1411)	(0.7603)
Purchasing cost	-0.0283	-0.0046	-1.1583**	-0.5811**	-0.5382*	-0.6130**
	(0.0211)	(0.0148)	(0.4243)	(0.2074)	(0.2197)	(0.1498)
Labor/acre	0.0002	-0.0173	-0.0174	-0.0130	0.0036	-0.0027
	(0.0075)	(0.0225)	(0.0399)	(0.0107)	(0.0091)	(0.0066)
Age	-0.0544	0.2067	-0.2005	-0.0025	-0.0423	-0.0859
	(0.1001)	(0.1743)	(0.2425)	(0.1568)	(0.1423)	(0.1036)
Experience	0.0027	-0.0390+	-0.0162	-0.0064	-0.0117	-0.0004
	(0.0099)	(0.0198)	(0.0225)	(0.0167)	(0.0155)	(0.0108)
Education	0.0946	0.4457**	0.0824	-0.2301	-0.0286	-0.0657
	(0.1121)	(0.1536)	(0.2416)	(0.1680)	(0.1800)	(0.1246)
Training	-0.0010	-0.1133	-0.0209	0.0232	-0.0587	-0.0069
	(0.0043)	(0.1004)	(0.0558)	(0.0161)	(0.0340)	(0.0158)
Total land	-0.0017	0.0005	-0.0052	-0.0029	0.0002	-0.0005
	(0.0015)	(0.0071)	(0.0139)	(0.0019)	(0.0018)	(0.0013)
Cropping ratio	0.5694*	1.0823	1.7809	0.3276	0.3845	0.4467+
	(0.2406)	(0.8959)	(1.3044)	(0.3408)	(0.3259)	(0.2317)
Paddy ratio	-0.7306	-3.0536**	-2.2399+	1.0619+	-0.8675	-0.0714
	(0.4706)	(0.9489)	(1.3044)	(0.6514)	(0.8267)	(0.1240)
Orchard ratio	0.3498	-2.0321	16.6375*	1.1299	-1.0571	0.1037
	(0.9449)	(2.2029)	(6.2076)	(1.2429)	(1.2237)	(0.8540)
Irrigation ratio	0.1363	1.0257	0.0787	0.0356	0.1362	0.3130
	(0.2266)	(0.9368)	(0.3213)	(0.3623)	(0.5561)	(0.3214)
Rental ratio	0.4918	2.4376**	-1.2361	0.4656	0.8711	0.3963
	(0.3905)	(0.6781)	(1.0313)	(0.4299)	(0.8213)	(0.4082)
Farm sale/ acre	0.0131	0.1097*	-0.0218	0.0191	0.0153	0.0163
	(0.0172)	(0.0502)	(0.0640)	(0.0244)	(0.0214)	(0.0115)
Off-farm income	0.0070	-06998**	0.6474*	0.0578*	-0.0062	0.0073
	(0.0136)	(0.2126)	(0.2702)	(0.0246)	(0.0133)	(0.0112)
Debt/acre	0.1086*	-0.563	-0.4352*	0.1186*	0.4071**	0.1690**
	(0.0512)	(0.1913)	(0.2099)	(0.0511)	(0.0935)	(0.0465)
Compost/ acre	-0.0347	0.1776	-0.7537*	0.0921	-0.0372	0.0019
	(0.0958)	(0.2306)	(0.3458)	(0.1326)	(0.1302)	(0.0378)
Variety/ acre	0.4769	4.8525**	-3.2972	0.1567	1.1569	0.8249
	(0.5814)	(1.4543)	(3.0520)	(0.6202)	(0.9058)	(0.5356)
$\bar{R}^2$	0.0345	0.5762	0.4140	0.2491	0.1866	0.1433
F	1.6291	3.3195**	3.8681**	2.7383**	2.4709**	2.9590**

Note: ** significant at 1 percent; * significant at 5 percent; + significant at 10 percent; ( ) standard error.

Table V-13.--Estimated statistics of the demand relationships for mixed fertilizer per farm, sample farms 1972, Korea

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	25.2004	77.4171	372.0394	103.6914	302.5201	24.9018
	(81.8087)	(47.7482)	(187.4486)	(75.5403)	(199.1672)	(10.5854)
Purchasing cost	6.6551	25.3279+	15.1648	18.4723)	-1.8134	-2.7273
	(6.5621)	(9.1195)	(11.6188)	(15.9138)	(16.7867)	(12.1562)
Labor	0.0124	0.1088	0.0232	0.0602	0.0102	0.0044
	(0.0190)	(0.0690)	(0.0410)	(0.0375)	(0.0322)	(0.0239)
Age	-3.1064	4.9740	0.7600	-0.3408	0.3638	-4.0816
	(6.5046)	(22.5423)	(8.6906)	(7.3874)	(14.0174)	(9.2161)
Experience	0.4246	0.6087	-1.0446	-1.0105	0.2196	0.3487
	(0.6571)	(2.6339)	(8.7978)	(0.7792)	(1.5965)	(0.9929)
Education	1.5428	19.5144	-15.1385+	-6.451	9.1659	1.0948
	(7.4184)	(19.7207)	(8.3785)	(9.0149	(18.4841)	(11.5984)
Training	-0.0311	-1.8838	-0.0777	0.4283	-0.2504	0.2397
	(0.2874)	(7.8330	(0.1780)	(0.9068)	(3.6526)	(1.5131)
Cropping acre	2.5061	2.1001+	5.4037**	1.2134**	2.5943**	2.4259**
	(0.3171)	(1.1187)	(0.8769)	(0.3057)	(0.7236)	(0.4131)
Paddy	-0.1791	-3.2706	-3.0897	1.5847**	-0.1423	0.2945
	(0.4388)	(2.0992)	(1.0554)	(0.5593)	(1.1688)	(0.6727)
Orchard	-1.9433**	-1.5273	-16.5464**	2.2461	-2.0579**	-1.8875**
	(0.3339)	(1.5117)	(5.5809)	(0.8477)	(0.7294)	(0.4277)
Irrigated acre	-0.0502	1.3705	0.0977	0.1643	-0.7667	-0.7240
	(0.2832)	(1.9546)	(0.2077)	(0.4920)	(1.5062)	(0.709)
Rental acre	0.2779	3.4503*	-1.1361	-1.5435**	-1.9015	-0.1751
	(0.4510)	(1.6216)	(0.9147)	(0.5624)	(1.8592)	(0.6831)
Farm Sale	0.1301**	0.0987	0.0839	0.0119	0.0119+	0.1440**
	(0.0345)	(0.1551)	(0.0587)	(0.0495)	(0.0650)	(0.0460)
Off-farm income	-0.0476	-07628*	-0,0332	0.0431	-0.0965	-0.0260
	(0.0578)	(0.3256)	(0.2940)	(0.0602)	(0.1028)	(0.0687)
Debt	0.3373*	-0.0405	0.1707	0.1300	0.8580**	0.4933**
	(0.0836)	(0.2592)	(0.1829)	(0.1031)	(0.1970)	(0.1114)
Compost	-0.2784	0.2341	0.4580	0.4778*	-1.1792*	-0.2701
	(0.2168)	(0.5963)	(0.4333)	(0.2079)	(0.5889)	(0.3038)
Variety	-2.4713*	3.6465	-2.8247	1.4592+	-5.9408*	-1.8770
	(1.0103)	(3.0034)	(2.9695)	(0.8804)	(2.7616)	(1.4121)
P of N	-38.7506*	-214.7063+	-59.2747*	-21.8396*	-29.1614	-31.7227+
	(13.4758)	(125.6332)	(27.9971)	(10.7102)	(31.4442)	(16.4952)
P of P	-9.3471	59.2578	-9.2744	-0.4646	-17.8224	-8.5202
	(6.7974)	(80.0654)	(14.3659)	(11.6925	(12.2055)	(9.1035)
P of K	-0.9977	8.2093	-4.2152	-8.3828	-8.4543	2.9454
	(1.4608)	(8.0642)	(24.5887)	(16.4546)	(31.1859)	(19.4359)
$\bar{R}^2$	0.5815	0.7336	0.6151	0.7514	0.6266	0.5984
F	22.8744**	5.2036**	6.8041**	15.1620**	10.6286**	16.6073**

Note: ** significant at 1 percent; * significant at 5 percent; + significant at 10 percent; ( ) standard error.

Table V-14.--Estimated statistics of the demand relationships for mixed fertilizer per acre, sample farms 1972, Korea.

	Nation	Upland region	Single cropping region	Double cropping region		
				West	East	Combined
Observation	300	30	70	90	110	200
Intercept	6.9782	22.6020	3.5296	2.6766	12.4651	7.4971
	(1.3809)	(6.2252)	(4.4640)	(1.8639)	(2.3573)	(1.5664)
Purchasing cost	0.3336*	0.5907**	3.2423	0.4127	-0.1788	-0.0637
	(0.1113)	(0.1504)	(3.2144)	(0.3996)	(0.2106)	(0.1739)
Labor/acre	0.0028	2.0041	0.0196	0.0071	-0.0047	0.0007
	(0.0083)	(0.0308)	(0.0380)	(0.0137)	(0.0110)	(0.0088)
Age	0.0029	0.5277+	-0.0305	0.3349+	0.0705	-0.0278
	(0.1103)	(0.3149)	(0.2236)	(0.1994)	(0.1700)	(0.1376)
Experience	-0.0045	-0.0033	-0.0181	-0.0538*	-0.0225	-0.0081
	(0.0109)	(0.0279)	(0.0209)	(0.0211)	(0.0186)	(0.0144)
Education	-0.0255	0.1621	-0.3033	-0.1091	-0.1050	-0.0020
	(0.1238)	(0.2147)	(0.2225)	(0.2123)	(0.2186)	(0.1670)
Training	0.0000	0.3389*	0.0014	0.0194	0.0086	0.0093
	(0.0048)	(0.1521)	(0.0051)	(0.0206)	(0.0416)	(0.0210)
Total land	-0.0029+	0.0081	0.0257+	-0.0017	-0.0036	-0.0027
	(0.0017)	(0.0097)	(0.0133)	(0.0025)	(0.0025)	(0.0018)
Cropping ratio	1.6923**	-1.6505	7.0907**	1.4890**	0.3705	1.1241**
	(0.2709)	(1.4063)	(1.3004)	(0.4910)	(0.3908)	(0.3190)
Paddy ratio	-0.9879+	-3.1720*	-1.2233	1.5730+	-4.4524**	-1.3681+
	(0.5249)	(1.4012)	(1.2088)	(0.8436)	(0.9955)	(0.1739)
Orchard ratio	-0.7269	-6.5807*	-4.7304	0.5163	-3.8800*	-1.1206
	(1.0483)	(2.9129)	(5.7547)	(1.7456)	(1.4947)	(1.1472)
Irrigation ratio	0.2747	1.2979	0.1314	-0.2996	1.4011*	0.3334
	(0.2498)	(1.2966)	(0.3050)	(0.4671)	(0.6850)	(0.4300)
Rental ratio	-0.1118	3.2307**	-0.3714	-0.6027	-1.2431	-0.0447
	(0.4318)	(0.9051)	(0.9944)	(0.5464)	(1.0078)	(0.5480)
Farm sale/ acre	0.0270	0.0687	0.0593	-0.0294	0.0271	0.0225
	(0.0190)	(0.0710)	(0.0609)	(0.0312)	(0.0256)	(0.0207)
Off-farm income/acre	0.0019	-1.0558**	-0.0258	0.0445	-0.0235	0.0038
	(0.0150)	(0.2950)	(0.2549)	(0.0316)	(0.0160)	(0.0149)
Debt/acre	0.0552	0.5413+	-0.0858	0.2187**	0.1959	0.1025
	(0.0588)	(0.2791)	(0.1963)	(0.0652)	(0.1645)	(0.0668)
Compost/ acre	0.0550	0.1799	0.1136	0.2244	-0.0181	0.0863
	(0.1051)	(0.3234)	(0.3367)	(0.1677)	(0.1572)	(0.1171)
Variety/ acre	-0.1487	-1.2579	-2.8552	0.7698	-0.6480	0.3007
	(0.6434)	(2.3147)	(3.0193)	(0.7923)	(1.0810)	(0.7151)
P of N	-0.8792**	-3.5856*	-1.2374+	-0.7531*	-0.6950+	-0.6272*
	(0.2274)	(1.5139)	(0.7241)	(0.2951)	(0.3766)	(0.2429)
P of P	-0.2005+	-0.3822	-0.1474	0.0953	-0.3777+	-0.1353
	(0.1184)	(0.0957)	(0.3894)	(0.2944)	(0.1995)	(0.1414)
P of K	-0.0229	0.0271	-0.2489	0.0453	0.5053	0.2454
	(0.0246)	(0.0992)	(0.6499)	(0.4172)	(0.3670)	(0.2833)
$\bar{R}^2$	0.2189	0.7722	0.4035	0.3829	0.2889	0.1388
F	5.1897**	5.9173**	3.3338**	3.7620**	3.2148**	2.6038*

Note: ** significant at 1 percent; * significant at 5 percent; + significant at 10 percent; ( ) standard error.

balanced fertilization of three plant nutrients. It is observed that some farmers complain about unnecessary amount of mixed fertilizer which has to be bought in order to buy straight nitrogen of urea. There are some possibility that farmers buying large quantity of urea have to transport mixed fertilizer with high cost. This is true especially in the upland region where road conditions are poor due to mountainous topography, and of which coefficients of purchasing cost of mixed fertilizer are positive and statistically significant in both the per farm and per acre functions. The statistically significant relationships between the purchasing costs of straight phosphate and potash can not be found except negative coefficients of the purchasing cost of straight phosphate in national and the east double cropping regional demand function for mixed fertilizer, which is statistically significant at the 10 percent level.

