AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION
A. PRIMARY
Agriculture
B. SECONDARY
Soils and Fertilizers

2. TITLE AND SUBTITLE
Fertilizer Distribution in Korea

3. AUTHOR(S)
Sang-Woo Park

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
July 1975	241p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
University of Minnesota
Economic Development Center
St. Paul, Minnesota 55108

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

9. ABSTRACT
The ultimate goal of this study is to define an efficient fertilizer distribution system for Korea. As indicated, such a system would deliver the right type of fertilizer to the farmers at the right time and place, in sufficient quantities, and at a minimum cost. To achieve this, spatial and temporal aspects of the Korean fertilizer distribution system in 1972 and in 1978 were considered.

Specific objectives of this study are:

1. to discuss the analytical approach and select analytical models to solve certain fertilizer distribution problems;
2. to identify the characteristics of the Korean fertilizer distribution system;
3. to approximate the fertilizer supply and utilization in 1972 and in 1978;
4. to determine the optimum fertilizer flow and storage patterns and minimum fertilizer distribution cost for the 1972 fertilizer distribution system; and
5. to determine the optimum fertilizer flow patterns and the optimum number, size, and location of fertilizer storage centers for the 1978 fertilizer distribution system. For the 1978 fertilizer distribution system, bagging, storage and blending activities are introduced at regional storage centers.

10. CONTROL NUMBER
PN-AAB-383

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Fertilizer Distribution, Korea, Model, Storage, Bagging, Blends

13. PROJECT NUMBER
931-11-140-122

14. CONTRACT NUMBER
AID/CSD- 2815

15. TYPE OF DOCUMENT
Thesis

AID 590-1 (4-74)

FERTILIZER DISTRIBUTION IN KOREA

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA

By

SANG-WOO PARK

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

July 1975

Dedicated very affectionately
to my late father, Young-Soon Park, and to
my mother, Bong-Lim Park.

ACKNOWLEDGEMENTS

This research was supported by grants to the University of Minnesota Economic Development Center from the U. S. Agency for International Development, for which the author wishes to express his sincere appreciation.

The author also wishes to express his thanks to all members of the thesis committee: Professors Dale C. Dahl, Martin E. Abel, Herbert M. Mohring, Truman R. Nodland, and Harlan M. Smith.

Special thanks are due to my major advisor, Professor Dale C. Dahl, academic advisor, Professor Truman R. Nodland, for the guidance, warm encouragement, and generosity contributed much to the completion of the Ph.D. degree, and Professor Young Kun Shim for gathering data and guidance.

Helpful criticisms and suggestions were made by Professor Martin E. Abel, Professor Herbert M. Mohring, and Mr. Winston W. Grant.

The author is grateful to Mrs. Barbara Miller for editorial assistance and making his English readable. His gratitude is extended to Mrs. Joan Taylor who typed the thesis.

Deep appreciation is expressed to the author's wife, Chong-Sook, for her encouragement, understanding, and patience throughout the graduate study.

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INTRODUCTION

1.1 Problem Statement

Agriculture is the most important sector of the Korean economy. In 1972, 45 percent of the population was engaged in agricultural production and 26 percent of the GNP was derived from farm production.

Korean agriculture is labor intensive and devoted primarily to the grain production. In 1972, 92 percent of the total agricultural production was derived from cultivation and grain production accounted for 63 percent of the total cultivation. Because of the mountainous topography, only 23 percent of the total land area is under cultivation. On the average, a farm consists of 0.9 hectares of land and is operated by and for six family members.

Under the constraint of limited arable land and a history of insufficient crop production to feed the people, one of the major agricultural concerns is how to increase land productivity. Much of the new technology needed to raise land productivity is embodied in the form of chemical and/or biological inputs.

Chemical fertilizer is by far the most important input in Korean agriculture. On the average, farm expenditure on chemical fertilizer has been the biggest item among expenditures on material inputs. It accounted for 42 percent of the total expenditure on material inputs in 1972. Material inputs include seeds, chemical fertilizer, pesticides, domestic animals, and agricultural implements.

The Korean fertilizer economy has grown very rapidly since 1961 when the government resumed control of the fertilizer distribution. On an actual weight basis, total fertilizer usage increased by 50 percent from 958,000 metric tons in 1961 to 1,429,000 metric tons in 1972. Domestic production increased by 20 times from 65,000 metric tons in 1961 to 1,361,000 metric tons in 1972. As the fertilizer economy grew, the efficient distribution of fertilizer became a critical policy issue, a problem not yet solved.

Decisions regarding fertilizer distribution are all made by experience and judgement rather than by any systematic analysis. A fertilizer distribution system would be efficient if that system could deliver the right types of fertilizer to the farmers, at the right time and place, in sufficient quantities, and at a minimum cost. It is important to define an efficient fertilizer distribution system for Korea because (1) up to 40 percent of the farm price of fertilizer consists of handling and transportation costs and (2) a ton of fertilizer may be handled seven to 15 times from the day it is manufactured to the day it is applied (TVA, 1969, p. 139).

Unique economic problems concerning an efficient fertilizer distribution system in Korea include:

1. In 1972, 68 percent of the total fertilizer production capacity was concentrated in and around the Ulsan Manufacturing Complex, in the southeastern corner of the country. Because most farm production occurs in the west, this involves considerable fertilizer logistic problems. In the long run, the location, size and number of manufacturing plants should be considered with respect to the logistic problems, as well as other economic and political factors.

2. In the case of imported fertilizer, it is questionable whether the available harbors are efficiently utilized to minimize fertilizer distribution costs of imported fertilizer.

3. It appears that unnecessarily high stock levels exist at the beginning of the year, causing a great amount of storage expense. The average beginning stock accounted for 72 percent of total fertilizer consumption and 41 percent of total fertilizer supply in the period 1970-1972.

4. There is an apparent shortage of fertilizer storage facilities and some existing facilities are in a state of deterioration. The size, number, and location of storage facilities should be adequate in order to improve the efficiency of the fertilizer distribution system.

5. There are no large-scale regional storage, bagging, and blending facilities in Korea. Introduction of these fertilizer distribution facilities would improve the efficiency of the system and reduce the distribution cost.

1.2 Objectives

The ultimate goal of this study is to define an efficient fertilizer distribution system for Korea. As indicated, such a system would deliver the right type of fertilizer to the farmers at the right time and place, in sufficient quantities, and at a minimum cost. To achieve this, spatial and temporal aspects of the Korean fertilizer distribution system in 1972 and in 1978 were considered.

Specific objectives of this study are:

1. to discuss the analytical approach and select analytical models to solve certain fertilizer distribution problems;

2. to identify the characteristics of the Korean fertilizer distribution system;

3. to approximate the fertilizer supply and utilization in 1972 and in 1978;

4. to determine the optimum fertilizer flow and storage patterns and minimum fertilizer distribution cost for the 1972 fertilizer distribution system; and

5. to determine the optimum fertilizer flow patterns and the optimum number, size, and location of fertilizer storage centers for the 1978 fertilizer distribution system. For the 1978 fertilizer distribution system, storage, bagging, and blending activities are introduced at regional storage centers.

1.3 Procedures and Limitations

Valuable information was provided by the various official reports issued by the Ministry of Agriculture and Fisheries, National Agricultural Cooperative Federation, and National Railway Office. A fertilizer distribution system field survey of 123 randomly selected county cooperatives was conducted in order to understand the workings and performance of the existing fertilizer distribution system. A farm survey of 300 randomly selected farmers provided data to estimate the fertilizer consumption relationships and to investigate the farmers' needs, wants, attitudes, and whims about the fertilizer distribution system.

The linear programming transportation model was selected to determine the optimum fertilizer flow and storage patterns for the 1972 fertilizer distribution system. The linear programming transshipment model was chosen to determine optimum fertilizer flow patterns and optimum number, size, and location of fertilizer storage centers for the 1978 system.

Fertilizer origins and destinations and regional fertilizer quantities were specified to meet the requirements of the economic models. Several limitations were involved in this study due to the availability and accuracy of data. In determining monthly fertilizer flow patterns for 1972, monthly fertilizer consumption requirements for regions were approximated by seasonal consumption patterns for the nation. To obtain regional fertilizer consumption requirements for 1978, the statistical consumption relationships with the farm survey data for 1972 were extended based on linear time trend and judgement.

The cost of distributing fertilizer includes transportation, storage, handling, blending, and other costs. Actual cost functions could be estimated for each of these distribution activities. The distribution cost, however, was approximated by transportation cost for the 1972 analysis and by combined costs of transportation and storage for the 1978 analysis. The storage and transport rates used were rates established by the government. Investigations on the real cost functions could not be estimated. This study assumed that the existing fertilizer distribution system controlled by the government would continue.

1.4 Organization of the Study

Chapter II presents models for the economic analysis of the Korean fertilizer distribution system in 1972 and 1978. In Chapter III, characteristics of the Korean fertilizer distribution system are discussed. Chapter IV presents fertilizer supply and utilization relationships for 1972 and 1978. Seasonal fertilizer consumption patterns are also explained in this chapter. Chapter V presents the optimum fertilizer flow and storage patterns determined by the transportation model for 1972. Chapter VI presents the optimum fertilizer flow patterns and optimum number, size, and location of regional storage centers determined by the transshipment model for the 1978 system. Finally, Chapter VII summarizes the analysis and presents conclusions that may be drawn.

CHAPTER II

METHODOLOGY AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter presents the methodology and theoretical framework to achieve the objective of this study. The major objective of this study was to improve the marketing efficiency of the Korean fertilizer distribution system.

Marketing efficiency was well defined by Kohls and Downey:

> . . . marketing efficiency is usually subdivided into two different categories -- operational (technological) efficiency and pricing (economic) efficiency. Operational efficiency assumes the essential nature of outputs of goods and services to remain unchanged and focuses on reducing costs of inputs of doing the job.
>
> Pricing efficiency is concerned with improving the operation of the buying, selling, and pricing aspects of the marketing process so that it will remain responsive to consumer direction. (Kohls, R. L., and O. D. Downey, 1972, p. 11).

Improvement of the operational efficiency of the Korean fertilizer distribution system may be realized by a decrease in fertilizer distribution costs. Pricing efficiency of the system may be increased by providing the right type of fertilizer to farmers at the right time and place.

At the present time, the Korean fertilizer distribution system is under control by the government. The government controls fertilizer utilization. The government establishes an equal price of fertilizer for farmers at every fertilizer distribution outlet regardless of the fertilizer prices paid by the government and the distribution costs. Agricultural cooperatives administer fertilizer marketing and the Korean Express Company handles all fertilizer shipments. Such a market structure is most likely to be unchanged in the foreseeable future.

The government's behavior, however, is quite different from that of a monopolist. The government attempts not to maximize its profit but to maximize benefits to farmers. The differences in the two types of behavior may be demonstrated as in Figure II-1. The revenue situation is represented by the demand and marginal revenue curves, D and MR, respectively. Costs are depicted by the average total cost and marginal cost curves, ATC and MC, respectively.

The monopolist will sell his output at point M where marginal cost equals marginal revenue and, hence, maximizes profit. The associated price and quantity will be OP_m and OQ_m.

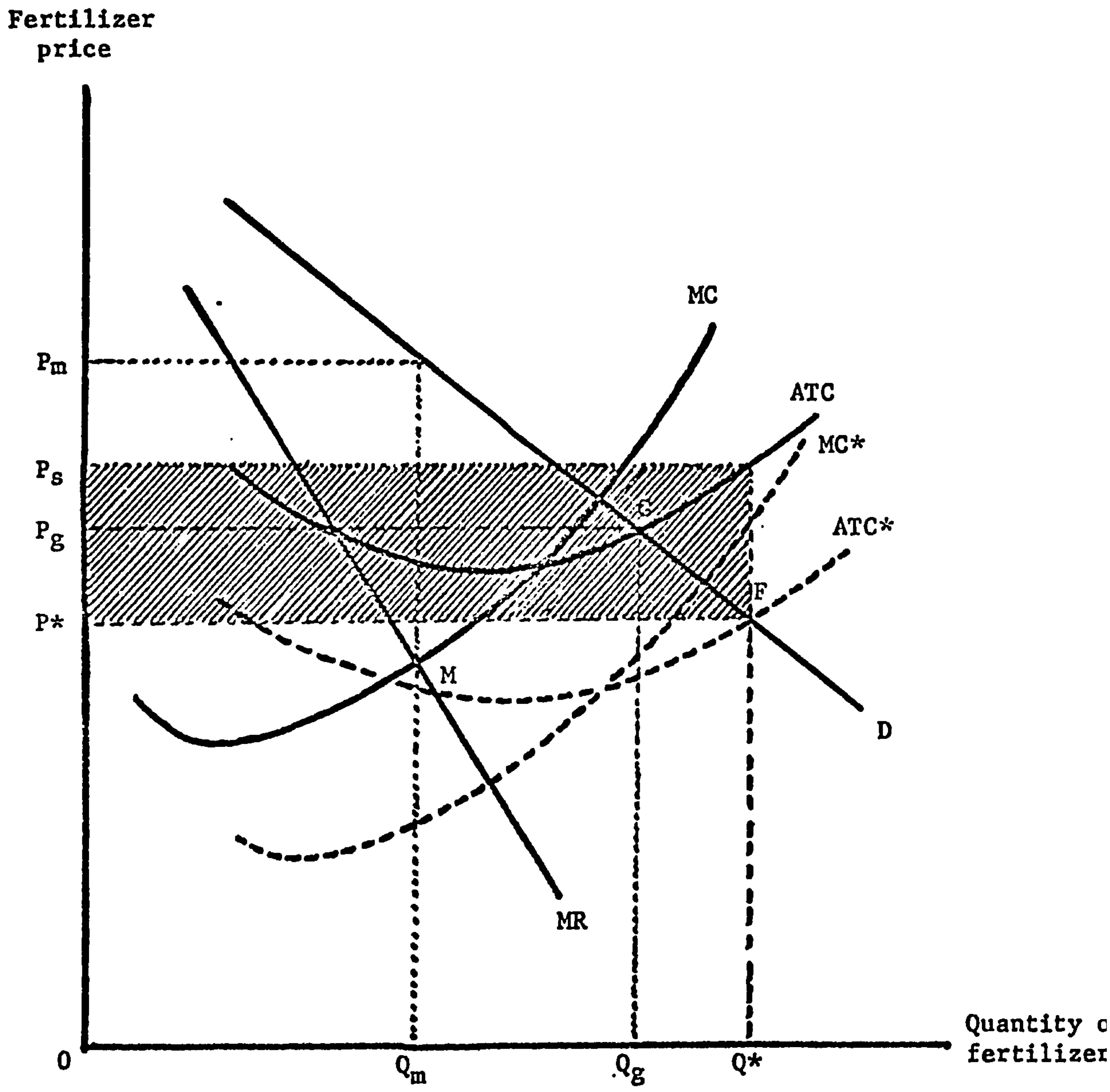

Figure II-1. Alternative solutions under monopoly market structure.

In the Korean fertilizer market, however, the government will sell fertilizer at point G where the average total cost and demand curves intersect. The government only wishes to cover costs; profit is of no concern. In this case, price and output are OP_g and OQ_g, respectively. Greater quantities are sold at a lower price than in the monopoly case.

In many cases, the Korean government subsidizes farmers to sell more fertilizer than OQ_g. Suppose that OQ^* is the quantity that the government wants to sell. The price that farmers are willing to pay is OP^* and the associated average total cost is OP_s. In that case, the total government subsidy for farmers is OQ^* times P_sP^* which is the shaded area in figure II-1.

The objective of the 1972 fertilizer distribution analysis can be achieved by a decrease in distribution costs resulting in downward shift of cost curves from ATC and MC most-desirably to ATC^* and MC^*. This will bring about lower subsidy with constant price, lower price with constant subsidy, or combination of both.

The objectives of the 1978 analysis include increases in both operational and pricing efficiency. Introduction of large scale regional storage, bagging, and blending facilities at strategic locations will satisfy those objectives.

The fertilizer distribution problems are approached by spatial economic models which are related to analyses of supply, utilization, transportation, storage, and other distribution activities involved in the movement of fertilizer over space and time.

2.2 Spatial Economic Models

A spatial economic model may be defined as any economic theoretical framework including space as one component. Spatial economic models involve one or more commodities (primary, intermediate, and/or final goods) and depict one or more of the following activities: (1) the regional location and level of production including primary and/or secondary stages; (2) shipping patterns of primary, secondary, and/or final goods; (3) the regional level of consumption of final goods; and (4) the relative and/or absolute level of regional prices (Bawden, 1964).

Solutions to spatial economic models render one or a combination of the following types of information: (1) efficient shipping patterns; (2) forecasts of the shipping patterns; (3) efficient regional production and resource allocation; (4) forecasts of regional production and resource allocation;

(5) forecasts of total storage and regional consumption and prices; and (6) the effects of changes in the exogeneous variables upon the models (Bawden, 1964).

The models can be broadly grouped into two types: (1) standard equilibrium formulations (e.g., spatial price equilibrium model) using demand and supply relationships and (2) activity analysis formulations (e.g., transshipment model) involving physical production activities and demand relationships. The two groups, however, are not mutually exclusive. Both depict partial or complete equilibrium, deal similarly with shipping and demand activities and each has the transportation model as its simplest form. The relative merit of each model depends on the purpose for which it is used (Bawden, 1964).

The transportation model served as the analytical tool for the 1972 distribution analysis. Given regional availability and requirement, the main concern was the shipment of fertilizer at minimum transfer cost. For the 1978 distribution analysis, the transshipment model was used to simultaneously determine optimum fertilizer flow patterns for each fertilizer material and an efficient system of fertilizer distribution facilities.

2.2.1 Transportation Model

Any problem meeting the following formal characteristics can be approached by the transportation model:

> (1) One unit of any input can be used to produce one unit of any output.
>
> (2) The cost or margin which will result from conversion of one unit of a particular input into one unit of a particular output can be expressed by a single figure regardless of the number of units converted.
>
> (3) The quantity of each individual input and output is fixed in advance, and the total of the inputs equals the total of the outputs. (Henderson and Schlaifer, 1954, p. 98).

In general terms, in order to use the transportation model, quantities available and required must be predetermined for each region which is represented by a single point. The model is restricted to one commodity or a group of perfectly substitutable commodities. Solutions determined by the model provide the least cost of shipment, shipment pattern, and quantities traded between regions.

Hitchcock (1941) originated and solved the transportation model before the general concept of linear programming was formulated. Koopmans (1949) illustrated the usefulness of the model. Since algorithms of the transportation model were developed in the early 1950's, the transportation model has been used by economists. Judge (1956) used the model for eggs; Snodgrass (1956) for dairy products; and Henry and Bishop (1957) for broilers.

2.2.2 Transshipment Model

The transshipment model developed as an extension of the transportation model by Orden (1956) allows transshipment by relaxing the transportation model's restriction of direct movement from one of the origins to one of the destinations. Intermediate activity, such as storage or processing between origins and destinations, can be included in the model. Using Orden's formulation to solve the warehousing problem with continuous production and seasonal demand, Kriebel (1961) demonstrated that an intermediate activity, storage in this case, can be incorporated into the model.

The transshipment model has been used by economists as an analytical tool in determining the number, size, and location of plants and the primary and final product flow patterns simultaneously. Stollsteimer (1963) attacked the problem of simultaneously determining the number, size, and location of processing plants that would minimize the combined costs of assembling and processing the raw material produced in varying amounts at scattered areas. The location of a plant was dependent upon the transportation costs of the raw material from production areas to a potential plant site. Unit processing costs were assumed to be a function of plant size. Keeping decisions on plant location and plant size separate, he admitted failure in being able to determine the number, size, and location of plants simultaneously.

In a cattle slaughtering plant study in California, King and Logan (1964) utilized the transshipment model to simultaneously minimize the costs of shipping the raw material (live animals), processing (slaughtering cattle), and shipping the final product (meat). Given regional quantities of slaughter animals and regional meat consumption, the number, size, and location of processing plants and the flow patterns of primary and final products were determined simultaneously.

Hurt and Tramel (1965) presented an alternative formulation of the transshipment model to solve the type of problem discussed by King and Logan (1964) and simplified the solution procedure. They extended the formulation to deal with the multiproduct problem and demonstrated that such a problem can be solved by computers with much less capacity than would be required for general linear programming. King (1971) successfully used the transshipment model formulated by Hurt and Tramel to determine the optimum number, size, and location of apple packing plants for the New England apple packing industry. Grant (1972) also used the Hurt-Tramel formulation to find an efficient system of tablestock potato packing plants in Maine.

2.3 Formulation of Empirical Models

A simplified fertilizer flow system for Korea is presented in figure II-2 as a conceptual aid in the formulation of empirical models. Fertilizer supply for a period includes domestic production, imports, and fertilizer stocks at the beginning of the period. Fertilizer stocks include stocks at the plant warehouses and at regional storage centers.

The fertilizer produced by a plant is shipped to the regional storage centers, exported, or stored at its own warehouse as end stock for future shipment or exportation. Fertilizer imported is transferred from importing harbors to various regions for consumption or stock purposes. The fertilizer at regional storage centers is transferred for consumption and the residual is held in storage as end stock. Fertilizer utilization for a period includes domestic consumption, exports, and end stock. Fertilizer end stocks are stored at plant warehouses and regional storage centers. At the present

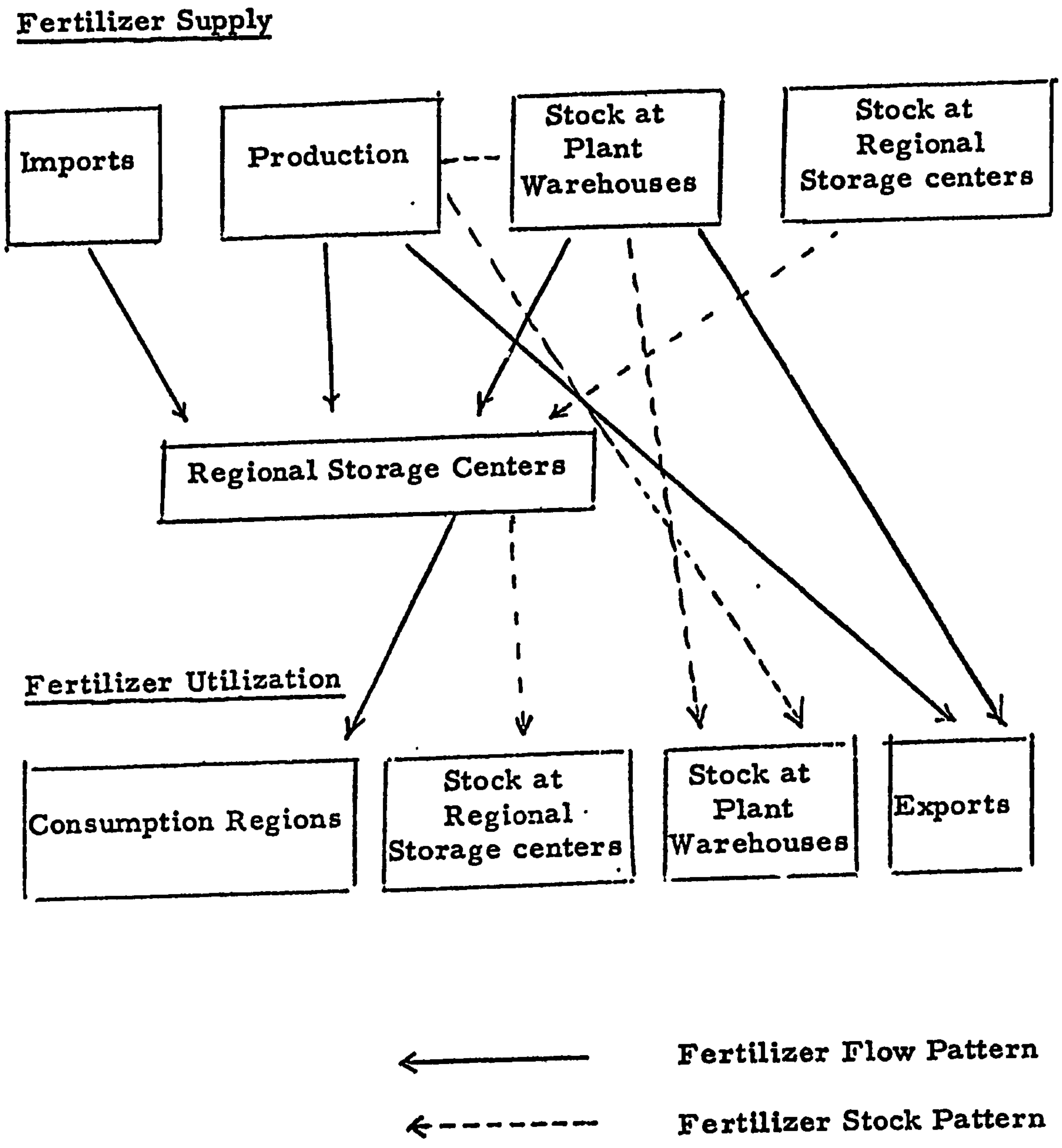

Figure II-2. Simplified flow chart of Korean fertilizer distribution system.

time, all fertilizer shipments are made by bag, because all fertilizer is bagged at production plants and import harbors.

The determinants affecting a fertilizer distribution system are many, some of which are not relevant to economic analysis; others that are relevant can not be measured. The basic determinants considered in this study are: (1) regional fertilizer availability; (2) regional fertilizer requirements; (3) transportation costs and facilities; (4) storage costs and facilities; and (5) other distribution facilities such as regional bagging and blending facilities. A complete description of these determinants is presented in Chapters III and IV.

2.3.1 Mathematical Formulation

Assumptions inherent in the formulation of the model for the analysis of the Korean fertilizer distribution system are presented below:

(1) Production of fertilizer at each manufacturing plant is given.

(2) Consumption of fertilizer in each consumption region is given.

(3) The total quantities of fertilizer beginning and end stocks for the nation are known.

(4) The total quantities of fertilizer imports and exports are known.

(5) The unit transportation cost between any two points is known and is independent of quantity transferred.

(6) The storage cost per unit of time period is known and is independent of quantity stored.

(7) Fertilizer for the purpose of consumption is used immediately after it reaches in any consumption region. Fertilizer for the purpose of exports is exported immediately after it arrives at any export outlet. Therefore, no storage costs for the fertilizers consumed and exported are included in their distribution costs.

(8) Imported fertilizer is immediately transferred to various regions for consumption and stock without delay.

(9) Consumers are indifferent to the sources of fertilizer supply.

Formulation of the transportation model for the 1972 fertilizer distribution analysis

Given the fertilizer market structure, distribution facilities, and regional quantities, the linear programming transportation model was formulated to determine optimum fertilizer flow patterns for 1972.

Notations:

$i = 1, \ldots, m$: Number of origins. Origins include production points, import harbors, and regional storage centers.

$j = 1, \ldots, n$: Number of destinations. Destinations include consumption regions, regional storage centers, plant warehouses, and export harbors.

X_{ij} = Quantity of fertilizer transferred from region i to region j.

t_{ij} = Unit transfer cost of bagged fertilizer from region i to region j.

a_i = Quantity of fertilizer available at origin i. Quantities available at origins are: sum of current production and beginning stock for production plants, imported fertilizer for import harbors, and beginning stock for regional storage centers.

b_j = Quantity required at destination j. Quantity required in a consumption region is the current consumption. Quantity required at an export harbor is the fertilizer exported through the harbor. Regional storage centers and plant warehouses store end stock at their storage facilities.

Then, the problem takes the form

$$\sum_{i} X_{ij} = a_i \qquad i = 1, \ldots, m$$

$$\sum_{j} X_{ij} = b_j \qquad i = 1, \ldots, n$$

$$\sum_{i} a_i = \sum_{j} b_j$$

$$X_{ij},\ a_i,\ b_j \geqq 0$$

Minimize the objective function:

$$TC = \sum_{i}\sum_{j} t_{ij}\, X_{ij}$$

where a_i, b_j and t_{ij} are given parameters.

<u>Formulation of the transshipment model for the 1978 fertilizer distribution analysis</u>

In the 1978 analysis, large scale regional fertilizer distribution facilities including storage, bagging, and blending facilities were introduced to improve the efficiency of the Korean fertilizer marketing.

Since the bagging operation was shifted from production and import origins to regional storage centers, fertilizer shipment is made in bulk from production and import origins to regional storage centers and in bags from regional storage centers to consumers in the analysis. The objective of the

1978 fertilizer distribution analysis was to simultaneously determine the optimum number, size, and location of regional storage centers and optimum fertilizer flow patterns. The linear programming transshipment model was the most efficient analytical tool available for that purpose.

Notations:

h = 1, . . ., n = number of production origins

i = 1, . . ., n = number of import harbors

j = 1, . . ., n = number of regional storage centers

k = 1, . . ., n = number of consumption regions

m= 1, . . ., n = number of export harbors

1. Transportation cost functions:

1.A. Transportation cost function for domestically produced fertilizer:

$$TC_H = \sum_h \sum_j \sum_k T_{hjk} Q_{hjk} + \sum_h \sum_j T_{hj} Q_{hj} + \sum_h \sum_m T_{hm} Q_{hm}$$

Where:

TC_H = Total transportation costs of fertilizer from manufacturing plants to other regions.

T_{hjk} = Unit transportation cost of fertilizer from plant h to consumption region k through regional storage center j.

Q_{hjk} = Quantity of fertilizer transferred from plant h to consumption region k through regional storage center j.

T_{hj} = Unit transportation cost from plant h to regional storage center j.

Q_{hj} = Quantity of fertilizer transferred from plant h to regional storage center j. All Q_{hj}'s are a part of the end stock of an analysis period at regional storage centers and become the beginning stock for the next period.

T_{hm} = Unit transportation cost of fertilizer from plant h to exporting harbor m.

Q_{hm} = Quantity of fertilizer transferred from plant h to exporting harbor m.

1.B. Transportation cost function for imported fertilizer:

$$TC_I = \sum_i \sum_j \sum_k T_{ijk} Q_{ijk} + \sum_i \sum_j T_{ij} Q_{ij}$$

Where:

TC_I = Total transportation costs of imported fertilizer from import harbors to other regions.

T_{ijk} = Unit transportation cost of the imported fertilizer from import harbor i to consumption region k through regional storage center j.

Q_{ijk} = Quantity of imported fertilizer from import harbor i to consumption region k through regional storage center j.

T_{ij} = Unit transportation cost of imported fertilizer from import harbor i to regional storage center j.

Q_{ij} = Quantity of the imported fertilizer from import harbor i to regional storage center j. All Q_{ij}'s are a part of the end stock at the regional storage centers.

1.C. Transportation cost function for the beginning fertilizer stock at the regional storage centers:

$$TC_J = \sum_j \sum_k T_{jk} Q_{jk}$$

Where:

TC_J = Total transportation costs of the beginning fertilizer stock from regional storage centers to consumption regions.

T_{jk} = Unit transportation cost of fertilizer stock from regional storage center j to consumption region k which j serves.

Q_{jk} = Quantity of fertilizer stock transferred from regional storage center j to consumption region k.

2. Storage cost function for the end stock of fertilizer at regional storage centers:

$$SC_J = \sum_j \sum_t \sum_{t'} S_{tt'} Q_{jtt'}$$

Where:

SC_J = Total storage costs of end stock at regional storage centers.

$Q_{jtt'}$ = Quantity of end stock of regional storage center j in period t for consumption in period t'. $Q_{jtt'}$ is the summation of fertilizer received from plants $(\sum_h Q_{hj})$ and from import harbors $(\sum_i Q_{ij})$.

3. The objective function includes all of the transportation and storage cost functions as follows:

$$DC = TC_H + TC_I + TC_J + SC_J$$

Where:

DC = Total distribution costs of fertilizer.

The objective function is to minimize subject to the following four constraints:

3.A. The total quantity supplied is equal to the total quantity utilized:

$$\left[\sum_h Q_{ph} + \sum_i Q_i + \sum_j Q_{j,t-1,t}\right] - \left[\sum_j Q_{jtt'} + \sum_k Q_{hjk} + \sum_k Q_{ijk} + \sum_k Q_{jk} + \sum_m Q_{hm}\right] = 0$$

Where:

Q_{ph} = Quantity of fertilizer produced by plant h.

$Q_{j,t-1,t}$ = Beginning stock at regional storage center j.

Q_i = Quantity of fertilizer imported through harbor i.

3.B. Excess capacity at regional storage centers is zero or positive:

$$KA_j - Q_{j,t-1,t} - \sum_j Q_{hjk} - \sum_j Q_{ijk} \geqq 0$$

$$KA_j - Q_{jtt'} - \sum_j Q_{hjk} - \sum_j Q_{ijk} \geqq 0$$

for all j's

Where:

KA_j = Capacity of storage at regional storage center j.

3.C. All quantities are non-negative:

$$Q_{ph};\ Q_i;\ Q_{j,t-1,t};\ Q_{jtt'};\ Q_{hjk};\ Q_{ijk};\ Q_{hj};\ Q_{ij};\ Q_{jk};\ Q_{hm} \geqq 0$$

3.D. All unit costs are equal to or greater than zero. Sufficiently high unit costs are used to block back-shipments:

$$T_{hh} = T_{ii} = T_{jj} = T_{kk} = T_{mm} = 0$$

$$T_{hjk};\ T_{ijk};\ T_{jk};\ T_{hj};\ T_{ij};\ T_{hm};\ S_{tt'} \geqq 0$$

To block the backshipments,

$$T_{kjh};\ T_{kji};\ T_{kj};\ T_{jh};\ T_{ji};\ T_{h};\ S_{t't} = \infty$$

2.3.2 Programming Formulation

Utilizing the modified linear programming transshipment model developed by Hurt and Tramel (1965), the analytical model of the Korean fertilizer distribution system may be formulated as indicated in figure II-3. In the matrix format, submatrix A provides for shipment of fertilizer from each supply region to each transshipment point, submatrix B has no relevance to the problem, submatrix C allows excess

	Transshipment Point 1, 2, 3. . . m, m+1 . . . m+n	Demand Region 1, 2, 3. . . n	
Supply Origins 1 2 3 . . . . . . m	A Transfer cost from supply origins to transshipment points	B Irrelevant to the problem	Quantity Supplied
Transshipment Point 1 2 3 . . . m m+1 . . . m+n	C Excess capacity at transshipment point	D Transfer cost from transshipment points to consumption and export regions and storage cost for stocks at transshipment points	Trans-ship-ment Capacity
	Transshipment Capacity	Fertilizer Demand	

Figure II-3. Matrix format of the linear programming transshipment model.

capacity for each transshipment point, and submatrix D provides for shipment to consumption and export regions and fertilizer end stock at storage facilities. With the proper constraints and assumptions, the Hurt-Tramel formulation of the transshipment model also was applicable to transportation problems.

CHAPTER III

CHARACTERISTICS OF THE KOREAN FERTILIZER DISTRIBUTION SYSTEM

The performance of a marketing system is dependent upon the structure and characteristics of the system. The purpose of this chapter is to identify the characteristics of the Korean fertilizer distribution system needed to make the analytical model operational. The characteristics of the Korean fertilizer distribution system are described; fertilizer origins and destinations are delineated; regional quantity relationships are specified; and storage and transportation constraints are identified in the following sections.

3.1 Characteristics of the Fertilizer Distribution System in Korea

In Korea, the government allocated to the farmers all of the fertilizer that was imported during the period 1945-1950.

In 1951 the government allowed free fertilizer marketing, while the government handled a great proportion of the fertilizer supply. The ratio of the quantity of fertilizer supplied through the free market to the total fertilizer supply jumped from 10 percent in 1954 to 51 percent in 1959. Under the dual fertilizer supply scheme, several defects appeared, mainly on the part of private dealers. Importation by merchants of too much of the most profitable item, nitrogen fertilizer, and only negligible amounts of phosphate and potash fertilizers was an obstacle to the government balanced N-P-K application promotion program. Unreasonable profits were also obtained by exploiting farmers and by an uneven distribution of fertilizer with respect to consumption regions.

In 1961, the government controlled system was reintroduced as a measure to protect farmers from exploitation by private fertilizer suppliers and to normalize fertilizer administration. As indicated in figure III-1, the annual fertilizer supply and utilization plan is initiated by the Ministry of Agriculture and Fisheries (MAF). Fertilizer sales are exclusively handled by agricultural cooperatives. The National Agricultural Cooperative Federation (NACF) purchases and distributes all the fertilizer, whether domestically produced or imported. Neither the manufacturers nor other private parties are allowed to participate in the fertilizer distribution process.

The National Agricultural Cooperative Federation contracts with the Korean Express Company (KEC) for

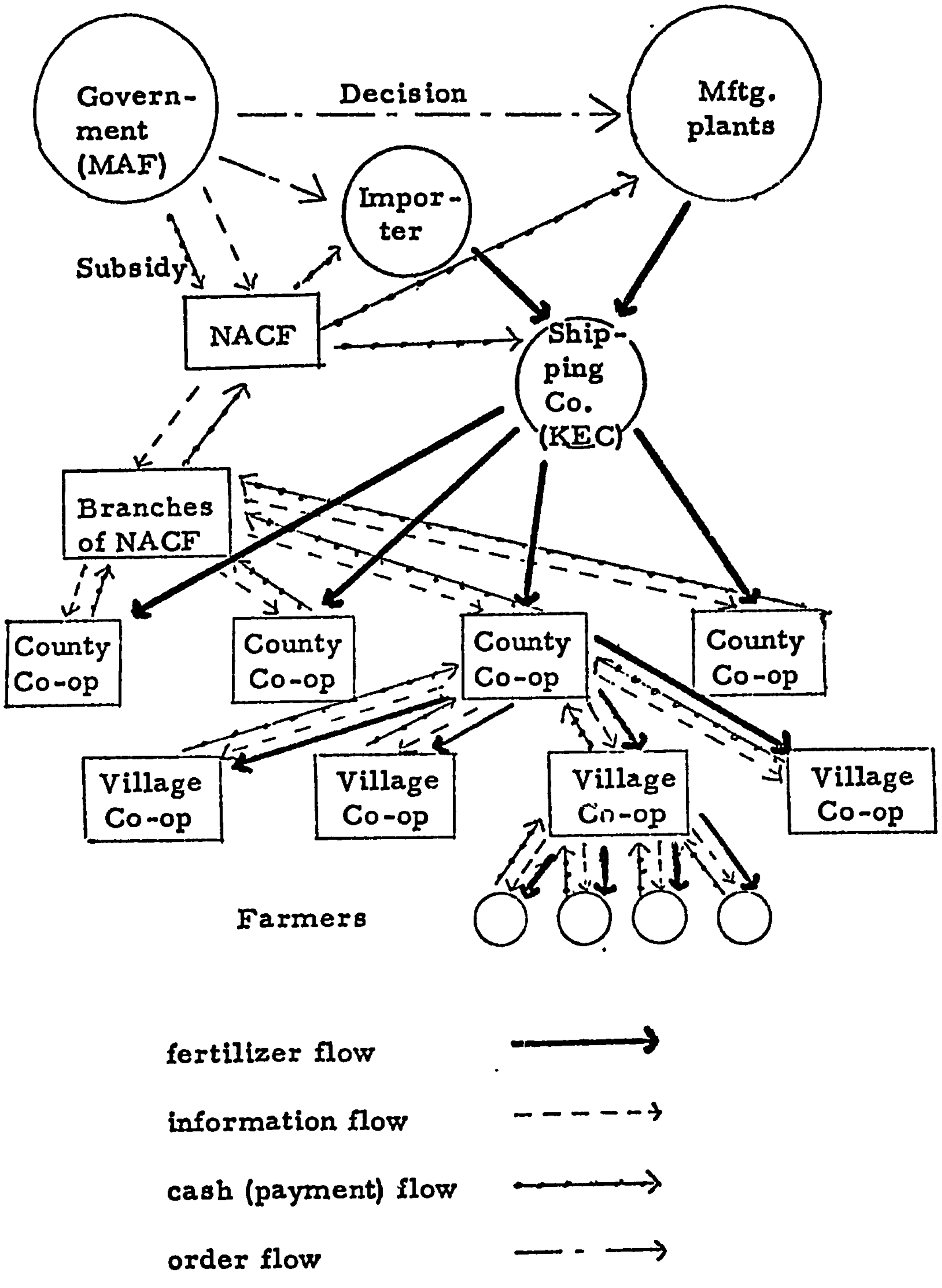

Figure III-1. Marketing channel of fertilizer distribution, Korea.

fertilizer shipments from manufacturing plants or importing harbors to distribution points. Fertilizer distribution points are regional storage facilities of various sizes which are owned or rented by agricultural cooperatives. Fertilizer is shipped by rail wherever feasible and by truck from railway stations to storage facilities. Farmers who are village cooperative members carry purchased fertilizer from distribution points to their farms at their own expense.

Because the government controls the fertilizer supply, the government rations fertilizer to farmers with respect to crop specification and planted area. The fertilizer distribution survey[1] indicated that the cash-credit sales ratio is set at 60 and 40 percent, respectively. The Grain Fertilizer Exchange Law was legislated with the primary objective to stabilize the real price of fertilizer by permitting the exchange of grain for fertilizer at a proper rate, and secondly to increase the production of grains.

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[1]The fertilizer distribution field survey of 123 randomly selected county cooperatives was conducted under the supervision of Dr. Young Kun Shim, Professor of Agricultural Economics, Seoul National University, Suwon, Korea in 1973. Interviewers were selected from students in the Department of Agricultural Economics, Seoul National University who were trained appropriately. A pretest was made prior to the survey.

The fertilizer price at the distribution point, which is equal all over the country, was based on government expenditure on fertilizer incurred by selling at lower prices than purchased prices until 1966. In 1967, the fertilizer prices were reduced by 15 percent for nitrogen and 10 percent for phosphate, potash and mixed fertilizers, in order to reduce the burden for farmers. In 1969, a further adjustment was made; the price of mixed fertilizer was reduced by 20 percent, phosphate and potash by 10 percent, but the nitrogen price was increased by 17 percent. Any difference between the government fertilizer expenses and the uniform price to farmers was a burden to the government, i.e., the government subsidized farmers. In recent years, fertilizer prices to farmers were increased due to inflation and the oil crisis: 10 percent in 1972; 30 percent in 1973; and 65 percent in 1974.

3.2 Regional Delineation

3.2.1 Fertilizer Origins

Fertilizer origins include production origins, importing harbors, and local storage centers. Delineation of these origins and the fertilizer quantities available in each region are discussed below. The discussion of regional storage centers is presented in section 3.3.

Production origins: Production origins are represented by the towns where the manufacturing plants are located (see figure III-2). In 1972, urea was produced at Chungju, Naju, Ulsan, and Jinhae. Fused phosphate was produced at Sosa and Janghang. Mixed fertilizer plants were located at Ulsan and Jinhae. Samcheok was the single production origin for calcium cyanamide. No straight potash fertilizer was produced in 1972. In 1978, a new urea and mixed fertilizer manufacturing plant is expected to be in full operation at Yosu.

Until 1961, when the Chungju urea plant began production, almost all of the fertilizer consumed was imported. Most of the new plants have come into the picture since 1967. The existing capacity of nitrogen fertilizer manufacturing plants far exceeds the present consumption requirements, but phosphate and potash production is still below that required for the increasing rate of use, especially in the case of potash fertilizer. This factor causes problems of fertilizer supply-demand imbalance and the situation is likely to worsen in the years ahead.

The limited capacity of these manufacturing plants places a production constraint on the fertilizer supply.

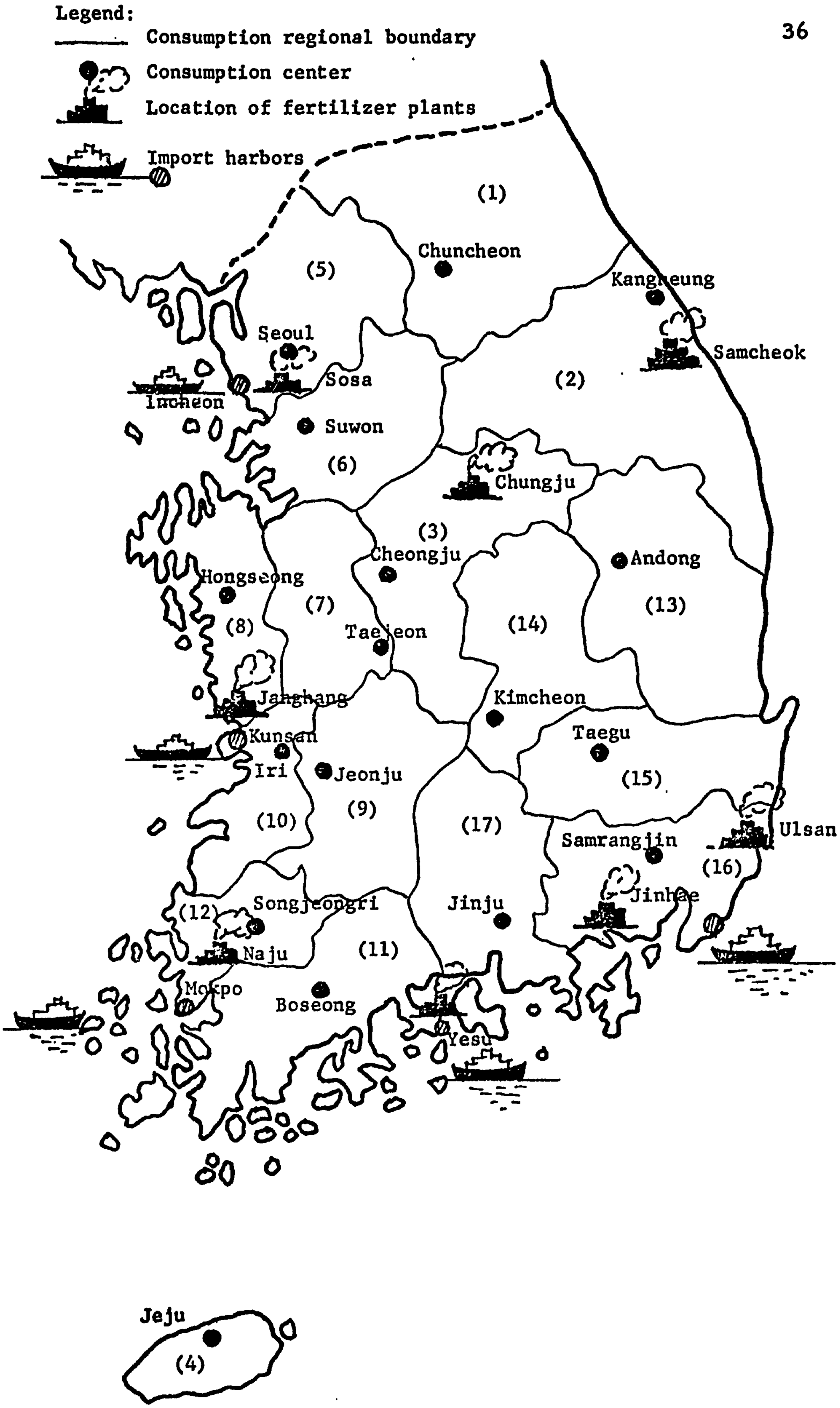

Figure III-2. Location of fertilizer manufacturing plants, Korea.

However, as the information presented in table III-1 indicates, actual production exceeded planned capacity in recent years. The 1970-1972 average ratios of production to capacity were 109 percent for urea, 106 percent for fused phosphate, 127 percent for mixed fertilizer, and 114 percent for total fertilizer (table III-1). It should be pointed out that in 1972, 71 percent of urea production capacity and 100 percent of mixed fertilizer were concentrated in the southeastern corner (Ulsan and Jinhae) of the country, resulting in logistic problems within the fertilizer distribution system. The expansion of urea production capacity of the Chungju plant in 1974 and the construction of a new urea and mixed fertilizer manufacturing plant at Yosu in 1978 will result in improved regional dispersion of urea and mixed fertilizer production. The quantity of fertilizer available at each production origin during a period is the fertilizer produced during the period plus the beginning stock at the plant warehouses.

Import harbors: The supply origins of imported fertilizers are import harbors. The analysis of imported fertilizers distribution is concerned with the shipments from Korean import harbors to various regions for consumption and stock. There are no potential importing harbors on the east coast. As shown

Table III-1. Fertilizer production capacity and production on an actual weight basis, 1972 and 1978, Korea.

Name of plant	Location of plant	1972 Capacity (100 M/T)	1972 Production (100 M/T)	1972 Prod/Cap %	1978 Capacity (100 M/T)	1978 Production (100 M/T)	1978 Prod/Cap[1] %
Urea		6256	6822	109	10998	11959	109
Chungju	Chungju	868	898	103	2310	2449	106
Honam	Naju	950	621	63	950	761	80
Yongnam	Ulsan	659	810	123	659	827	125
Hankuk	Ulsan	3120	3592	115	3120	3413	109
Jinhae	Jinhae	659	901	137	650	912	138
Yosu	Yosu	---	---	---	3300	3597	109
Calcium cyanamide		237	162	68	237	195	82
Samcheok	Samcheok	237	162	68	237	195	82
Fused phosphate		1476	1567	106	1476	1490	101
Kyongki	Sosa	467	483	103	467	470	101
Pungnong	Janghang	1009	1084	107	1009	1020	101
Mixed fertilizer		3976	5058	127	4676	5344	115
Yongnam	Ulsan	1998	2619	131	1998	2316	117
Jinhae	Jinhae	1998	2439	122	1998	2223	112
Yosu	Yosu	---	---	---	700	805	115
Fertilizer total		11945	13609	114	17387	18988	109

Note: [1] Production/capacity ratios for 1978 are the average ratios during 1970-1972. Therefore, production of 1978 were calculated by the multiplication of capacity and the ratios.

in figure III-2, designated potential import harbors include Incheon and Kunsan on the west coast and Mokpo, Yosu, and Pusan on the south coast. The criteria used for designation of harbors as potential importing harbors were: (1) the fertilizer consumption within regions that may be served by a harbor; (2) the loading and unloading capacity for ocean vessels of a certain harbor; and (3) the railway network available at the harbor.

Each potential import harbor was given unlimited capacity. The quantity of fertilizer imported through each harbor was dependent upon the total import and regional consumption. Given total imports, the analytical models determined the quantity imported through each harbor in such a way that the distribution cost was minimized. Consideration of fertilizer shipment from any exporting country to Korea was beyond the scope of this study.

3.2.2 Fertilizer Destinations

Fertilizer destinations include the consumption regions, export outlets, and the various storage facilities where fertilizer end stocks are stored.

Consumption regions: Prior to delineation of consumption regions, Korea was divided into four cropping areas according to geographical and administrative boundaries and cropping patterns. The provincial boundaries served as one criterion in the delineation because each provincial branch office of the agricultural cooperative serves the county cooperatives within the province. Provinces were grouped into four areas according to their cropping patterns: (1) the upland cropping area (Kangwon, Chungbuk, and Jeju provinces); (2) the single cropping area (Kyongki and Chungnam provinces); (3) the western double cropping area (Jeonbuk and Jeonnam provinces); (4) and the eastern double cropping area (Kyongbuk and Kyongnam provinces) (figure III-3). An island in the south, Jeju province, was included in the upland area due to its heavy ratio of upland to total arable land and single cropping pattern.

The arable land ratios and fertilizer consumption ratios for the four cropping areas are compared in table III-2. The relatively lower ratios of fertilizer consumption compared to the arable land ratios in the single and upland cropping areas are due to the high ratio of upland to arable land and the single cropping pattern. The double cropping areas require more fertilizer per hectare of arable land than the northern

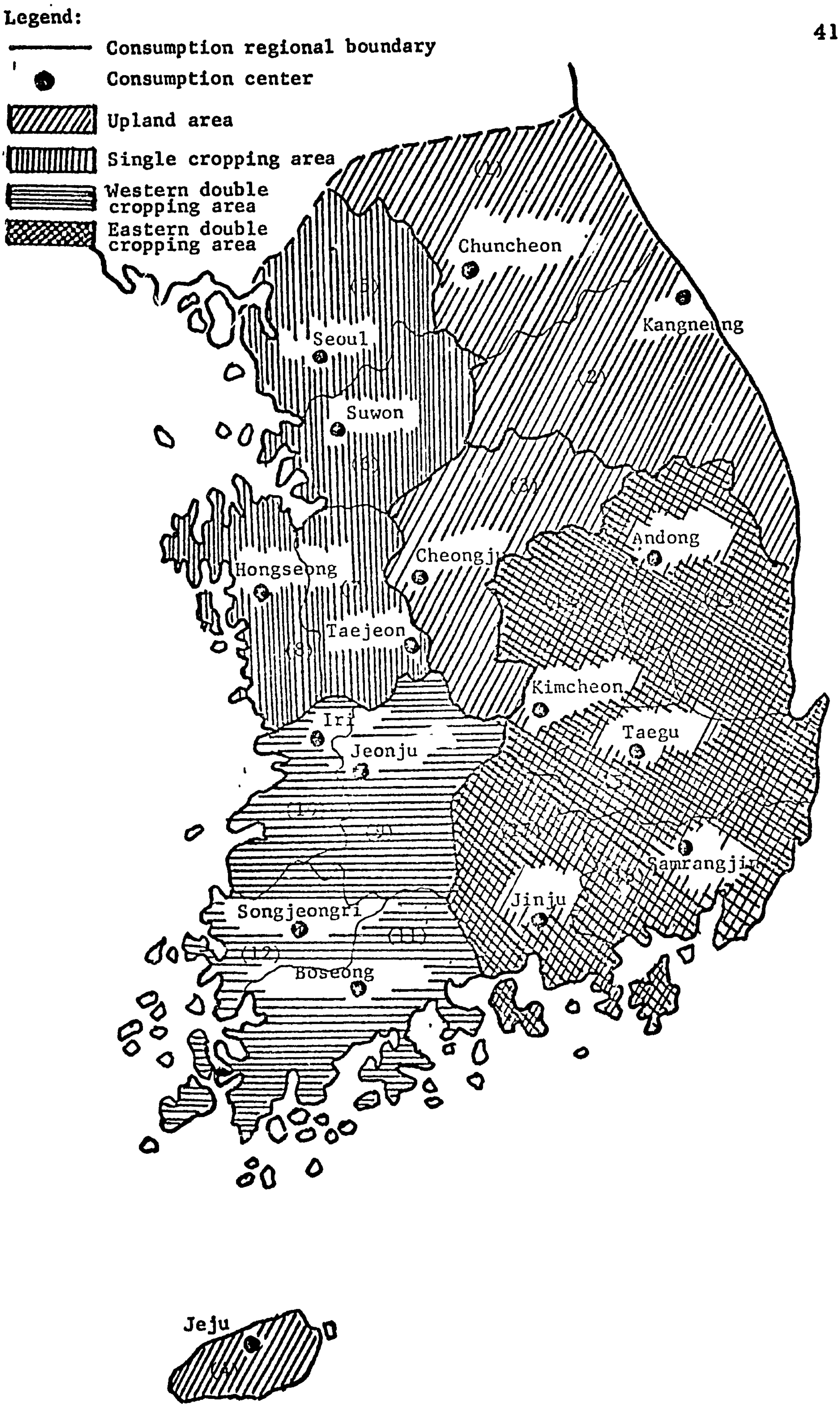

Figure III-3. Fertilizer consumption regions and cropping areas, Korea

Table III-2. Area fertilizer consumption pattern on the plant nutrient basis, 1970-1972, Korea.

Cropping Area		Total area 1,000 ha	%	Arable land 1,000 ha.	%	Average fertilizer consumption ratio Total	N	P	K
						--------	%	--------	
I	upland	2598	26	388	17	15	15	15	17
II	single cropping	2027	21	603	27	23	23	22	23
III	western doublè cropping	2011	20	614	27	31	31	32	29
IV	eastern double cropping	3212	33	656	29	31	31	31	31
	All Korea	9848	100.0	2261	100.0	100.0	100.0	100.0	100.0

Source: Yearbook of Agricultural and Forestry Statistics, MAF, Korea, 1973.

areas, because these areas are characterized as double cropping paddy areas. This division of the country into four cropping areas is used later along with farm survey data in Chapter IV to estimate fertilizer consumption.

Assuming homogeneity of agricultural production within a cropping area, seventeen fertilizer consumption regions were delineated according to the railway network and the county agricultural cooperative boundaries (figure III-3). Location of consumption regions, consumption centers, and counties included in the regions are presented in table III-3. Each cropping area includes four or five consumption regions. Each consumption region consists of nine counties on the average. The consumption center selected to represent a consumption region is a centrally located town through which one or more railways pass.

The fertilizer consumption on an actual weight basis is estimated using the actual plant nutrient consumption for 1972 and the statistical relationships of the 1972 farm survey data in Chapter IV. Given an area's fertilizer consumption estimate, the regional consumption was calculated by applying regional arable land ratios to total arable land within the cropping area (see table III-4).

Table III-3. Consumption regions, consumption centers, and counties included in consumption regions, Korea.*

Consumption regions in provinces	Consumption centers	Counties included
1. Northern Kangwon	Chuncheon	Cheolwon, Hwacheon, Yangku, Koseong, Chunseong, Injae, Hongcheon, Yangyang.
2. Southern Kangwon	Kangneung	Hoengseong, Pyongchang, Myongju, Wonseong, Yongwol, Jeongseon, Samcheok.
3. Chungbuk	Cheongju	Jincheon, Eumseong, Jungwon, Jecheon, Danyang, Koysan, Cheongwon, Boeun, Okcheon, Yongdong.
4. Jeju	Jeju	Bukjeju, Namjeju
5. Northern Kyongki	Seoul	Yoncheon, Paju, Yangju, Pocheon, Kapyong, Kanghwa, Kimpo, Ongjin, Bucheon, Koyang, Seoul.
6. Southern Kyongki	Suwon	Siheung, Kwangju, Yangpyong, Hwaseong, Yongju, Icheon, Yoju, Pyongtaek, Anseong.
7. Eastern Chungnam	Taejeon	Asan, Cheonwon, Kongju, Yonki, Nonsan, Daedeok, Keumsan.
8. Western Chungnam	Hongseong	Dangjin, Seosan, Yesan, Hongseong, Boryong, Cheongyang, Buyo, Seocheon.

Table III-3. (continued)

Consumption regions in provinces	Consumption centers	Counties included
9. Eastern Jeonbuk	Jeonju	Wanju, Jinan, Muju, Imsil, Jangsu, Sunchang, Namwon.
10. Western Jeonbuk	Iri	Iksan, Oku, Kimjae, Buan, Jeongeup, Kochang.
11. Eastern Jeonnam	Boseong	Kokseong, Kuriae, Hwasun, Seungju, Kwangyang, Yongam, Jindo, Haenam, Kangjin, Jangheung, Boseong, Koheung, Wando, Yocheon.
12. Western Jeonnam	Songjeongri	Yongkwang, Jangseong, Damyang, Hampyong, Kwangsan, Sinan, Muan, Naju.
13. Eastern Kyongbuk	Andong	Yongju, Bonghwa, Uljin, Andong, Yongyang, Cheongsong, Yongdeok, Yongil, Ulneung.
14. Western Kyongbuk	Kimcheon	Munkyong, Yaecheon, Sangju, Euseong, Seonsan, Kunwy, Keumneung.
15. Southern Kyongbuk	Taegu	Seongju, Chilkok, Yongcheon, Koryong, Dalseong, Kyongsan, Cheongdo, Wolseong.

Table III-3. (continued)

Consumption regions in provinces	Consumption centers	Counties included
16. Eastern Kyongnam	Samrangjin	Changyong, Milyang, Uljin, Haman, Changwon, Kimhae, Yangsan, Dongrae, Keojae, Pusan.
17. Western Kyongnam	Jinju	Keochang, Hamyang, Habcheon, Sancheong, Euryong, Hadong, Jinyang, Sacheon, Namhae, Koseong, Tongyong.

*Seoul (in region 5) and Pusan (in region 6) are special cities but they are treated as counties in this analysis because the level of agricultural output in these cities is similar to that in counties.

Table III-4. Fertilizer consumption regions, centers, and arable land - total land ratios, 1972, Korea.

Cropping area	Consumption region	Consumption center	Total land	Arable land: Total	Arable land: Paddy	Arable land: Upland	Regional arable land ratio within area (%)
			-----	-----1000 ha-----	-----	-----	
I. Upland Area			2598	388	135	253	(100.0)
	1	Chuncheon	839	69	29	40	18
	2	Kangneung	832	93	27	66	24
	3	Cheongju	744	177	78	99	45
	4	Jeju	183	49	1	48	13
II. Single Cropping Area			2027	603	364	239	(100.0)
	5	Seoul	616	136	81	55	23
	6	Suwon	541	174	104	70	29
	7	Taejeon	416	129	77	52	21
	8	Hongseong	454	164	102	62	27
III. Western Double Cropping Area			2011	614	381	233	(100.0)
	9	Jeonju	486	98	59	39	16
	10	Iri	319	153	108	45	25
	11	Boseong	811	215	129	86	35
	12	Songjeongri	395	148	85	63	24

Table III-4. (continued)

Cropping area	Consumption region	Consumption center	Total land	Arable land Total	Arable land Paddy	Arable land Upland	Regional arable land ratio within area (%)
			-----	-----	1000 ha	-----	
IV.			3212	656	390	266	(100.0)
Eastern	13	Andong	794	120	51	69	18
Double	14	Kimcheon	610	139	79	60	21
Cropping	15	Taegu	576	127	80	47	19
Area	16	Samrangjin	566	134	93	41	21
	17	Jinju	666	136	87	49	21
All Korea			9848	2261	1270	991	

Source: Yearbook of Agricultural and Forestry Statistics, MAF, Korea, 1973.

Export outlets: Korea exported urea and mixed fertilizers in 1972. Mixed fertilizers exported were not the same types as those imported. By 1978, it is expected that no mixed fertilizer will be exported due to increasing mixed fertilizer consumption.

Each designated potential export outlet selected is a harbor located in close proximity to a domestic fertilizer manufacturing plant. Potential harbors were: (1) Incheon for the Chungju plant; (2) Mokpo for the Honam plant; (3) Ulsan for the Hankuk and Yongnam plants; (4) Jinhae for the Jinhae plant; and (5) Yosu for the Yosu plant.

The quantity of fertilizer exported through any potential harbor depends upon the total fertilizer exportation and the quantity exported from the manufacturing plant which the harbor serves as its export outlet.

3.3 Fertilizer Distribution Facilities

Fertilizer distribution facilities may include transportation, storage, bagging, and blending facilities. Fertilizers domestically produced are all bagged at manufacturing plants. Bulk fertilizers imported are all bagged at importing harbors. Domestic fertilizer shipments are all made by bag. There are no fertilizer blending facilities at this time. It is, however, an hypothesis of this study that the introduction of bagging and blending facilities in local areas will improve the marketing efficiency of the Korean fertilizer distribution system.

Storage facilities: As indicated in table III-5, the total storage capacity managed by the agricultural cooperatives was 1,441,268 metric tons in 1972. The number of storage facilities was 6,792 scattered throughout the country with the average size of 212 metric tons. County agricultural cooperatives owned 29.9 percent of total storage capacity. Sub-county and village owned 63.1 percent and 7.0 percent of the total capacity was rented from administrative organizations, the National Express Company, private parties and others.

The same storage facilities were used for grains, fertilizer, and other materials. The estimated capacity available for fertilizer stock was 507,800 metric tons. The regional distribution of estimated fertilizer storage facilities is presented in table III-6. To facilitate the analysis, each consumption center was designated as a storage center and was treated as though it was the location of the entire storage

Table III-5. The total storage capacity managed by agricultural cooperatives, 1972, Korea.