The negative coefficients of paddy acre and ratio in the demand relationship for mixed fertilizer per farm and per acre imply that mixed fertilizer is most likely to be used on upland crops. This result is true in regions where upland is a dominant cropping pattern and is used more intensively--the upland region and the east double cropping region as shown in table V-14. The other results are similar with those of the total fertilizer model.

vi. Elasticity considerations.

The coefficients of the linear equations will differ according to scale of measurement for both dependent and independent variables. To compare the response in fertilizer use to changes in each variable between models and between regions, the elasticity is more meaningful concept than linear coefficients. But the elasticity concept has limitations to be applied to the variables to which an arbitrary scale value is given and in which percentage change has no meaning, such as level and strata variables.

Demand elasticities of total and individual nutrient fertilizer with respect to the selected independent variables are calculated at mean values as shown in table V-15. The independent variables selected have statistically significant and/or consistent coefficients through all functions.

The elasticities of the demand for total fertilizer per acre with respect to purchasing cost are about the same as those per acre in the same region. They are most elastic in the single cropping region, implying that the demand for output is most elastic among regions because there is a big city of Seoul in that region. This is true for the demand for potash. The purchasing cost elasticities of demand for nitrogen is most elastic in the west double cropping region. The possible explanation for this result may be that farmers in this region purchase large quantities of nitrogen for rice cultivation so that purchasing cost of nitrogen is the largest proportion

Table V-15.--Elasticities of demand for fertilizers with respect to selected independent variables at mean values, calculated from table V-5 to V-14

	Per farm				Per acre			
	Price	Cropping acre	Farm sale	Price of N	Price	Cropping ratio	Farm sale/ acre	Price of N
Total fertilizer								
Nation	-.939	.784	.093		-.702	.574	.027*	
Upland	-1.098*	.599	.100*		-1.104*	.566*	.120*	
Single	-1.654	1.027	.125		-1.838	1.573	.017*	
Double	-.853	.763	.089		-.511	.391	.033	
West	-1.404	.570	.073*		-1.701	.696	***	
East	-.772	.746	.054*		-.382	.282	.040*	
Nitrogen								
Nation	-.317	.759	.053		-.361	.599	.026	
Upland	-.071*	.668	.089*		-1.195*	.069*	.059*	
Single	-.117*	.730	.112		**	1.190	.066	
Double	-.459	.801	.033*		-.388	.435	.017*	
West	-.818	.054	.075		-1.058	.552	.022*	
East	-.443*	.824	.019*		-.061*	.381	***	
Phosphate								
Nation	**	.875	.190		**	.492	.039*	
Upland	**	.885*	.018*		**	.816*	.125*	
Single	**	1.756	.111*		**	2.074	***	
Double	-.093*	.812	.235		**	.309	.061	
West	**	.286	.095*		**	.434	.008*	
East	-.201*	.928	.200		**	.056*	.069*	

- continued -

Table V-15.--(continued)

	Per farm				Per acre			
	Price	Cropping acre	Farm sale	Price of N	Price	Cropping ratio	Farm sale/ acre	Price of N
Potash								
Nation	-.048*	.765	.153		-.062*	.581	.047*	
Upland	-.030*	.879	.471*		-.027*	1.361*	.547	
Single	-1.954	1.079	.341		-2.441	1.501*	***	
Double	-.981	.729	.092*		-1.157	.470	.062*	
West	-1.213	.603	***		-1.232	.377*	.070*	
East	-.804*	.534	.049*		-.933	.382*	.060*	
Mixed fertilizer								
Nation	**	.920	.175	-1.594	****	.615	.036*	-1.354
Upland	****	1.022	.177*	-10.928	****	.772*	.126*	-9.138
Single	**	1.720	.111*	-2.655	**	2.220	.070*	-2.000
Double	-.082*	.911	.188	-1.237	-.070*	.418	.030*	-.898
West	**	.960	.014*	-.965	**	.574	***	-.999
East	-.050*	.466	.162	-1.122*	-.180*	.134*	.038*	-.935

Note: * Calculated from statistically insignificant coefficient.
** Positive insignificant coefficient.
*** Negative insignificant coefficient.
**** Positive significant coefficient.

of total production cost among regions. The cross-elasticities of demand for mixed fertilizer are elastic in national, upland and single cropping regional demand functions and most elastic in the upland region, saying that mountainous topography makes farmers in this region very responsive to increases in transportation costs.

The cross-elasticities of demand for fertilizer per farm with respect to cropping acre are very stable across the nutrients, ranging from .8 to .9, and those per acre also stable, ranging from .5 to .6. The single cropping region has the most elastic demand for every fertilizer with respect to cropping acre and ratio. This cross-elasticity greater than 1 implies that large farmers use land more intensively and apply more fertilizer per acre.

The cross-elasticities of demand for total and various nutrients with respect to farm sale are very inelastic and most of them are calculated from statistically insignificant coefficients of regression. This implies that most of farms in most regions have little cost constraints to buy fertilizer for farming.

6. Summary

The farm is a basic unit of decision making on the purchases of fertilizer to be used for its production. The farm demand is aggregated to arrive at total demand for all and individual nutrients at both the national and regional level.

To eliminate possible multi-collinearity between variables related to land and to understand effects of various variables on intensive use of fertilizer per acre, the demand functions for all and individual nutrients per acre are estimated. The introduced economic, demographic, environmental and technological characteristics of each farm which could influence the purchasing pattern of fertilizer per farm have similar effect on intensity of fertilizer use per acre.

Regional demand functions show the differences in the effect of various variables incorporated among regions. Korea is divided into four regions according to cropping pattern, urban development and administrative networks--the upland, single cropping, and west and east double cropping regions. The results obtained in this study are summarized on the basis of each variable considered except that of the straight nutrient models because of the statistically insignificant regression equations fitted and similarity.

1. The purchasing costs at farmgate reflect mostly the variation in transportation costs of fertilizer from a unit cooperative pickup point to the farmgate and in credit costs. Purchasing cost has a significant negative effect on the purchase of total, nitrogen and potash fertilizer, and their elasticities are greater than 1.0. The demands for total and potash fertilizer are most elastic in the single cropping region where the biggest city in Korea is located partly due

to a likely elastic demand for agricultural output in this region. The demand for nitrogen is most elastic in the west double cropping region where large nitrogen compared with other inputs is purchased for rice cultivation. Their significant influence on purchase of phosphate and mixed fertilizer can not be due to the complimentarity of these fertilizers with nitrogen and/or due to the small portion of their expenditures to total expenditures for fertilizer.

2. The complimentary relationship between mixed fertilizer and straight nitrogen was observed. This implies that farmers purchase mixed fertilizer as a main source of P_2O_5 and K_2O, and that sufficient quantity of straight P_2O_5 and K_2O fertilizer might not be available to purchase. The political emphasis on balanced fertilization encourages the complementary relationship. High cross-elasticity between quantity purchased of mixed fertilizer and the purchasing cost of straight nitrogen in the upland region where mountainous topography incurs high transportation costs also indicates the balanced fertilization policy.

3. The labor input, measured as total family working days including yearly employed labor, has a statistically insignificant effect on the purchase of commercial fertilizer. But there are indications of positive effects, implying that labor is a possible complement for commercial fertilizer in crop production. The effect of the compost used is not significant.

4. Cropping acreage and its ratio to total land are positively related to the purchase of fertilizer per farm and per acre. The paddy acre and its ratio to total land are positively related to use of nitrogen and are negatively related to use of phosphate, potash and mixed fertilizer, implying that rice cultivation on paddy field requires more nitrogen. These results are true between regions. Their effects are positive in the regions where paddy is the dominant cropping pattern and negative in the region where upland is dominant or is used more intensively than paddy land. The large farms have trend to use fertilizer less intensively.

Orchard and mulberry acres and their ratio influence negatively the use of fertilizer per farm and per acre. This is true in all regions.

5. The gross farm sale measured as cost constraint is positively related to purchase of commercial fertilizer but has insignificant effect for most of nutrients and regions, implying that farmers have little cost constraint in buying fertilizer.

The off-farm income and debt as other possible variables representing the cash expenditure constraint on the purchase of fertilizer have negative and positive effects in all the models and in most regions. The poor farm needs income outside farming to support family and cannot get credit while the larger farm has the ability to carry debt for his farm operation.

6. The farmers having large rental acre and ratio use less fertilizer per farm and per acre. This fact is also true in every region except in the upland region where positive relationships between the tenant variable and the purchase of total and individual nutrients are observed. Possible effect of this factor depends on the tenant arrangement. If the farmer pays fixed amount of rent and share production costs with landlord, he can use more fertilizer per farm and per acre than other farmers do.

7. As a technological change variable the new variety of rice has an insignificant effect on the purchase of fertilizer in all models and in all regions except in the upland region. If the landlords share production cost, they may force their tenants to adopt the new variety so that the farmers can use more fertilizer on the new variety of rice.

The farmers having more irrigated land use more fertilizer, especially nitrogen nutrients. This result is supported by the fact that rice required more nitrogen nutrient when grown on irrigated paddy field.

8. As the demographic variables which influence the sociological factors of awareness, attitude and motivation to make a purchase decision by operator of the farm, age, farming experience, formal education level and training of farm operator are indicated to be positively related to the purchases of fertilizer but its effect is not found to be statistically significant.

9. The estimated demand functions for fertilizer per farm have higher coefficients of determination adjusted for degree of freedom ($\bar{R}^2$) and higher F-value than the demand functions for fertilizer per acre do in every model and in all regions. This implies that the per farm demand functions possess more power for prediction, considering stable estimated results in both demand functions for fertilizer per farm and per acre.

CHAPTER VI

PROJECTION OF THE DEMAND FOR FERTILIZER

1. Introduction

These projections provide a guideline for decision making by persons or organizations involved with the production and marketing of fertilizer. Estimated demand functions can be used to predict the future demand for fertilizer if the exogeneous variables incorporated into the demand functions are valued at a given future time. The quantity demanded of fertilizer in the future will vary according to the predicting power of the estimated functions, the stability of the relationships identified, and the validity of predicted values of the exogeneous variables under different assumptuons. The results of the three analyses employed are used to predict the quantity demanded of fertilizer to show possible ranges and to provide for a comparative examination of the predicted results.

The aggregate demand functions estimated from the time-series data provide predictions of quantities demanded of total and individual nutrients at the national level. The farm demand functions estimated from the survey data are used to project the demand for total and individual nutrients at both national and regional levels. The optimum fertilization rates are aggregated to provide the future needs for total and individual nutrients at national and regional levels. The projections of fertilizer use are made for the three years of 1975, 1980 and 1985.

Section 2 of this chapter presents the projection procedures and the specification of the variables used for the projection. The projected values of the variables used and the corresponding assumptions and data sources are presented in Section 3. Section 4 presents the projected results and a comparative examination of the results projected by three analyses. These results are compared with other projection results made by different agents or organizations in Section 5. Finally, Section 5 also summarizes the results of this chapter.

2. Projection Model

The estimated results of three analyses of demand for fertilizer are utilized in the projection. The variables employed in these studies are grouped into several categories according to their characteristics: economic (E), sociological (S), financial (F), technological (T), environmental (V), and policy (P) variables.