Owner	Classification	Storage facility %	Storage facility number	Capacity	Av. capacity per storage	Distribution of storage capacity	
				M/T	M/T	%	
County Ag. coop.	A[1]	(10.6)	162	67,213	415	15.6	
	B[2]	(41.2)	628	198,623	316	46.1	
	C[3]	(48.2)	734	164,730	224	38.2	
	Total	(100.0)	1524	430,566	283	(100.0)	29.9
Unit[4] Ag. coop.	A	(6.8)	318	121,153	381	13.3	
	B	(36.9)	1740	398,891	229	43.9	
	C	(56.3)	2654	388,809	146	42.8	
	Total	(100.0)	4712	908,853	193	(100.0)	63.1
Rented[5]	A	(3.1)	17	3,415	201	3.3	
	B	(30.6)	170	40,883	240	40.1	
	C	(66.3)	369	57,551	156	56.5	
	Total	(100.0)	556	101,849	183	(100.0)	7.0
Total	A	(7.3)	497	191,781	386	13.3	
	B	(37.4)	2538	638,397	252	44.3	
	C	(55.3)	3757	611,090	163	42.4	
	Total	(100.0)	6792	1441,268	212	(100.0)	(100.0)

Footnotes for Table III-5.

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[1]Class A includes storages which can store more than 4 M/T per Pyung.

[2]Class B includes storages which can store 3.5-4 M/T per pyung.

[3]Class C includes storages which can store less than 3.5 M/T per pyung.

[4]Unit cooperatives are sub-county cooperatives or village cooperatives.

[5]Number of rented storages consist of 49 from administrative organizations, 26 from the Korean Express Company, 440 from private parties, and 43 from others.

Table III-6. Estimated fertilizer storage capacity, 1972, Korea.

Number of consumption region	Storage center designated	Capacity M/T	Distribution of capacity %
1	Chuncheon	13200	2.6
2	Kangneung	17500	3.5
3	Cheongju	33500	6.6
4	Jeju	12800	2.5
Area I		77000	15.2
5	Seoul	24900	4.9
6	Suwon	31600	6.2
7	Taejeon	23700	4.7
8	Hongseong	30200	5.9
Area II		110400	21.7
9	Jeonju	29100	5.7
10	Iri	45600	9.0
11	Boseong	45800	9.0
12	Songjeongri	31800	6.3
Area III		152300	30.0
13	Andong	28600	5.6
14	Kimcheon	33200	6.5
15	Taegu	30400	6.0
16	Samrangjin	38000	7.5
17	Jinju	37900	7.5
Area IV		168100	33.0
All Korea		507800	100.0

capacity for its respective consumption region for the 1972 fertilizer distribution analysis. In the 1978 analysis, however, an efficient system of regional storage centers is determined by the model.

The current storage rate regulated by the government is a flat rate regardless of size and location of storage facility and is independent of quantity of fertilizer stored. The rate per unit of time does not vary in accordance with the length of time for fertilizer storage. Estimation of the real cost functions was desirable to use in determining optimum fertilizer distribution patterns, but could not be made due to the availability of data.

Possible differences between the government-regulated rate and real cost may be explained by figure III-4. Storage cost per unit of fertilizer per unit of time is expressed as a function of the length of time for fertilizer storage in figure III-4. The pegged storage rate is represented by the horizontal line "GSC." The real cost function may be a curvilinear function as shown by SC_1 or SC_2. Therefore, the real storage cost may be greater or smaller than the pegged rate.

Since the fertilizer distribution analyses were conducted using the current pegged storage rate, the results may not render socially optimum solutions, but the best feasible

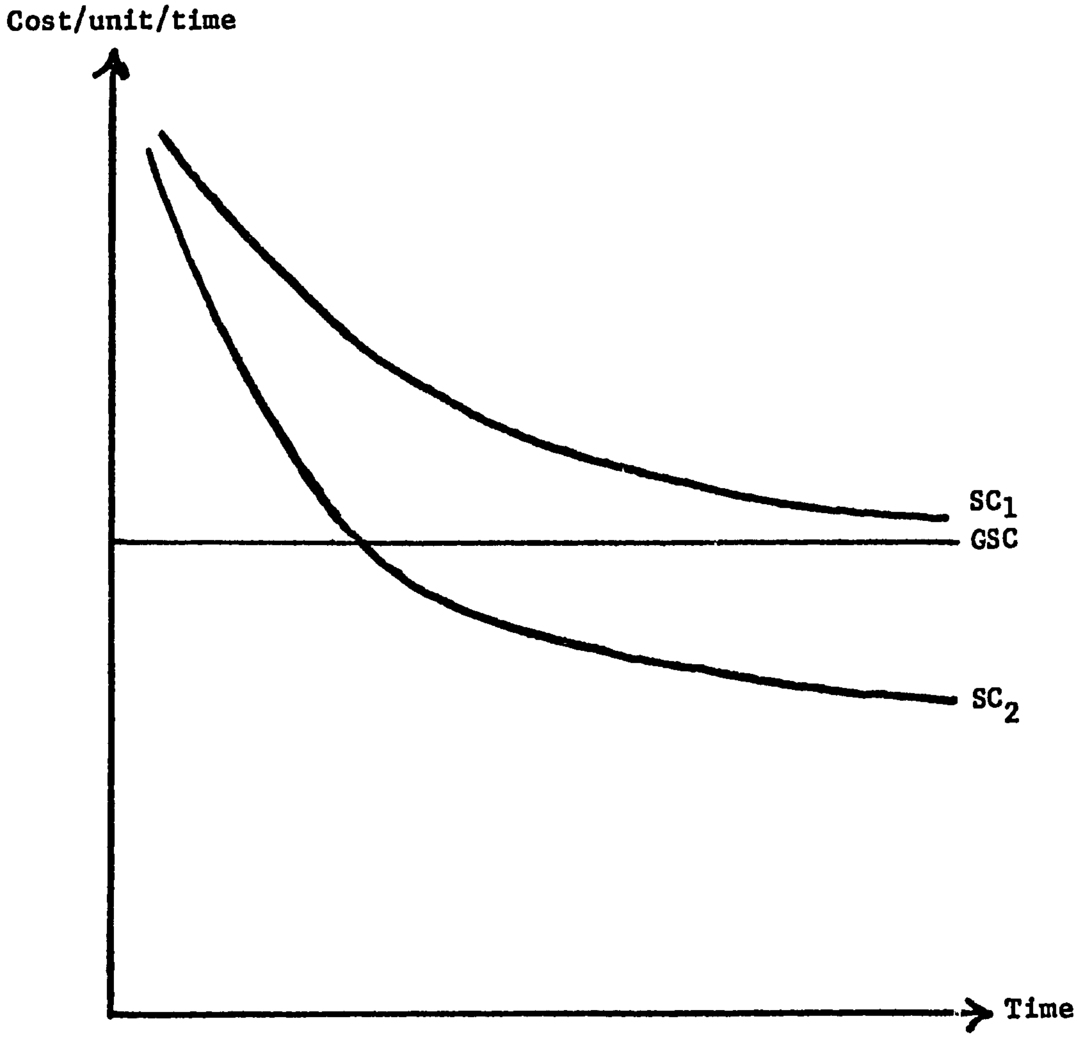

Figure III-4. A diagramatic representation of alternative storage cost functions.

solutions under given storage rates. The flat storage rate used was 75 wons per metric ton of fertilizer per 15 days.

Transportation facilities: Korean Express Company transports fertilizer from supply regions to local distribution points by rail whenever feasible, because the rail freight rate is cheaper than other freight rates. Trucks and vessels are used when rail transportation is not feasible, usually from railway stations to distribution points.

Every pair of regions in this study are connected by the railway network with the exception of the Jeju consumption region. The loading and unloading capacities of regional consumption centers were not considered.

The rail freight rate structure was a flat freight rate set up by the National Railway Office. For the purpose of freight rate determination, bagged fertilizer falls within the category of the fourth grade commodities. The rail freight rate was 83 wons per metric ton of bagged fertilizer per 50 kilometers and was independent of the volume transferred (The National Railway Office, 1972). Shipment of fertilizer by bulk could reduce the transportation cost of fertilizer, because fertilizer in bulk falls within the category of the fifth grade materials and its freight rate was 73 wons per metric ton per 50 kilometers. Both the bagged and bulk rates could only be applied on a full carload basis. If the shipment was less than full carload, higher freight rates than the rates indicated above were charged.

Since the current rail freight rates are pegged by the government, two questions are raised regarding freight rates: whether the freight rates reflect the real costs; and whether the difference between bagged and bulk rates is the real cost difference. Investigation of the real transportation cost functions could not be conducted due to the lack of data. However, a judgement regarding possible difference between pegged freight rate and real transportation cost can be made by figure III-5. The unit transportation cost per kilometer is expressed as a function of distance in figure III-5. The pegged freight rate is depicted by the horizontal straight line "GTC." Possible real unit transportation cost functions are represented by curvilinear curves "TC_1" and "TC_2." Hence, the government-regulated rate may be greater or smaller than real unit transportation cost.

Since the real transportation costs for shipping bulk and bagged fertilizers could not be estimated, the question of the real cost reduction resulting from fertilizer shipment from bag to bulk was unanswered.

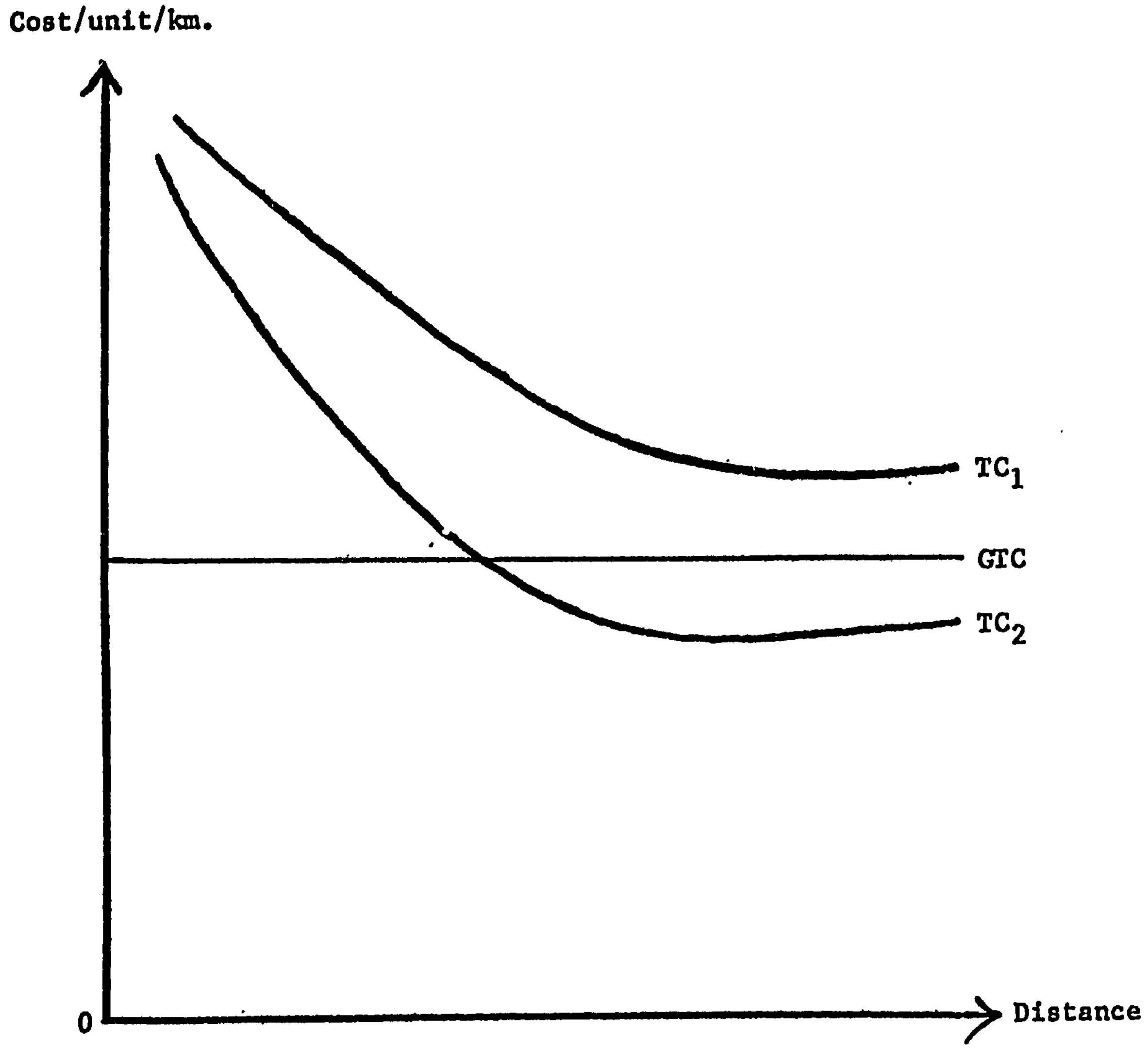

Figure III-5. A diagramatic representation of alternative transportation cost functions.

The current rail freight rates were used in the distribution analyses. Therefore, results indicate the most feasible solutions under given freight rate structure rather than social optimum solutions.

Transportation costs per metric ton of fertilizer on a full carload basis are presented in Appendix tables A-1 and A-2 for bagged fertilizer and fertilizer in bulk, respectively.

CHAPTER IV

FERTILIZER SUPPLY AND UTILIZATION

4.1 Introduction

Given fertilizer origins and destinations delineated in the previous Chapter, it is necessary to specify regional fertilizer quantity relationships to solve the fertilizer distribution problems. The purpose of this chapter is to approximate the fertilizer quantities supplied and utilized for 1972 and 1978.

To satisfy the requirements of the mathematical model used in this analysis, relationships between quantities supplied and utilized were expressed in the form of a fertilizer supply and utilization accounting equation:

Beginning stock + Production + Imports

= Consumption + Exports + End stock

where:

Quantity supplied = Beginning stock + Production + Imports

Quantity utilized = Consumption + Exports + End stock

Approximation of fertilizer quantities supplied and utilized for 1972 and 1978 was based on production and consumption. Production estimates were presented in table III-1 for 1972 and 1978. In section 4.2, the statistical fertilizer plant nutrient consumption relationships are estimated using the 1972 farm survey data. The prediction of 1978 fertilizer plant nutrient consumption is made based on the statistical consumption relationships. Fertilizer nutrient consumption is converted to actual fertilizer to provide quantity information for the fertilizer distribution problem. Section 4.3 presents approximation of fertilizer quantities supplied and utilized for 1972 and 1978. Seasonality of fertilizer consumption is discussed in section 4.4. Regional quantities estimated in this chapter are incorporated in the following two chapters.

4.2 Estimation of Fertilizer Consumption

4.2.1 Estimation of Fertilizer Plant Nutrient Consumption Using 1972 Farm Survey Data Empirical Model[1]

Using cross-section data, fertilizer consumption models have been developed by Griliches (1959), Daniel (1970), and

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[1] In developing this section, the author drew heavily from Demand for Fertilizer in Korea by Bai Yung Sung, Unpublished Ph.D. Thesis, University of Minnesota, 1974.

Sung (1974) to study the differences in fertilizer consumption between regions or between farmers. Their models were based on economic theory in which the quantity of an input demanded for a profit maximizing firm depends on the price of that input, price of output for which the input is employed, and prices of close substitutes and complements. In this analysis, it was assumed that each farmer maximizes his profit under perfect competition in the input and output markets.

In estimating fertilizer plant nutrient consumption relationships per farm for total fertilizer, all nitrogen, all phosphate, and all potash fertilizers, the following regression models were used for each plant nutrient and cropping area by the ordinary least squares method:

$$Y = b_0+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+U$$

where:

Y = quantity of fertilizer plant nutrient consumed by a sample farm (Kg)

X_1 = expense on Y paid by a sample farm (10 wons)

X_2 = expenditure on agricultural chemicals by a sample farm (1,000 wons). Pesticides were used as a proxy variable for agricultural chemicals.

X_3 = expenditure on agricultural implements by a sample farm (1,000 wons)

X_4 = expenditure on hired labor by a sample farm (1,000 wons)

X_5 = farmer income which includes gross farm income and off-farm income (1,000 wons)

X_6 = planted area per sample farm (10 pyungs)

U = disturbance term

The disturbance term was assumed to be normally distributed with an expected value of zero and constant variance. It was also assumed that the disturbance terms associated with each set of observations are independent of other sets of observations and that the disturbance terms are not correlated with any predetermined variables. These assumptions insure the attainment of maximum likelihood estimations of the parameters in the equations above.

Independent variables in the above regression models include only one endogenous variable. Cross effects between fertilizer nutrients were not considered. Since an increase in the use of a fertilizer may not be explained by completely different endogenous variables but may be explained by common variables, the assumption of independent disturbance terms in three individual fertilizer nutrient consumption models may not hold and the OLS estimation would result in inefficient estimates. Hence, the simultaneous estimation of the parameters using the generalized least squares method (GLS) would result in more efficient estimates than the OLS. Too many variables, however, are incorporated into the three individual fertilizer nutrient models for computer programming to allow estimates of parameters simultaneously. Therefore, the ordinary least squares method was employed to estimate the fertilizer consumption functions.

Data: A field survey[1] was conducted in 1972 to study differences in fertilizer use between cropping areas. Villages were randomly selected from each cropping area and 10 farms were randomly selected from each sample village. Three hundred observations for all Korea included 30 from the upland area (I), 70 from the single cropping area (II), 90 from the western double cropping area (III), and 110 from the eastern double cropping area (IV).

Results: Statistical results are presented in tables IV-1 through IV-4 for total fertilizer, all nitrogen, all phosphate, and all potash. They show the fertilizer consumption relationships per farm for all Korea and four cropping areas.

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[1]The field survey was conducted under the supervision of Dr. Young Kun Shim, Professor of Agricultural Economics, Seoul National University, Suwon, Korea. Interviewers were selected from students in the Department of Agricultural Economics, Seoul National University who were trained appropriately for the survey. A pretest was made prior to the survey.

Table IV-1. Regression coefficients and related statistics for total fertilizer consumption function per sample farm on the plant nutrient basis, 1972, Korea.

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Number of observations	300	30	70	90	110
Intercept	340.1540**	361.6977+	413.5919**	500.1169**	342.4647**
	(56.4599)	(198.4798)	(105.8085)	(84.1929)	(88.7640)
Price of fertilizer	-59.0356**	-60.6648	-74.3826**	-93.2303**	-53.3686**
	(10.2566)	(36.8097)	(20.2585)	(16.1606)	(15.0922)
Agricultural chemicals	5.3403**	17.6692**	-0.3136	1.8462*	8.5633**
	(0.7112)	(4.0053)	(1.4660)	(0.8033)	(1.1721)
Agricultural implements	0.4980**	0.2289	-0.1448	1.2691*	0.3669+
	(0.1642)	(0.8953)	(0.3291)	(0.5977)	(0.2194)
Labor	0.8285**	0.1089+	-0.0223	-0.0704	1.9125**
	(0.2281)	(0.7626)	(0.4411)	(0.2549)	(0.4009)

Table IV-1. (continued)

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Farmer income	0.0457 (0.0383)	-0.0225 (0.0955)	0.1785* (0.0802)	0.0804 (0.0529)	0.0656 (0.0596)
Planted area	0.3823** (0.0303)	0.2457** (0.0843)	0.4915** (0.0676)	0.4738** (0.0307)	0.2725** (0.0551)
$\bar{R}^2$	0.73	0.77	0.70	0.85	0.79
F - statistic	132.80**	16.82**	28.02**	84.60**	69.21**

Note: $\bar{R}^2$: coefficient of determination adjusted for degrees of freedom
+ : significant at 10% level
* : significant at 5% level
** : significant at 1% level

Values in parentheses are standard errors of coefficients.

Table IV-2. Regression coefficients and related statistics for all nitrogen fertilizer consumption function per sample farm on the plant nutrient basis, 1972, Korea.

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Number of observations	300	30	70	90	110
Intercept	112.9011**	158.7657	66.2040	158.6299**	169.9187*
	(37.9730)	(195.4500)	(90.3149)	(37.7287)	(65.4090)
Price of all nitrogen	-15.8261*	-22.5890	-8.6701	-24.5059**	-22.7303*
	(6.2398)	(32.2177)	(15.3494)	(6.3544)	(10.3837)
Agricultural chemicals	2.5938**	7.3426**	0.3692	0.3401	4.4267**
	(0.3008)	(1.8456)	(0.6459)	(0.3106)	(0.5041)
Agricultural implements	0.0189	0.2082	-0.0778	0.0825	-0.0300
	(0.0686)	(0.4526)	(0.1428)	(0.2284)	(0.0925)
Labor	0.2504*	0.3407	-0.0550	0.0938	0.4466*
	(0.0965)	(0.3925)	(0.1930)	(0.0974)	(0.1721)

Table IV-2. (continued)

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Farmer income	0.0243	-0.0047	0.0861*	0.0637**	0.0271
	(0.0162)	(0.0504)	(0.0347)	(0.0204)	(0.0258)
Planted area	0.2347**	0.1648**	0.2668**	0.2787**	0.1803**
	(0.0128)	(0.0446)	(0.0300)	(0.0120)	(0.0234)
$\bar{R}^2$	0.79	0.77	0.78	0.93	0.80
F - statistic	183.69**	16.87**	40.90**	185.65**	74.00**

Note: $\bar{R}^2$: coefficient of determination adjusted for degrees of freedom
+ : significant at 10% level
* : significant at 5% level
** : significant at 1% level

Values in parentheses are standard errors of coefficients.

Table IV-3. Regression coefficients and related statistics for all phosphate fertilizer consumption function per sample farm on the plant nutrient basis, 1972, Korea.

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Number of observations	300	30	70	90	110
Intercept	7.0625 (15.6570)	-3.0878 (47.1260)	-10.7997 (38.7112)	-10.9550 (30.2363)	33.6632 (24.5051)
Price of all phosphate	-1.4993 (2.9104)	2.7943 (9.9211)	3.0031 (7.3118)	2.4438 (6.3397)	-6.1160 (4.0787)
Agricultural chemicals	1.1248** (0.3167)	5.0176** (1.6593)	-0.5268 (0.6856)	0.6404 (0.5197)	1.9390** (0.4849)
Agricultural implements	0.1017 (0.0724)	-0.2226 (0.4221)	0.0445 (0.1550)	0.2213 (0.3479)	0.0606 (0.0948)
Labor	0.3835** (0.1006)	-0.2822 (0.3349)	-0.0338 (0.2072)	0.0201 (0.1454)	0.9635** (0.1657)

Table IV-3. (continued)

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Farmer income	0.0274 (0.0168)	0.0014 (0.0405)	0.0328 (0.0378)	0.0267 (0.0304)	0.0407+ (0.0246)
Planted area	0.1106** (0.0134)	0.0708+ (0.0361)	0.1557** (0.0315)	0.1189** (0.0174)	0.0867** (0.0228)
$\bar{R}^2$	0.54	0.45	0.40	0.53	0.71
F - statistic	60.12**	4.89**	8.62**	17.43**	45.74**

Note: $\bar{R}^2$: coefficient of determination adjusted for degrees of freedom
+ : significant at 10% level
* : significant at 5% level
** : significant at 1% level

Values in parentheses are standard errors of coefficients.

Table IV-4. Regression coefficients and related statistics for all potash fertilizer consumption function per sample farm on the plant nutrient basis, 1972, Korea.

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Number of observations	300	30	70	90	110
Intercept	64.9967**	49.6076*	105.6524**	82.9092**	104.7447**
	(13.6575)	(23.1659)	(26.5190)	(20.3861)	(27.5108)
Price of all potash	-19.6707**	-16.5475+	-30.8158	-27.1359**	-29.6844**
	(4.3707)	(8.2457)	(8.2429)	(7.0323)	(8.3235)
Agricultural chemicals	1.5797**	8.2001**	-0.0065	0.6341+	2.1991**
	(0.2625)	(1.0557)	(0.6680)	(0.3186)	(0.4374)
Agricultural implements	0.2658**	-0.6883**	-0.1283	-0.2550	0.3448**
	(0.0601)	(0.2490)	(0.1491)	(0.2491)	(0.0852)
Labor	0.2019*	-0.1929	0.1970	0.0572	0.4720**
	(0.0842)	(0.2303)	(0.1988)	(0.0987)	(0.1495)

Table IV-4. (continued)

	All Korea	Upland area (I)	Single cropping area (II)	Western double cropping area (III)	Eastern double cropping area (IV)
Farmer income	0.0147 (0.0141)	0.0027 (0.0287)	0.0772* (0.0362)	0.0121 (0.0209)	0.0064 (0.0221)
Planted area	0.0398** (0.0112)	0.0164 (0.0256)	0.0399 (0.0302)	0.0611** (0.0120)	0.0174 (0.0205)
$\bar{R}^2$	0.45	0.75	0.37	0.45	0.59
F - statistic	42.60**	15.48**	7.76**	13.31**	27.28**

Note: $\bar{R}^2$: coefficient of determination adjusted for degrees of freedom
+ : significant at 10% level
* : significant at 5% level
** : significant at 1% level

Values in parentheses are standard errors of coefficients.

The statistical results can be summarized as follows:

1. Coefficients of determination adjusted for degrees of freedom ($\bar{R}^2$) are higher for the total fertilizer and nitrogen functions (0.70 - 0.92) than for phosphate and potash functions (0.37 - 0.75).

2. Estimated F-statistics indicate that the regressions are statistically significant at the 1% level for all functions.

3. The negative effect of price on fertilizer consumption is true in most cases, with some exceptions in the case of phosphate.

4. Positive and significant coefficients for planted area indicate that an increase in planted area will increase the fertilizer consumption.

5. Insignificant and alternating signs of the coefficients for farmer income suggest that farmer income has little effect on fertilizer consumption.

6. In most cases, agricultural chemicals and implements appeared to be complements of fertilizer.

7. From the analysis it was difficult to judge whether labor is a complement of fertilizer or a substitute for fertilizer.

Estimated area fertilizer consumption: Expected values of independent variables in the fertilizer consumption relationships and the number of farms within each cropping area for 1972 and 1978 are presented in table IV-5. To obtain area fertilizer consumption it was necessary to know the number of farms in each area because the consumption relationships were estimated at farm level.

The 1972 expected values of independent variables were the sample means. Number of farms per area in 1972 was obtained from the Yearbook of Agricultural and Forestry Statistics (1973). The actual and estimated area consumption of fertilizer plant nutrients for 1972 are compared in table IV-6. The 1972 actual consumption was obtained from the Yearbook of Agricultural and Forestry Statistics (1973). The 1972 consumption estimates for all individual nutrients and all cropping areas deviated from actual consumption by 14 to 53 percent for the eastern double cropping area (IV) and by one to 16 percent for other areas.

The 1978 expected values of variables except fertilizer prices were estimated by linear time trend using 1962-1972 data and were expressed in terms of the 1972 price level (table IV-5). No attempt was made to study any possible structural changes that may affect the coefficients of the independent

Table IV-5. Expected values of independent variables in the fertilizer plant nutrient consumption relationships and number of farms within cropping area for 1972 and 1978, Korea.

		All Korea		Area I		Area II		Area III		Area IV	
	Unit	1972	1978	1972	1978	1972	1978	1972	1978	1972	1978
Price of total fertilizer	won	52.3	52.3	52.0	52.0	51.8	51.8	52.7	52.7	52.5	52.5
Price of all nitrogen	won	60.2	60.2	59.6	59.6	59.8	59.8	60.5	60.5	60.4	60.4
Price of all phosphate	won	48.7	48.7	46.0	46.0	49.6	49.6	47.8	47.8	49.7	49.7
Price of all potash	won	28.5	28.5	26.7	26.7	29.1	29.1	28.1	28.1	28.9	28.9
Agricultural chemicals	1,000 wons	8.2	12.8	5.2	8.2	8.6	13.5	9.1	14.2	8.1	12.6
Agricultural implements	1,000 wons	14.4	19.1	12.7	16.8	14.3	20.0	7.4	9.8	20.6	27.4
Labor costs	1,000 wons	17.9	23.2	17.2	22.2	17.3	22.4	21.3	27.5	15.8	20.4
Farm income	1,000 wons	202.2	250.7	199.0	247.5	171.6	212.8	190.0	235.6	232.3	288.0
Planted area	Pyung	4899.3	5144.3	5239.0	5500.9	4262.7	4475.8	5143.2	5400.3	5012.1	5262.7
Number of farms	1,000 farms	2451.8	2306.0	370.9	349.0	564.3	531.0	733.4	690.0	783.2	736.0

Note: The 1978 fertilizer prices listed in the table are the 1972 constant prices assuming no change in fertilizer prices. Fertilizer prices in cases where prices are decreased by 5, 10, 20, and 30 percents and where prices are increased by 5, 10, 20, and 30 percents can be easily calculated from the values given in the table.

Table IV-6. Actual and estimated consumption of fertilizer plant nutrients, 1972, Korea.

Unit: 1,000 M/T

Area	Total fertilizer 1972		Nitrogen 1972		Phosphate 1972		Potash 1972	
	actual	est.	actual	est.	actual	est.	actual	est.
I	97.2	98.1	53.0	57.1	25.3	24.2	18.9	16.8
II	140.7	150.8	81.9	82.4	35.3	41.1	23.5	27.3
III	205.7	214.1	119.6	125.7	56.8	55.7	29.3	32.7
IV	203.9	254.9	118.0	134.8	53.4	70.3	32.5	49.8
All Korea	647.5	717.9	372.5	400.0	170.8	191.3	104.2	126.6

Note:

I : upland area.
II : single cropping area.
III : western double cropping area.
IV : eastern double cropping area.
actual : values copied from the <u>Yearbook of Agricultural and Forestry Statistics</u>, MAF, Korea, 1973.
est. : values estimated with cross-section data.

variables. This implies parallel shifts of the consumption functions according to the changes in the values of independent variables. The linear time trend and parallel shifts of functions may not yield accurate estimates. However, in this case, it was the most feasible method to use because of the availability and accuracy of data.

Real prices of fertilizer were decreasing during 1967-1972 in Korea. The oil crisis and inflation resulted in increases in fertilizer real prices; twenty-two percent in 1973 and forty-seven percent in 1974. In such a situation, it was judged that the time trend was not appropriate for the purpose of fertilizer price projections. Therefore, effects of different fertilizers on the 1978 quantity consumed were tested using: (1) constant 1972 prices; (2) increases in 1972 prices by five percent, 10 percent, 20 percent, and 30 percent; and (3) decreases in 1972 prices by five percent, 10 percent, 20 percent, and 30 percent. Given 1978 values of independent variables, consumption estimates depending upon various 1978 prices are presented in table IV-7 and compared with the 1972 consumption.

A judgement on the 1978 expected fertilizer prices was made considering world wide fertilizer production capacity, oil prices, and increasing demand for food in Korea.

Table IV-7. Estimated consumption of fertilizer plant nutrients, 1978, Korea.

1978 prices in terms of 1972 price level	Total nutrient 100 M/T	%	Nitrogen 100 M/T	%	Phosphate 100 M/T	%	Potash 100 M/T	%
	-------1972 consumption-------							
	6475	100.0	3725	100.0	1708	100.0	1402	100.0
	-------1978 consumption-------							
30% increase	6327	97.7	3379	90.7	2045	119.7	903	64.4
20% increase	6748	104.8	3656	98.1	2047	119.8	1081	77.1
10% increase	7244	111.9	3936	105.7	2048	119.9	1260	89.9
5% increase	7474	115.4	4074	109.4	2049	120.0	1351	96.4
1972 constant	7702	118.9	4212	113.1	2051	120.1	1439	102.6
5% decrease	7933	122.5	4351	116.8	2051	120.1	1531	146.9
10% decrease	8160	126.0	4490	120.5	2052	120.1	1618	155.3
20% decrease	8618	133.1	4768	128.0	2055	120.3	1795	172.3
30% decrease	9078	140.2	5046	135.5	2057	120.4	1895	189.5

Consideration of these factors led to a five percent decrease per annum in real fertilizer prices from 1975 to 1978. Then, the 1978 fertilizer price paid by farmers would remain at the 1972 price level. The 1978 fertilizer plant nutrient consumption would be 770,200 metric tons which is 18.9 percent greater than the actual 1972 consumption of 647,500 metric tons (table IV-7).

All nitrogen nutrient consumption will increase by 13.1 percent from 372,500 metric tons in 1972 to 421,200 metric tons in 1978, all phosphate by 20.1 percent from 170,800 metric tons to 250,100 metric tons, and all potash by 2.6 percent from 140,200 metric tons to 143,900 metric tons.

4.2.2 Conversion of the Fertilizer Quantity Consumed From Plant Nutrient Weights to Actual Weight Equivalents

At the point of final consumption, plant nutrients are consumed in the form of various fertilizer types. For the purpose of the fertilizer distribution analysis it was necessary to convert plant nutrients into actual weight equivalents. In Korea, nitrogen nutrient is supplied by urea, calcium cyanamide and mixed fertilizers; phosphate nutrient by fused phosphate, triple superphosphate, and mixed fertilizers; and potash nutrient by potassium chloride, potassium sulphate, and mixed fertilizers. Percentages of plant nutrient contained in different fertilizer types for nitrogen, phosphate, and potash are presented in table IV-8. Combining 1972 actual plant nutrient consumption (table IV-6) and distribution of nutrients in different fertilizer types (table IV-8), 1972 fertilizer consumption on an actual weight basis was estimated for upland (I), single cropping (II), western double cropping (III), and eastern double cropping (IV) areas and for all Korea and is presented in the first two columns of each area in table IV-9. Values for 'actual' are the fertilizer consumption estimates on an actual weight basis using 1972 actual plant nutrient consumption data and values for 'est' are the fertilizer consumption estimates on an actual weight basis estimated by the plant nutrient consumption estimates with farm survey data.

The following procedure was used to make the conversion:

(1) Total fertilizer consumption on an actual weight basis was obtained by dividing total plant nutrient consumption (table IV-6) by percentage of plant nutrient content of total fertilizer (the last row of the first column in table IV-8).

(2) Consumption estimates for straight nitrogen, straight phosphate, and straight potash fertilizers were

calculated using the consumption estimates of three plant nutrients (table IV-6 and table IV-8).

(3) Mixed fertilizer consumption on an actual weight basis was obtained by subtracting converted straight fertilizer quantities from the converted quantities of total fertilizer.

Using actual and estimated fertilizer plant nutrient consumption data, actual fertilizer equivalents converted based on the procedure above are presented in table IV-9. According to actual plant nutrient consumption data, the total fertilizer quantities consumed on an actual weight basis were 1,428,500 metric tons, including 581,400 metric tons of straight nitrogen fertilizers, 210,000 metric tons of straight phosphate fertilizers, 56,600 metric tons of potash fertilizers, and 580,500 metric tons of mixed fertilizers. Conversion of estimated fertilizer consumption resulted in 1,584,800 metric tons of actual fertilizer equivalents of total consumption which are 11 percent greater than the estimate obtained by actual plant nutrient consumption data.

In converting the 1978 fertilizer plant nitrient estimates (table IV-9), into actual fertilizer types, the following assumptions and predictions were made:

Table IV-8. Percentages of plant nutrients contained in different fertilizer types and percentages of plant nutrient distribution among different fertilizer types for nitrogen, phosphate, and potash, 1972, Korea.

	Percentage of plant nutrient content	Percentage of plant nutrient distribution
Nitrogen (N)		(100.0)
Urea	46.0	68.9
Calcium cyanamide	21.0	1.3
N in mixed fertilizer	19.0	29.8
Phosphate (P)		(100.0)
Fused phosphate	20.0	22.2
Triple super-phosphate	46.0	5.4
P in mixed fertilizer	21.3	72.4
Potash (K)		(100.0)
Potassium chloride	60.0	29.6
Potassium sulphate	60.0	2.5
K in mixed fertilizer	12.1	67.9
Mixed fertilizer	52.4	
Total fertilizer	45.3	

Source: Yearbook of Agricultural and Forestry Statistics, MAF, Korea, 1973.

Table IV-9. Actual and estimated area fertilizer consumption on the actual weight basis, 1972 and 1978, Korea.

Unit: 1000 M/T

	All Korea			Area I			Area II			Area III			Area IV		
	1972		1978	1972		1978	1972		1978	1972		1978	1972		1978
	Actual	Est.		Actual	Est.		Actual	Est.		Actual	Est.		Actual	Est.	
Straight N	581.4	622.9	694.5	81.5	88.7	105.6	128.1	128.3	136.8	186.0	195.9	209.1	185.8	210.0	243.0
Urea	558.6	599.1	675.0	78.2	85.4	102.6	122.9	123.5	133.0	178.8	188.3	203.2	178.7	201.9	236.2
Cal. Cyan.	22.8	23.8	19.5	3.3	3.3	3.0	5.2	4.8	3.8	7.2	7.6	5.9	7.1	8.1	6.8
Straight P	210.0	234.9	261.8	31.5	29.8	35.3	44.1	50.3	50.8	69.4	68.5	74.3	65.0	86.3	101.4
Fused Phos.	190.1	212.5	149.0	28.5	27.0	20.1	40.0	45.5	28.9	62.7	62.0	42.3	58.9	78.0	57.7
Triple Super phos.	19.9	22.4	112.8	3.0	2.8	15.2	4.1	4.8	21.9	6.7	6.5	32.0	6.1	8.3	43.7
Straight K	56.6	67.9	130.2	10.1	9.0	21.4	12.5	14.7	25.4	16.2	17.5	30.8	17.8	26.7	52.6
Pot. Clor.	51.5	62.7	114.8	9.3	8.3	18.8	11.7	13.5	22.4	14.5	16.2	27.2	16.0	24.7	46.4
Pot. Sul.	5.1	5.2	15.4	0.8	0.7	2.6	0.8	1.2	3.0	1.7	1.3	3.6	1.8	2.0	6.2
Mixed fertilizer	580.5	659.1	561.1	91.3	89.1	84.2	125.7	139.6	110.0	182.8	190.7	159.4	180.7	239.7	207.5
Total fertilizer	1428.5	1584.8	1647.6	214.4	216.6	246.5	310.4	332.9	323.0	454.4	472.6	473.6	449.3	562.7	604.5

Note: Est: values estimated with cross-section data.

1. Domestic consumption should have priority over exports for the domestically produced fertilizers.

2. High analysis products such as triple super-phosphate (0-46-0) and potassium chloride (0-0-60) should be imported if necessary to reduce distribution costs.

3. The historical data shows that during the period 1970-1972, five percent of the total mixed fertilizer consumption was imported. Imported mixed fertilizers were of different kinds from those domestically produced and were used for special cropping purposes. Therefore, it was assumed that such a mixed fertilizer consumption pattern will remain unchanged by 1978.

4. The 1970-1972 mixed fertilizer consumption data indicated that the fertilizer nutrient ratios of N:P:K for all mixed fertilizer was 19:22:12. Most of the mixed fertilizers were supplied by the types of 22-22-11, 18-18-18, and 14-37-12. To obtain N:P:K ratios indicated above, 64.7 percent of mixed fertilizer should be supplied by 22-22-11, 21.6 percent by 18-18-18, and 13.7 percent by 14-37-12 (see Appendix B). Such a mixed fertilizer consumption pattern is expected to hold in 1978.

5. During the period 1970-1972, 95 percent of straight potash fertilizer consumption was in the form of potassium

chloride and the rest was potassium sulphate. That pattern is expected not to change by 1978.

Approximated 1978 fertilizer quantities consumed in actual fertilizer equivalents are presented in table IV-9. Fertilizer types available in 1978 will be urea, calcium cyanamide, fused phosphate, triple superphosphate, potassium chloride, potassium sulphate and mixed fertilizers.

The total fertilizer consumption estimate for 1978 amounted to 1,647,600 metric tons which is a 15 percent increase in the 1972 estimate using actual plant nutrient consumption data. The 1978 estimate includes 694,500 metric tons of straight nitrogen fertilizers, 261,800 metric tons of straight phosphate fertilizers, 130,200 metric tons of straight potash fertilizers, and 561,100 metric tons of mixed fertilizers (see table IV-9).

4.3 Fertilizer Quantities Supplied and Utilized

The 1972 and 1978 fertilizer quantities supplied and utilized are presented in this section. Fertilizer quantities are expressed on an actual weight basis to provide quantity information for the distribution analysis in the following two chapters.

4.3.1 Fertilizer Quantities Supplied and Utilized in 1972

Using actual production, consumption, and trade data, the 1972 fertilizer quantities supplied and utilized were estimated on an actual weight basis (table IV-10). Given the 1970 fertilizer beginning stock (*Yearbook of Agricultural and Forestry Statistics*, 1971), the 1972 beginning stock was estimated by studying the actual 1970 and 1971 fertilizer supply and utilization relationships.

The fertilizer quantities supplied were simply obtained by adding estimated beginning stock, actual production (table III-1), and imports. Since the fertilizer quantities supplied should be equal to the quantities utilized, the end stock was calculated by subtracting consumption and exports from the fertilizer quantities supplied.

The estimate of the 1972 total fertilizer supplied was 2,267,700 metric tons including 806,800 metric tons of beginning stock, 1,360,900 metric tons of production, and 100,000 metric tons of imports. Total fertilizer quantities utilized consist of 1,428,500 metric tons of consumption, 172,900 metric tons of exports, and 666,300 metric tons of end stock.

Table IV-10. Fertilizer quantities supplied and utilized, 1972, Korea. Unit: 1000 M/T

	Total fert.	Nitrogen (N)			Phosphate (P)			Potash (K)			Mixed fert.
		Total	Urea	Other	Total	Fused Phos.	Other	Total	Pot. chlor.	Other	
Beginning stock	806,8	263.7	233.7	30.0	289.0	260 1	28.9	49.9	45.1	4.8	204.2
Production	1360.9	698.4	682.2	16.2	156.7	156.7	--	--	--	--	505.8
Imports	100.0	--	--	--	--	--	--	57.0	52.0	5.0	43.0
SUPPLY	2267.7	962.1	915.9	46.2	445.7	416.8	28.9	106.9	97.1	9.8	753.0
Actual consumption	1428.5	581.9	558.6	23.3	210.3	190.1	20.2	55.8	51.3	4.5	580.5
Exports	172.9	78.6	78.6	--	--	--	--	--	--	--	94.3
Actual end stock	666.3	301.6	278.7	22.9	235.4	226.7	8.7	51.1	45.8	5.3	78,2
UTILIZATION	2267.7	962,1	915.9	46,2	445.7	416.8	28.9	106.9	97.1	9.8	753,0

4.3.2 Fertilizer Quantities Supplied and Utilized in 1978

Given production (table III-1) and consumption (table IV-9) estimates, it was necessary to approximate stock levels to obtain the fertilizer quantities supplied and utilized. According to supply and utilization patterns and seasonal consumption pattern during the period 1970-1972, the levels of stock would be adequate at 35 percent of annual consumption for domestically produced fertilizers and at 60 percent of annual consumption for imported fertilizers.

Approximated fertilizer quantities supplied and utilized for 1978 are presented in table IV-11. The total fertilizer quantities supplied are expected to be 2, 815, 200 metric tons, a 24 percent increase in the 1972 quantity. The total fertilizer supply includes 637, 300 metric tons of beginning stock, 1, 898, 800 metric tons of production, and 279, 100 metric tons of imports. The total fertilizer utilization consists of 1, 647, 600 metric tons of consumption, 516, 200 metric tons of exports, and 651, 400 metric tons of end stock.

4.4 Seasonality of Fertilizer Consumption

Seasonality of fertilizer consumption is an important factor affecting fertilizer storage and transportation problems.

Monthly fertilizer consumption patterns for Korea are presented in figure IV-1. The patterns represent monthly

Table IV-11. Fertilizer quantities supplied and utilized, 1978, Korea. Unit: 1000 M/T

	Total fert.	Nitrogen			Phosphate			Potash			Mixed fert.
		Total	Urea	Cal. Cyan.	Total	Fused Phos.	Triple Sup. Ph.	Total	Pot. chlor.	Pot. sul.	
Beginning stock	637.3	243.0	236.2	6.8	119.8	52.1	67.7	78.1	68.9	9.2	196.4
Production	1898.8	1215.4	1195.9	19.5	149.0	149.0	--	--	--	--	534.4
Import	279.1	--	--	--	114.8	--	114.8	131.8	116.2	15.6	32.5
SUPPLY	2815.2	1458.4	1432.1	26.3	383.6	201.1	182.5	209.9	185.1	24.8	763.3
Consumption	1647.6	694.5	675.0	19.5	261.8	149.0	112.8	130.2	114.8	15.4	561.1
Exports	516.2	516.2	516.2	--	--	--	--	--	--	--	--
End stock	651.4	247.7	240.9	6.8	121.8	52.1	69.7	79.7	70.3	9.4	202.2
UTILIZATION	2815.2	1458.4	1432.1	26.3	383.6	201.1	182.5	209.9	185.1	24.8	763.3

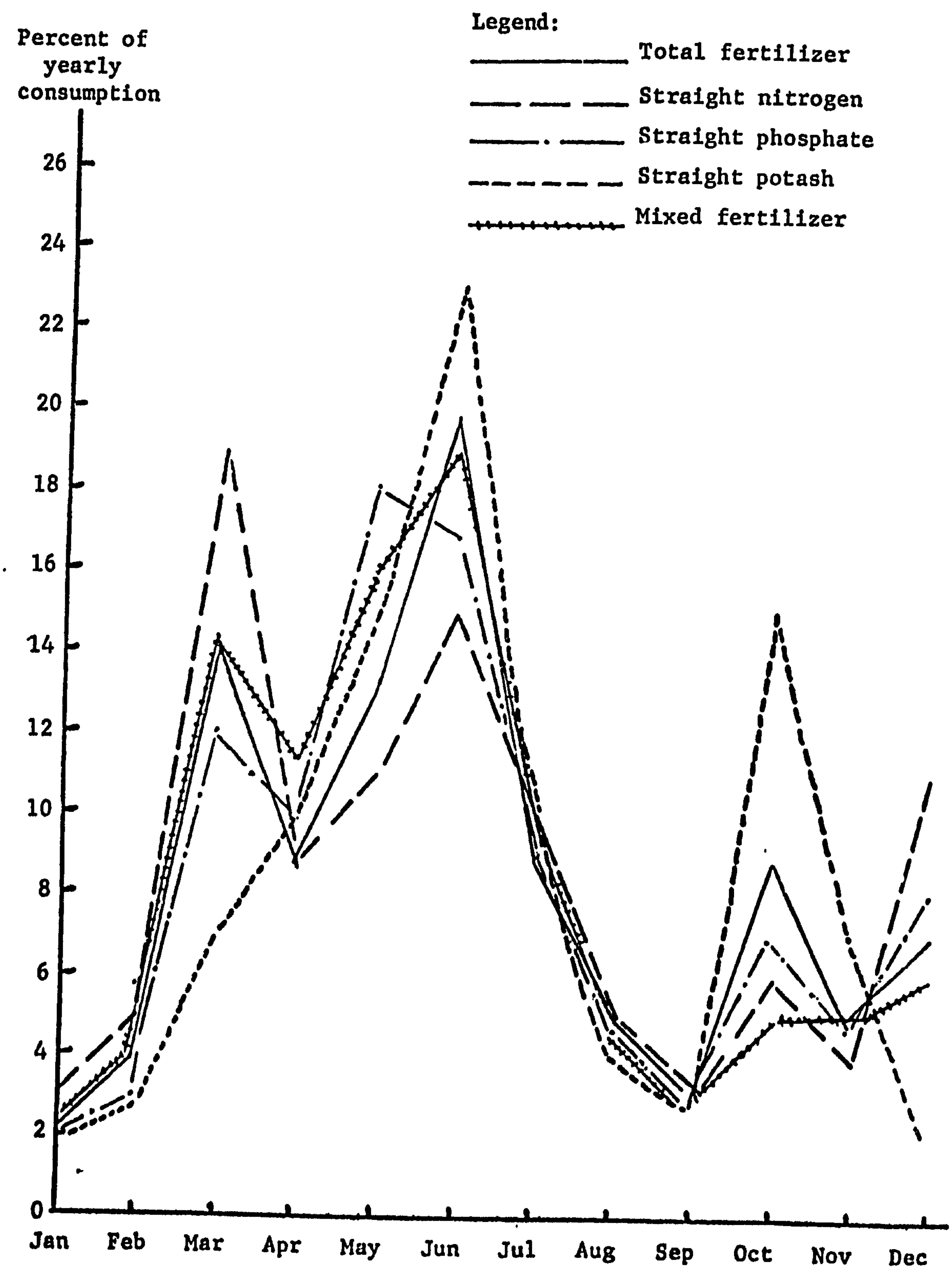

Figure IV-1. Average monthly fertilizer consumption patterns during period 1970-1972, Korea.

consumption as a percent of yearly consumption during 1970-1972 for total fertilizer, straight nitrogen, straight phosphate, straight potash and mixed fertilizer.

Figure IV-1 shows high monthly consumption in March and June which reflects the planting and growing seasons of summer crops, especially rice. High consumption in October and December reflects the planting and growing seasons of winter crops, wheat and barley.

The consumption seasonality problem is manifested in the concentration of 56 percent of total annual consumption in the four months from March to June. The seasonal consumption patterns for each type of fertilizer and each region could not be measured due to the availability of data. However, it is conceivable that fertilizer consumption seasonality is greater in the upland and single cropping areas than in western and eastern double cropping areas.

Given continuous production, discrete imports and exports, and beginning stock of fertilizer, the seasonality of fertilizer consumption may result in unnecessary storage and transportation costs to the fertilizer distribution system. The timing of fertilizer imports could be adjusted to reflect the seasonal consumption patterns. Therefore, it is hypothesized that the amount of fertilizer stock is unnecessarily high, resulting in an expensive storage burden to a fertilizer distribution system which already has a shortage in fertilizer storage facilities.

CHAPTER V

OPTIMUM FERTILIZER FLOW PATTERNS FOR THE 1972 FERTILIZER DISTRIBUTION SYSTEM

5.1 Introduction

The characteristics of the 1972 Korean fertilizer distribution system may be summarized as follows:

1. The system was administered by the Korean government. The fertilizer supply and utilization plan was initiated by the Ministry of Agriculture and Fisheries. Under government control, the National Agricultural Cooperative Federation distributed all the fertilizer whether domestically produced or imported. The Korean Express Company shipped fertilizer from supply origins to demand destinations, usually by rail, under contract with the National Agricultural Cooperative Federation.

2. The fertilizer domestically produced was bagged at manufacturing plants. Fertilizer imported by bulk was all bagged at importing harbors. Therefore, all fertilizer shipment was in bags.

3. The rail freight was 83 wons per metric ton of bagged fertilizer per 50 kilometers applied on a full carload basis.

4. The storage rate was 75 wons per metric ton per 15 days. The storage rate was the same for all of the storage facilities regardless of size and location.

5. The National Agricultural Cooperative Federation attempted to maintain full regional storage facilities at all times. Regional fertilizer storage capacity for the nation, however, fell short of demand during high stock months.

6. Mixed fertilizer was produced by a chemical process. There were noregional fertilizer blending facilities.

Under such a system, the fertilizer distribution problem involved determination of the least cost fertilizer distribution pattern for transfer from origins to destinations. Handling, loading and unloading costs were beyond the scope of the study.

As indicated in section 3.3, the real cost functions of transportation and storage could not be estimated because of the availability of data. Instead, transportation and storage rates established by government were used for fertilizer distribution analysis. Uniform storage rate could not affect fertilizer flow patterns. Therefore, the flow patterns and their effect on transportation cost were the major considerations for optimization. This chapter provides optimum fertilizer flow patterns which minimize fertilizer transportation costs for the 1972 distribution system under given storage and freight rates.

The data used for the analysis presented in this chapter were the national supply and utilization estimates presented in table IV-10. Utilizing the ratios of regional consumption to total national consumption (table III-4) and seasonal consumption patterns (figure IV-1), monthly regional consumption estimates were derived from the national consumption estimates. The transportation model was used to determine optimum flow patterns per shipment for urea, fused phosphate, potassium chloride, and domestically produced mixed fertilizer.

Fertilizer origins and destinations, the quantities available at each origin and quantities required at each destination are specified by month in section 5.2. Optimum fertilizer flow patterns and transportation cost comparisons are presented in section 5.3. Efficient stock levels are discussed in section 5.4. Finally, conclusions are presented in section 5.5.

5.2 Fertilizer Supply and Utilization Situations in 1972

In 1972, 2,267,700 metric tons of fertilizer were handled by the Korean fertilizer distribution system (table IV-10). Distribution of urea, fused phosphate, potassium chloride, and domestically produced mixed fertilizer were analyzed in the study because they were the most commonly-used fertilizer materials in 1972. Urea accounted for 95 percent of the straight nitrogen fertilizer use, fused phosphate for 94 percent of the straight phosphate fertilizer use, and potassium chloride for 91 percent of the straight potash fertilizer use. Ninety-four percent of mixed fertilizer was domestically produced. Because the analysis was confined to these four fertilizer materials, the fertilizer quantities analyzed in this study totalled 2,139,800 metric tons which accounted for 94 percent of the 1972 total fertilizer quantity. Assuming one shipment per month, regional fertilizer availabilities and requirements are specified in the following subsections.

5.2.1 Monthly Production of Fertilizer

In 1972, 1,360,900 metric tons of fertilizer were produced in Korea including 682,200 metric tons of urea, 156,700 metric tons of fused phosphate, 505,800 metric

Table V-1. Monthly production of fertilizer, 1972, Korea. Unit: 100 M/T

Plant location	1972	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Urea	6822	569	569	569	568	569	567	569	568	569	569	569	367
Chungju	898	75	75	75	75	75	74	75	75	75	75	75	74
Naju	621	52	52	52	51	52	52	52	51	52	52	52	51
Ulsan	4402	367	367	367	367	367	366	367	367	367	367	367	366
Jinhae	901	75	75	75	75	75	75	75	75	75	75	75	76
Fused phos.	1567	130	130	131	131	130	131	130	131	131	130	130	132
Sosa	483	40	40	40	41	40	40	40	41	40	40	40	41
Janghang	1084	90	90	91	90	90	91	90	90	91	90	90	91
Mixed fert.	5058	422	421	421	422	422	421	421	422	422	421	421	422
Ulsan	2619	218	218	218	219	218	218	218	219	218	218	218	219
Jinhae	2439	204	203	203	203	204	203	203	203	204	203	203	203
Calcium cyan.	162	14	13	14	13	14	13	14	13	14	13	13	14
Samcheok	162	14	13	14	13	14	13	14	13	14	13	13	14
All Korea	13609	1135	1133	1135	1134	1135	1132	1134	1134	1136	1133	1133	1135

tons of mixed fertilizer, and 16,200 metric tons of calcium cyanamide. Total and monthly production for each fertilizer material and each plant are presented in table V-1.

Assuming continuous production over time, a monthly production schedule for each manufacturing plant was calculated by dividing annual production by 12 months.

5.2.2 Monthly Consumption of Fertilizer

As indicated in table IV-10, 1972 fertilizer consumption was 1,428,500 metric tons including 558,600 metric tons of urea, 190,100 metric tons of fused phosphate, 51,300 metric tons of potassium chloride, and 580,500 metric tons of mixed fertilizer. Annual and monthly regional fertilizer consumption estimates for urea, fused phosphate, and potassium chloride, are presented in tables V-2, V-3, and V-4, respectively. Mixed fertilizer imports were 43,000 metric tons in 1972 (table IV-10). It was assumed that all of the imports were consumed during the year. Therefore, 537,500 metric tons of domestically produced mixed fertilizer consumption were the difference between total consumption of mixed fertilizer and imported mixed fertilizer. Regional consumption estimates of domestically produced mixed fertilizer are presented in table V-5.

Table V-2. Monthly consumption of urea, 1972, Korea. Unit: 100 M/T

Consumption region	1972	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1. Chuncheon	141	5	13	37	9	14	18	17	9	4	9	5	1
2. Kangneung	188	7	17	49	12	19	24	23	12	5	12	6	2
3. Cheongju	352	13	32	92	23	36	45	42	22	10	22	12	3
4. Jeju	101	4	9	26	7	10	13	12	6	3	6	4	1
5. Seoul	283	10	26	74	18	29	36	34	17	8	18	10	3
6. Suwon	356	13	33	93	23	37	45	43	22	10	22	12	3
7. Taejeon	258	10	24	67	17	26	33	31	16	7	16	9	2
8. Hongseong	332	12	31	87	22	34	42	40	20	9	21	11	3
9. Jeonju	286	11	26	75	19	29	37	34	17	8	18	10	2
10. Iri	447	16	41	117	29	46	57	54	27	13	28	15	4
11. Boseong	626	23	58	163	41	64	80	75	38	18	39	21	6
12. Songjeongri	429	16	39	112	28	44	55	51	26	12	27	15	4
13. Andong	322	12	30	84	21	33	41	39	19	9	20	11	3
14. Kimcheon	375	14	34	98	24	39	48	45	23	11	23	13	3
15. Taegu	340	13	31	89	22	35	44	41	21	9	21	11	3
16. Samrangjin	375	14	34	98	24	39	48	45	23	11	23	13	3
17. Jinju	375	14	34	98	24	39	48	45	23	11	23	13	3
All Korea	5586	207	512	1459	363	573	714	671	341	158	348	191	49

Table V-3. Monthly consumption of fused phosphate, 1972, Korea. Unit: 100 M/T

Consumption region	1972	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1. Chuncheon	52	2	4	5	3	7	9	5	3	2	6	5	1
2. Kangneung	68	3	5	6	3	9	13	7	4	2	8	7	1
3. Cheongju	128	5	11	11	7	17	24	12	7	4	16	13	1
4. Jeju	37	2	3	3	2	5	7	3	2	1	5	4	-
5. Seoul	92	3	8	8	5	12	17	9	5	3	11	10	1
6. Suwon	116	4	10	11	6	15	22	11	6	4	14	12	1
7. Taejeon	84	3	7	8	4	11	16	8	4	3	10	9	1
8. Hongseong	108	4	9	10	6	14	20	11	6	3	13	11	1
9. Jeonju	100	4	8	9	5	13	19	10	5	3	12	11	1
10. Iri	157	6	13	14	8	21	29	16	8	5	19	16	2
11. Boseong	219	8	18	20	12	28	41	22	12	7	26	23	2
12. Songjeongri	151	6	12	14	8	20	28	15	8	5	18	16	1
13. Andong	106	4	9	10	5	14	20	10	6	3	13	11	1
14. Kimcheon	123	5	10	11	6	16	23	12	7	4	15	13	1
15. Taegu	112	4	9	10	6	15	21	11	6	4	13	12	1
16. Samrangjin	124	5	10	11	7	16	23	12	7	4	15	13	1
17. Jinju	124	5	10	11	7	16	23	12	7	4	15	13	1
All Korea	1901	73	156	172	100	249	355	186	103	61	229	199	18

Table V-4. Monthly consumption of potassium chloride, 1972, Korea. Unit: 100 M/T

Consumption region	1972	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1. Chuncheon	16	1	1	2	1	2	2	3	1	1	1	1	-
2. Kangneung	21	1	1	2	1	2	3	4	2	1	2	2	-
3. Cheongju	39	1	3	4	2	5	5	7	4	2	3	3	-
4. Jeju	11	-	1	1	1	1	1	2	1	1	1	1	-
5. Seoul	27	1	2	3	2	3	3	5	3	1	2	2	-
6. Suwon	34	1	2	4	2	4	4	6	3	2	3	2	1
7. Taejeon	25	1	1	3	2	3	3	5	2	1	2	2	-
8. Hongseong	32	1	2	4	2	4	4	6	3	1	2	2	1
9. Jeonju	24	-	2	3	1	3	3	5	2	1	2	2	-
10. Iri	37	1	2	4	2	4	5	7	4	2	3	3	-
11. Boseong	52	1	4	6	3	6	7	10	5	2	4	3	1
12. Songjeongri	36	1	2	4	2	4	5	7	3	2	3	3	-
13. Andong	29	1	2	3	2	3	4	5	3	I	2	2	1
14. Kimcheon	33	1	2	4	2	4	4	6	3	2	2	2	1
15. Taegu	30	1	2	3	2	3	4	6	3	1	2	2	1
16. Samrangjin	34	1	2	4	2	4	4	6	3	2	3	2	1
17. Jinju	33	1	2	4	2	4	4	6	3	2	2	2	1
All Korea	513	15	33	58	31	59	65	96	48	25	39	36	8

Table V-5. Monthly consumption of domestically produced mixed fertilizer, 1972, Korea. Unit: 100 M/T

Consumption region	1972	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1. Chuncheon	145	2	4	16	16	21	30	13	4	4	23	11	1
2. Kangneung	193	2	6	22	21	28	39	18	5	6	30	15	1
3. Cheongju	363	4	10	42	39	53	74	34	10	10	57	27	3
4. Jeju	105	1	3	12	11	15	22	10	3	3	16	8	1
5. Seoul	272	3	8	31	29	40	55	25	7	8	43	21	2
6. Suwon	343	4	10	39	37	50	70	32	9	10	54	26	2
7. Taejeon	248	3	7	28	27	36	51	23	7	7	39	18	2
8. Hongseong	320	3	9	37	34	47	65	30	9	9	51	24	2
9. Jeonju	275	3	8	31	30	40	56	26	7	8	43	21	2
10. Iri	430	5	12	49	46	63	88	40	12	12	68	32	3
11. Boseong	602	7	17	69	64	88	123	56	16	18	95	45	4
12. Songjeongri	413	4	12	48	44	61	84	38	11	12	65	31	3
13. Andong	300	3	8	35	32	44	61	28	8	9	47	23	2
14. Kimcheon	350	4	10	40	37	52	71	32	10	10	55	26	3
15. Taegu	316	3	9	36	34	46	65	29	9	9	50	24	2
16. Samrangjin	350	4	10	40	37	52	71	32	10	10	55	26	3
17. Jinju	350	4	10	40	37	52	71	32	10	10	55	26	3
All Korea	5375	59	153	615	575	788	1096	498	147	155	846	404	39

Total regional consumption estimates for 1972 are shown in the second column, '1972', in tables V-2 through V-5. They were derived from the cropping area consumption estimates (table IV-9) based on the assumption that the regional fertilizer consumption functions were homogeneous within a cropping area.

Given cropping area consumption estimates, regional consumption was calculated by multiplying the regional arable land ratio (table III-4) by the consumption estimate for the cropping area which the consumption region belongs to.

Given the regional fertilizer consumption estimates, the monthly consumption estimates for each region were calculated by using seasonal consumption patterns for the nation (figure IV-1) because data on seasonal fertilizer consumption patterns for each cropping area were not available.

5.2.3 Monthly Fertilizer Trade

In 1972, Korea exported 172, 900 metric tons of fertilizer including 78, 600 metric tons of urea and 94, 300 metric tons of mixed fertilizer. Fertilizer imports totalled 100, 000 metric tons, including 52, 000 metric ton of potassium chloride, 5, 000 metric tons of potassium sulphate, and 43, 000 metric tons of mixed fertilizer.

A T.V.A. study (TVA, 1965) showed that vessel sizes used for international fertilizer trade were 5, 10, 15, 20 and 40 thousand tons. The study indicated that in the case of bulk shipment with no back-haul, the operating cost of 10,000 ton vessels were 33 percent lower than the costs of 5,000 ton vessels and 12 percent higher than the costs of 15,000 ton vessels. For the purpose of this study the 10,000 ton vessel was most appropriate with respect to the volume of Korean fertilizer trade and the capacities of Korean harbors.