The prices or quantities of inputs and output such as prices of total and individual nutrients, wages, prices of machines, prices received by farmers, family labor used, compost, and total land are included in the economic variables. All of these variables are likely to change in the near future except total land. They are closely related to pricing policies.

The sociological variables include age, formal education, farming experience and training of farm operator affecting his manageability. These are expected to be constant over a short period of time.

The financial variables include gross farm sale, debt and non-farm income as the cost constraints to purchasing fertilizer. These variables are expected to be increased along with development of overall economy.

Development of new variety (IR-667), irrigation and/or time are included in the technological variables and are likely to be influenced by the other variables. These are expected to be steadily increased with upper limit over time.

The environmental variables include cropping acres, paddy acres, orchard and mulberry acres, all of which are largely determined by agro-climate conditions, rental acres and regional factors. The regional factors are accounted for in the regional demand functions estimated separately. Policies regarding prices, production, marketing, income and employment can influence all the variables mentioned above.

Therefore the projection is made in the functions form of

$$Q_{F_i}^{FD} = F(E, S, F, T, V, P)$$

where i represents total and individual nutrients at national and regional levels in three analyses, and comma between variables means and/or. In projection of demand based on the aggregated demand functions estimated from time-series data, the economic and technological variables are utilized. An assumption is made that other variables remain constant over time and/or are reflected into the variables considered. The aggregate demand

functions have weaknesses in projection in that only a few yearly observations are available. Thus, the non-statistical error might be great and multi-collinearity between independent variable due to the trend of these variables over time could distort the econometric analysis by providing unstable estimates.

All the variables included in the projection function are utilized to project demand for fertilizer based on the farm demand functions estimated from the farm survey data. This projection might be subject to the aggregation bias. The assumption that each farmer faces perfectly competitive input and output market may be invalid in the aggregate sense.

The projection of fertilizer requirements based on the optimum rates of fertilization uses some of economic, technological and environmental variables such as price of fertilizers and crops, technological change and cropping acre of crops. This projection is underestimated because the effects of technological change for the optimum rates of fertilization are reflected only for rice due to data limitations.

3. Projected Exogeneous Variables.

The projected values of economic variables in 1975, 1980 and 1985 are presented in table VI-1 and table VI-2.

The real price indices of total fertilizer nutrients, nitrogen, phosphate and potash, farm wage, price index of machine and index of price received by farm are predicted by the

trend from 1959 to 1971. The real price indices are made by dividing linear projected indices of these variables by the projected wholesale price index.

The differences in the purchasing costs among farmers are mostly reflected by differences in transportation costs from county crop distribution point to farmgate. The possible improvements of feeder road conditions and transportation facilities of farmers attribute to reduce transportation costs but the increase in wage is assumed to offset the reduction of the costs. Therefore, the purchasing costs in 1975, 1980 and 1985 as shown in table VI-1 are obtained assuming that prices of total and individual nutrients have the same trend as their real price indices. The differences in the purchasing costs among regions result from the differences in regional average purchasing costs in 1972.

Family labor inputs including yearly employed labor are projected by multiplying farm employment obtained from the Korean Sector Study[1/] by the assumed annual labor days of 175 days. This family labor projection might be overestimated because of the assumption that all hired labor is employed on annual basis.

Compost is projected for only animal manure which is obtained by multiplying trend projection of number of important livestock

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1/ Korean Agricultural Sector Study Team, Korean Agricultural Sector Analysis and Recommended Development Strategies 1971-1985, East Lansing, Michigan, 1972. All the quoted data are under Alternative I which bases on the Third Five-Year Economic Development Plan of Korea.

Table VI-1.--Projection of real prices of fertilizers and farm machines, farm wages and price received by farm, 1975, 1980 and 1985, Korea

	1975	1980	1985
		(1965 = 100)	
Total fertilizer	64.2	61.1	59.3
Nitrogen	62.8	59.2	56.9
Phosphate	67.5	66.6	65.9
Potash	66.7	65.0	64.0
Farm wage	205.3	246.6	287.9
Price of machine	111.0	111.4	111.8
Price received by farm	128.1	131.3	133.4
Purchasing costs			
Nation		(Won/Kg. at 1972 price)	
Total fertilizer	46.2	40.8	35.4
N	51.9	46.6	39.2
P	44.8	41.0	36.3
K	28.1	25.4	22.3
Upland			
Total	46.2	40.8	35.4
N	51.5	45.2	38.9
P	42.3	38.7	34.2
K	36.2	31.8	26.8
Single			
Total	45.7	40.3	35.0
N	51.6	45.4	39.0
P	45.6	41.7	36.9
K	26.5	23.8	21.0
Double			
Total	46.4	40.9	35.5
N	52.1	45.8	40.0
P	44.9	41.1	36.3
K	25.9	23.4	20.6

by the 'manure coefficients' which mean amounts of manure, ready for field application, produced per head by farm animal in a year, excluding that voided while the animals were in the yard or at work. The manure coefficients are taken from U.S. figures.[2/]

Draft cattle, dairy cattle, beef cattle, horse, hog, sheep and chicken are assumed to produce manure of 6.0, 6.6, 6.0, 6.0, 1.7, 0.75 and 0.01 tons annually, respectively.

Projections of number of farm households, total arable land and rental acre shown in table VI-2 are made by trend from 1962 to 1971. Rental acre by region is not available so that national average per farm is used for regional fertilizer demand projections.

Among sociological variables average age and the farming experience of farm operators are assumed to increase by one year every five years due to an off-farm migration of the younger generation in rural areas. They are an average of 41 and 23 years in 1972. The formal education levels of farm operators can be expected to be steadily increased. It is assumed that the average education level of elementary school remains the same until 1975 and the one-quarter of total farm operators has junior high school education every five years after 1975. In the single cropping region a half of the farmers finished junior high school and the other half finished elementary school on the average in 1972. Number of days farmers attended training and workshop is different among regions but it is assumed that the number of days

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[2/] Morrison, F. B., Feed and Feeding, Morrison Publishing Company, New York, 1962, pp. 564-573.

Table VI-2.--Projection of family labor, compost, farm households and total arable land 1975, 1980, and 1985 Korea

	1975	1980	1985
Family labor		(million man-days)	
Upland	134.8	124.3	87.5
Single	197.8	182.0	129.5
Double	565.3	521.5	367.5
Total	897.8	827.8	584.5
Animal manure		(1,000 M/T)	
Upland	1,920	1,866	1,814
Single	1,930	1,985	2,042
Double	5,472	5,317	5,163
Total	9,311	9,168	9,020
Farm household		(1,000 household)	
Upland	394	345	307
Single	582	509	451
Double	1,662	1,450	1,228
Total	2,638	2,304	2,042
Total arable land		(1,000 hectare)	
Upland	325	320	315
Single	565	555	548
Double	1,254	1,230	1,213
Total	2,144	2,106	2,077
Rental acre		(Pyung/farm)	
Nation	536	548	559

be the same in 1975 and that it be twice in 1980 and triple in 1985 as much as that of 1972.

Projections of financial variables are shown in table VI-3. The proportion of gross cash farming income relative to gross agricultural income per farm which includes non-farm income is projected by its trend from 1962 to 1971. These proportions are 34 percent in 1975, 37 percent in 1980 and 40 percent in 1985 and is utilized to arrive at cash farm sale from gross agricultural income projected by Korean Agricultural Sector study. The projected proportions of off-farm income relative to gross agricultural income per farm using its trend of 1962 to 1971 are 22 percent in 1975, 23 percent in 1980 and 24 percent in 1985. Multiplying gross agricultural income by the trend value of off-farm income proportions results in a projected increase of gross off-farm income. The proportion of farm liabilities relative to gross agricultural income per farm was stable, having range of 5 to 6 percent during 1962 to 1971 period. The poor farms have to end up with liabilities while the rich farms are able to bear debt needed to their farming. Increase in farm income over time is assumed to offset a decreasing trend in liabilities for poor farms by increasing trend in credit for rich farms. Therefore it is assumed that the proportion of debt to gross agricultural income will remain at the same level of 5 percent during the projection period. The regional data on the financial variables of gross farm sales, off-farm income and farm debt are not available

over time. National average proportions of these variables have to be used in estimating regional financial variables.

Table VI-3.--Projection of financial variables 1975, 1980 and 1985, Korea

	1975	1980	1985
	(Billion Won)		
Gross farm sale	349	426	547
Upland	48	60	78
Single	85	104	134
Double	217	262	335
Off-farm income	225	264	328
Upland	31	37	46
Single	54	65	80
Double	140	163	201
Debt	51	58	69
Upland	7	8	10
Single	13	14	17
Double	32	36	42

As to technological variables, the average ratio of irrigated paddy to total paddy field was 70 percent in 1970 and is assumed to be 75 percent in 1975, 80 percent in 1980 and 85 percent in 1985. The projected rice cultivated acres by Korean Agricultural Sector Study are multiplied by well irrigated paddy ratio to obtain irrigated land acreage. A decreasing trend in rice cultivated acres seems to take account of the conversion of some rain-paddy fields into upland type. This implies that the 85 percent of irrigated paddy ratio can not be said to be overestimated. The new rice variety of IR-667 (Tongil) was planted on about 250 thousand

hectares in 1972 as estimated by the farm survey results. The suitable land for IR-667 is estimated to be 300 thousand hectares and assumed to be fully cultivated during the projection period.

Among environmental variables reflecting agro-climate conditions and regional factors cropping acreages, totally and by crop, are obtained from the Korean Agricultural Sector Study as shown in table IV-4. All of these data are used to project the fertilizer requirements based on the optimum rates of fertilization but total rice, fruit and mulberry cropping acres are utilized to estimate the future demand for total and individual nutrients at both national and regional levels. The regional factors are reflected in the regional demand functions estimated separately. The policies regarding the variables used are assumed to make the same efforts during the projection period as did in the past in order to make the trend projection of many variables reasonable.

4. Projected Results

Time Series Projection. The actual quantities of fertilizers consumed in 1971 and conditional projections of demand for fertilizers based on the aggregated demand functions are presented in table VI-5. The quantities demanded of total fertilizer are 701, 882 and 1,053 thousand metric tons in 1975, 1980 and 1985 respectively by linear equation estimated. The sums of quantities projected of individual nutrients are 717, 880 and 1,044 thousand metric tons in 1975, 1980 and 1985 respectively. These quantities demanded result in increases by 17, 46 and 75 percents compared with actual consumption of

Table VI-4.--Projections of land allocation by crops, 1975, 1980 and 1985, Korea Unit: 1,000 hectare

Crops	1975				1980				1985			
	Single	Double	Upland	Total	Single	Double	Upland	Total	Single	Double	Upland	Total
Rice	339	724	127	1,190	333	711	125	1,169	329	701	123	1,153
Barley	133	712	94	939	135	722	95	952	135	739	98	975
Wheat	33	05	28	166	33	102	27	162	32	100	26	158
Other grains	9	50	48	107	6	32	30	68	3	16	16	35
Fruit	25	46	12	83	31	59	15	105	37	71	18	126
Pulses	112	179	88	379	114	181	90	385	150	183	91	424
Vegetables	100	171	47	318	113	194	53	360	123	210	57	390
Potatoes	32	160	55	247	36	178	61	275	39	198	68	305
Tobacco	8	28	16	52	9	33	18	60	10	38	21	69
Mulberry	15	70	28	113	18	82	32	132	14	88	36	138
Industrial crops	12	58	18	88	14	64	20	98	15	68	21	104
TOTAL	818	2,303	561	3,682	842	2,358	566	3,766	890	2,412	575	3,897

Source: Korean Agricultural Sector Study Team; Korean Agricultural Sector Analysis and Recommended Development Strategies 1971 - 1985, 1972

fertilizer in 1971. Among increase in quantities demanded of 345 thousand metric tons from 1975 to 1985, 60 percent comes from time (technological change), 34 percent from increase in wages, 3 percent from increase in cropping acres, and 1 percent from decrease in price of fertilizer.

Among total fertilizer projected, nitrogen occupies 56, 55 and 55 percents, phosphate 25, 24 and 23 percents, potash 19, 21 and 22 percents in 1975, 1980 and 1985 respectively. The projection of regional demand for fertilizer is not available from the time-series data. The quantities demanded of total fertilizer are projected as 668, 969 and 1,390 thousand metric tons for 1975, 1980 and 1985 respectively by linear in logarithmic equation as shown in total (2) in table VI-5.