A schedule of monthly fertilizer trade is presented in table V-6. In a preliminary test, the least transportation cost solution for 1972 indicated that total urea and mixed fertilizer export should be satisfied by the fertilizers produced at plants in Ulsan. Assuming that one or two 10,000 ton vessels per month were used for the purpose of exportation except the October mixed fertilizer exportation, urea and mixed fertilizer exportation were spread all over the year for smooth domestic distribution until the total export requirements are shipped.

It was assumed that all stocks resulting from imports were stored at regional storage facilities rather than at harbor storages. The number and timing of fertilizer import

Table V-6. Monthly fertilizer trade, 1972, Korea. Unit: 100 M/T

	1972	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Export	1729	200	100	200	100	200	100	200	100	200	143	186	--
Urea	786	100	--	100	--	100	--	100	100	100	--	186	--
Mixed fert.	943	100	100	100	100	100	100	100	--	100	143	--	--
Import	1000	--	--	220	--	--	210	300	50	--	220	--	--
Pot. chlor.	520	--	--	--	--	--	--	300	--	--	220	--	--
Pot. sul.	50	--	--	--	--	--	--	--	50	--	--	--	--
Mixed fert.	430	--	--	220	--	--	210	--	--	--	--	--	--

Note: The kinds of mixed fertilizer imported were different from the kinds of mixed fertilizer exported.

shipments were considered with respect to the stock on hand and monthly consumption. It is evident that an increase in the number of import shipments reduces the quantity per shipment resulting in a decrease in storage cost, but an increase in transportation costs. Two import shipments of potassium chloride, 30,000 metric tons in July and 22,000 metric tons in October, were designated arbitrarily to keep an adequate stock level for efficient domestic potassium chloride distribution (table V-6).

5.2.4 Monthly Fertilizer Stocks

In 1972, estimated fertilizer beginning stocks totalled 806,800 metric tons and estimated end stocks totalled 666,300 metric tons (table IV-10). Total regional storage capacity for the nation was estimated at 507,800 metric tons (table III-6). Data on the beginning stocks on hand at specific individual storage facilities were not available for 1972. The capacities of fertilizer plant warehouses also were unknown.

To formulate the linear programming transportation problem, the quantities available at each plant and the quantities required at each consumption region must be specified for each analysis period. In other words, the analysis requires specification of quantities of stocks at every plant warehouse and storage center because the quantities available at a plant include current production plus stocks on hand at the plant warehouse and because quantities required at a consumption region consist of current consumption plus end stock net of beginning stock.

To facilitate the analysis, it was assumed that regional storage facilities were fully utilized at all times and that all stocks from imports were stored at regional storage facilities. Therefore, regional storage space for stocks from domestic production was the difference between total regional storage capacity and stocks from imports for each analysis period. Regional storage capacity for stocks resulting from production was allocated to stocks of urea, fused phosphate, and mixed fertilizer was allocated on the basis of the stock-to-production ratios.

With the exception of July and August, there was a shortage of regional storage capacity for stocks from production. Therefore, excess stocks were assigned to plant warehouses where the fertilizer was produced. Stocks at plant warehouses fluctuated from month to month depending on availability of regional storage.

Since plant warehouse capacities were unknown, fertilizer stocks at plant warehouses were set equal to stocks that could not be stored at regional storage facilities. Given the total plant warehouse capacity requirement for each type of fertilizer, the storage capacity assigned to a manufacturing plant was calculated by multiplying the total capacity requirement by the plant-to-national production ratios.

A one month lag between production and exportation was assumed for the exportation of urea and mixed fertilizer. It was assumed that export materials remained at Ulsan harbor until shipment, and storage was ignored. It was assumed that fertilizer was consumed immediately upon arrival at a consumption region and storage capacity at the ultimate fertilizer consumption level was not considered.

Monthly beginning stocks of urea, fused phosphate, potassium chloride, and mixed fertilizer, calculated by the procedure discussed above, are presented in tables V-7, V-8, V-9, and V-10, respectively. The beginning stock of each month is the end stock of the previous month.

In summary, the monthly stock of potassium chloride, an imported fertilizer, was not affected by regional storage capacity. Stocks of urea, fused phosphate, and mixed

Table V-7. Monthly beginning stock of urea, 1972, Korea. Unit: 100 M/T

Storage location	1972 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1973 Jan
Plant whse	984	1173	1240	542	639	387	100	100	100	286	303	257	824
Chungju	117	155	151	72	71	51	--	--	--	38	15	34	108
Naju	80	107	103	49	49	35	--	--	--	26	11	23	74
Ulsan	670	756	835	350	448	250	100	100	100	184	262	166	532
Jinhae	117	155	151	71	71	51	--	--	--	38	15	34	110
Regional storage	1353	1426	1416	1124	1232	1380	1520	1318	1445	1570	1774	2012	1963
1. Chuncheon	35	37	37	29	32	36	40	34	38	41	46	52	51
2. Kangneung	47	50	50	40	43	48	53	46	51	55	62	71	69
3. Cheongju	89	94	93	74	81	91	100	87	95	104	117	133	129
4. Jeju	34	36	35	28	31	35	38	33	36	39	45	50	49
5. Seoul	66	70	69	55	60	68	74	64	71	77	87	99	96
6. Suwon	84	88	88	70	76	85	94	82	90	97	110	125	122
7. Taejeon	64	67	67	53	58	65	72	62	68	74	83	94	92
8. Hongseong	80	84	83	66	73	81	90	78	85	93	105	119	116
9. Jeonju	77	82	81	64	70	79	87	75	82	89	101	115	112
10. Iri	122	128	127	101	111	124	137	119	130	141	160	181	177
11. Boseung	122	128	128	101	111	124	137	119	130	142	160	181	177
12. Songjeongri	85	90	89	71	78	87	95	83	91	99	111	126	123
13. Andong	76	80	79	63	69	77	85	74	81	88	99	112	110
14. Kimcheon	88	92	92	73	80	90	99	85	94	102	115	131	128
15. Taegu	81	86	85	68	74	83	91	79	87	94	107	121	118
16. Samrangjin	102	107	107	84	93	104	114	99	108	118	133	151	147
17. Jinju	101	107	106	84	92	103	114	99	108	117	133	151	147
ALL KOREA	2337	2599	2656	1666	1871	1767	1620	1418	1545	1856	2077	2269	2787

Table V-8. Monthly beginning stock of fused phosphate, 1972, Korea. Unit: 100 M/T

Storage location	1972 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1973 Jan
Plant whse	1025	1155	1172	841	797	548	---	---	131	245	135	243	375
Sosa	316	356	361	259	245	169	--	--	41	75	42	75	116
Janghang	709	799	811	582	552	379	--	--	90	170	93	168	259
Regional storage	1576	1503	1460	1750	1825	1955	2279	2223	2120	2076	2087	1910	1892
1. Chuncheon	41	39	38	46	47	51	59	58	55	54	54	49	48
2. Kangneung	55	52	51	61	64	68	80	78	74	73	73	67	66
3. Cheongju	104	99	96	115	120	129	150	147	140	137	138	126	125
4. Jeju	39	37	37	44	46	49	57	55	53	52	52	48	48
5. Seoul	77	74	72	86	89	96	112	109	104	101	102	94	93
6. Suwon	98	94	90	109	113	121	141	138	132	129	130	118	117
7. Taejeon	74	71	69	82	86	92	107	104	100	98	98	90	89
8. Hongseong	93	89	86	103	108	115	135	131	125	122	123	113	112
9. Jeonju	90	86	83	100	104	112	130	127	122	118	119	109	108
10. Iri	142	136	131	157	164	176	205	200	192	187	188	172	170
11. Boseung	142	134	132	158	165	176	205	200	188	187	188	172	170
12. Songjeongri	99	93	92	110	115	123	144	140	132	131	131	120	119
13. Andong	88	84	82	98	102	109	128	124	118	116	117	107	106
14. Kimcheon	103	98	95	114	119	127	148	145	138	135	136	124	123
15. Taegu	95	91	88	105	109	117	137	133	127	124	125	115	114
16. Samrangjin	118	113	109	131	137	147	171	167	160	156	157	143	142
17. Jinju	118	113	109	131	137	147	170	167	160	156	156	143	142
ALL KOREA	2601	2658	2632	2591	2622	2503	2279	2223	2251	2321	2222	2153	2267

Table V-9. Monthly beginning stock of potassium chloride, 1972, Korea. Unit: 100 M/T

Storage location	1972 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1973 Jan
1. Chuncheon	12	11	10	9	8	7	5	10	9	9	13	12	12
2. Kangneung	16	15	14	12	11	9	7	14	12	11	18	16	16
3. Cheongju	30	29	27	23	21	17	12	26	23	21	33	31	30
4. Jeju	11	11	10	8	8	6	5	10	9	8	12	12	12
5. Seoul	22	21	20	17	15	12	9	19	17	16	25	23	22
6. Suwon	28	27	25	21	19	16	12	24	22	20	31	29	28
7. Taejeon	21	21	19	16	15	12	9	19	16	15	24	22	22
8. Hongseung	27	26	24	21	19	15	11	23	20	19	29	27	27
9. Jeonju	26	25	23	20	18	15	11	22	20	18	29	27	26
10. Iri	40	39	36	31	28	23	17	35	31	29	45	42	41
11. Boseong	41	39	36	31	28	23	17	36	31	29	45	42	41
12. Songjeongri	28	28	26	22	20	16	12	25	22	20	32	29	29
13. Andong	25	24	23	19	18	14	11	22	19	18	28	26	26
14. Kimcheon	29	28	26	22	20	17	12	26	22	21	33	30	30
15. Taegu	27	26	24	21	19	15	12	24	21	19	30	28	27
16. Samrangjin	34	33	30	26	24	19	14	30	26	24	38	35	35
17. Jinju	34	33	30	26	23	19	14	29	26	24	37	35	34
ALL KOREA	451	436	403	345	314	255	190	394	346	321	502	466	458

Table V-10. Monthly beginning stock of domestically produced mixed fertilizer, 1972, Korea.

Unit: 100 M/T

Storage location	1972 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1973 Jan
Plant whse	864	1095	1157	778	658	398	100	--	100	231	25	41	293
Ulsan	496	567	648	451	389	254	100	--	100	189	13	21	200
Jinhae	368	528	509	327	269	144	--	--	--	42	12	20	93
Regional storage	1178	1210	1316	1401	1268	1062	585	508	683	719	357	358	489
1. Chuncheon	31	31	34	36	33	28	15	13	18	19	9	9	13
2. Kangneung	41	42	46	49	44	37	20	18	24	25	12	13	17
3. Cheongju	78	80	87	93	84	70	39	34	45	47	24	23	32
4. Jeju	29	30	33	35	32	26	15	12	17	18	9	9	12
5. Seoul	58	59	64	68	62	52	29	25	34	36	18	18	24
6. Suwon	73	75	82	87	79	66	36	31	42	44	22	22	30
7. Taejeon	55	57	62	66	59	50	27	24	32	34	17	17	23
8. Hongseong	70	71	78	82	75	62	35	30	40	42	21	21	29
9. Jeonju	67	69	75	80	72	60	33	29	39	41	20	20	28
10. Iri	106	109	118	126	114	96	52	46	61	65	32	32	44
11. Boseung	106	109	119	126	114	96	53	46	62	65	32	32	44
12. Songjeongri	74	76	83	88	80	67	37	32	43	45	23	23	31
13. Andong	66	68	73	79	71	59	33	28	38	40	20	20	27
14. Kimcheon	77	79	85	91	83	69	38	33	45	47	23	23	32
15. Taegu	71	73	79	84	76	64	35	31	41	43	21	22	29
16. Samrangjin	88	91	99	105	95	80	44	38	51	54	27	27	37
17. Jinju	88	91	99	105	95	80	44	38	51	54	27	27	37
ALL KOREA	2042	2305	2473	2179	1926	1460	685	508	783	950	382	399	782

Note: Stocks may be greater than the actual stocks resulting from production because stocks resulting from imports are included.

fertilizer at regional storage facilities were affected by the relative magnitudes of each type of fertilizer stock and regional storage capacity. The stocks of domestically produced mixed fertilizer include small amounts of imported mixed fertilizer which were not deducted because of their relative insignificance.

5.3 Empirical Analysis

Given specified origins, destinations, and quantities at each origin and destination, this section presents optimum flow patterns for urea, fused phosphate, potassium chloride, and mixed fertilizer, determined by the linear programming transportation model. Flow patterns were determined on an annual basis and on a monthly basis. The results are presented in this section.

As indicated earlier, the rail freight rate of 83 wons per metric ton of bagged fertilizer per 50 kilometers could only be applied on a full carload basis. In the analysis, fertilizer shipments were made in full carloads. Optimum fertilizer flow patterns presented in this section indicate the most feasible solutions under given freight rates, but may not be the socially optimum solutions.

5.3.1 Optimum Fertilizer Flow Patterns

Urea: The urea distribution problem consisted of determination of optimum urea flows with respect to transportation costs. Points of origin included manufacturing plants located in Chungju (C), Naju (N), Ulsan (U), and Jinhae (J). Destinations included seventeen scattered consumption centers and exporting harbors (table III-3).

The derivation of optimum flow patterns for urea required the identification of export points and the quantities available for export at each export harbor. As indicated in section 3.2, urea export harbors selected are Incheon for the Chungju plant, Mokpo for the Naju plant, Ulsan for the Ulsan plants (the Yongnam and Hankuk plants), and Jinhae for the Jinhae plant. A solution in which all harbors were assigned unlimited export capacity indicated that the total fertilizer export requirements should be satisfied by the urea produced by the Ulsan plants and should be exported from Ulsan harbor.

The initial computer run of the transportation model specified unlimited plant capacity. The result of that run indicated that of all existing plant locations in 1972, Ulsan, the location of Yongnam and Hankuk plants, was the least desirable location and Naju, the location of the Honam plant, was the best plant location with respect to transportation costs.

The optimum monthly flow patterns of urea are presented in table V-11. Given the availability of regional urea stock and the possibility of exporting 10,000 metric tons of plant output in January 1973, no urea shipments from plants to consumption regions were required in December 1972. Therefore, no urea flow patterns were determined for December 1972.

The table V-11 is interpreted as follows: The first column at the left shows cities which represent the seventeen consumption centers, exports, total (quantity transferred), and the four plant locations. The top row shows months for which flow patterns were calculated. Numbers in the main body indicate the volume of urea shipped to consumption regions, and exported from plants. The letters in parentheses indicate the plants of origin. For example, in January, 700 metric tons of urea were transferred from the Chungju plant to consumption region one, represented by Chuncheon, while consumption region three received 200 metric tons from the Ulsan plant and 1600 metric tons from the Chungju plant. In January, 10,000 metric tons of urea were exported from Ulsan harbor. The total quantity of urea transferred in January was 38,000 metric tons which included 3,700 metric tons from Chungju, 2,500 metric tons from Naju, 3,700 metric tons from Jinhae and

Table V-11. Monthly flow patterns of urea, 1972, Korea. Unit: 100 M/T

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Aggregated monthly flows	Single annual flows
Consumption													
1. Chunchcon	7(C)	13(C)	29(C)	12(C)	18(C)	22(C)	11(C)	13(C)	7(C)	14(C)	11(C)	157(C)	157(C)
2. Kangneung	10(U)	17(U)	39(U)	15(U)	24(U)	29(U)	16(U)	17(U)	9(U)	19(U)	15(U)	210(U)	210(U)
3. Cheongju	2(U)		8(U)		6(U)						5(U)	21(U)	
	16(C)	31(C)	65(C)	30(C)	40(C)	54(C)	29(C)	30(C)	19(C)	35(C)	23(C)	372(C)	392(C)
4. Jeju	6(J)	8(J)	19(J)	10(J)	14(J)	16(J)	7(J)	9(J)	6(J)	12(J)	9(J)	116(J)	116(J)
5. Seoul	14(C)	25(C)	60(C)	23(C)	37(C)	42(C)	24(C)	24(C)	14(C)	28(C)	22(C)	313(C)	313(C)
6. Suwon	17(U)	33(U)	75(U)	29(U)	46(U)	54(U)	31(U)	30(U)	17(U)	35(U)	27(U)	394(U)	394(U)
7. Taejeon	13(U)	24(U)	53(U)	22(U)	33(U)	40(U)	21(U)	22(U)	13(U)	25(U)	20(U)	286(U)	286(U)
8. Hongseung		20(U)		18(U)			17(U)	19(U)	7(U)	25(U)		303(U)	323(U)
	16(U)	10(C)	70(U)	11(C)	42(U)	44(U)	11(C)	8(C)	10(C)	8(C)	25(U)	65(C)	45(C)
9. Jeonju	10(J)	17(J)	39(J)	15(J)	24(J)	29(J)	15(J)	15(J)	9(J)	18(J)	15(J)	206(J)	205(J)
	6(U)	8(U)	19(U)	10(U)	14(U)	16(U)	7(U)	9(U)	6(U)	12(U)	9(U)	116(U)	116(U)
10. Iri	1(J)	21(J)	21(J)	18(J)	7(J)	22(J)	23(J)	19(J)	15(J)	16(J)	1(J)	164(J)	166(J)
	21(U)	19(U)	70(U)	21(U)	52(U)	48(U)	13(U)	19(U)	9(U)	31(U)	35(U)	338(U)	336(U)
11. Boseung	25(U)	40(U)	124(U)	35(U)	64(U)	69(U)	44(U)	32(U)	15(U)	38(U)	32(U)	518(U)	521(U)
	4(N)	18(C)	12(N)	16(N)	13(N)	24(N)	13(N)	17(N)	15(N)	19(N)	10(N)	161(N)	160(N)
12. Songjeongri	21(N)	38(C)	94(N)	35(N)	53(N)	63(N)	39(N)	34(N)	20(N)	39(N)	30(N)	466(N)	467(N)
13. Andong	16(U)	29(U)	68(U)	27(U)	41(U)	49(U)	28(U)	26(U)	16(U)	31(U)	24(U)	355(U)	356(U)
14. Kincheon	18(U)	34(U)	79(U)	31(U)	49(U)	57(U)	31(U)	32(U)	19(U)	36(U)	29(U)	415(U)	415(U)
15. Taegu	18(U)	30(U)	72(U)	28(U)	44(U)	52(U)	29(U)	29(U)	16(U)	34(U)	25(U)	377(U)	377(U)
16. Samrangjin	19(U)	34(U)	75(U)	33(U)	50(U)	58(U)	30(U)	32(U)	21(U)	38(U)	31(U)	421(U)	420(U)
17. Jinju	20(J)	33(J)	76(J)	32(J)	50(J)	59(J)	30(J)	32(J)	20(J)	39(J)	31(J)	422(J)	421(J)
Export	100(U)	--	100(U)	--	100(U)	--	100(U)	100(U)	100(U)	--	186(U)	786(U)	786(U)
Total	380	502	1267	471	821	854	569	568	383	552	615	6982	6982
Chungju (C)	37	79	154	76	95	125	75	75	50	85	56	907	907
Naju (N)	25	56	106	51	66	87	52	51	35	58	40	627	627
Ulsan (U)	281	288	852	269	565	516	367	367	248	324	463	4540	4540
Jinhae (J)	37	79	155	75	95	126	75	75	50	85	56	908	908

28, 100 metric tons from Ulsan to seventeen consumption regions and export harbor.

The two columns at the right in table V-11 provide a comparison of 1972 flow patterns when the analysis was performed on a monthly basis versus a yearly basis. Entries in "Aggregate Monthly Flows" column were found by adding entries from the 11 monthly flow patterns. Quantities in the "Single Annual Flows" column, were the result of performing the analysis with annual data rather than monthly data as though the total quantity of fertilizer was distributed in one shipment during the year. Comparison of the two columns indicates that the single shipment solution closely approximated the monthly urea flow patterns.

The urea flow patterns were dependent upon the relative quantity requirements within each region as well as transportation costs. Figure V-1 is based on "Aggregate Monthly Flows" presented in table V-11. The urea flow patterns can be summarized as follows:

1. Consumption regions received 90, 700 metric tons from the Chungju plant, 62, 700 metric tons from the Naju plant, 375, 400 metric tons from the Ulsan plants, and 90, 800 metric tons from the Jinhae plant;

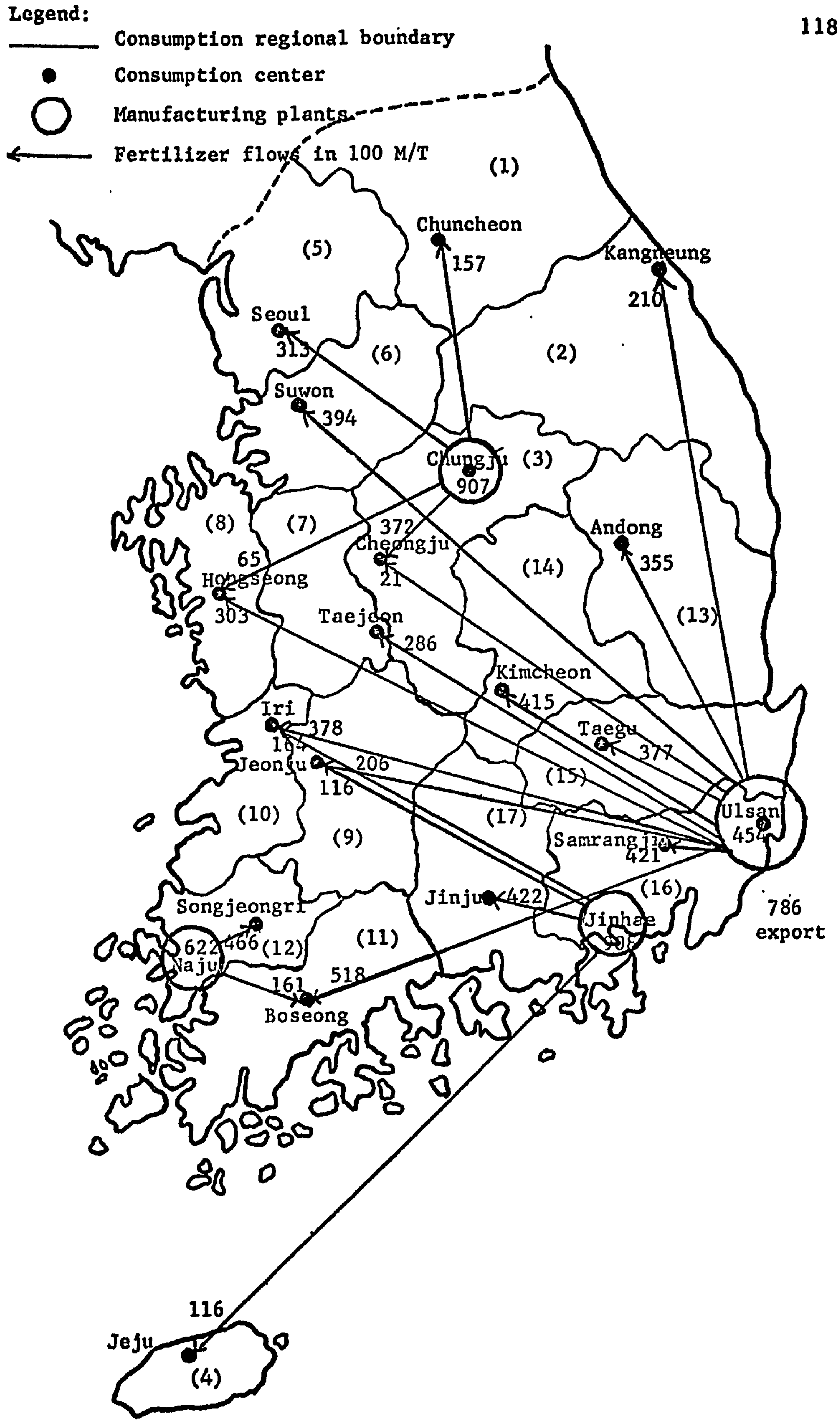

Figure V-1. Urea flows, 1972, Korea.

2. The Ulsan plants exported 78,600 metric tons of urea;

3. Consumption regions one and five received urea exclusively from the Chungju plant;

4. Consumption regions two, six, seven, 13, 14, 15, and 16 received urea exclusively from the Ulsan plant;

5. Consumption regions four and 17 received all the urea produced at the Jinhae plant;

6. The total urea requirement of consumption region 12 was met by the Naju plant;

7. Urea requirements for consumption regions three and eight were originated at the Chungju and Ulsan plants;

8. Urea requirements for consumption regions nine and 10 were transferred from the Jinhae and Ulsan plants;

9. Requirements for consumption region 11 were originated at the Naju and Ulsan plants.

<u>Fused phosphate:</u> Korea did not import or export fused phosphate in 1972. Fused phosphate stock on hand exceeded production in every month. Such a situation could lead to inefficient fused phosphate distribution unless the stock was adequately stored with respect to regional consumption and availability of regional storage facilities.

The 1972 fused phosphate distribution problem involved the satisfaction of consumption and end stock as efficiently as possible with production and beginning stock. The least cost shipment pattern indicated that 68,300 metric tons of fused phosphate should be transferred from the Sosa plant 153,400 metric tons from the Janghang plant to the various consumption regions. The flow pattern is presented in detail in table V-12. Interpretation of table V-12 is similar to that discussed with respect to table V-11. The symbols "(S)" and "(H)" indicate flows from the Sosa and Janghang plants, respectively.

The transportation cost for fused phosphate could have been reduced if the plants had been located in more than one cropping area. The plant at Janghang caused especially high transportation costs since Janghang is located at a remote corner of the railway network. Therefore, when the time comes to replace the Janghang plant, a more strategic location than Janghang should be selected. The analysis indicated high stocks of fused phosphate which yielded high storage costs and further complicated the already existing shortage in regional storage. Under conditions of continuous production, 100,000 metric tons of the 1972 beginning stock, rather than 260,100 metric tons,

Table V-12. Monthly flow patterns of fused phosphate, 1972, Korea.

Unit: 100 M/T

	Feb	Mar	Apr	May	June	July	Sept	Oct	Nov	Aggregated monthly flows	Single annual flows
Consumption											
1. Chuncheon	3(S)	13(S)	4(S)	11(S)	17(S)	4(S)	1(S)	6(S)		59(S)	59(S)
2. Kangneung	4(S)	16(S)	6(S)	13(S)	25(S)	5(S)	1(S)	8(S)	1(S)	79(S)	79(S)
3. Cheongju	8(H)	30(H)	12(H)	26(H)	45(H)	9(H)	1(H)	17(H)	1(H)	149(H)	149(H)
4. Jeju	3(H)	10(H)	4(H)	8(H)	15(H)	1(H)		5(H)		46(H)	46(H)
5. Seoul	6(S)	22(S)	8(S)	19(S)	33(S)	6(S)		12(S)	2(S)	108(S)	108(S)
6. Suwon	6(S)	30(S)	10(S)	23(S)	42(S)	8(S)	1(S)	15(S)		135(S)	135(S)
7. Taejeon	2(H)	19(H)	3(H)	14(H)	25(H)	2(H)		8(H)		73(H)	69(H)
	3(S)	2(S)	5(S)	3(S)	6(S)	3(S)	1(S)	2(S)	1(S)	26(S)	30(S)
8. Hongseung	6(H)	27(H)	11(H)	21(H)	40(H)	7(H)		14(H)	1(H)	127(H)	127(H)
9. Jeongju										1(S)	
	5(H)	26(H)	9(H)	21(H)	37(H)	7(H)		13(H)	1(S)	118(H)	118(H)
10. Iri	8(H)	40(H)	15(H)	33(H)	58(H)	11(H)		20(H)		185(H)	185(H)
11. Boseung	16(H)	46(H)	19(H)	39(H)	70(H)	17(H)	5(H)	27(H)	7(H)	246(H)	247(H)
12. Songjeongri	11(H)	32(H)	13(H)	28(H)	49(H)	11(H)	4(H)	18(H)	5(H)	171(H)	171(H)
13. Andong	7(S)	26(S)	9(S)	21(S)	39(S)	6(S)	1(S)	14(S)	1(S)	124(S)	124(S)
14. Kimcheon										2(S)	
	7(H)	30(H)	11(H)	24(H)	44(H)	9(H)	1(S)	16(H)	1(S)	141(H)	143(H)
15. Taegu	6(H)	27(H)	10(H)	23(H)	41(H)	7(H)	1(H)	14(H)	1(H)	130(H)	131(H)
16. Samrangjin	6(S)	33(S)	13(S)	26(S)	47(S)	8(S)		16(S)		149(S)	148(S)
17. Jinju	6(H)	33(H)	13(H)	26(H)	46(H)	9(H)		15(H)		148(H)	148(H)
Total	113	462	175	379	679	130	17	240	22	2217	2217
Sosa (S)	35	142	55	116	209	40	6	73	7	683	683
Janghang (H)	78	320	120	263	470	90	11	167	15	1534	1534

would have been sufficient to satisfy seasonal consumption of fused phosphate.

Reviewing quantities available and required, it was found that shipments of fused phosphate were not needed for January, August, and December. Comparison of the columns "Aggregate Monthly Flows" and "Single Annual Flows" in table V-12 indicate that the single shipment solution provided a very close approximation to the optimum flow patterns resulting from aggregation of nine monthly shipments.

Figure V-2 is based upon "Aggregate Monthly Flows" from table V-12. The fused phosphate flow patterns can be summarized as follows:

1. During 1972, consumption regions received 221,700 metric tons of fused phosphate including 68,300 metric tons from the Sosa plant and 153,400 metric tons from the Janghang plant;

2. Requirements of consumption regions one, two, five, six, 13, and 16 originated at the Sosa plant;

3. Requirements of consumption regions three, four, eight, 10, 11, 12, 15, and 17 were met by the production of the Janghang plant;

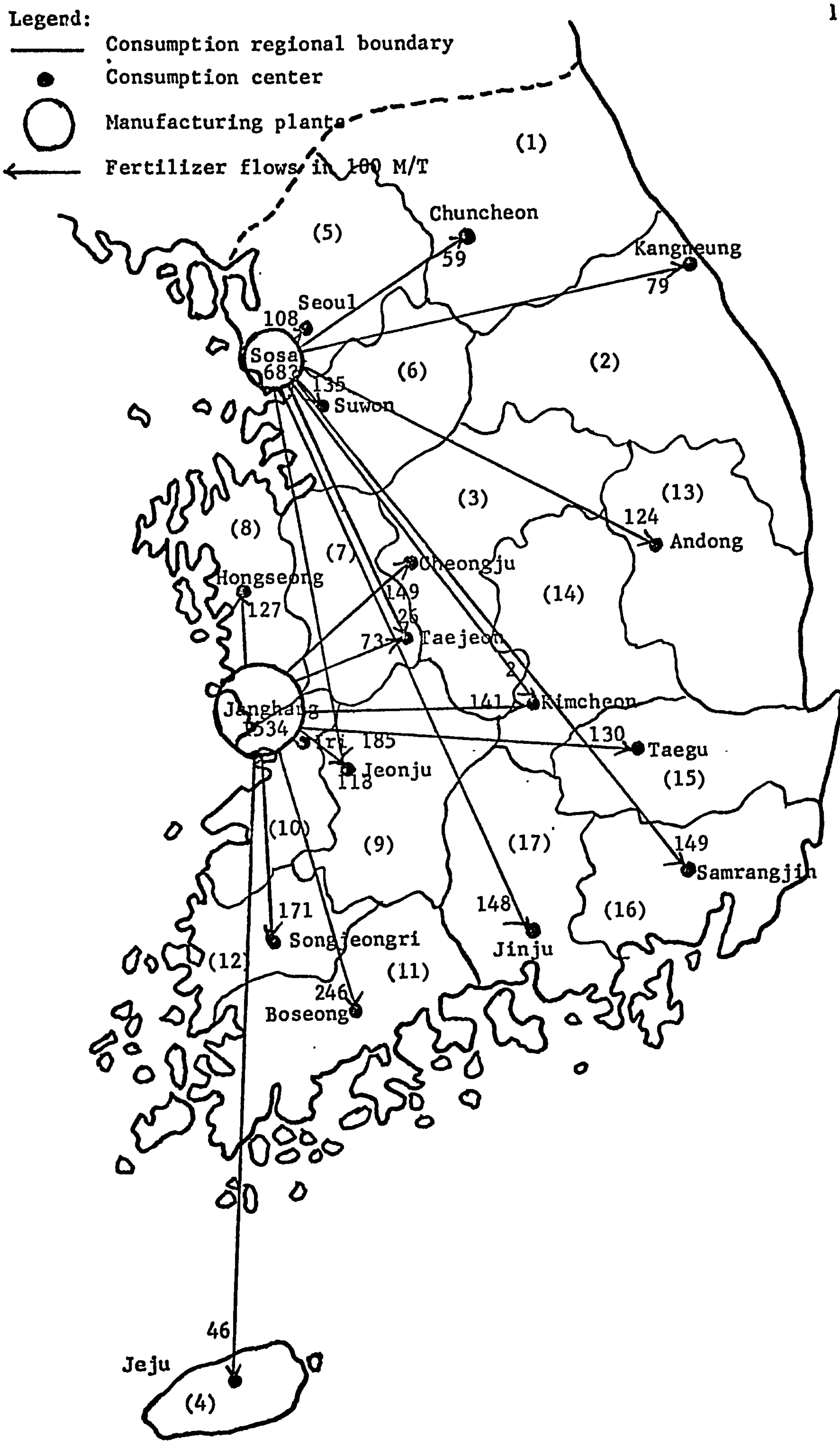

Figure V-2. Fused phosphate flows, 1972, Korea.

4. Both the Sosa and Janghang plants supplied fused phosphate to consumption regions seven, nine, and 14.

Domestically Produced Mixed Fertilizer: The mixed fertilizer distribution problem was similar to that of urea distribution. The problem involved satisfaction of consumption, export, and end stock requirements with production and beginning stock in such a way as to minimize transportation costs.

Mixed fertilizer exports in 1972 amounted to 94,300 metric tons. The exportation schedule was presented in table V-6. An attempt was made to find the origins of exports and the quantities exported from each origin. Ulsan served as exporting harbor for the plant at Ulsan, and Jinhae harbor for the plant at Jinhae. The unit transportation cost from a plant to its exporting harbor was assumed to be zero. When both harbors were assigned unlimited export capacity, the solution indicated that the total export requirement of mixed fertilizer should be met by production at the Ulsan plants in order to minimize domestic transportation costs.

Optimum flow patterns for domestically produced mixed fertilizer are presented in table V-13. Results of the optimum solution for mixed fertilizer distribution may be less impressive

Table V-13. Monthly distribution of domestically produced mixed fertilizer, 1972, Korea.

Unit: 100 M/T

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Aggregated monthly flow	Single annual flow
Consumption													110(U)	
1. Chuncheon	2(U)	7(J)	18(U)	13(U)	16(U)	17(U)	11(U)	9(U)	5(J)	13(U)	11(U)	2(J)	14(J)	124(U)
2. Kangneung	3(U)	10(U)	25(U)	16(U)	21(U)	22(U)	16(U)	11(U)	7(U)	17(U)	16(U)	2(J)	164(U)	
													2(J)	166(U)
3. Cheongju	2(J)		18(J)	13(J)	16(J)	17(J)	11(J)	16(J)		13(J)	11(J)		159(U)	124(J)
	4(U)	17(J)	30(U)	17(U)	23(U)	26(U)	18(U)	5(U)	12(J)	21(U)	15(U)	7(J)	153(J)	188(U)
4. Jeju	2(J)	6(J)	14(J)	8(J)	9(J)	11(J)	7(J)	8(J)	4(J)	7(J)	8(J)	2(J)	86(J)	86(J)
5. Seoul	3(J)						19(J)				16(J)		8(U)	
	1(U)	13(J)	35(J)	23(J)	30(J)	32(J)	2(U)	16(J)	10(J)	25(J)	5(U)	4(J)	226(J)	234(J)
6. Suwon		3(J)							1(J)				286(U)	
	6(U)	14(U)	44(U)	29(U)	37(U)	40(U)	27(U)	20(U)	11(U)	32(U)	26(U)	4(J)	8(J)	294(U)
7. Tacjeon													187(U)	
	5(U)	12(J)	32(U)	20(U)	27(U)	28(U)	20(U)	15(U)	9(J)	22(U)	18(U)	4(J)	25(J)	212(U)
8. Hongseung	4(J)	16(J)	42(J)	26(J)	34(J)	38(J)	25(J)	19(J)	11(J)	30(J)	24(J)	5(J)	274(J)	274(J)
9. Jeonju	5(J)	14(J)	36(J)	22(J)	28(J)	29(J)	22(J)	17(J)	10(J)	22(J)	21(J)	5(J)	231(J)	231(J)
10. Iri	8(J)	21(J)	57(J)	34(J)	45(J)	44(J)	34(J)	27(J)	16(J)	35(J)	32(J)	7(J)	360(J)	360(J)
11. Boseung			38(J)	45(J)	45(J)	52(J)				2(J)			262(U)	409(J)
	10(U)	27(J)	38(U)	7(U)	25(U)	28(U)	49(U)	32(J)	21(J)	60(U)	45(U)	8(J)	270(J)	123(U)
12. Songjeongri	6(J)	19(J)	53(J).	36(J)	48(J)	54(J)	33(J)	22(J)	14(J)	43(J)	31(J)	5(J)	364(J)	364(J)
13. Andong	5(U)	13(U)	41(U)	24(U)	32(U)	35(U)	23(U)	18(U)	11(U)	27(U)	23(U)	5(J)	252(U)	
													5(J)	257(U)
14. Kimcheon	6(U)	16(J)	46(U)	29(U)	38(U)	40(U)	27(U)	22(U)	12(J)	31(U)	26(U)	6(J)	265(U)	
													34(J)	299(U)
15. Taegu	5(U)	15(J)	41(U)	26(U)	34(U)	36(U)	25(U)	19(U)	11(J)	28(U)	25(U)	4(J)	239(U)	
													30(J)	269(U)
16. Samrangjin	7(J)	18(J)	46(J)	27(J)	37(J)	35(J)	26(J)	23(J)	13(J)	28(J)	26(J)	6(J)	292(J)	292(J)
17. Jinju	7(J)	18(J)	46(J)	27(J)	37(J)	35(J)	26(J)	23(J)	13(J)	28(J)	26(J)	6(J)	292(J)	292(J)
Export	100(U)	100(U)	100(U)	100(U)	100(U)	100(U)	100(U)		100(U)	143(U)			943(U)	943(U)
	191	359	800	542	682	719	521	322	291	627	405	82	5541	5541
Ulsan (U)	147	137	415	281	353	372	318	119	129	394	210		2875	2875
Jinhae (J)	44	222	385	261	329	347	203	203	162	233	195	82	2666	2666

than those for the other fertilizer types because both manufacturing plants were located in a single consumption region, region 16. The transportation costs from either of the two plants to any single consumption center were similar because the two plants were located close to one another.

Figure V-3 depicts the mixed fertilizer flows as presented in the column "Aggregate Monthly Flows" in table V-13. Mixed fertilizer flow patterns may be summarized as follows:

1. The total flow of mixed fertilizer was 554, 100 metric tons including 193, 200 metric tons from the Ulsan plant and 266, 600 metric tons from the Jinhae plant to consumption regions and 94, 300 metric tons of exports from the Ulsan plant;

2. Consumption at regions four, eight, nine, 10, 12, 16 and 17 was satisfied by production from the Jinhae plants only;

3. Other regions received fertilizer from both plants;

4. The Ulsan plant was not allowed any December shipments so that 10, 000 metric tons would be available for export in January, 1973. The solution reflects a constraint

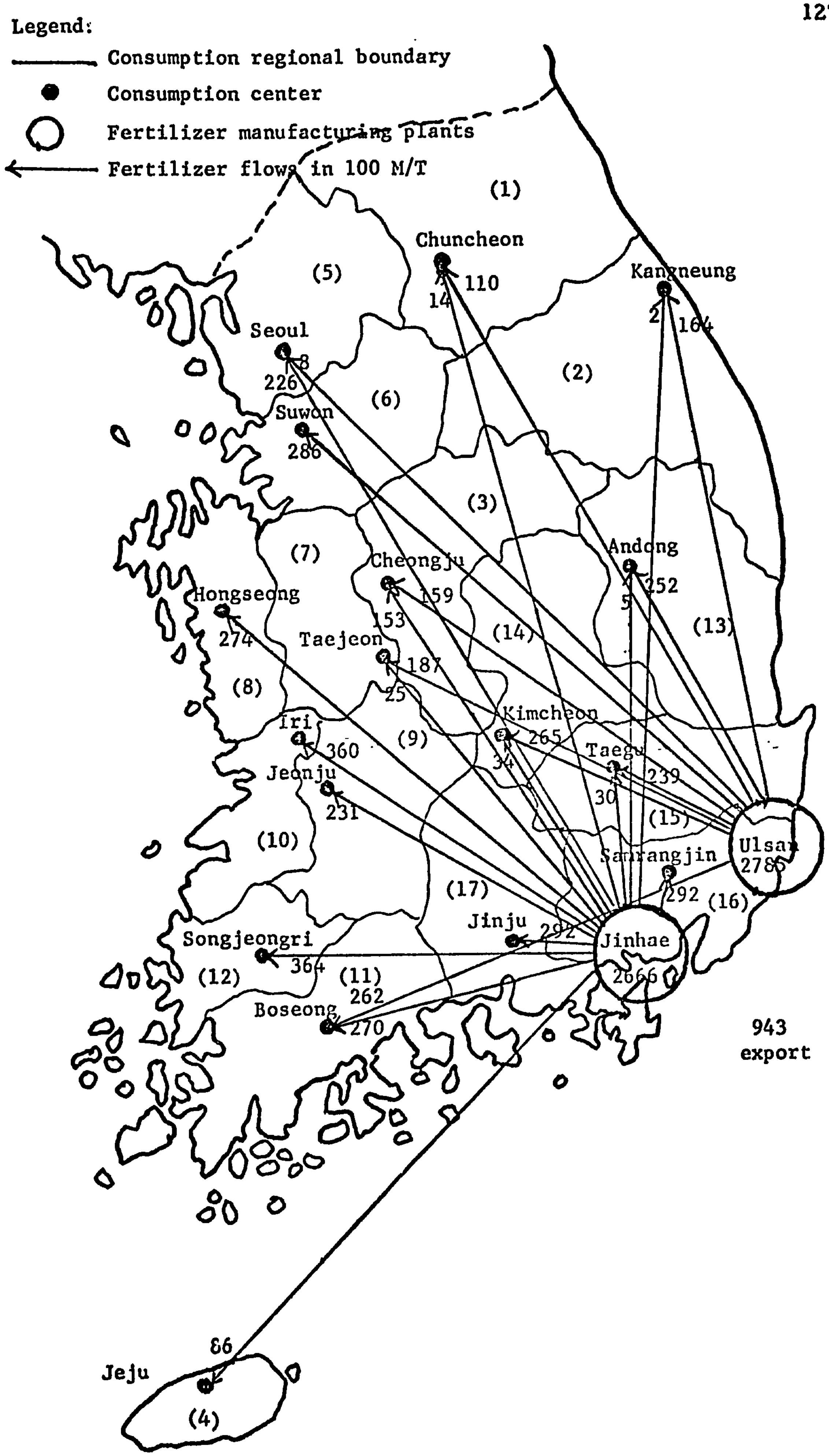

Figure V-3. Domestically produced mixed fertilizer flows, 1972, Korea.

which allowed no fertilizer transfer from the Ulsan plant in December. Total regional requirements were satisfied by the production at the Jinhae plant. If the constraint was relaxed the solution would be different from the one presented in table V-13.

Potassium Chloride: In 1972, no potassium chloride was produced in Korea. Instead, 52,000 metric tons of potassium chloride were imported. Several problems were involved in the distribution of potassium chloride. One was the determination of optimum number, timing, and size of import shipments. These were discussed in section 5.2.3. Another problem was determination of quantities imported through potential importing harbors.

As indicated in section 3.2, consideration of transportation costs from exporting countries to Korea was beyond the scope of the study. Incheon, and Kunsan on the West Coast and Mokpo, Yosu, and Pusan on the South Coast were harbors selected as potential importing harbors. As indicated in section 5.2.3, two import shipments of potassium chloride, 30,000 metric tons in July and 22,000 metric tons in October were arbitrarily decided to keep an adequate level of stock for efficient domestic potassium chloride distribution (table V-6).

In the potassium chloride distribution analysis, cases of single annual shipment and two shipments were tested to investigate their effects on transportation costs and flow patterns.

Table V-14 shows several flow patterns of potassium chloride for the annual import case for 1972 for alternative combinations of harbor capacities. Column one shows the least cost solution when each of the harbors was allowed unlimited capacity. No more than 16,900 metric tons were imported through any harbor. Therefore, the flow pattern was exactly the same as that in column two which allowed 20,000 metric tons of imports through each harbor. As indicated by the patterns presented in columns three, four, five and six, the average transportation costs increased as the number of importing harbors decreased. Column seven presents the pattern resulting when Mokpo harbor was allowed to import 10,000 metric tons of fertilizer and all other harbors have a 10,500 metric tons capacity. The solution indicated 13 percent increase in average transportation cost over the least cost solutions (columns one and two).

Table V-15 indicates the potassium chloride flow patterns for July, 1972. Patterns presented in columns one and two indicate that no harbor received more than 9,100

Table V-14. Flow patterns of potassium chloride, 1972, Korea: 52,000 M/T Case.

Unit: 100 M/T

Consumption region	Alternative arrangements 1	2	3	4	5	6	7
	Quantity received[1]						
1. Chuncheon	16(I)	16(I)	16(I)	16(I)	16(I)	16(I)	16(I)
2. Kangneung	21(I)	21(I)	21(I)	21(I)	21(I)	21(P)	21(P)
3. Cheongju	39(I)	39(I)	39(I)	39(I)	39(I)	28(K) 11(I)	9(Y) 13(M) 17(K)
4. Jeju	12(M)	12(M)	12(P)	12(P)	12(Y)	12(P)	12(M)
5. Seoul	27(I)	27(I)	27(I)	27(I)	27(I)	27(I)	27(I)
6. Suwon	34(I)	34(I)	34(I)	34(I)	34(I)	34(I)	34(I)
7. Taejeon	26(K)	26(K)	26(K)	26(K)	26(K)	26(K)	26(K)
8. Hongseong	32(I)	32(I)	32(I)	32(I)	32(I)	32(I)	4(M) 28(I)
9. Jeonju	24(K)	24(K)	24(K)	24(K)	24(K)	24(K)	24(K)
10. Iri	38(K)	38(K)	38(K)	38(K)	38(K)	38(K)	38(K)
11. Boseung	52(Y)	52(Y)	52(K)	52(K)	52(Y)	5(P) 47(K)	52(Y)
12. Songjeongri	37(M)	37(M)	37(K)	37(K)	37(K)	37(K)	37(M)
13. Andong	30(P)	30(P)	30(P)	30(P)	30(P)	30(P)	30(P)
14. Kimcheon	34(P)	34(P)	34(P)	34(P)	34(P)	34(P)	34(M)
15. Taegu	30(P)	30(P)	30(P)	30(P)	30(P)	30(P)	19(P) 11(Y)
16. Samrangjin	35(P)	35(P)	35(P)	35(P)	35(P)	35(P)	35(P)
17. Jinju	33(Y)	33(Y)	33(P)	33(P)	33(Y)	33(P)	33(Y)
	520	520	520	520	520	520	520

Table V-14. (continued)

	Alternative arrangements						
	1	2	3	4	5	6	7
Importing harbors	Quantity imported						
Incheon	169	169	169	169	169	120	105
Kunsan	88	88	177	177	125	200	105
Mokpo	49	49	--	--	--	--	100
Yosu	85	85	--	--	97	--	105
Pusan	129	129	174	174	129	200	105
Constraints[2]	Assigned capacity						
Incheon	520 (351)	200 (31)	520 (351)	200 (31)	200 (31)	120	105
Kunsan	520 (432)	200 (112)	520 (343)	200 (23)	200 (75)	200	105
Mokpo	520 (471)	200 (151)	--	--	--	--	100
Yosu	520 (435)	200 (115)	--	--	200 (103)	--	105
Pusan	520 (391)	200 (71)	520 (346)	200 (26)	200 (71)	200	105
A.T.C.[3]	271.6	271.6	296.1	296.1	280.7	297.7	306.9

[1]Letters in parentheses represent harbors from which consumption regions received shipments.
[2]Numbers in parentheses indicate unused capacity for each harbor.
[3]A.T.C. indicate average transportation costs for each constraint.

Table V-15. Flow patterns of potassium chloride, July 1972, Korea: 30,000 M/T Case.

Unit: 100 M/T

	Alternative arrangements				
	1	2	3	4	5
Consumption region	Quantity received[1]				
1. Chuncheon	8(I)	8(I)	8(I)	8(I)	8(I)
2. Kangneung	11(I)	11(I)	11(I)	11(I)	11(I)
3. Cheongju	21(I)	21(I)	21(I)	21(I)	21(I)
4. Jeju	7(M)	7(M)	7(P)	7(Y)	3(P) 4(I)
5. Seoul	15(I)	15(I)	15(I)	15(I)	15(I)
6. Suwon	18(I)	18(I)	18(I)	18(I)	18(I)
7. Taejeon	15(K)	15(K)	15(K)	15(K)	10(K) 5(I)
8. Hongseung	18(I)	18(I)	18(I)	18(I)	18(I)
9. Jeonju	16(K)	16(K)	16(K)	16(K)	16(K)
10. Iri	25(K)	25(K)	25(K)	25(K)	25(K)
11. Boseong	29(Y)	29(Y)	29(K)	29(Y)	29(K)
12. Songjeongri	20(M)	20(M)	20(K)	20(K)	20(K)
13. Andong	16(P)	16(P)	16(P)	16(P)	16(P)
14. Kimcheon	20(P)	20(P)	20(P)	20(P)	20(P)
15. Taegu	18(P)	18(P)	18(P)	18(P)	18(P)
16. Samrangjin	22(P)	22(P)	22(P)	22(P)	22(P)
17. Jinju	21(Y)	21(Y)	21(P)	21(Y)	21(P)
	300	300	300	300	300
Importing harbors	Quantity imported				
Incheon	91	91	91	91	100
Kunsan	56	56	105	76	100
Mokpo	27	27	--	--	--
Yosu	50	50	--	57	--
Pusan	76	76	104	76	100
Constraints	Assigned capacity[2]				
Incheon	300 (209)	100 (9)	300 (209)	100 (9)	100
Kunsan	300 (244)	100 (44)	300 (295)	100 (24)	100
Mokpo	300 (273)	100 (73)	--	--	--
Yosu	300 (250)	100 (50)	--	100 (43)	--
Pusan	300 (224)	100 (24)	300 (195)	100 (24)	100
A.T.C.[3]	265.9	265.9	290.4	274.7	293.9

Table V-15.

Footnotes

[1] Letters in parentheses represent harbors from which consumption regions received shipments.

[2] Numbers in parentheses indicate unused capacity for each harbor.

[3] A. T. C. indicates average transportation costs for each constraint.

metric tons even if every harbor was allowed to import the total 30,000 metric tons. As the number of harbors decreased the average transportation costs increased as expected.

Table V-16 presents alternative flow patterns for ten variations of the October potassium chloride distribution problem. The first flow pattern presents the case in which each harbor was assigned unlimited capacity. No harbor imported more than 6,600 metric tons. Flow patterns four through seven represent cases in which various pairs of two harbors were allowed to import 11,000 metric tons each. Flow patterns eight through ten show results when one harbor, e.g., Incheon, Kunsan, or Pusan was allowed to import the total potassium chloride requirement, 22,000 metric tons. As the number of importing harbors decreased, the average transportation cost increased sharply due to the scattered consumption regions throughout the country.

Without capacity constraints on importing harbors, the solutions suggested the following flow patterns of potassium chloride as is shown by figure V-4.

1. Approximately 30 percent of the total potassium chloride imported through Incheon, 19 percent through Kunsan, nine percent through Mokpo, 16 percent through Yosu, and 25 percent through Pusan;

Table V-16. Flow patterns of potassium chloride, October 1972: 22,000 M/T Case.

Unit: 100 M/T

	Alternative arrangements									
	1	2	3	4	5	6	7	8	9	10
Consumption region	Quantity received[1]									
1. Chuncheon	5(I)	5(I)	5(I)	5(I)	5(I)	5(P)	5(I)	5(P)	5(I)	5(K)
2. Kangneung	9(I)	9(I)	9(I)	9(I)	9(P)	9(P)	9(I)	9(P)	9(I)	9(K)
3. Cheongju	15(I)	15(I)	15(I)	15(I)	15(I)	15(K)	15(I)	15(P)	15(I)	15(K)
4. Jeju	5(M)	5(M)	5(P)	5(I)	5(P)	5(P)	5(P)	5(P)	10(I)	10(K)
5. Seoul	11(I)	11(I)	11(I)	11(I)	11(I)	11(K)	11(I)	11(P)	11(I)	11(K)
6. Suwon	14(I)	14(I)	14(I)	14(I)	14(I)	14(K)	14(I)	14(P)	14(I)	14(K)
7. Taejeon	11(K)	11(K)	11(K)	11(I)	11(I)	11(K)	11(K)	11(P)	11(I)	11(K)
8. Hongseong	12(I)	12(I)	12(I)	12(I)	12(I)	12(K)	12(I)	12(P)	12(I)	12(K)
9. Jeonju	13(K)	13(K)	13(K)	13(K)	13(I)	13(K)	13(K)	13(P)	13(I)	13(K)
10. Iri	19(K)	19(K)	19(K)	19(K)	19(I)	19(K)	19(K)	19(P)	19(I)	19(K)
11. Boseong	20(Y)	20(Y)	20(K)	20(K)	20(P)	20(P)	20(K)	20(P)	20(I)	20(K)
12. Songjeongri	15(M)	15(M)	15(K)	15(K)	10(I) 5(P)	15(K)	15(K)	15(P)	15(I)	15(K)
13. Andong	12(P)	12(P)	12(P)	12(I)	12(P)	12(P)	12(P)	12(P)	12(I)	20(K)
14. Kimcheon	14(P)	14(P)	14(P)	3(I) 11(K)	14(P)	14(P)	14(P)	14(P)	14(I)	14(K)
15. Taegu	13(P)	13(P)	13(P)	13(I)	13(P)	13(P)	13(P)	13(P)	13(I)	13(K)
16. Samrangjin	17(P)	17(P)	17(P)	17(K)	17(P)	17(P)	17(P)	17(P)	17(I)	17(K)
17. Jinju	15(Y)	15(Y)	15(P)	15(K)	15(P)	15(P)	15(P)	15(P)	15(I)	15(K)
Total	220	220	220	220	220	220	220	220	220	220

Table V-16. (continued)

	Alternative arrangements									
	1	2	3	4	5	6	7	8	9	10
Importing harbors	Quantity imported									
Incheon	66	66	66	110	110	--	110	--	220	--
Kunsan	43	43	78	110	--	110	110	--	--	220
Mokpo	20	20	--	--	--	--	--	--	--	--
Yosu	35	35	--	--	--	--	--	--	--	--
Pusan	56	56	76	--	110	110	110	220	--	--
Constraints	Assigned capacity[2]									
Incheon	220(154)	110(44)	220(154)	110	110	--	110(44)	--	220	--
Kunsan	220(177)	110(67)	220(142)	110	--	110	110(32)	--	--	220
Mokpo	220(200)	110(90)	--	--	--	--	--	--	--	--
Yosu	220(185)	110(75)	--	--	--	--	--	--	--	--
Pusan	220(164)	110(54)	220(144)	--	110	110	110(34)	220	--	--
A.T.C.[3]	263.6	263.6	287.7	380.4	400.5	363.5	287.7	552.9	566.9	431.5

[1]Letters in parentheses represent harbors from which consumption regions received shipments.
[2]Numbers in parentheses indicate unused capacity for each harbor.
[3]A.T.C. indicates average transportation costs for each constraint.

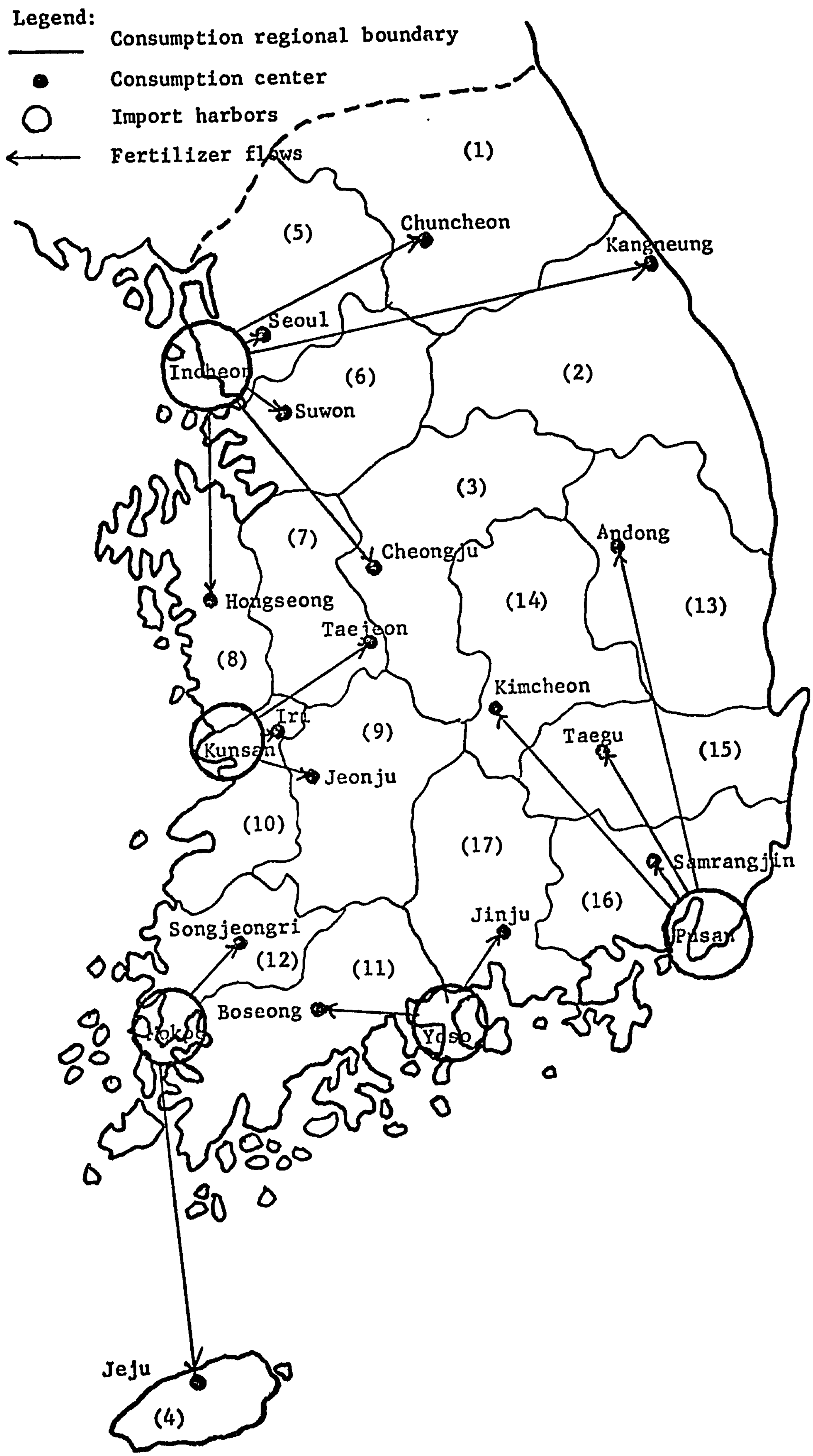

Figure V-4. Potassium chloride flows, 1972, Korea.

2. Potassium chloride imported through Incheon was distributed to regions one, two, three, five, six and eight;

3. Fertilizer imported through Kunsan was transferred to regions seven, nine, and 10;

4. Regions four and 12 received fertilizer from Mokpo;

5. Regions 11 and 17 were supplied by Yosu;

6. Fertilizer imported through Pusan was transferred to regions 13, 14, 15, and 16.

5.3.2. Comparison of Fertilizer Flow Patterns and Transportation Costs

Optimum flow patterns for individual fertilizer type have been discussed so far. In table V-17, optimum fertilizer flow patterns with respect to transportation costs and average transportation costs for urea, fused phosphate, domestically produced mixed fertilizer, and imported potassium chloride are compared. This table is concerned with the total volume of fertilizer material shipped through the entire system during each time period considered from plants or importing harbors to consumption centers and the associated average transportation costs involved. The potassium chloride patterns presented

Table V-17. Comparison of fertilizer flow patterns and transportation costs, 1972, Korea.

Unit: Quantity: 100 M/T
Average transportation cost: wons

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Aggregate monthly flows	Single annual flows
Urea														
quantity	(280)	(502)	(1167)	(471)	(721)	(854)	(469)	(468)	(283)	(552)	(429)	--	(6196)	6196
A.T.C.	444.7	420.1	443.9	423.5	443.2	431.2	419.3	421.1	406.0	428.5	431.9	--	431.9	432.0
Fused Phos.														
quantity	--	(113)	(462)	(175)	(379)	(679)	(130)	--	(17)	(240)	(22)	--	(2217)	(2217)
A.T.C.	--	568.4	545.4	561.3	555.4	556.2	553.6	--	620.1	553.9	607.4	--	555.4	557.3
Mixed fert.														
quantity	(91)	(259)	(700)	(442)	(582)	(619)	(421)	(322)	(191)	(484)	(405)	(82)	(4598)	(4598)
A.T.C.	524.9	544.3	537.4	543.0	546.6	547.2	539.8	535.8	540.1	543.8	539.6	545.0	540.7	540.2
Pot. chlor.														
quantity	--	--	--	--	--	--	(300)	--	--	(220)	--	--	(520)	(520)
A.T.C.	--	--	--	--	--	--	265.9	--	--	263.6	--	--	264.9	271.6

Note:
1. Potassium chloride solutions presented here are the solutions when each harbor is allowed to import the total amount.
2. Numbers in parentheses represent volume transferred from plants or importing harbors to consumption regions.
3. A.T.C. Indicates average transportation cost per metric ton in the solutions.

here are the result of solutions obtained when each of the five available harbors was assigned unlimited import capacity. Quantities transferred and average transportation costs for each type of fertilizer fluctuated from period to period.

The highest average transportation cost was associated with fused phosphate and the lowest cost with potassium chloride for comparable periods. The average transportation cost for urea was higher than that for potassium chloride, but lower than for mixed fertilizer. This may be related to the number of origins and the quantities available at each origin. The number of origins was five for potassium chloride, four for urea, and two for fused phosphate and mixed fertilizer. It is natural that the greater number of origins at scattered locations results in lower transportation cost. The higher average transportation cost for fused phosphate relative to mixed fertilizer, which has the same number of origins, may be affected by the relatively large quantity of fused phosphate produced at the Janghang plant, located at a remote corner of the rail transportation network. Mixed fertilizer was produced in almost equal amounts by the less remotely located Ulsan and Jinhae plants.

A comparison of the last two columns in table V-17, "Aggregate Monthly Flows" and "Single Annual Flows" indicate that the frequency of the shipments has very little effect on average transportation costs.