Requirement projection. The fertilizer requirements at national and regional levels are calculated based on the optimum rates of fertilization as shown in table IV-6 and IV-10.

The requirements are 1,473, 621, 435 and 416 thousand metric tons of total, nitrogen, phosphate and potash nutrients in 1985.

Among national requirements of total fertilizer, 15 percent goes to the upland region, 23 percent to the single cropping region and 63 percent to the double-cropping region in all the projection years. These proportions are similar for individual nutrients, implying that cropping patterns among regions won't be drastically changed in the projection period. About 40 percent of national requirements of total fertilizer acccunts for nitrogen, 31 percent

Table VI-5.--Projection of fertilizer use in 1975, 1980, and 1985 based on aggregate demand functions and the optimum rate of fertilization

		1971 Actual date	Aggregate demand (time series analysis)			Potential demand (experiment data analysis)		
			1975	1980	1985	1975	1980	1985
		(M/T)	---(1,000 M/T)----			----(1,000 M/T)-----		
Nation	Total(1)	605,137	709	882	1,053	1,295	1,364	1,473
	N	347,318	401	486	576	504	540	621
	P	165,030	177	212	242	406	423	435
	K	92,789	139	182	226	385	401	416
	$\sum$		717	880	1,044			
	Total(2)		668	969	1,390			
Upland	Total	97,481				190	197	225
	N	56,165		Not available		72	75	99
	P	25,301				59	61	62
	K	16,015				59	61	61
Single	Total	137,958				301	320	335
	N	81,679		Not available		117	127	134
	P	35,529				94	99	102
	K	20,750				90	94	98
Double	Total	369,798				803	846	913
	N	209,474		Not available		315	337	388
	P	104,200				253	263	270
	K	56,024				235	246	254

for phosphate, and 29 percent for potash. These proportions of individual nutrients relative to total nutrients are not different among regions. The proportions of N, P and K are 38, 31 and 31 percent in the upland region, 40, 31 and 29 percent in the single cropping region, and 40, 31 and 29 percent in the double cropping region.

Farm survey projection. Table VI-6 shows the aggregated consumption computed from the survey data in 1972 and conditional projections based on the farm demand functions in 1975, 1980 and 1985, of total and individual nutrients at national and regional levels. The figures in parentheses are the corresponding projections consistently adjusted to total fertilizers projected by its own estimated demand function. National demand for total fertilizer will be 729 thousand metric tons in 1975, 810 thousand metric tons in 1980 and 892 thousand metric tons in 1985 as estimated by the demand function for total fertilizer itself. These increases come mostly from decrease in fertilizer price and increases in cropping acres and farm sale. The sums of regional demand projection for total fertilizer are 765, 848 and 951 thousand metric tons in 1975, 1980 and 1985 respectively. These projections result in increases by 9, 21 and 36 percent in 1975, 1980 and 1985 respectively compared to national consumption of total fertilizer computed from the survey data in 1972. Proportions of nitrogen relative to total fertilizer are decreased over time as 52 percent in 1975, 51 percent in 1980 and 48 percent in 1985. Those of phosphate remain the same level of 26 percent and

Table VI-6.--Projection of fertilizer use in 1975, 1980, and 1985 based on the farm demand functions

		Aggregated farm survey data 1972	Farm demand (farm survey analysis) 1975	1980	1985
		(M/T)	(M/T)	(M/T)	(M/T)
Nation	Total		729,165	810,313	892,271
	N		359.349	376,189	396,838
			(401,055)	(437,658)	(462,117)
	P		172,425	186,471	209,409
			(192,146)	(216,940)	(243,856)
	K		122,463	133,815	159,956
	Σ		(136,448)	(155,680)	(186,268)
			654,387	696,471	766,203
Upland	Total	83,221	105,613	120,448	131,931
	N	41,588	73,859	75,343	82,192
			(58,666)	(65,149)	(72,412)
	P	24,571	33,474	34,184	32,013
			(26,598)	(29,558)	(28,203)
	K	17,071	25,591	29,763	35,523
	Σ		(20,334)	(25,736)	(31,295)
			132,924	139,290	149,737
Single	Total	148,941	176,684	200,189	231,383
	N	80,940	80,632	83,106	92,371
			(87,919)	(95,430)	(107,199)
	P	40,400	46,558	49,046	54,721
			(50,761)	(56,313)	(63,491)
	K	27,189	34,837	42,156	52,266
	Σ		(38,005)	(48,406)	(60,645)
			162,027	174,308	199,358
Double	Total	469,097	455,392	508,895	570,454
	N	259,552	241,726	253,938	261,973
			(239,067)	(259,423)	(265,457)
	P	126,094	116,794	129,803	156,104
			(115,509)	(132,606)	(158,180)
	K	83,449	101,936	113,374	144,837
	Σ		(100,814)	(116,822)	(146,763)
			460,456	498,895	562,915
Nation	Σ Total	701,254	765,004	848,374	951,574
	Σ N	382,080	400,844	430,196	454,848
	Σ P	191,465	199,744	223,103	253,684
	Σ K	127,709	164,410	194,991	242,931

Note: Figures in parenthesis proportionally adjusted to total demand.

those of potash are increased over time with trends of 22, 23 and 26 percents in 1975, 1980 and 1985 respectively. Sixteen percent of total fertilizer goes to the upland region, 24 percent to the single cropping region and these proportions remain same over time. The regional proportions of nitrogen and potash remain the same over time with proportions of 18 and 15 percents in the upland region, 22 and 25 percents in the single cropping region, and 60 and 60 percents in the double cropping region. But the proportions of phosphate in the upland region decrease with trends of 17, 15 and 13 percents in 1975, 1980 and 1985 respectively, while those in the double-cropping region are increased as 50, 60 and 62 percent in 1975, 1980 and 1985 respectively.

Comparison of three projections. Conditional projections of three different approaches are compared in figure VI-1 and table VI-7. Figure VI-1 shows projected trend of the demand for total and individual nutrients by three approaches. The requirements of fertilizer projected by the optimum rate of fertilization are higher relative to projections by other approaches for total, phosphate and potash nutrients. Projection results of total fertilizer by the aggregate demand function and the estimated farm demand function have similar trends. Nitrogen of time-series projection is higher than that of the farm survey projection and lower than requirement of nitrogen. The quantities projected of phosphate and potash by the farm demand function are greater than those by the aggregate demand function.

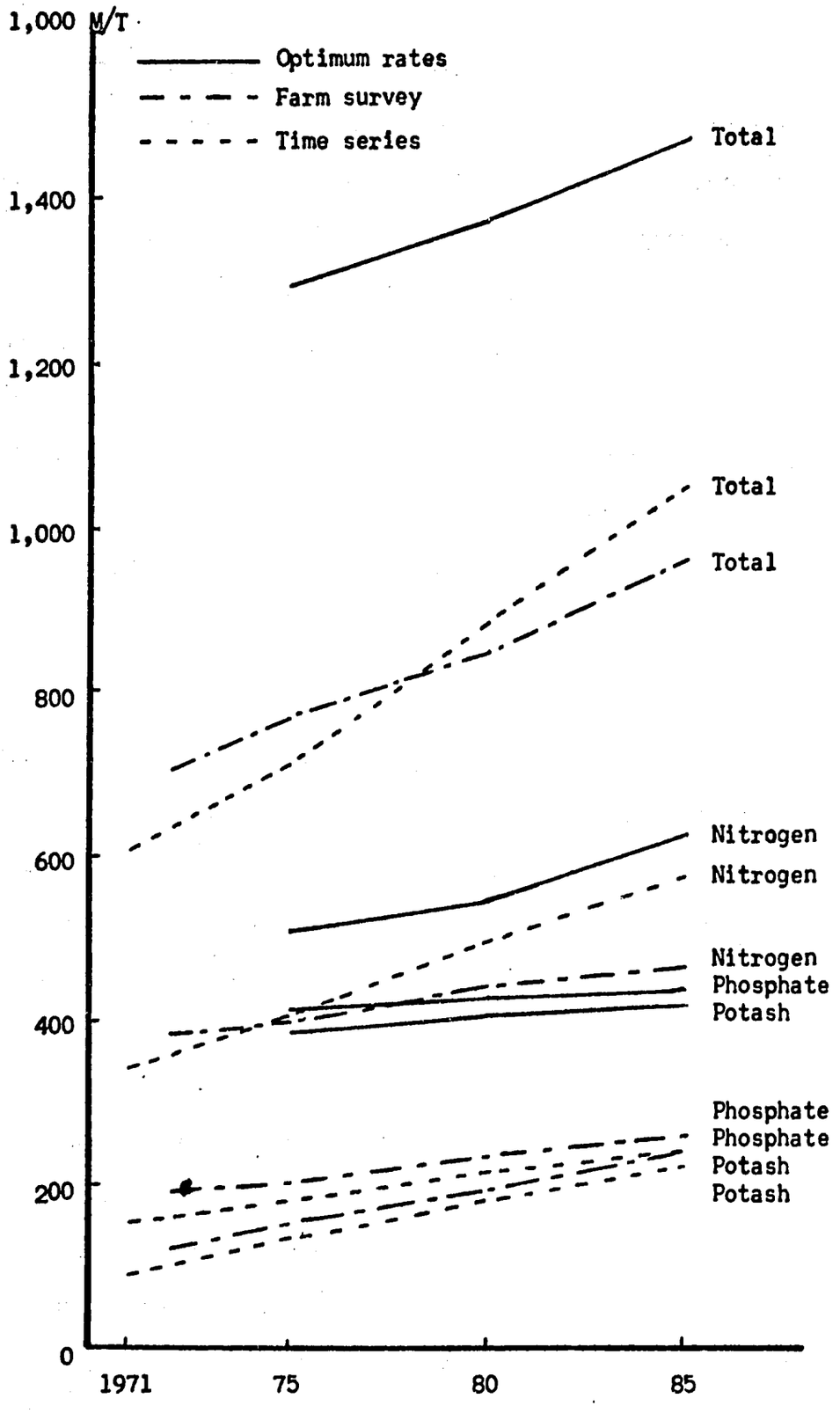

Figure VI-1. Projection of the demand for fertilizers in Korea, 1975, 1980 and 1985

The same argument can be found in table VI-7 which show the proportion of individual nutrients predicted by three approaches. The proportions of nitrogen estimated by the experimental data analysis are lower than those by other two approaches. Adverse results are observed for phosphate and potash. The proportion of nitrogen projected by time-series data analysis remains constant over time while that by the farm survey data analysis decreased. Proportion of phosphate projected is decreased in the time-series data analysis and constant in the farm survey data analysis. That of potash is increased in both analyses. Finally the conditional projection results of the farm survey analysis have tendency to approach those of the experimental data analysis.

5. Comparison With Other Studies

Haweyama[3/] estimated requirements of fertilizer in developing Asian countries in 1971 based on experiment data analysis by giving priority to input and output ratios, taking into account the possible insufficiency of the agricultural infrastructure and limiting the area proposed to be fertilized to estimated irrigated area or well rainfed area. He presented only total fertilizer requirements of 634, 884 metric tons in 1975 and 1985 respectively. These figures

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3/Haseyama, T., The Scope for Agricultural Development and Fertilizer Requirement in Developing Asian Countries, ECAFE/FAO Agricultural Division ECAFE, Bangkok, 1972. A paper read as a guest speaker at the Seminar on "Economics of Fertilizer Use," Taipei, Taiwan, June 5-15, 1972, sponsored by the Asian and Pacific Council, Food and Fertilizer Technology Center.

Table VI-7.--Proportion of individual nutrients projected by three analyses, Korea

	Time-series data analysis				Experimental data analysis			Farm survey data analysis			
	1971	1975	1980	1985	1975	1980	1985	1972	1975	1980	1985
	percent										
Nation											
N	58	56	55	55	39	40	42	55	52	51	48
P	27	25	24	23	31	31	30	27	26	26	25
K	15	19	21	22	30	29	28	18	22	23	26
Upland											
N	58	--	--	--	38	38	44	51	56	54	54
P	26	--	--	--	31	31	30	29	25	25	23
K	16	--	--	--	31	31	28	20	19	21	23
Single											
N	59	--	--	--	39	40	40	55	50	48	46
P	26	--	--	--	31	31	31	27	28	28	28
K	15	--	--	--	30	29	29	18	20	24	26
Double											
N	57	--	--	--	39	40	42	55	53	51	46
P	28	--	--	--	31	31	30	27	25	26	28
K	15	--	--	--	30	29	28	18	22	23	26

These figures are smaller than all projections of total fertilizer by three approaches in this study in the corresponding years.

The Korean Agricultural Sector Study presented total fertilizer requirements with three alternatives. For alternative I the requirements are estimated based on the optimum rates of fertilization for each crop. This is obtained from several authorities in Korea, and considers projected cropping acre and yield increases of each crop. Changes in the optimum rates of increase in yield were made by multiplying an arbitrary factor of 1.3 that considers a diminishing marginal product of fertilizer input.

For alternative II, projected yields were assumed to be increased by twice as much as that in alternative I so that the optimum rates were estimated by multiplying the optimum rates in alternative I by the arbitrary factor of 1.3 for increased yield. For alternative III, projected yields were assumed to be increased by a half as much as that in alternative I so that the optimum rates were calculated by multiplying those in alternative I by .8 for changes in yield assuming a low price of output. Projected requirements were 1.15, 1.35 and 1.61 million metric tons in 1975, 1980 and 1985 respectively for alternative I, 1.43, 1.90 and 2.26 million metric tons for alternative II, and .93, 1.03 and 1.11 million metric tons for alternative III. All of these requirements are greater than the projection of this study made by the time-series and farm survey data analyses in every year. But only the requirements for alternative III are smaller than projected requirements of our study.

made by the experimental data analysis. Their recommended requirements were 1.4, 2.0 and 2.3 million metric tons in 1975, 1980 and 1985 respectively, implying that averages of 380, 531 and 573 kilograms are used per hectare of all cropping acres. Division of Fertilizer, Ministry of Agriculture and Fishery of Korea estimated the demand for fertilizer from 1970 to 1976 by linear equation of time. Estimated demand for total fertilizer in 1975 was the same as that of 1980 projected by our time-series data analysis. In time-series data analysis the farmer used only time as explanatory variable while the latter introduced prices of input and output as well as time variable. The period concerned in both studies is the same except 1960 data are included in our study. The proportions of individual nutrients were similar in estimations. The projection results of different studies are shown in figure VI-2.

6. Summary

The conditional projections of demand for fertilizer provide guidelines for decision-making of persons or organizations involved with production and marketing of fertilizer. After all exogenous variables introduced are estimated by trend or are obtained from the Korean Agricultural Sector Study, the demand for total and individual nutrients is projected at national and regional levels by all three approaches which results are presented in the previous chapters to show the possible ranges of the demand in the future.

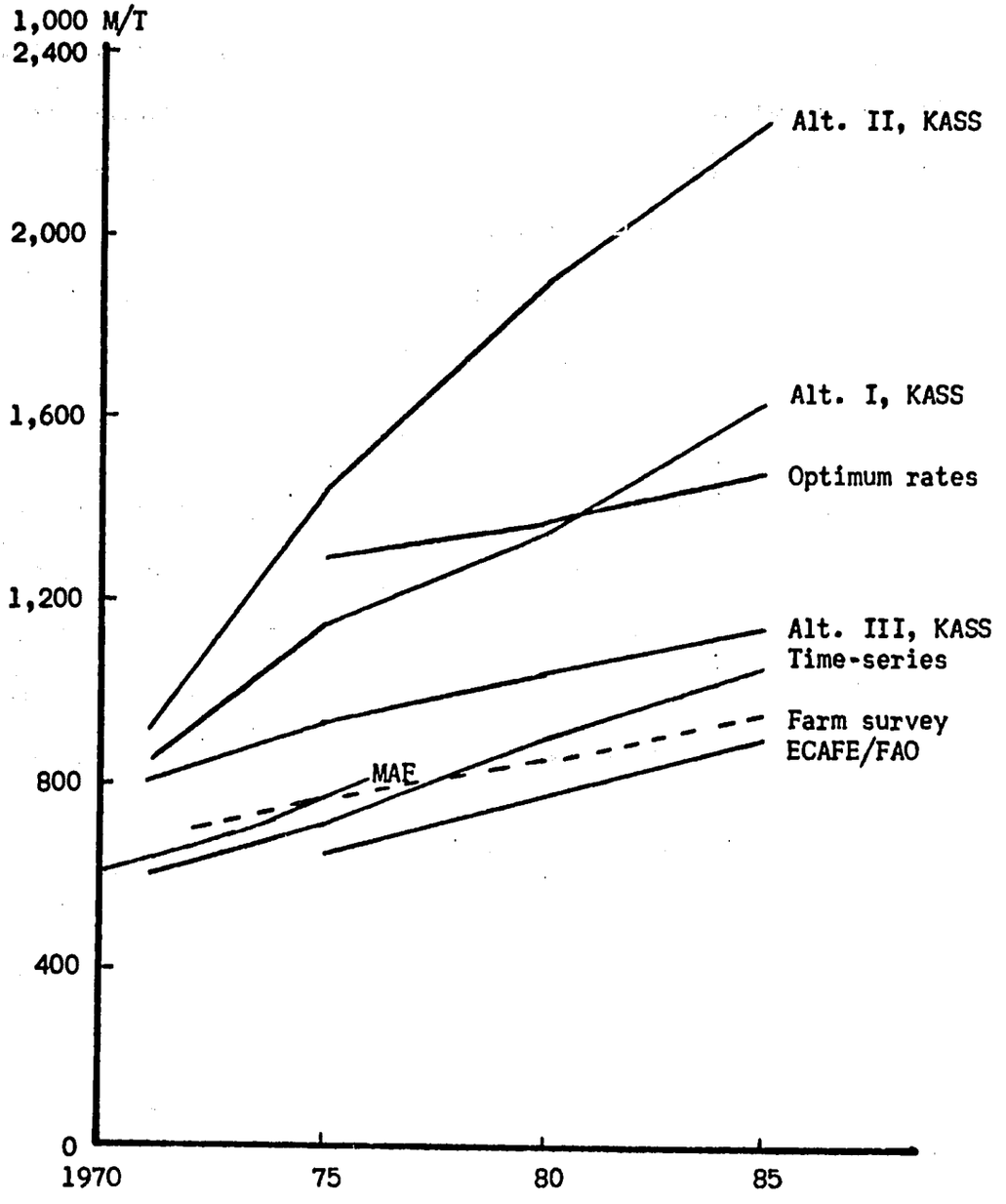

Figure VI-2. Projection of the demand for fertilizer by different studies, Korea

1. All economic variables considered are predicted by trends in the 1960's. Reasonable assumptions are made for sociological and technological variables. Financial variables are forecasted by a combination of trend estimation and from data obtained from the Korean Agricultural Sector Study while some of environmental variables are quoted from the latter. Regional factors are reflected in the regional demand functions estimated separately. The grouping of these variability of each variable, aiming at making the projection easier.

2. The projection of demand for total fertilizer by the time-series data analysis results in increase by 17, 46 and 75 percents in 1975, 1980 and 1985 respectively compared to actual consumption in 1971. Proportion of nitrogen remains constant over time, that of phosphate is decreased, and that of potash is increased.

3. Total fertilizer requirements projected by the experimental data analysis are about 1.5 million metric tons for 1985 and the proportions of individual nutrients are stable over time. The upland region needs 15 percent, the single region, 23 percent and the double cropping region, 62 percent of national requirements of total and individual nutrients.

4. The demand for total fertilizer projected by the farm survey data analysis results in increase by 9, 21 and 36 percents in 1975, 1980 and 1985 respectively, relative to farms' consumption estimated the farm survey data in 1972. The proportion of individual

nutrients are increased for nitrogen and potash and remain constant for phosphate over the projection period. About 16 percent of fertilizer projected is needed in the upland region, 24 percent in the single cropping region and 60 percent, in the double cropping region.

5. The fact that the projected results by the farm survey data analysis approaches that of fertilizer requirements implies that farmers have been educated about the effects of phosphate and potash in their farming. The proportion of nitrogen projected by the time-series analysis has tendency to be constant over the projection period while that of the farm survey data analysis has decreased. Proportion of potash has tendency to be increased over time.

6. Generally, the projected demand for fertilizer in this study falls between that of Haseyama's ECAFE/FAC, and that of Korean Agricultural Sector Study.

CHAPTER VII

SUMMARY AND CONCLUSIONS

1. Commercial fertilizer is one of the most important factors contributing to an increase in the productivity of Korean Agriculture, given its resource endowment. Yet the economic and noneconomic variables affecting the level of fertilizer use are little understood. The primary objectives of this study was to identify, quantify and analyze the factors affecting the demand for commercial fertilizer in Korea. More specific objectives include (1) to estimate aggregate and individual farmers' demand functions for fertilizer totally and by nutrients, (2) to evaluate the effects of the selected economic, sociological and environmental variables on the demand for fertilizer by farm, (3) to determine agronomic optimum rates of fertilization and (4) to forecast consumption of total and individual nutrients at both national and regional levels. Three different data are used in the analysis. One data set consists of time-series data and is used to estimate the aggregate demand for total and individual nutrients. The data is obtained from the official reports issued by Korean Government. The relevant variables introduced are based on both economic theory and the characteristics of the Korean fertilizer market. Another study uses experimental data to determine agronomic optimum levels of fertilization for various crops. The optimum levels are derived from estimated fertilizer response functions for each crop. The third

set of dat derives from a farm survey. An interview survey of 300 sample farms was conducted to obtain economic and demographic variables affecting the purchasing patterns of fertilizer by farm. The future demand for fertilizer is estimated based on pre-determined excgeneous variables obtained from the previous studies and/or from direct estimation of trend values.

2. The derived demand for an input is a function of prices of the input, substitute and complement, and output under assumption which farms maximize their profit without any capital constraints. If farmers are limited in purchases of an input by capital constraints, these constraints should be considered in the demand function. The assumptions that farmers make their decision to purchase input based on current prices and that they adjust instantaneously the quantities purchased to change in prices can be relaxed by introducing adopted expectation and adjustment models. The reduced demand function has the previous period's variables. The primary objective of individual farm operator may not be profit maximization, but maximum security for his family. Demographic and sociological factors can effect the use of inputs. Technological change in both input industry and agriculture tends to have a gradual influence on the demand for inputs over time. National price policies are important factors which determine the interdependency of supply of and demand for the input. Automistic farm and government control for price of the input may exclude the possibility of this interdependency.

Different sets of variables are used for different analysis: economic and technological variables for time-series analysis, and in addition sociological variables for farm survey analysis, according to characteristics of cross-sectional analysis.

3. In the time-series analysis demand functions of total and individual nutrients are estimated using prices of total and individual nutrients, wage rate, machine price, cropping acres and technological change as explanatory variables from 1960 to 1972 on an annual basis. All prices are constant at 1965. Linear and linear in logarithm equations are estimated under both assumptions of instantaneous quantity adjustment and that the quantity adjustment takes place over time.

(1) Prices of fertilizer do not have significant coefficients in the demand relationships of total and nitrogen nutrients mainly due to little variation in it, but have significantly negative effect on the use of phosphate and potash. Prices of output measured as the price index received by farm are insignificantly related to use of total nitrogen and potash nutrients, and positively related to use of phosphate. These results imply that nitrogen occupies a large proportion of total fertilizer and might have been overutilized relative to its requirements. An increase in farmers' awareness about the effects of phosphate and potash on their crop due to increasing effort of extension and field demonstration

mainly contributes to significant effects of prices on uses of them. Poor market information system and subsistence farming are partly related to the insignificant price responses.

(2) The substitutability of fertilizer for labor is observed in nitrogen but not in phosphate and potash. The fact that the self-supplied manure contains mostly nitrogen nutrients may explain that the increase in farm wage induces substitutions of commercial nitrogen for labor. None of significant effects of farm machinery price are found in any of the nutrient models.

(3) An insignificant positive relationship between uses of total and individual nutrients and planting acre are observed. The positive relationships are expected but small variance in the planting acre results in this insignificance.

(4) Because of a constant trend of the seed improvement index and because of the same results for irrigation acre with that of time, a time variable is used as technological change variable with limitations of multicolinearity between other explanatory variables due to trends of them over time and with assumption of constant rate of technological change. Large increasing trends in use of fertilizer are observed, especially in the uses of phosphate and potash. Awareness of farmers about the effectiveness

of these nutrients as well as the government's encouragement of balanced fertilization contribute greatly to these trend increases. The quantity adjustment is about 20 percent in one year to a change in real price of fertilizer.