In summary, the aggregate monthly flow patterns indicate that the total transportation costs of shipping 1,353,100 metric tons of fertilizer from production and import origins to consumption centers amounted to 639,351,000 wons and the associated average transportation cost was 472.5 wons per metric ton. In the single annual flow case, the total transportation cost was 648,151,000 wons and the associated average transportation cost was 479 wons. Assuming that each storage facility has once-a-year turnover, the total storage cost for 806,800 metric tons of approximated fertilizer stocks was 726,120,000 wons and the average storage cost was 900 wons for six months.

5.4 Efficient Fertilizer Stock Level

It was mentioned in section 4.5 that unnecessarily high stocks and the seasonality of consumption have negative effects on the efficiency of the fertilizer distribution system in Korea. It was pointed out that reductions in stock to more efficient levels could reduce storage costs and the problem of a shortage in storage facilities.

Then, the problem was to determine what an adequate level of fertilizer beginning stock for 1972 would be. Consideration of the monthly supply and consumption relationships helped to shed some light on the problem. The relationships for total fertilizer were analyzed to understand the whole picture. The relationships for each type of fertilizer were not studied here.

Using fertilizer quantities supplied and utilized in 1972 (table IV-10), beginning stock and production were directly related to consumption. In order to eliminate the effects of exports and imports, the following adjustments were made:

1. The quantities produced for consumption and end stock (1, 188, 000 metric tons) were calculated by subtracting exports (172, 900 metric tons) from production (1, 360, 900 metric tons). Assuming continuous production, average monthly production was 99, 000 metric tons.

2. The quantities supplied by production and beginning stock for consumption and end stock (2, 167, 700 metric tons) were obtained by subtracting quantity imported (100, 000 metric tons) from utilization (2, 267, 700 metric tons).

3. Assuming that all imported fertilizer was consumed during the year, consumption satisfied by production and beginning stock was estimated as 1, 328, 500 metric tons.

4. Using the ratios of monthly consumption to yearly consumption (figure IV-1), quantities consumed monthly were calculated and presented in figure V-5.

5. The monthly quantities supplied were simply the beginning stock of the month plus production during the month, as shown in figure V-5.

Figure V-5 shows great excess supplies for every month. Considering the efficiency of the fertilizer distribution system in 1972 only, adequate levels of monthly supplies are shown by the solid line assuming the system could transport and store fertilizer efficiently to satisfy monthly consumption. The solid line was based on monthly supply and consumption relationships. Since stocks are depleted in August, an adequate level of stocks in August was first approximated to find an efficient level of stocks for each month. The excess stock level, the difference between actual supply and adequate supply remains constant over 12 months. The level of the beginning stock could have been reduced by the amount of 560,000 metric tons as indicated by the distance from the top of the histogram to the solid line in figure V-5. The system could have saved 100.8 million wons on storage costs from such a reduction in stock level. If transportation, handling, loading, and unloading

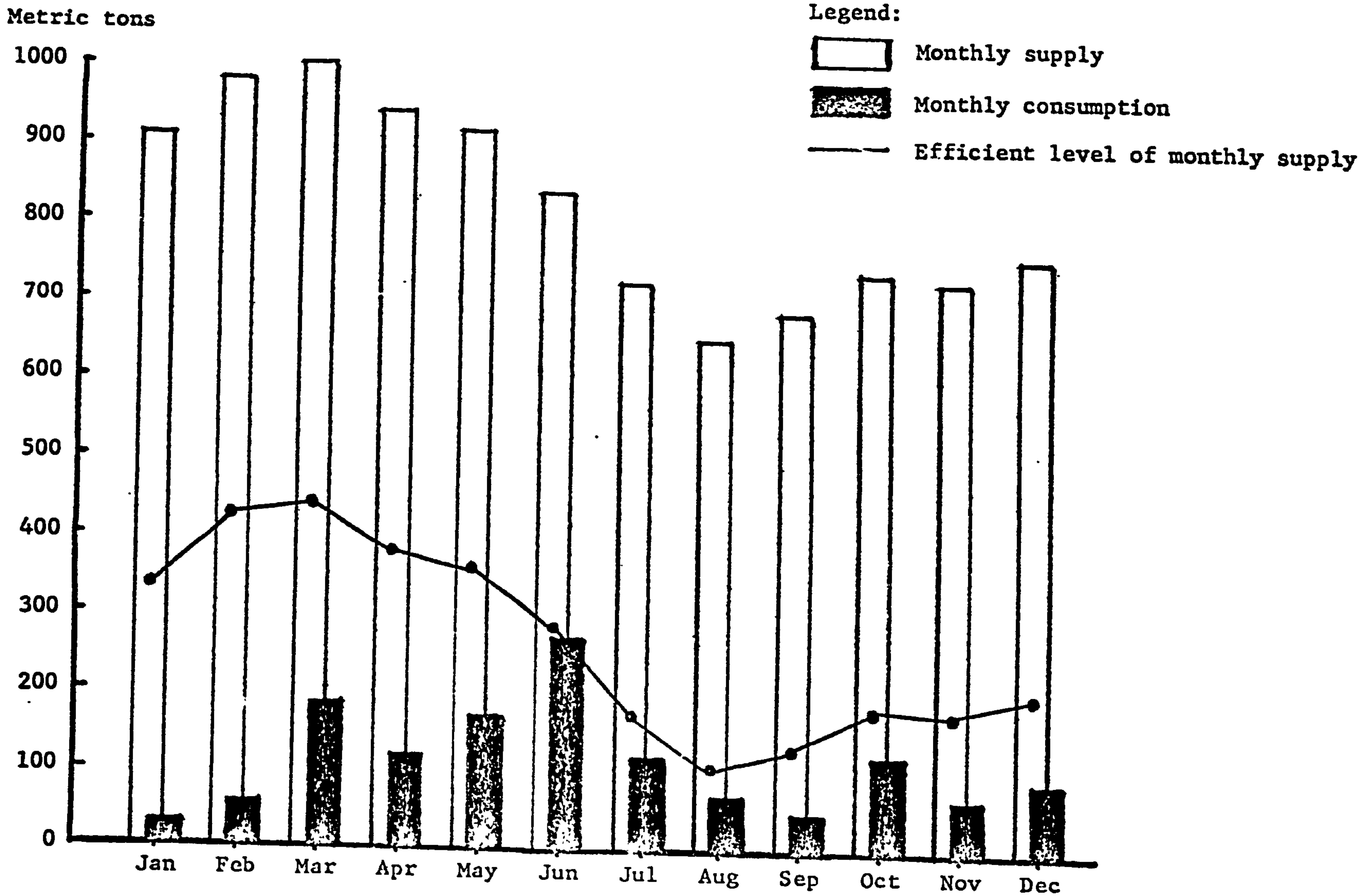

Figure V-5. Monthly supply and consumption of total fertilizer, 1972, Korea.

costs had been considered, the savings would have been greater.

5.5 Conclusions

The distribution costs of fertilizer include handling, storage, transportation, and other costs. The 1972 analysis, however, considered only transportation cost as an approximation of the distribution costs. Because the fertilizer flow patterns were determined using the government regulated freight rates, the results obtained may not be the socially optimum solutions, but the most feasible solutions under the current freight rate structure. If all the real distribution costs were involved, the results might indicate different flow patterns.

The transfer of fertilizer was restricted to rail transportation since the rail freight rate was the lowest of all freight rates. It was assumed that rail transportation had no capacity constraint as required in the transportation model.

The solutions were affected by fertilizer supply and utilization situations as discussed in section 5.2. An important constraint was the shortage in storage capacity. Assuming that all fertilizer materials were equally important to farmers, fertilizer stocks were then allocated to available storage capacities on the basis of the relative magnitudes of each stock with respect to the total quantity of fertilizer stocks.

As a result, fertilizer stocks at regional storages were different from period to period. This may alter the natural flow of fertilizer from origins to destinations. The analysis, however, suggested fertilizer flow patterns which could minimize transportation costs and raise the efficiency of the fertilizer distribution system under the 1972 seasonal supply and utilization situations.

CHAPTER VI

DETERMINATION OF EFFICIENT FERTILIZER DISTRIBUTION FACILITIES AND OPTIMUM FERTILIZER FLOW PATTERNS FOR THE 1978 FERTILIZER DISTRIBUTION SYSTEM

6.1 Introduction

The purpose of this chapter is to provide a model of an efficient fertilizer distribution system under estimated supply and utilization situations for 1978. The major concern in the 1978 analysis is marketing efficiency for Korean fertilizer distribution.

As indicated, the institutional structure of the system is most likely to remain unchanged by 1978. It is impractical to attempt relocation of the existing manufacturing plants in the analysis. The introduction of regional distribution facilities into the Korean fertilizer distribution system were considered to improve operational and pricing efficiencies of the system. Efficiencies of the system will be realized in the form of better marketing services and reduced distribution costs.

In determining an efficient system of regional fertilizer distribution facilities, the transportation and storage rates established by the government were used. Therefore, the rates used in this analysis may not reflect the real costs. The results obtained in this chapter may not be the socially optimum solutions, but the most feasible solutions under given pegged storage and freight rates.

Instead of having small storage facilities in many different locations as was the case in 1972, building regional storage centers with sizeable warehouses could reduce storage costs by taking advantage of economies of scale. Estimates indicate that fertilizer storage cost can be reduced by as much as 57 percent as the storage capacity increases from smallest unit to largest unit.

The transfer of bagging operations from supply origins to regional storage centers will allow bulk fertilizer shipment. This change can reduce fertilizer transportation cost between supply origins and storage centers by 12 percent by inland distribution at the bulk freight rate of 73 rather than at the bag rate of 83 wons. Estimated figures indicate that building bagging facilities at regional storage centers will result in savings in transportation cost without any increase in bagging cost.

At the present time, there are no blending facilities in Korea. Bulk fertilizer shipment and large storage facilities make it feasible to locate fertilizer blending facilities at regional storage centers. Fertilizer blending will allow the Korean fertilizer distribution system to provide a better service to farmers by making different fertilizer nutrient mixtures for special cropping purposes and soil types. It will also accelerate the Korean government's N-P-K balanced promotion program. Such an integration of storage, blending, and bagging activities at regional storage centers will make it possible for farmers to purchase the right type of fertilizer at a minimum distribution cost whenever they want.

There are two major aspects to the 1978 analysis: (1) determination of optimum number, size, and location of regional storage centers and (2) determination of optimum fertilizer flow patterns that would minimize fertilizer distribution cost. The modified, linear programming, transshipment model formulated by Hurt and Tramel (1965) was used to simultaneously determine an efficient system of storage centers and optimum fertilizer flow patterns.

Storage, bagging, and blending facilities and costs are explained in section 6.2. Section 6.3 presents the 1978 fertilizer supply and utilization situations. Optimum number, size, and location of storage centers and optimum fertilizer flow patterns are determined in section 6.4. Finally, section 6.5 presents the conclusions.

6.2 Fertilizer Distribution Facilities

There were few regional fertilizer distribution facilities in the United States until 1955. Large scale regional storage, bagging, and blending operations were introduced as the fertilizer market developed. Such a market development pattern provides a guide by which a growing fertilizer market can follow.

It was hypothesized that if the fertilizer distribution system was to include regional centers having storage, bagging, and blending activities, the system would be more efficient in terms of decreased marketing costs and improved services to fertilizer consumers. Saving in distribution costs may be realized from the system of regional storage centers in the following ways:

1. When fertilizer is shipped by bulk instead of by bag from manufacturing plants or importing harbors to storage centers, the fertilizer material drops from fourth grade to fifth grade for the purpose of rail freight rate and the freight rate drops from 83 wons to 73 wons per metric ton per 50 kilometers. This change alone can reduce transportation costs by as much as 12 percent;

2. The introduction of strategically located, large scale warehouses at regional storage centers can reduce

fertilizer storage costs by as much as 57 percent due to the realization of economies of scale;

3. Bagging costs at regional storage centers with large scale bagging facilities will be equal to or less than those at manufacturing plants and importing harbors;

4. The introduction of fertilizer blending facilities at regional storage centers will provide more adequate fertilizer nutrient mixes for special cropping purposes and soil types which could result in higher crop yields. Regional fertilizer blending should also help to expedite the government's balanced N-P-K promotion program.

6.2.1 Storage Facilities and Costs

Since data on storage cost in Korea were not available, a study by Henderson, Perkins, and Bell (1972) was used to estimate different costs for different capacities.

Table VI-1 presents different storage costs for different storage capacities. Storage costs estimated by Henderson, Perkins, and Bell (Agricultural Economics Report No. 190, pp. 59-60) were utilized to set up the table. The table indicates that storage cost decreases sharply from 3.75 dollars to 1.84 dollars as the capacity increases from 250 metric tons to 625 metric tons and that storage cost

Table VI-1. Storage costs for dry fertilizer materials in the United States.[1]

Item	Unit	Blender storage	Retailer storage	Blender storage	Blender storage	Blender storage
Blending capacity	tons	1,000	--	2,500	9,000	20,000
Storage capacity	tons	250	450	625	2,250	5,000
Storage thru-put[2]	tons	500	900	1,250	4,500	10,000
Capital investment	dollars	4,165	7,500	8,325	29,970	66,600
Annual operating capital	dollars	5,500	5,076	13,750	49,500	105,000
Expected life	years	10	10	10	10	10
Storage cost per metric ton		3.75	2.20	1.84	1.84	1.84
Depreciation/ton thru-put[3]	dollars	0.83	0.83	0.66	0.66	0.66
Variable cost/thru-put[4]	dollars	2.92	1.37	1.28	1.28	1.28

[1] The table was compiled from: Hanson (1970); Douglas and Parker (1969); Wise (1968).

[2] It is assumed that the facilities have twice-a-year inventory turnover.

[3] Straight line method of depreciation schedule was used.

[4] 0.70 U.S. dollars of unloading costs from incoming carriers were added to blender storages in order to make blender storage comparable to retailer storage.

remains unchanged as storage capacity increases beyond 625 metric tons.

Korea had 6,792 storages with a mean capacity of 212 metric tons ranging from 146 metric tons capacity to 415 metric tons capacity in 1972. The mandatory storage rate of fertilizer was 75 wons per ton per 15 days regardless of size of storage facility. Storage costs in table VI-2 were calculated based on the U. S. data in table VI-1. In Korea, the storage facilities were gradually filled prior to the spring consumption period, emptied during July and August, then gradually filled again prior to the next spring in accordance with previous consumption trends. This allowed each storage facility to be filled and emptied, on the average, once a year. The storage costs in Korea, therefore, were estimated for the average inventory period, six months. Storage cost with a mean size of 212 metric tons was 900 wons per metric ton per six months. Storage costs for Korea (table VI-2) were calculated based on the U. S. storage costs presented in table VI-2. If 900 wons of storage cost are charged for 212 metric tons capacity, then a proportionate cost of 458 wons can be charged for 450 metric tons capacity, and 380 wons for 625 metric tons capacity. The storage cost of 380 wons for

Table VI-2. Estimated storage costs for dry fertilizer materials in the U.S.A. and Korea.

	U.S.		Korea
Storage capacity	Storage cost	Storage cost as percentage of 212 metric ton capacity cost	Storage cost[1]
M/T	dollars/ ton	%	wons/ton
212	4.32	100.0	900
250	3.75	87.0	782
450	2.20	51.0	458
625	1.82	43.0	380
2,250	1.82	43.0	380
5,000	1.82	43.0	380

[1] It is assumed that each facility has once-a-year inventory turnover.

the largest storage capacity is only 43 percent of the storage cost of 900 wons for the smallest capacity.

With storage facilities having capacity equal to or greater than 625 metric tons at storage centers, the Korean fertilizer distribution system will save 57 percent fertilizer storage costs.

6.2.2 Blending and Bagging Facilities and Their Costs

As was the case with storage costs, there are no blending and bagging cost data available for the Korean fertilizer industry. Therefore, U. S. blending and bagging costs estimated by Henderson, Perkins, and Bell (Agricultural Economics Report No. 190, p. 44) were used to derive best approximation of the Korean data (table VI-3).

Table VI-3 is interpreted as follows: Depreciation per ton thru-put indicates average fixed cost of blending. Average variable cost of blending includes three components: operating capital per ton thru-put, other variable costs per ton thru-put, and labor input per ton of blended fertilizer. The wage rate used was 4.00 dollars per man-hour. The table indicates that both the average fixed and variable costs decrease as blending capacity increases. In other words,

Table VI-3. Bagged blended fertilizer production horizontal plant with rotary drum mixer and value-pack bagger in the U.S.[1]

Item	Unit	Annual thru-put (ton) plant			
		1,000	2,500	9,000	20,000
Capital investment	dollars	59,630	59,630	59,630	59,630
Annual operating capital	dollars	16,150	36,173	121,761	235,400
Thru-put	tons/yr	1,000	2,500	9,000	20,000
Expected life	years	10	10	10	10
Depreciation/ton thru-put	dollars	5.96	2.38	0.66	0.24
Operating capital/ton thru-put	dollars	16.12	14.47	13.53	11.77
Other variable costs/ton thru-put	dollars	12.85	6.58	3.63	2.25
Labor input per ton of blended fertilizer	man-hour	0.792	0.633	0.348	0.255
Labor input per ton of bagged fertilizer	man-hour	0.5	0.5	0.5	0.5

[1] The table was compiled from: Bond and Swanson (1958); Douglas and Johnson (1963); Eichers (1964); Hanson (1970); Hignett and Scott (1968); Whittington (1968); Allen (1970).

economies of scale are realized as capacity increases. The average total cost of blending with 20,000 tons of capacity is only 41 percent of that with 1,000 capacity. The labor input per ton of blended fertilizer drops as much as 68 percent as capacity increases from 1,000 tons to 20,000 tons.

Henderson, Perkins, and Bell did not estimate components of bagging costs separately. They only provided labor input per ton of bagged fertilizer. The table shows that the labor cost of bagging remains unchanged with respect to changes in bagging capacity. It was conceived that the average fixed cost of bagging would not change very much due to size of operation. These findings imply that the cost of bagging would remain fairly constant regardless of bagging capacities. This indicates that bagging cost at storage centers would not be much different from bagging cost at plants and importing harbors.

To facilitate the analysis, it was assumed that bagging cost at storage centers would be equal to bagging cost at plants and importing harbors. The bagging cost was not included in the analysis because a uniform bagging cost does not affect in determining an efficient system of storage centers and optimum fertilizer flow patterns. However, each storage center was assumed to have bagging facilities. This assumption allowed bulk fertilizer shipment from plants and importing harbors to storage centers.

It was difficult to impute blending costs for Korea using the U. S. data because there are no blending facilities in Korea. Therefore, blending cost was not included in the analysis. Blending facilities at storage centers were recommended to the Korean fertilizer system to increase its marketing efficiency. The largest size of blending facility was one of the factors in determining optimum size of storage center because the Korean fertilizer distribution can take advantage of economies of scale from blending by introducing largest blending facilities at storage centers.

6.3 1978 Fertilizer Supply and Utilization Situation

Total urea production has been predicted to increase by 74 percent and total mixed fertilizer production by six percent from 1972 to 1978. Production capacities of fused phosphate and calcium cyanamide will remain unchanged during the same period.

The 1978 fertilizer supply and demand equilibrium quantities were estimated based on expected production and consumption. As indicated in table IV-11, the 1978 fertilizer quantities handled by the Korean fertilizer distribution system will be 2,815,200 metric tons, 24 percent increase from the 1972 quantity of 2,267,700 metric tons.

The analysis deals with distribution of urea, fused phosphate, triple superphosphate, potassium chloride, and domestically produced mixed fertilizer. Production origins and quantities of the above fertilizer materials at production points are presented in table III-1. The 1978 consumption of fertilizer materials were approximated for four cropping areas in table IV-9. Assuming homogeneity in agriculture within a cropping area, regional consumption for each type of fertilizer was obtained by multiplying the area consumption by the ratio of arable land to the total arable land of the cropping area as done in Chapter V. Regional consumption of fertilizer is presented in table VI-4. The consumption of imported mixed fertilizers was excluded from the analysis because imported mixed fertilizers are of different kinds of mixed fertilizer from those domestically produced and are used for special cropping purposes. Imported mixed fertilizer consumption accounts for only five percent of total mixed fertilizer consumption. Hence, consumption of mixed fertilizer in table VI-5 indicates consumption of domestically produced mixed fertilizer only.

Table IV-4. Regional consumption of fertilizer materials, 1978, Korea. Unit: 100 M/T

	Urea	Fused phosphate	Triple super-phosphate	Potassium chloride	Mixed fertilizer[1]
1. Chuncheon	185	36	27	34	144
2. Kangneung	246	48	37	45	193
3. Cheongju	462	91	68	85	361
4. Jeju	133	26	20	24	104
Area I	1026	201	152	188	802
5. Seoul	306	66	50	52	241
6. Suwon	386	84	64	65	304
7. Taejeon	279	61	46	47	220
8. Hongseong	359	78	59	60	282
Area II	1330	289	219	224	1047
9. Jeonju	325	68	51	44	243
10. Iri	508	106	80	68	380
11. Boseong	711	148	112	95	531
12. Songjeongri	488	101	77	65	364
Area III	2032	423	320	272	1518
13. Andong	425	104	79	84	356
14. Kimcheon	496	121	92	97	415
15. Taegu	449	110	83	88	376
16. Samrangin	496	121	92	98	415
17. Jinju	496	121	91	97	415
Area IV	2362	577	437	464	1977
ALL KOREA	6750	1490	1128	1148	5344

[1] Mixed fertilizer consumption consists of consumption of domestically produced mixed fertilizer only.

6.4 Empirical Analysis

Quantities of urea, fused phosphate, triple superphosphate, potassium chloride, and domestically produced mixed fertilizer in the analysis were 2,731,600 metric tons which accounts for 97 percent of the 1978 total quantity of 2,815,200 metric tons.

Fertilizer distribution costs in the analysis include transportation and storage costs. The rail freight rate and storage rates were assumed to remain unchanged at the 1972 level.

A computer program formulation of the Hurt-Tramel modified transshipment model was used to simultaneously determine optimum number, size, and location of regional storage centers and optimum fertilizer flow patterns. The requirements of the model with respect to the Korean fertilizer distribution problem are discussed in the following paragraph.

Production origins were the manufacturing plant sites at Chungju, Naju, Ulsan, Jinhae, and Yosu for urea; Sosa and Janghang for fused phosphate; and Ulsan, Jinhae, and Yosu for domestically produced mixed fertilizer. Quantities available at each production origin were fertilizer produced at each plant site.

Incheon and Kunsan on the west coast and Mokpo and Pusan on the south coast were selected as potential importing harbors. Each harbor was given unlimited capacity to import during the run of the program to minimize the distribution costs of imported fertilizers.

The 17 consumption centers as well as Jecheon in Chungbuk province and Cheonan in Chungnam province were designated as regional storage centers in the transfer of fertilizer from production or import origins to consumption regions. Storage and bagging activities were involved at the storage centers. The regional storage centers designated are treated as transshipment points in the model.

The bulk rail freight rate of 73 wons per ton of bulk fertilizer per 50 kilometers was used for the shipment from production and import origins to storage centers since bagging operations were shifted from points of origins to regional storage centers for this analysis.

It was assumed that fertilizer would be transferred to the farmers in bags, because farms would not have access to bulk transportation modes and would not have adequate bulk storage facilities. Therefore, under the proposed fertilizer distribution system for 1978, fertilizer would be shipped by bulk from origins to regional storage centers, bagged at storage centers and transferred by bag from storage centers to consumers. Hence, the bag rail freight rate of 83 wons per ton per 50 kilometers was used for the fertilizer transfer from regional storage centers to consumption centers. Harbors designated as export outlets were those closest to manufacturing plants. The four harbors designated were Incheon for the Chungju plant; Mokpo for the Naju plant; Ulsan for the Ulsan plants; Jinhae for the Jinhae plant; and Yosu for the Yosu plant. Urea will be the only fertilizer material exported in 1978. During the first run of the program, each urea manufacturing plant was allowed to export its whole production during the year. Such an initial run provided useful information necessary for simultaneous minimization of distribution costs and the export excess capacities of both plants and harbors. Direct transfer of export fertilizer from plants to export outlets was imposed on the model because given the coincidence of plants and harbors in Korea, transshipment of export fertilizer designated for export through storage centers would amount to a redundancy.

One town was designated to represent each consumption center. Therefore, transportation costs within a consumption region was assumed to be zero. To facilitate the analysis, it was assumed that all fertilizer materials were consumed or shipped immediately upon delivery to consumption centers or export harbors, respectively. Therefore, storage cost was not included in the distribution cost of fertilizer consumed or exported in the analysis. Storage cost of fertilizer stock at storage centers were included in the distributions cost of fertilizer stock.

Given the above constraints and requirements, the transshipment model derived optimum number, size, and location of regional storage centers and optimum flows for urea, fused phosphate, triple superphosphate, potassium chloride, and domestically produced mixed fertilizer under given government-regulated storage and freight rates. The results are presented in the following two subsections.

6.4.1 Determination of Number, Size, and Location of Storage Centers

Three different storage sizes (see table VI-2) were considered in determining the number, size, and location of storage centers. The smallest storage was 212 metric tons capacity, which was the average 1972 storage capacity in Korea, and its storage cost per metric ton was 900 wons per six month inventory. The medium size storage was 450 metric tons at a cost of 458 wons per metric ton per six months. The largest storage facility considered was that with a capacity of 625 metric tons. The storage cost for the largest facility was 380 wons. The cost range from smallest to largest storage facility was 43 percent.

The transshipment model was separately applied to the distribution of urea, fused phosphate, triple superphosphate, potassium chloride, and domestically produced mixed fertilizer. However, the separate applications were not independent. It was necessary to place such a constraint on the problem that quantities of three fertilizer nutrient (N, P, K) would be stored at each storage center so that ingredients would be available to the proposed blending operations. This availability should also help to facilitate the coordination of transportation, storage, bagging, and blending activities.

Urea has been the most important fertilizer in terms of quantities produced and consumed in Korea. It's predicted 1978 quantity accounted for 51 percent of the 1978 total fertilizer quantity. In the solution procedure, it was rather arbitrarily decided to first determine an optimum system of urea regional storage centers and then let the urea regional storage system become a constraint in determining optimum storage systems for the other fertilizer materials. That decision was based solely on the fact that the largest quantity of any fertilizer material moving through the system is that of urea. This kind of constraint was necessary to secure the availability of each fertilizer nutrient at all storage centers for blending and better service to the consumers.

Given 19 potential storage center locations, the solution process for obtaining the optimum number, size and location of urea storage centers was an iterative one in which certain potential storage centers were either added to or deleted from the system depending on cost and excess capacity. In the iterative process, it was found that storage facilities at Jecheon and Cheonan would not be used at all. Hence, they were eliminated as potential storage centers. Jecheon and Cheonan were the only potential storage sites which did not coincide with consumption center locations. Because consumption at each of the designated consumption regions was so large in relation to the three possible storage sizes and because each consumption center was designed as a potential storage location, each consumption center remained in the final solution as a storage center site. Therefore, each consumption center was given a capacity in terms of end stock in an amount equivalent to the ratio of regional consumption to national consumption. The urea storage capacity required at each storage center is presented in table VI-5. The

Table IV-5. Optimum size and location of fertilizer storage centers, Korea. Unit: 100 M/T

Storage centers	Urea	Fused phosphate	Triple super-phosphate	Potassium chloride	Mixed fertilizer	Total*
1. Chuncheon	66	13	17	21	53	170
2. Kangneung	88	17	23	27	71	226
3. Cheongju	165	31	42	52	133	423
4. Jeju	47	9	12	15	38	121
Area I	366	70	94	115	295	940
5. Seoul	109	23	31	31	88	282
6. Suwon	138	29	39	40	112	358
7. Taejeon	100	21	28	29	81	259
8. Hongseong	128	28	37	37	104	334
Area II	475	101	135	137	385	1233
9. Jeonju	116	24	32	27	89	288
10. Iri	181	37	49	42	140	449
11. Boseong	254	52	69	58	195	628
12. Songjeongri	174	35	48	40	134	431
Area IV	725	148	198	167	558	1796
13. Andong	152	36	48	51	131	418
14. Kimcheon	177	43	57	60	152	489
15. Taegu	160	38	51	54	138	441
16. Samrangjin	177	43	57	60	153	490
17. Jinju	177	42	57	59	152	487
Area IV	843	202	270	284	726	2325
ALL KOREA	2407	521	697	703	1964	6294

*Storage center may contain more than one storage facility, each of which will not be smaller than 625 tons capacity.

relationship between regional storage requirements and available storage sizes resulted in an optimum solution where all regions required multiples of the largest storage size, 625 metric tons. Therefore, the analysis suggests a single storage cost of 380 wons per ton per six months for all of the seventeen regional storage centers. Optimum storage sizes of other fertilizer materials for each regional storage center determined are presented in table VI-5.

The solution indicates that the Korean fertilizer distribution system will require total storage capacity of 629,400 metric tons in 17 storage centers in different sizes for urea, fused phosphate, triple superphosphate, potassium chloride, and domestically produced mixed fertilizer stocks. The introduction of storage centers will reduce the storage cost per metric ton by 57 percent compared to 1972 storage cost.

6.4.2 Optimum Fertilizer Flow Patterns

This section presents the optimum flow patterns of urea, fused phosphate, triple superphosphate, potassium chloride, and domestically produced mixed fertilizer determined by the transshipment model.

Since every consumption center was determined as a storage center, it was sufficient to present the fertilizer flows from production origins and importing harbors to consumption centers. Monthly flow patterns were not determined. Instead, a single annual flow pattern was derived for each of the five fertilizer materials.

Urea Flows: In 1972, 78 percent of urea production was concentrated in the eastern double cropping area while nine percent of the urea was produced in the western double cropping area and 13 percent in the upland area. Urea production capacity at the Chungju plant was expanded from 86,800 metric tons in 1972 to 244,900 metric tons in 1974. Construction of a new plant at Yosu will add another 312,000 metric tons to urea capacity by 1978. As a result, 43 percent of urea is expected to be produced in the eastern double cropping area, 37 percent in the western double cropping area, and 20 percent in the upland area in 1978. Such widely scattered locations of urea production facilities will certainly reduce the transportation cost of urea. The 1978 urea distribution problem involves the consumption of 675,000 metric tons, exports totalling 516,200 metric tons, and end stock totalling 240,900 metric tons. Urea production in 1978 is expected to add 1,195,900 metric tons to a beginning stock of 236,200 metric tons for a total supply of 1,432,100 metric tons.

Identification of the sources of exports and quantities available for export at each source was necessary to determination of the optimum flow pattern for urea. Each plant was allowed to export its entire production if such an export pattern could minimize the urea distribution costs.

Table VI-6 presents the optimum flow patterns for urea from manufacturing plants to consumption centers and to export outlets. The table is interpreted as follows: Seventeen consumption centers and exports are shown at the left-hand side and production origins across the top of the table. The quantities produced at each plant are presented in the bottom row of the table. Numbers in the main body of table indicate 100 metric ton units of urea transferred from plants to consumption centers or export harbors.

The results presented in table VI-6 are summarized in the following paragraph.

Urea was transferred from the Chungju plant to consumption centers one, two, three, five, six, seven, eight, and 13. The Naju plant supplied urea to consumption centers 11 and 12. Plants at Ulsan (the Yongnam and Hankuk plants) supplied fertilizer to consumption centers 13, 14, 15, and 16 and provided 257,200 metric tons for

Table VI-6. Optimum flow patterns of urea from manufacturing plants to consumption centers and export outlets, 1978, Korea.