4. In the experimental data analysis the optimum rates of fertilization for rice, barley, wheat, corn, sweet and white potatoes and soybeans are estimated from the estimated fertilizer response functions using experimental farm data in 1964-1972 for rice, 1965-1969 for barley and 1967 for other crops under the assumption of a perfectly competitive market for fertilizer and output. Quadratic equations with and without interaction terms are used for the response functions and their optimum rates are similar at given prices of fertilizer and crops. Taking into account possible technological changes which affect the optimum level of fertilization actual average yield of a crop on farm at a given region as a proxy of the combination of technological changes and weather variability and is incorporated into the response functions estimated by using the experimental data series. Some limitations of this proxy variable are a lack of uniformity of experimental variety with that of actual farming, technical gap between experimentation and actual farming and yield effect of fallow land, which can be removed or alleviated by selection of the right variety in an experiment and the exclusion of fallow land data. Using experimental data for rice across provinces during 1964-1972, estimated response functions including technological

change variables have higher coefficients of determination (R^2) and F-values relative to those excluding it. Increase in yield by 10 kilograms per hectare needs more of nitrogen by 0.37 kilogram per acre. The elasticity of optimum rates of nitrogen with respect to actual yield in farming become 1.1, implying that 11 percent more nitrogen is required to increase yield by 10 percent.

5. For the farm survey data analysis 300 sample farmers were interviewed, selected in proportion to the total numbers of farms located in four regions which are divided by cropping system, political/geographic subdivision and/or difference in stage of urban development: the upland cropping region which includes Kangwon, Chung-buk and Jeju provinces, the single cropping region which is composed of Kyonggi and Chung-nam provinces, the western double cropping region which includes Jeon-buk and Jeon-nam provinces and the eastern double cropping region which includes Kyong-buk and Kyong-nam provinces. Using data obtained from the survey, demand function of total and individual nutrients are estimated at national and regional levels. All demand functions are based on a per farm and per acre basis. The results of demand functions of fertilizers per farm and per acre are almost the same at national and regional levels in terms of sign and significance of coefficients.

(1) Farmgate prices of fertilizer are quite important to the farmer in his purchase of fertilizer except phosphate and mixed fertilizer. The price elasticity of demand varies among regions.

The complementary relationship between mixed fertilizer and straight nitrogen is observed. This complementarity is strongest in the upland region where mountaneous topography causes high transportation cost.

(2) The labor input and compost used are not significantly related to the purchase of fertilizer.

(3) Farmers having more cropping acres and a higher ratio of it relative to total arable land uses more fertilizer, total fertilizer as well as individual nutrients. This is true in all regions except the upland region.

(4) Farmers use more nitrogen and less potash and phosphate on paddy fields, and less of all kinds of fertilizer on orchard and mulberry land. Farmers in the region where paddy land is the dominant cropping pattern use more fertilizer on paddy field and farmer in the region where upland cropping patterns are dominant uses less fertilizer on paddy field.

(5) Farmers having more gross farm sale, less off-farm income and more debt use more fertilizer. The positive effects of gross farm sale on the purchase of all kinds of fertilizers are observed in all the regions.

(6) The more rented acres the less fertilizer farmer uses in all regions except in the upland region.

(7) The farmer that has more irrigated land and a higher ratio of it relative to his total land, uses more fertilizer, especially nitrogen. The expected positive effect of

cultivated acre of new rice variety on the use of fertilizer cannot be found.

(8) Demographic characteristics of farm operator such as age, education, farming experience and training are not significantly related to the purchase of all fertilizer nutrients but are positive. These relationships are not consistent across regions.

6. Results of the three analyses were utilized to project the future demand for fertilizer, total and individual nutrients, at national and regional levels in 1975, 1980 and 1985. This was done to provide a guideline for decision-making by persons and organizations involved in the production, marketing and consumption of fertilizer. The exogenous variables are predicted by estimating their trend values and/or obtained from the Korean Agricultural Sector Study. The projected demand for total fertilizer based on the time-series data analysis is similar with that based on the farm survey data analysis. But the demand for nitrogen projected by the time-series data analysis is greater than that projected by the experimental and farm survey data analyses. Proportions of demand for nitrogen projected by the time-series data analysis is highest and constant while that projected by the farm survey data analysis decreases and approaches that of the experimental data analysis over the projection period. The comparison implies that farmers over-utilized nitrogen relative to its requirement and that their awareness about the effects of phosphate and potash on

their crops is increasing. Regional shares of total and individual nutrients projected by the farm survey data analysis are similar to that by the experimental data analysis. Korean farmers as a whole will demand fertilizer of about 1 million metric tons in 1985.

7. This study found that farmers' purchasing patterns of fertilizer was sensitive to change in farmgate prices of fertilizer and the elasticity of demand was different among the regions. Price differentials among regions reflecting location advantages promote consumption of fertilizer to result in change in cropping patterns according to given economic conditions. Increase in price of fertilizer in the remote region due to regional price differential results in decrease in agricultural production, while decrease in the region close to supply point results in increase in the production. Net social effect of price differential among regions is an increase in total agricultural production as long as demand for fertilizer is not perfectly inelastic. Uniform price of fertilizer at railhead can give farmers in the close-to-the-average farming area an incentive to buy more fertilizer and contribute to a further development of the cropping system in terms of its economic location. This price system provides room for efficient competition in case of entering private firms in the distribution in the future when free market conditions for fertilizer distribution will be developed. Decrease in overall transportation costs contributes increase in total consumption fertilizer. Feeder road development will result in a greater use of the fertilizer

input as well as other agricultural resources and will contribute to a decrease in marketing costs of agricultural products along with national agricultural development efforts.

8. Production capacity of total fertilizer in 1971 was 587 thousand metric tons: nitrogen of 392 thousand metric tons, phosphate of 145 thousand metric tons and potash of 50 thousand metric tons. These capacities can not satisfy projected demand for every nutrient in 1975. Government holdings of fertilizer for emergency will widen the gap between production and demand. Planned capacity of ammonia production at Chungju contribute to increase nitrogen fertilizer production. And available domestic supply of raw materials for nitrogen provides a room to expand nitrogen production. Production capacities of phosphate and potash is below the projected demand as well as the current demand for them. In addition, all of raw materials for phosphate and potash fertilizer are not domestically available. Therefore, demand for nitrogen should be satisfied by either import or construction of new plant. But demand for potash and phosphate can be met by import in form of either finished fertilizer or raw materials. The study for possible alternatives to fulfill the demand for fertilizer should be carried out.

9. The increased demand for fertilizer in the future as shown in this study will need more marketing facilities to channel it from supply point to demand point unless there are excess capacities of these facilities. If the existing distribution

system and facilities are bottlenecks against smooth flow of increased quantity demanded and supplied of fertilizer, the best alternative distribution system should be found out. This alternative system should be suggested based on the increased demand and supply as well as regional difference in farmers' response in purchase of fertilizer to changes in economic, sociological and technological situations. Creation of competitive conditions of existing cooperative distribution system or free market system can be considered as an alternative based on the results of this study. Estimated regional demand contributes to analyze the efficient allocation of fertilizer input among regions under current supply conditions and marketing facilities. This also provides a criterion for economic location of new fertilizer plant, if any, to meet the increased demand.

10. The tendency of farmers in general to over-utilize the nitrogen component relative to other nutrients can be alleviated by stress in the educational programs. The education and extension program about balanced fertilization appropriately have been emphasized and should continue. Not only the extension worker but all persons involved with distribution of fertilizer have to be able to provide necessary information and guidance to the farmer.

11. Cooperative experimentation of fertilization is suggested by agromists and agricultural economists. The experiment designed for the significant test by agromist has some difficulty in application to economic analysis. Only three rates of

of fertilizer input in experiments frequently require extrapolation beyond the known maximum rate. Collection of experimental data is most difficult. Pooling all experiment data of every region and over sequent years will help an analyst who needs access to them.

12. Regional divisions which includes large areas and many heterogeneous factors may result in inconsistent results in demand study. If county cooperative as a distribution firm of fertilizer estimates its own county demand, the results can be very helpful in making decisions about transportation, storage and procurement. The farm survey analysis method is suggested to be utilized for the county demand estimation. Farmers' responses in purchase of fertilizer to change in economic, technological, financial and sociological situations of a given region can be a criterion for the county cooperative's activities about fertilizer marketing. Not only can county cooperatives easily obtain the relevant data but also collection of data over sequent years makes it combine cross-sectional and time-series analysis to observe farmers' purchasing behavior of fertilizer across farmers and over time.

The same studies for other agricultural inputs such as farm machinery, feed, agricultural chemistry and farming labor are suggested to be conducted to provide general characteristics of input markets for developing Korean agriculture.

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APPENDIX

Appendix A-1.--Fertilizer response functions with interaction terms of various crops, 1967, Korea

	Wheat	Corn	White potatoes	Sweet potatoes	Soybeans
Intercept	154.674	133.309	358.214	138.5669	100.769
	(9.137)	(21.872)	(75.594)	(32.945)	(2.072)
N	22.2520**	34.9934**	40.3801+	47.1096**	
	(4.4748)	(4.9763)	(21.9970)	(12.8082)	
P	3.4342	13.6212**	89.6549*	25.9235**	2.5608*
	(3.9561)	(3.4609)	(20.4561)	(8.6972)	(1.1255)
K	1.9447	0.7231	10.0757	17.5572**	2.8034+
	(6.3298)	(3.9362)	(11.1376)	(3.9137)	(1.5006)
N^2	-0.9747*	-1.1240**	-3.2076**	1.5085	
	(0.3844)	(0.2735)	(1.5517)	(1.1164)	
P^2	-0.3058*	-0.4907**	-4.5219**	-1.3269+	-0.1225
	(0.1362)	(0.1443)	(1.5653)	(0.7469)	(0.1350)
K^2	-0.0830	-0.0389	-0.6965	-0.3420*	-0.1623
	(0.3488)	(0.1931)	(0.4396)	(0.1450)	(0.2400)
NP	0.3165	0.1512	1.8873	-0.9264	
	(0.3798)	(0.1990)	(1.6019)	(0.7211)	
NK	0.1064	0.0954	0.5714	-0.5460	
	(0.6078)	(0.2261)	(0.6971)	(0.3245)	
PK	0.0287	0.0465	0.3195	0.0413	-0.1410
	(0.3214)	(0.1159)	(0.4781)	(0.2269)	(0.1200)
R^2	.982	.959	.947	.931	.901
SE	9.183	22.644	77.682	35.587	3.102
F	38.08**	47.00*	36.37**	25.05**	7.32**

Note: ** significant at the 1 percent level.
* significant at the 5 percent level.
+ significant at the 10 percent level.

Appendix A-2. Derivation and Characteristics of Algebraic Demand Function

The true or natural form of a production function cannot be theoretically deduced.[1/] In practice, algebraic forms are chosen for their simplicity as well as for their close approximation to the supposed true algebraic form. Estimated demand functions are affected by the algebraic form chosen for the production function as well as by environmental conditions, prices and the number of variable resources. In some instances, some algebraic forms of the production function impose restrictions which result in unrealistic and unacceptable estimates of static demand although the original data are satisfactory. The Spillman and Mitscherlish production functions are the examples.

The following is the algebraic derivation of demand function from the quadratic, square root and Cobb-Douglas functions.

A. Quadratic function

General form of quadratic function is

$$Y = b_{00} + b_{10}N + b_{20}P + b_{30}K + b_{11}N^2 + b_{22}P^2 + b_{33}K^2 + b_{12}NP + b_{13}NK + b_{23}PK$$

where Y = output

N = nitrogen

[1/] Earl O. Heady and John L. Dillon, Agricultural Production Function, Iowa State University Press, Ames, 1961.

$P = P_2O_5$

$K = K_2O$

b_{ij} = parameters

We would expect the linear terms to be positive, squared terms to be negative and the interaction terms to be positive for logica. results.

The producer's input demands are derived from the underlying demand for commodity which he produces. The total revenue of a producer who sells his output in a perfectly competitive market is given by the number of units he sells multiplied by the fixed unit price (P_y) he receives. This profit (π) is the difference between his total revenue and his total cost:

$$\pi = P. (b_{00} + b_{10}N + b_{20}P + b_{30}K + b_{11}N^2 + b_{22}P^2 + b_{33}K^2 + b_{12}NP + b_{13}NK + b_{23}PK) - (P_nN + P_pP + P_kK + F)$$

where P_n, P_p and P_k are price of nitrogen, phosphate and potash per unit respectively and F is fixed cost which is assumed to be independent with the use of three nutrients. It is also assumed that the price of each nutrient is perfectly competitive price and it is independent with use of its quantity. Then the profit is a function of N, P and K and is maximized with respect to these variables. The first order conditions require that the partial derivative of π with respect to N, P and K equals zero.

$$\frac{\partial \pi}{\partial N} = P_y (b_{10} + b_{11}N + b_{12}P + b_{13}K) - P_n = 0$$

$$\frac{\partial \pi}{\partial P} = P_y (b_{20} + b_{22}P + b_{12}N + b_{23}K) - P_p = 0$$

$$\frac{\partial \pi}{\partial K} = P_y (b_{30} + b_{33}K + b_{13}N + b_{23}P) - P_k = 0$$

This means that $MPP_n = \frac{P_n}{P_y}$, $MPP_p = \frac{P_p}{P_y}$ and $MPP_k = \frac{P_k}{P_y}$

The second order conditions require that the principal minors of the relevant Hessian determinant is negative definite:

$$\frac{\partial^2 \pi}{\partial N^2} = 2b_{11} < 0, \quad \frac{\partial^2 \pi}{\partial p^2} = 2b_{22} < 0, \quad \frac{\partial^2 \pi}{\partial K^2} = 2b_{33} < 0$$

and

$$P_y^2 \begin{bmatrix} 2b_{11} & b_{12} & b_{13} \\ b_{12} & b_{22} & b_{23} \\ b_{13} & b_{23} & b_{33} \end{bmatrix} < 0$$

The producer's input demand functions are obtained by solving his first order conditions for N, P and K as functions of P_n, P_p, P_k and P_y. These are defined for strictly concave regions of his production function where his second order conditions are satisfied.

Solving the first order conditions for N, P and K we obtain:

$$\begin{bmatrix} 2b_{11} & b_{12} & b_{13} \\ b_{12} & b_{22} & b_{23} \\ b_{13} & b_{23} & 2b_{33} \end{bmatrix} \begin{bmatrix} N \\ P \\ K \end{bmatrix} = \begin{bmatrix} P_n/P_y & - b_{10} \\ P_p/P_y & - b_{20} \\ P_k/P_y & - b_{30} \end{bmatrix}$$

$$\begin{bmatrix} N \\ P \\ K \end{bmatrix} = D^{-1} \begin{bmatrix} P_n/P_y & - b_{10} \\ P_p/P_y & - b_{20} \\ P_k/P_y & - b_{30} \end{bmatrix} \qquad \text{where } D = \begin{bmatrix} 2b_{11} & b_{12} & b_{13} \\ bb_{12} & 2b_{22} & b_{23} \\ b_{13} & b_{23} & 2b_{33} \end{bmatrix}$$

$$\text{Let } D^{-1} = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$$

D is the symmetric matrix and D^{-1} is also symmetric.

$$N = -b_{10} C_{11} - b_{20} C_{12} - b_{30} C_{13} + C_{11} P_n/P_y + C_{12} P_p/P_y + C_{13} P_k/P_y$$

$$P = -b_{10} C_{21} - b_{20} C_{22} - b_{30} C_{23} + C_{21} P_n/P_y + C_{22} P_p/P_y + C_{23} P_k/P_y$$

$$K = -b_{10} C_{31} - b_{20} C_{32} - b_{30} C_{33} + C_{31} P_n/P_y + C_{32} P_p/P_y + C_{33} P_k/P_y$$

where C_{11}, C_{22} and C_{33} are negative if the second order conditions are satisfied. The elasticity of demand for N with respect to its own price is:

$$E_{nP_n} = \frac{C_{11}}{P_y} \cdot \frac{P_n}{N}$$

Cross elasticity of demand with respect to output price, with respect to P_p and P_k are respectively:

$$E_{nP_y} = -\frac{1}{P_y}\ (C_{11}\ P_n + C_{12}\ P_p + C_{13}\ P_k) \cdot \frac{1}{N}$$

$$E_{nP_p} = \frac{C_{12}}{P_y} \cdot \frac{P_p}{N}$$

$$E_{nP_k} = \frac{C_{13}}{P_y} \cdot \frac{P_k}{N}$$

We can expect that $E_{nP_n} < 0$, E_{nP_p} and E_{nP_k} are negative since we expect the interaction effect to be positive. If we assume that there is no interaction effect, E_{nP_p} and E_{nP_k} will be zero.

B. Square root function

$$Y = b_{00} + b_{10}N + b_{20}P + b_{30}K + b_{11}N^{1/2} + b_{22}P^{1/2} + b_{33}K^{1/2}$$
$$+ b_{12}\ (NP)^{1/2} + b_{13}\ (NK)^{1/2} + b_{23}\ (PK)^{1/2}$$

where $b_{10}, b_{20}, b_{30} < 0$

$$b_{11}, b_{22}, b_{33}, b_{12}, b_{23}, b_{13} > 0$$

The derived demand functions are:

$$\begin{bmatrix} N \\ P \\ K \end{bmatrix} = \left[-\tfrac{1}{2} \begin{bmatrix} b_{10} - \frac{P_n}{P_y} & 1/2\ b_{12} & 1/2\ b_{13} \\ 1/2\ b_{12} & b_{20} - \frac{P_p}{P_y} & 1/2\ b_{23} \\ 1/2\ b_{13} & 1/2\ b_{23} & b_{30} - \frac{P_k}{P_y} \end{bmatrix}^{-1} \begin{bmatrix} b_{11} \\ b_{22} \\ b_{33} \end{bmatrix} \right]^2$$

The procedure of the derivation is the same as in the case of quadratic function.

C. Cobb-Douglas form

$$Y = b_0 N^{b_1} P^{b_2} K^{b_3}$$

where $b_1\ b_2\ b_3 > 0$ and $b_1 + b_2 + b_3 <$

First order conditions say:

$$\begin{bmatrix} b_1-1 & b_2 & b_3 \\ b_1 & b_2-1 & b_3 \\ b_1 & b_2 & b_3-1 \end{bmatrix} \begin{bmatrix} \ln N \\ \ln P \\ \ln K \end{bmatrix} = \begin{bmatrix} \ln Pn - \ln(P_y\ b_1 b_0) \\ \ln Pp - \ln(P_y\ b_2 b_0) \\ \ln Pk - \ln(P_y\ b_3 b_0) \end{bmatrix}$$

Derived demand functions are:

$$\begin{bmatrix} \ln N \\ \ln P \\ \ln K \end{bmatrix} = \begin{bmatrix} b_1-1 & b_2 & b_3 \\ b_1 & b_2-1 & b_3 \\ b_1 & b_2 & b_3-1 \end{bmatrix} \begin{bmatrix} \ln Pn - \ln(P_y\ b_1 b_0) \\ \ln Pp - \ln(P_y\ b_2 b_0) \\ \ln Pk - \ln(P_y\ b_3 b_0) \end{bmatrix}$$

$$\begin{bmatrix} N \\ P \\ K \end{bmatrix} = \text{Antilog} \begin{bmatrix} \ln N \\ \ln P \\ \ln K \end{bmatrix}$$

Appendix A-3. Weather Uncertainty Model for Response Function and Derived Demand

1. Risk neutral

For a given variety, at a given function, for a given season, a series of experimental data over time was observed. The variations of yield between years are assumed to be due to weather conditions.

The weather conditions affecting the variations of yield can be regarded as the following variables:

(1) Total number of drought days occurring during the growing season.

(2) Rainfall in the growing season. These variables are good proxies of weather conditions in poorly irrigated areas where damage from drought is serious.

(3) Solar energy during the growing season. This variable will be better proxy than the previous ones in the well-irrigated area and wet season (monsoon season). During the wet season the solar energy is more of a constraint and insects and disease are more prevalent.

First the proxy variable will be stratified into several levels with the same interval. Let D_i be the classes where $i = 1,2,\ldots,n$. A pooled response function will be estimated for corresponding the classes, say f^i. If the probability of each group were estimated we could calculate the expected production function as follows:

Classes	Pooled response function	Probability
D_1	$f^1(n)$	$P(D_1)$
D_2	$f^2(n)$	$P(D_2)$
.	.	.
.	.	.
.	.	.
.	.	.
D_n	$f^n(n)$	$P(D_n)$

The expected production function is:

$$E(Y) = f^1 p(D_1) + f^2 p(D_2) + \ldots\ldots\ldots f^n P(D_n)$$

The optimum levels of fertilizer are determined by solving t following equation:

MP of $E(Y) = \frac{P_n}{P_y}$, as if farmers try to maximize the expected profit. For example, the quadratic equation is assumed to be used for regression function, i.e., $Y_i = a_i + b_i N + c_i N^2$

$$E(Y) = \sum_i (a_i + b_i N + c_i N^2) P(D_i)$$

$$= \sum a_i P(D_i) + \sum b_i P(D_i) N + \sum P(D_i) c_i N^2$$

$$\text{MP of } E(Y) = \sum P(D_i) b_i + 2 \sum P(D_i) c_i N = \frac{P_n}{P_y}$$

$$N = \frac{1}{2 \sum P(D_i) c_i} \left[\frac{P_n}{P_y} - P(D_i) b_i \right]$$

The prices of output and fertilizer are determined by competitive market and are assumed to be constant.

Consider the determination of probability of each class. The proxy variable D will be observed over series of time periods say 1930 - 1970, and expected to be normally distributed. The probability distribution of D is

$$P(D < D_j) = \alpha_j$$

where: α_j is significance level

and $\alpha_j = 0.0 \sim 1.0$

At a given α_j, $D_j = \bar{D} + Z_{x_j} \sigma_{\bar{D}}$

where: $\bar{D}$ = expected value of D (mean value)

$\sigma_{\bar{D}}$ = standard deviation of D

Z_{α_j} = value of standard normal distribution corresponding to α_j

if $\alpha_j < .5$, then Z_{α_j} is negative

$\alpha_j > .5$, then Z_{α_j} is positive.

The probability of each class will be $P(D_i) = P(D < D_u) - P(D > D_L)$

where: D_u = upper limit of D_i

D_L = low limit of D_i.

The reason why the probability distribution function shown above is used for calculating the probability of D_i rather than simple frequency distribution is that the latter would be much affected by the size of sample.

So far production uncertainty due to weather variability is considered. If there were also price uncertainty, the expected value of price could be incorporated into profit function to get the optimum level of fertilizer. This approach is developed under assumption that farmers are risk-neutral. If farmers are not risk-neutral, several other approaches can be developed. From now on

the possible approach models will be explored--their applicability to actual problem will be examined.

2. Risk aversion

a. Safety-first model

Under uncertainty of production situations, farmers will make decisions by setting the acceptable probability of disaster. I.R. Day demonstrated how the Pearson system of probability density function could be used to convert uncertainty into risk.[2/] The method consists of:

(1) Collecting data on crop yield observed under the same or similar location and inputs

(2) Computing the sample moments of each such data set

(3) Using the sample moment as estimates of the moments of the parent population and generating the frequency distribution.

The cumulative function of frequency distribution can be denoted as $F_{f(n)}$, from which the inverse of the cumulative frequency distribution at an acceptable level of probability of disaster, $F^{-1}_{f(n)}(\bar{\alpha})$, can be derived.

The expected profit function will be

$$\pi = F^{-1}_{f(n)}(\bar{\alpha})\ P_y - P_n N - C$$

by using the constant prices of output and fertilizer.

The optimum level of N can be calculated from maximization conditions of the expected profit.

[2/] I. R. Day, "Probability Distributions of Field Crop Yield," Journal of Farm Economics, August 1965, pp. 713-741.

The determination of $\bar{\alpha}$ is subjective and is different from one farmer to another. Its applicability to actual data may be very difficult because the response function is not for farmers and because it is impossible to consider the levels of $\bar{\alpha}$ of all farmers.

b. Model of Expected Utility of Profit

Assuming a continuous and real-valued utility function in mean and variance of profits we will have the form of $U = U(u,\sigma^2)$ where:

U is the mathematical expectation of profit and σ^2 is the variance of profit.

Profit can be expressed as: $II = P_y f(N) - P_n(N) - C$

Consider only the production uncertainty

$$u = E(II) = P_y E(f(N)) - P_u N - C$$

$$\sigma^2 = P_y^2 [E(f(N)^2) - [E(f(N))]^2]$$

Utility maximization conditions are:

$$\frac{du}{dN} = U_1 \frac{du}{dN} + U_2 \frac{d\sigma^2}{dN} = 0$$

$$\frac{du}{dN} + \frac{U_2}{U_1} \frac{d\sigma^2}{dN} = 0$$

Since $\frac{U_2}{U_1} = -\left[\frac{du}{d\sigma^2}\right]_u$ for a utility maximum, the conditions will be $\frac{du}{dN} - \left[\frac{du}{d\sigma^2}\right]_u \left[\frac{d\sigma^2}{dN}\right] = 0$

The derivative of mean and variance of profit with respect to N are respectively,

$$\frac{du}{dN} = P_y \; E(f_N) - P_n$$

$$\frac{d\sigma^2}{dN} = 2 P_y^2 \; E(ff_N) - E(f) \; E(f_N)$$

$$= 2 P_y^2 \; Cov \; (f, f_N)$$

The optimum condition will be

$$P_y \; E(f(N)) - \left[\frac{du}{d\sigma^2}\right]_u \cdot \; 2 P_y^2 \; Cov \; (f, f_N) = P_n$$

Consider uncertainty as to both price of output and production. Following the same procedures as above the optimum conditions will be

$$E \; (P_y) \; E(f_N) + Cov \; (P_y, \; f_N) - \left[\frac{du}{d\sigma^2}\right]_u^2 \; Cov \; (P_y f, \; P_y f_N) = P_n$$

Under two situations the utility function should be set up to obtain the optimum level of N.

If utility function is linear the solution is the same as one of the risk-neutral cases.

Because it is very difficult to establish a utility function of a farmer and the assumption of identical utility function for every farmer cannot be said to be realistic. This approach includes many unsolved problems.

Appendix A-4. -- The survey questionnaire for 300 sample farms, 1972, Korea

Survey for Fertilizer Use by Farmers

1. Size of farm family

Age	Male	Female	Members who are not living at home	Why are they not living at home
Less than 10				
11 to 20				
21 to 30				
31 to 40				
41 to 50				
51 and over				
Hired labor living in (year around)				
Maids				

2. Who were the primary workers on your farm during the last 12 months? (71.7-72.6)

	Sex	Age	Days work
Operator	MF		
Helper	MF		
"	MF		
"	MF		

3. Farm Operator

1) Experience farming _____ years
2) No. of years on present farm _____ years
3) Educational background
   - No schooling _____
   - Graduate school _____
   - Middle school _____
   - High school _____
   - College agri. _____
   - " and other _____

4) Has the operator attended any kind of workshop or training course for better farming?

Duration	Date	What kind	By Whom Conducted

4. Size of farm

1) Area of land	Paddy field	No. of pieces	Dry field	No. of pieces	Others (forest)
Owned:	_____Pyung	_____	_____Pyung	_____	_____Pyung
Rented:	_____	_____	_____	_____	_____

2) Pyung of well irrigated land_____

3) No. of livestock

Kind	Number	Age on the average	Kind	Number	Age on the average
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

4) Size of greenhouse

No. of houses	Pyung	What kind
_____	_____	_____vinyl,glass,other
_____	_____	_____

5) Pyung of Orchard or Mulberry trees

What kind	Area of land	Age of trees	Irrigation facility
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

5. What crops did you harvest in the last 12 months (71.6-72.6)

Crops	Cultivated area	Volume of production	Volume of sales	Value of sales
Rice	_____Pyung	_____	_____	_____
Barley	_____	_____	_____	_____
Wheat	_____	_____	_____	_____
Soybean	_____	_____	_____	_____
Potatoes	_____	_____	_____	_____

6. Could you tell me the strains of rice planted, and area for each?

Strains	Area planted 1972	1971	1970
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

6. 1) Do you plan to expand anyone of the above rice strains next year?

Name of strains	Total area planned
_____	_____ Pyung
_____	_____

2) When are you going to use the new strains of "Tong-il" (IR667) in your fields?

Year	Pyung of paddy field
_____	_____ Pyung

7. What are your livestock? (Include income from work cattle)

Kinds	Number	Total amount from sale of them
_____	_____	_____ Won
_____	_____	_____

8. Did you and your family have any other earning sources in the last 12 months? (Include gifts from relatives and income from money-lending, but exclude borrowings)

Yes _____ No _____

If yes,

Kinds	By Whom	Amount during the year	How often
_____	_____	_____ Won	_____
_____	_____	_____	_____
_____	_____	_____	_____

9. How much did you pay for the items listed below in the last 12 months? (71.7-72.6)

New Barn	_____ Won
Tool or machine	_____
Seeds	_____
Insecticides and fungicides	_____
Commercial feed	_____
Other farming materials	_____
Hired labor	_____
Taxes & charges for farming	_____
Interest on farm debts	_____
Other (specify)	_____

10. Do you have any of the following things for your farming?

Hand-cart	_____	Bicycle	_____
Ox-cart	_____	Tractor	_____

11. How much are you in debt to others excepting fertilizer credit?

Date	Amount	Type of Creditors	What for	Interest rate
				%

12. Purchasing of fertilizer in the last 12 months? (71.7-72.6)

Purchasing date	Kind	Quantity	Official	Trans.	Cost Other	Charge total
		kg	Won	Won	Won	Won

Form of payments		Village	Where did you buy			Distance from your home
Cash	Credit	Co-op	Myun-Coop	Private dealers	Neighbor	

Method of transportation from place where farmer purchased?

Shoulder	Hand-Cart	Ox-Cart	Truck	Rail	Water	Kgs damaged in moving
						kg

13. Could you tell me the uses of fertilizer on your farm during the last 12 months? (71.7-72.6)

Date of application	Kinds of fertilizer	Use for farming	Which crops

14. If you bought mixed or compound fertilizer, what were the grades you purchased? (ex: N P K: 12-12-12)

No.	Mixed		Complex	
	Grades	Kg	Grades	Kg
1.				
2.				
3.				
4.				
5.				

15. How much did you increase your fertilizer use in 1972 (71.7-72.6) as compared to 1971? (70.7-71.6)

Kinds of Fertilizer	1972 Paddy	1972 Dry	1971 Paddy	1971 Dry
Urea	____kg	____kg	____kg	____kg
Ammonium Sulfate	____	____	____	____
Ammonium Chloride	____	____	____	____
Triple Sup. Phos.	____	____	____	____
Compound	____	____	____	____
_____	____	____	____	____
_____	____	____	____	____
_____	____	____	____	____

16. Was the quantity which the Co-op distributed to you during the last 12 months enough for your farming?

Yes ____
No ____

If No, did any of the following reasons prevent you from buying as much fertilizer as you would have liked in the last 12 months?

- coop did not make enough available _____
- no credit was available _____
- price was too high _____
- wrong kind of fertilizer allocated _____
- did not have time to buy it, because it was allocated in busy season _____
- required to pay back with grain _____
- other (specify) _____

17. Did you have some leftover fertilizer at the end of year?

What kinds	How much
Urea	_____kg
Ammonium Sulfate	_____
Ammonium Chloride	_____
Triple Sup. Phos.	_____
Compound	_____
_____	_____
_____	_____

18. What is the reason for such leftover fertilizer?

- I bought more than I could use _____
was distributed at the wrong time _____
wrong kind of element _____
I prefer to store some quantity for next year _____
size of package was too large,but I thought I had to buy it _____

19. Have you sold fertilizer to anyone else?

No ___
Yes ___, If yes, under what conditions:

To whom		At what	How		
Date	(occupation)	price	For cash	In kind	In exchange
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____

20. What were the credit arrangements by the co-op?

1) Interest rate
   - too high for farming _____
   - about right _____
   - too low a rate _____
2) Availability
   - too much red tape _____
   - collateral required _____
   - too small an amount _____
   - easy to borrow _____
3) Term of credit
   - too short _____
   - about right _____
   - too long _____
4) Requirement for paying back
   - with cash _____
   - with grain _____

21. How do you feel about the relative prices of fertilizer among the kinds of fertilizer below listed? Which one is the most expensive?

Kind	Extremely Expensive	Expensive	About Right	Cheap	Extremely Cheap
Ammonium Sulfate	_____	_____	___	___	_____
Ammonium Chloride	_____	_____	___	___	_____
Urea	_____	_____	___	___	_____
Triple Sup. Phos.	_____	_____	___	___	_____
Complex	_____	_____	___	___	_____

22. If the price of fertilizer is not increased, and under the current price of rice, would you plan to use more fertilizer and harvest more product, or would you maintain the present level of application next year?

- may keep present level _____
- will use more fertilizer _____
- do not know which was/is better for me _____

If you want to use more than this year, how many Kg of fertilizer would you need?

Kinds	Quantity
_____	_____kg
_____	_____

23. If the price of fertilizer goes up 20% or more, will you use more compost than before instead of commercial fertilizer?

Yes _____ No _____

If yes,

- How much would you increase? _____%
- What quantity of compost did you use last year? _____Kg

24. In order to produce at the maximum level of yield of crops, how much more fertilizer should you apply than in the last 12 months? (1971.7-1972.6)

	Paddy Field	Dry Field
Less than 5%	_____	_____
6 to 10	_____	_____
11 to 20	_____	_____
21 to 30	_____	_____
31 to 40	_____	_____

25. What do you think about the time of distribution by the co-op in the last 12 months for your farming?

- distribution time was always too late _____
- distributed fertilizer at time needed _____
- distribution time was always too early _____
- distribution time is not important to me _____
- others, (specify) _____

26. Are you satisfied with the service of the co-op people? (Please check one of the items listed below)

1) -provide us with kind service _____
2) -service good but without any kindness _____
3) -service bad _____

If service is bad,

- too slow _____
- bureaucratic _____
- other, specify _____

27. Do you think it would be better for fertilizers to be distributed through private market channels instead of only by the coops?

Yes _____ No _____

If yes, what benefits would you expect from this? (Number in order of importance)

Possible Criteria	Degree of Importance
Better price per bag or per kg	_____
Acceptable credit	_____
Better service offered	_____
Delivery to farm	_____
Free selection of elements	_____
Better time of delivery	_____
Larger or smaller volume of buying	_____

28. If you should be free to buy whatever kinds **or** quantities of fertilizer you want in the coming year,

A. What changes will you make in purchases?

Actually bought in 1972		Would have preferred to buy
Ammonium Sulfate	_____kg	_____kg
Ammonium Chloride Urea	_____	_____
Triple Sup. Phos.	_____	_____
Compound	_____	_____
_____	_____	_____
_____	_____	_____

B. What is the main reason why the kind of fertilizer you would choose is different from the combination you used last year?

-from my experience _____
-the know-how from neighbors _____
-recommendation of extension workers _____
-recommendation of coop people _____
-result from soil test _____
-use of a new species _____
-fertilizer price is cheaper than before _____
-easier to buy some kinds that I like _____
-others, specify _____

29. What is the usefulness of a soil test?

1) Gives guidance for decisions on kind of fertilizer _____
2) Indicates what crops to grow _____
3) Tells exactly what nutrients should be added for fertilizer _____
4) Don't know _____

30. If you look at a fertilizer bag and see the number 14-37-12, what do these numbers stand for?

    1) The relative amounts of manganese, phosphorous and nitrogen in the mixture _____
    2) The relative amounts of nitrogen, phosphorous and potassium in the mixture _____
    3) The date before which the fertilizer should be used _____
    4) Do not know _____

31. Does the amount of organic matter in the soil indicate which of the following elements is needed to be applied more?

    Nitrogen _____
    Phosphorous _____
    Potassium _____
    Don't know _____

32. Barnyard manures contain mostly which elements?

    Nitrogen _____
    Phosphorous _____
    Potassium _____
    Don't know _____

33. Which of the following ratios is good for the application on paddy fields of Tong-il Rice?

    15 - 7.5 - 9.0 kg/10a _____
    20 - 10.0 - 12.0 _____
    30 - 15.0 - 18.0 _____
    Don't know _____

34. Is there any relationship between the level of moisture in the soil and the amount of nitrogen needed?

    1) No relationship between them _____
    2) Higher level of moisture requires more nitrogen _____
    3) Excessive moisture prevents use of nitrogen _____
    4) Lower level of moisture requires more nitrogen _____
    5) Don't know _____

35. Is there any relationship between the temperature and the amount of fertilizer application?

    1) High temperature prevents the use of fertilizer _____
    2) High temperature enhances plant growth and necessitates more fertilizer _____
    3) Temperature has no impact on the level of fertilizer use _____
    4) Don't know _____