Unit: 100 M/T

Consumption Center \ Manufacturing Plant	(1) Chungju	(2) Naju	(3) Ulsan	(4) Jinhae	(5) Yosu
1. Chuncheon	186				
2. Kangneung	248				
3. Cheongju	465				
4. Jeju					134
5. Seoul	308				
6. Suwon	389				
7. Tacjeon	281				
8. Hongseong	362				
9. Jeonju					328
10. Iri					511
11. Boseong		270			448
12. Songjeongri		491			
13. Andong	210		218		
14. Kimcheon			499		
15. Taegu			452		
16. Samrangjin			499		
17. Jinju				500	
Export			2572	412	2178
Production	2449	761	4240	912	3597

export. Urea from the Jinhae plant was supplied to consumption center 17 and exported 41,200 metric tons from its production. The Yosu plant transferred urea to consumption centers four, nine, 10, and 11. Exports from Yosu amounted to 217,800 metric tons. Therefore, the total expected urea exportation of 516,200 metric tons should be met by 257,200 metric tons from the Ulsan plant, 41,200 metric tons from the Jinhae plant, and 217,800 metric tons from the Yosu plant. The total urea export requirement was met by plants located at harbors because the cost of transferring the urea from plant to dock is minimal in such cases as represented by a zero transportation cost in the transshipment model.

The total transportation cost for transfer of 679,700 metric tons of urea from plants to consumption centers was 178,096,100 wons. This resulted in an average transportation cost of 262 wons per metric ton of urea which is only 61 percent of the 1972 cost of 432 wons per ton in the optimum solution.

Fused Phosphate Flows: The capacity of fused phosphate production is not expected to change by 1978. Consumption of straight phosphate fertilizer, however, is expected to increase far beyond the expected production of fused phosphate. Therefore, large increases in phosphate imports are expected for 1978.

The Korean fertilizer distribution system will be able to reduce distribution costs by the importation of triple superphosphate rather than fused phosphate because triple superphosphate (0-46-0) is a higher analysis product than fused phosphate (0-21-0). No exportation of fused phosphate is expected in 1978.

The fused phosphate distribution problem involves consumption of 149,000 metric tons of fused phosphate and end stocks of 52,100 metric tons for the total requirements of 201,100 metric tons. The total requirements will need to be met by production of 149,000 metric tons and beginning stock of 52,100 metric tons or a total supply of 201,100 metric tons. There are two fused phosphate production facilities, the Sosa and Janghang plants.

Optimum fused phosphate flows from those two production origins to 17 consumption centers are presented in table VI-7. The transshipment solution matrix indicated that fertilizer produced at the Sosa plant should be distributed to consumption regions one, two, five, six, seven, 13, and 15. Consumption center seven and the remaining ten consumption centers should be served by the Janghang plant. The total transportation cost for the shipment of 149,000

Table VI-7. Optimum flow patterns of fused phosphate from manufacturing plants to consumption centers, 1978, Korea.

Unit: 100 M/T

Consumption Center \ Manufacturing Plant	(1) Sosa	(2) Janghang
1. Chuncheon	36	
2. Kangneung	48	
3. Cheongju		91
4. Jeju		26
5. Seoul	66	
6. Suwon	84	
7. Taejcon	22	48
8. Hongseong		78
9. Jeonju		68
10. Iri		106
11. Boseong		148
12. Songjeongri		92
13. Andong	104	
14. Kimcheon		121
15. Taegu	110	
16. Samrangjin		121
17. Jinju		121
Production	470	1020

metric tons of fused phosphate from plants to consumption centers was 74,087,900 wons. The average transportation cost per ton was 497 wons which is 89 percent of the 1972 cost of 558 wons.

Triple Superphosphate and Potassium Chloride Flows: An estimated 114,800 metric tons of triple superphosphate and 116,200 metric tons of potassium chloride will be imported in 1978. No domestic production is expected.

Given estimated imports for 1978, the problems of triple superphosphate and potassium chloride distribution were the determination of number, size, and location of importing harbors in such a way as to minimize transportation costs for those fertilizers. As indicated earlier, the potential importing harbors are Incheon and Kunsan on the west coast and Mokpo and Pusan on the south coast. Consideration of import transportation costs or differences in import transportation costs at the four harbors was beyond the scope of this study. Therefore, to facilitate the analysis, it was assumed that transportation costs were the same from any exporting country to any of the potential harbors. Having made that assumption, each harbor was given an unlimited capacity to import with the result being the least-cost distribution for the transfer of imported fertilizers from importing harbors to consumption centers.

Optimum flow patterns from importing harbors to consumption centers are presented in tables VI-8 and VI-9 for triple superphosphate and potassium chloride, respectively. Due to the unlimited capacities of importing harbors and consideration of the same four harbors, the transshipment solution indicated identical flow patterns for triple superphosphate and potassium chloride.

Triple superphosphate and potassium chloride imported through Incheon were transferred to consumption centers one, two, three, five, six, and eight. Consumption centers seven, nine, and 10 were supplied with imports through Kunsan. The fertilizers imported through Mokpo were transferred to consumption centers four, 11, and 12 and those from Pusan were transported to consumption centers 13 through 17.

The total costs of transfer in bulk form from harbors to consumption centers were 28, 242, 000 wons for shipments totalling 114, 800 metric tons of triple superphosphate and 29, 714, 800 wons for the transport of 116, 200 metric tons of potassium chloride. The average transfer cost for triple

Table VI-8. Optimum flow patterns of imported triple superphosphate from importing harbors to consumption centers, 1978, Korea.

Unit: 100 M/T

Consumption Center \ Importing Harbor	(1) Incheon	(2) Kunsan	(3) Mokpo	(4) Pusan
1. Chuncheon	28			
2. Kangneung	38			
3. Cheongju	69			
4. Jeju			20	
5. Seoul	51			
6. Suwon	65			
7. Taejeon		46		
8. Hongseong	60			
9. Jeonju		52		
10. Iri		81		
11. Boseong			114	
12. Songjeongri			79	
13. Andong				80
14. Kimcheon				94
15. Taegu				84
16. Samrangjin				94
17. Jinju				93
Imports	311	179	213	445

Table VI-9. Optimum flow patterns of imported potassium chloride from importing harbors to consumption centers, 1978, Korea.

Unit: 100 M/T

Importing Harbor / Consumption Center	(1) Incheon	(2) Kunsan	(3) Mokpo	(4) Pusan
1. Chuncheon	35			
2. Kangneung	45			
3. Cheongju	86			
4. Jeju			24	
5. Seoul	52			
6. Suwon	66			
7. Taejeon		48		
8. Hongseong	60			
9. Jeonju		45		
10. Iri		69		
11. Boseong			96	
12. Songjeongri			66	
13. Andong				85
14. Kimcheon				99
15. Taegu				89
16. Samrangjin				99
17. Jinju				98
Imports	344	162	186	470

superphosphate was 246 wons and that for potassium chloride was 256 wons. The 1978 transportation cost of potassium chloride was four percent lower than the 1972 cost of 265 wons.

Mixed Fertilizer Flows: No mixed fertilizer is expected to be exported in 1978. An estimated 32,500 metric tons of mixed fertilizer will be imported. The optimum flow patterns of domestically produced mixed fertilizer from production plants to consumption centers are presented in table VI-10.

The optimum flow patterns indicate that fertilizers from Ulsan should be shipped to consumption centers one, two, six, 13, 14, 15, and 16. Consumption centers three, four, five, seven, eight, 11, 12, 14, and 17 should be supplied by fertilizer from the Jinhae plant. The Yosu plant should supply fertilizer to consumption centers nine, 10 and 12.

The total transportation cost of mixed fertilizer was 216,959,100 wons for the shipment of 534,400 metric tons from plants to consumption centers. The average transportation cost per metric ton was 406 wons which is 75 percent of the 1972 average cost of 541 wons.

Table VI-10. Optimum flow patterns of domestically produced mixed fertilizer from manufacturing plants to consumption centers, 1978, Korea.

Unit: 100M/T

Consumption Center \ Manufacturing Plant	(1) Ulsan	(2) Jinhae	(3) Yosu
1. Chuncheon	13		
2. Kangneung	93		
3. Cheongju		361	
4. Jeju		104	
5. Seoul		129	
6. Suwon	416		
7. Taejeon		68	
8. Hongseong		282	
9. Jeonju			243
10. Iri			380
11. Boseong		531	
12. Songjeongri		182	182
13. Andong	487		
14. Kimcheon	416	151	
15. Taegu	376		
16. Samrangjin	415		
17. Jinju		415	
Production	2316	2223	805

6.4.3 Comparison of Fertilizer Distribution Costs

Using the flat rail freight and storage rates effective in 1972 for the 1978 analysis, the 1978 analysis demonstrated that the cost of distributing fertilizer in Korea can be reduced greatly by shipping fertilizer by bulk and by introducing large, centralized storage centers which include bagging and blending activities.

Since the real storage and transportation cost functions could not be measured due to the lack of data, the comparison between 1972 and 1978 fertilizer distribution costs is not clear. The 1978 distribution costs per metric ton of fertilizers are compared with the cost in the 1972 optimum solution (table VI-11). Only the cost of storing end stock was included in the distribution cost of fertilizer. The cost involved in storing fertilizers consumed during different seasons was not considered. The analysis indicated that 1978 storage costs can be reduced by as much as 57 percent from 900 wons to 380 wons per metric ton of fertilizer stock if regional storage centers are introduced.

The transfer of bagging activities from manufacturing plants or harbors to regional storage centers made it possible to take advantage of the lower bulk freight rate and that

Table VI-11. Comparisons of distribution costs per metric ton of fertilizers, 1972 and 1978, Korea.

Item	Unit	Urea	Fused phos.	Triple fused phos.	Pota. chlor.	Mixed fert.
1972						
transportation cost	wons	432	555	--	265	541
storage cost[1]	wons	900	900	--	900	900
distribution cost	wons	1332	1455	--	1165	1441
1978						
transportation cost	wons	262	497	246	256	406
storage costs[2]	wons	380	380	380	380	380
distribution cost	wons	642	877	626	636	786
1978 costs in percentage terms of 1972 costs:						
transportation cost	%	60.6	89.5	--	96.6	75.0
storage cost	%	42.2	42.2	--	42.2	42.2
distribution cost	%	48.2	60.3	--	54.6	54.5

[1] 1972 storage cost was included in distribution cost of end stock. 900 wons were storage cost per metric ton for six month inventory in storages with average capacity of 212 metric tons.

[2] 1978 storage cost was included in distribution cost of end stock. 380 wons were storage cost per metric ton for six month period which may be charged with storage capacity of equal to or greater than 625 metric tons.

resulted in a reduction of 12 percent from 83 wons to 73 wons per metric ton per 50 kilometers in transportation costs. The comparison of distribution costs were made between optimum solutions for 1972 and 1978. If the actual distribution costs in 1972 could be compared with distribution costs in the 1978 optimum solution, even much greater savings in distribution costs would be realized.

A sharp decrease in the urea transportation cost per metric ton from 432 wons in 1972 to 262 wons in 1978 or 61 percent resulted from bulk shipment rate and regional diversification of production origins. Savings in fused phosphate distribution cost were not significant due to the relatively rapid increase in consumption in regions remote from manufacturing plants. The 1978 cost of distributing potassium chloride could not be significantly reduced from the 1972 cost due to elimination of Yosu as a potential importing harbor. The cost of distributing mixed fertilizer in 1978 could be reduced by 25 percent for consumption and 45 percent for stock. The savings in distribution cost of stock were greater than those in distribution cost of consumption because savings in storage cost also were included in stock case.

Comparison of distribution costs for total fertilizer between the 1972 and 1978 optimum solutions can be made. In 1978 solutions, the total transportation cost of shipping 1,594, 100 metric tons of bulk fertilizers from production and import origins to 17 consumption centers amounted to 527, 089, 000 wons and the associated average transportation cost was 330 wons. The 1978 average transportation cost of 330 wons is 31 percent lower than the 1972 average transportation cost of 479 wons. The saving in transportation cost resulted from regional dispersion of manufacturing plants and bulk fertilizer shipment instead of bagged fertilizer.

Assuming that each storage facility has a once-a-year inventory turn-over, the total storage cost of 637, 300 metric tons of approximated stocks was 247, 174, 000 wons and the associated average storage cost was 380 wons for six months period in the 1978 solution. Introduction of regional storage centers resulted in saving in storage cost from 900 wons to 380 wons per metric ton by as much as 57 percent.

Since the costs of building those regional fertilizer facilities, it is not clear whether the savings in fertilizer distribution costs indicated above would be sufficient to cover the investment.

6.5 Conclusions

Given the 19 potential storage centers, optimum number, size, and location of storage centers and optimum fertilizer flows were determined under given transportation and storage rates. Therefore, the solution obtained may not be the social optimum. Bagging cost was not included in the fertilizer distribution cost even though bagging at regional centers was assumed in the analysis. The blending activities at regional storage centers were recommended but not included in the analysis. Hence, the analysis is a partial analysis. When data for all the components of fertilizer distribution costs are available, it will be possible to perform a more comprehensive analysis.

In this study, each potential storage center coincided with a consumption center consisting of nine counties on the average with a range of two to 14 counties. Each county has a number of fertilizer distribution outlets. Therefore, each potential storage center and each consumption region encompassed a very large geographical area. This represents a possible limitation of the analysis. If a greater number of potential storage centers had been considered, optimum number, size, and location of storage centers would have been different and estimates of potential savings might have been even greater than those indicated by this analysis.

It can be concluded that great savings in distribution costs can be realized from the Korean fertilizer distribution system by the introduction of large scale, regional facilities. Better marketing services will result from the introduction of regional fertilizer distribution facilities. However, it was not analyzed whether the savings in distribution costs would cover the cost of building those regional fertilizer distribution facilities.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

The Korean fertilizer distribution system has been under government administration since 1961. The annual fertilizer supply and utilization plan is initiated by the Ministry of Agriculture and Fisheries. Fertilizer sales are exclusively handled by agricultural cooperatives. The National Agricultural Cooperative Federation, under government control, purchases and distributes all the fertilizer, whether domestically produced or imported. Neither the manufacturers nor other private parties are allowed to participate in the fertilizer distribution process.

The Korean Express Company, under contract with the National Agricultural Cooperative Federation, transports fertilizer from production and import origins to distribution points where fertilizer storage facilities are located. In 1972, fertilizer was transported by rail wherever feasible at a flat rail freight rate of 83 wons per ton of bagged fertilizer per 50 kilometers on a full carload basis.

National fertilizer storage capacity was estimated at 507,800 metric tons for 1972. There was a shortage of storage capacity during peak periods of demand. The rate of storage was a mandatory flat rate of 75 wons per ton per 15 days regardless of size and location of storage facilities.

The Korean fertilizer economy grew very rapidly during the 1960's. On an actual weight basis, total fertilizer consumption increased by 50 percent from 958,000 metric tons in 1961 to 1,429,000 metric tons in 1972 and domestic production by more than 20 times from 65,000 metric tons in 1961 to 1,361,000 metric tons in 1972. As the quantity of fertilizer moving through the distribution system increased, the efficient distribution of fertilizer became a critical policy issue, but the problem is not yet solved.

The ultimate goal of this study was to identify an efficient fertilizer distribution system for Korea. Such a system would be one which can deliver the right type of fertilizer to farmers in sufficient quantities, at the right time and place, and at a minimum cost. Specific objectives include the following:

1. to discuss the analytical approach and select economic models to solve certain fertilizer distribution problems;

2. to identify characteristics of the Korean fertilizer distribution system;

3. to approximate the fertilizer quantities supplied and utilized in 1972 and 1978;

4. to determine optimum fertilizer flow and storage patterns and minimum fertilizer distribution cost for the 1972 fertilizer distribution system;

5. to determine optimum number, size, and location of regional fertilizer storage centers and optimum fertilizer flow patterns for the 1978 fertilizer distribution system.

The linear programming transportation model was selected to solve the 1972 fertilizer shipment problems. The Hurt-Tramel modified linear programming transshipment model was used to simultaneously determine the optimum number, size and location of storage centers and optimum fertilizer flow patterns for 1978. With the proper constraints and assumptions, the Hurt-Tramel model (1965) was the most efficient method applicable to both the 1972 and 1978 analyses.

Fertilizer origins and destinations were specified to meet the requirements of the economic models. Production origins included geographical points where plants are located:

Chungju, Naju, Ulsan, Jinhae, and Yosu for urea production; Sosa and Janghang for fused phosphate production; and Ulsan, Jinhae, and Yosu for mixed fertilizer production. Incheon, Kunsan, Mokpo, Yosu, and Pusan harbors were designated as potential fertilizer import origins.

Seventeen consumption regions were delineated based on cropping patterns, geographical and political boundaries, and the railway network. Each consumption region was represented by a consumption center with an adequate rail transportation facility. Every region was connected to every other region by rail with the exception of consumption region four, Jeju island.

A fertilizer supply and utilization accounting equation was used to approximate fertilizer quantities supplied and utilized. Supply includes three components: production, beginning stock and imports. Utilization also includes three components: consumption, exports, and end stock. The 1972 fertilizer quantities supplied and utilized on an actual weight basis were estimated from actual production, consumption, and trade data.

Estimation of the 1978 production was based on planned production capacity and historical capacity-utilization ratio data for the period 1970-1972. The statistical fertilizer consumption relationships for 1972 were extended to estimate regional fertilizer consumption characteristics in 1978. The 1978 fertilizer quantities supplied and utilized were approximated based on production and consumption estimates.

The 1972 fertilizer distribution analysis was concerned with problems in the distribution of urea, fused phosphate, potassium chloride, and domestically produced mixed fertilizer. The fertilizer quantities analyzed totalled 2, 139, 800 metric tons which accounted for 94 percent of the total 1972 fertilizer quantities supplied of 2, 267, 700 metric tons. Fertilizer distribution costs were approximated by the transportation cost. Storage cost was not included in the distribution cost because rate uniform regardless of size and location of storage facilities has no effect on fertilizer flows. Handling and other distribution costs were beyond the scope of the study. Hence, the 1972 fertilizer distribution problems were formulated as transportation problems. Optimum fertilizer flow patterns were determined by the linear programming transportation model.

The major concern in the 1978 analysis was the marketing efficiency of the Korean fertilizer distribution system. It was hypothesized that the introduction of large-scale, storage, bagging, and blending operations in strategically located regional centers would improve the marketing efficiency of the system and reduce fertilizer distribution costs as well.

Jecheon and Cheonan, in addition to the 17 designated consumption centers, were selected as potential regional storage center sites to determine optimum number, size, and location of storage centers for 1978.

Cost estimates were available for three different sizes of storage facility: (1) 212 metric tons of capacity at 900 wons per six month period; (2) 450 metric tons of capacity at 458 wons per six month period; (3) 625 metric tons of capacity at 380 wons per six month period.

The 1978 analysis considered distribution problems involving urea, fused phosphate, triple superphosphate, potassium chloride, and domestically produced mixed fertilizer. As a result, the 1978 fertilizer quantities handled in the analysis totalled 2,731,600 metric tons which accounted for 97 percent of the total 1978 estimate of 2,816,200 metric tons. The distribution cost was approximated by the combined costs of transportation and storage. Assuming uniform bagging cost at storage centers, manufacturing plants, and importing harbors, bagging cost was not included in the distribution cost because uniform bagging cost has no effect on fertilizer flows. Fertilizer blending activities were not incorporated in the analysis because blending cost for Korea was too difficult to impute. However, blending facilities at storage centers were proposed.

Because fertilizer blending activities require the availability of all three fertilizer elements (N, P and K) at each storage center, storage centers for each individual fertilizer material could not be independently located. Therefore, since urea is the most important fertilizer material in terms of quantity consumed, locations for urea storages were the first to be determined. The location of urea storage centers became a constraint in determining optimum storage systems for other fertilizer materials. This constraint was necessary to insure the availability of each fertilizer nutrient at all storage centers for blending.

The linear programming transshipment model determined optimum number, size, and location of storage centers and fertilizer flow patterns for 1978 simultaneously. The seventeen consumption centers remained in the final as optimum storage center locations. The results indicated that the 1978 Korean fertilizer distribution system will require 629,400 metric tons storage capacity and that each of the 17 storage centers will require one or more of the largest size facility for which cost estimates were available. Such a system could reduce transportation cost by as much as 12 percent and storage cost by 57 percent.

Conclusions

The results of this study provide general guides for improving the marketing efficiency of the Korean fertilizer distribution system. The 1972 fertilizer distribution analysis indicated an efficient distribution pattern that could have been achieved under the existing system. The results provided number of shipments, optimum flow and storage patterns, and minimum distribution cost. The total transportation cost for shipping 1,353,100 metric tons of total fertilizer from production and import origins to consumption centers was 639,351,000 wons and the associated average transportation cost was 479 wons.

In the 1978 fertilizer distribution analysis, it was attempted to provide a guideline for development of the Korean fertilizer distribution system. Introducing large-scale, regional storage, bagging, and blending facilities, the results demonstrated the existence of possible savings in fertilizer distribution costs and improvement on the marketing efficiency of the system.

Comparison of the 1972 and 1978 optimum solutions indicated that the average cost per metric ton of fertilizer decreased by as much as 31 percent from 479 wons in 1972 to 330 wons in 1978 and that the average storage cost per metric ton for six months reduced by 57 percent from 900 wons in 1972 to 380 wons in 1978. External economies and other benefits for farmers resulting from regional storage centers, however, could not be measured.

Seventeen consumption regions were designated in this study. Each region includes nine counties on the average with the range of two to 14 counties. Consumption in each of these regions was very large in relation to the three possible storage sizes and each consumption center was designated as a potential storage location. Therefore, in determining the optimum number, size, and location of regional storage centers for 1978, each consumption center remained as a storage center location in the optimum solution. Delineation of a larger number of smaller consumption regions and potential regional storage locations may have resulted in different fertilizer flow patterns and a more realistic system of storage centers in the optimum solution.

A fertilizer distribution system is affected by economic, political, institutional, social, and other factors. This study, however, was limited to the analysis of economic factors that could be measured and for which quantitative data were available.

The cost of distributing fertilizer includes transportation, storage, handling, blending, and other costs. Ideally, the optimum system of distribution would be one which minimizes all of these costs. However, the available data were inadequate for such a complete analysis in this study. Therefore, this study was a partial equilibrium analysis, where the distribution cost was approximated by transportation cost (1972) or the combined costs of transportation and storage (1978).

The transportation and storage rates used in this study were the rates established by the government. Since the rates may not reflect the real costs, optimum solutions may not be the socially optimum. However, given transportation and storage rate structures, the results provided the best feasible solutions to the Korean fertilizer distribution system under given pegged transportation and storage rates.

The use of other transportation modes than rail and vessel were not tested since the monopolized fertilizer shipment by rail and vessel is most likely to be unchanged in the foreseeable future. Lack of storage data and the monopolized storage facilities by agricultural cooperatives made it difficult to study the development of the warehousing industry. Economics of fertilizer blending was not analyzed because of the lack of data. When those data become available, it will be possible to perform a more comprehensive economic study.

Findings in this study will be beneficial to the Korean fertilizer distribution system only when the requirements are satisfied. In the short-run, efficient utilization of transportation and storage facilities is required to insure the efficient distribution. In the long-run, investment on regional fertilizer distribution facilities is necessary to deliver the right type of fertilizer to farmers at the right time and place, and at a minimum cost.

Shortage in fertilizer storage capacity was indicated. Due to extensive stock piling in 1972, a high level of excess fertilizer supply was found for every month. Reduction in stock to an efficient level would save the fertilizer storage cost and solve some of the recurring shortage problems in storage capacity.

Seasonality in consumption was great in 1972 resulting in inefficient utilization of transportation and storage facilities. The seasonality can be smoothed out to some extent by changes in sales management such as rearrangement of credit sales or offers of premiums to buyers in the slack consumption periods. Some of the shortage in storage and consumption seasonality problems may be solved by introduction of regional storage centers.

Fertilizer imports immediately before the peak consumption periods and exports during the slack consumption periods would help to minimize the fertilizer distribution costs.

Achievement of an efficient fertilizer distribution system may require ideal fertilizer production systems and better institutional framework in addition to the regional distributional facilities introduced in this study.

Comparative advantage between domestic production and imports, efficient fertilizer production system costs, and workings of the fertilizer distribution institutions remain as further research areas.

This analysis was made under the constraint of the system controlled by the government. Further research might include a comparison of distribution costs and marketing efficiencies among the government controlled system and a free market system or a mixed system. The efficiency of the current system might be improved even more if the profit motive of a free market could be considered.

This study does not provide a clear-cut basis for changing fertilizer distribution policy. Although the comparison between 1972 and 1978 models under the restrictive assumptions here suggest a saving of significant won value, it is not clear that these savings are sufficient enough to offset the cost of building 17 new regional facilities.

It is therefore recommended that the Ministry of Agriculture and Fisheries undertake a major investigation of transportation, storage, handling, mixing, and bagging costs to aid in determination of whether a major reconstruction of fertilizer distribution is desirable.

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APPENDICES

APPENDIX TABLE A-1. Transportation cost of bagged fertilizer between regions (wons per metric ton), Korea

	Chungju (1)	Naju (2)	Ulsan (3)	Jinhae (4)	Yosu (5)	Sosa (6)	Janghang (7)	Incheon (8)	Kunsan (9)	Mokpo (10)	Pusan (11)	Chuncheon (12)	Kangneung (13)	Cheongju (14)	Jecheon (15)	Jeju (16)	Seoul (17)	Suwon (18)	Cheonan (19)	Taejeon (20)	Hongseong (21)	Jeonju (22)	Iri (23)	Boseong (24)	Songjeongri (25)	Andong (26)	Kimcheon (27)	Taegu (28)	Samrangjin (29)	Jinju (30)
(1) Chungju	0	581	581	664	747	415	498	415	415	664	664	498	581	166	83	1920	332	332	249	249	332	415	415	664	581	249	415	498	581	747
(2) Naju	581	0	747	581	332	664	747	664	249	166	664	830	1079	498	664	1449	664	581	498	415	581	249	249	166	83	747	498	664	664	415
(3) Ulsan	581	747	0	332	581	747	830	830	664	913	166	913	747	581	498	1495	747	664	581	498	747	664	664	747	747	332	332	249	249	415
(4) Jinhae	664	581	332	0	415	830	830	830	664	664	166	996	830	581	581	1388	747	747	664	498	747	581	581	415	581	415	332	249	249	166
(5) Yosu	747	332	581	415	0	830	913	830	415	415	498	996	996	581	996	1340	830	747	664	498	747	332	332	249	332	747	664	498	415	249
(6) Sosa	415	664	747	830	830	0	415	83	498	747	747	249	747	332	332	1663	83	83	249	332	332	498	498	830	664	498	498	581	747	830
(7) Janghang	498	747	830	830	913	415	0	498	581	830	830	581	913	332	581	1505	415	332	249	415	166	581	581	747	747	747	581	664	747	913
(8) Incheon	415	664	830	830	830	83	498	0	581	747	830	249	830	332	415	1580	83	166	249	332	332	581	498	830	664	581	498	581	747	913
(9) Kunsan	415	249	664	664	415	498	581	581	0	332	664	664	913	332	498	1505	498	415	332	249	415	83	83	415	249	664	415	498	581	498
(10) Mokpo	664	166	913	664	415	747	830	747	332	0	747	913	1162	581	747	1200	747	664	581	498	664	332	332	332	166	913	581	747	664	498
(11) Pusan	664	664	166	166	498	747	830	830	664	747	0	913	830	581	581	1419	747	747	581	498	747	664	664	747	664	415	332	249	83	332
(12) Chuncheon	498	830	913	996	996	249	581	249	664	913	913	0	913	498	415	1820	249	249	332	498	498	664	664	913	830	581	664	747	830	996
(13) Kangneung	581	1079	747	830	1162	747	996	830	913	1162	830	913	0	664	498	2248	747	830	747	747	830	913	830	996	996	415	581	664	747	913
(14) Cheongju	166	498	581	581	581	332	332	332	332	581	581	498	664	0	249	1837	332	249	166	166	249	332	249	581	415	415	249	415	498	664
(15) Jecheon	83	664	498	581	996	332	581	415	498	747	581	415	498	249	0	1781	332	415	332	332	415	498	498	747	664	249	332	415	498	747
(16) Jeju	1920	1449	1495	1388	1340	1663	1505	1580	1505	1200	1419	1820	2248	1837	1781	0	1663	1746	1837	1754	1754	1663	1663	1589	1366	1834	1751	1663	1502	1554
(17) Seoul	332	664	747	747	830	83	415	83	498	747	747	249	747	332	332	1663	0	83	166	332	332	498	498	747	664	498	498	581	664	830
(18) Suwon	332	581	664	747	747	83	332	166	415	664	747	249	830	249	415	1746	83	0	166	249	249	415	415	664	581	581	415	498	664	830
(19) Cheonan	249	498	581	664	664	249	249	249	332	581	581	332	747	166	332	1837	166	166	0	166	166	332	332	581	498	498	332	415	498	664
(20) Taejeon	249	415	498	498	498	332	415	332	249	498	498	498	747	166	332	1754	332	249	166	0	249	249	166	498	332	415	166	332	415	581
(21) Hongseong	332	581	747	747	747	332	166	332	415	664	747	498	830	249	415	1754	332	249	166	249	0	415	415	664	581	581	415	581	581	830
(22) Jeonju	415	249	664	581	332	498	581	581	83	332	664	664	913	332	498	1663	498	415	332	249	415	0	83	415	249	664	415	498	581	415
(23) Iri	415	249	664	581	332	498	581	498	83	332	664	664	830	249	498	1663	498	415	332	166	415	83	0	332	249	581	332	415	581	415
(24) Boseong	664	166	747	415	249	830	747	830	415	332	747	913	996	581	747	1589	747	664	581	498	664	415	332	0	166	830	664	747	581	498
(25) Songjeongri	581	83	747	581	332	664	747	664	249	166	664	830	996	415	664	1366	664	581	498	332	581	249	249	166	0	747	498	581	581	415
(26) Andong	249	747	332	415	747	498	747	581	664	913	415	581	415	415	249	1834	498	581	498	415	581	664	581	830	747	0	332	249	332	581
(27) Kimcheon	415	498	332	332	664	498	581	498	415	581	332	664	581	249	332	1751	498	415	332	166	415	415	332	664	498	332	0	166	249	498
(28) Taegu	498	664	249	249	498	581	664	581	498	747	249	747	664	415	415	1668	581	498	415	332	581	498	415	747	581	249	166	0	166	332
(29) Samrangjin	581	664	249	249	415	747	747	747	581	664	83	830	747	498	498	1502	664	664	498	415	581	581	581	581	581	332	249	166	0	249
(30) Jinju	747	415	415	166	249	830	913	913	498	498	332	996	913	664	747	1554	830	830	664	581	830	415	415	498	415	581	498	332	249	0

APPENDIX TABLE A-2. Transportation cost of bulk fertilizer between regions (wons per metric ton), Korea

	Chungju (1)	Naju (2)	Ulsan (3)	Jinhae (4)	Yosu (5)	Sosa (6)	Janghang (7)	Incheon (8)	Kunsan (9)	Mokpo (10)	Pusan (11)	Chuncheon (12)	Kangneung (13)	Cheongju (14)	Jecheon (15)	Jeju (16)	Seoul (17)	Suwon (18)	Cheonan (19)	Taejeon (20)	Hongseong (21)	Jeonju (22)	Iri (23)	Boseong (24)	Songjeongri (25)	Andong (26)	Kimcheon (27)	Taegu (28)	Samrangjin (29)	Jinju (30)
(1) Chungju	0	511	511	584	657	365	438	365	365	584	584	438	511	146	73	1870	292	292	219	219	292	365	365	584	511	219	365	438	511	657
(2) Naju	511	0	657	511	292	584	657	584	219	146	584	730	949	438	584	1346	584	511	438	365	511	219	219	146	73	657	438	584	584	365
(3) Ulsan	584	657	0	292	511	657	730	730	584	803	146	803	657	511	438	1495	657	584	511	438	657	584	584	657	657	292	292	219	219	365
(4) Jinhae	657	511	292	0	365	730	730	730	584	584	146	876	730	511	511	1388	657	657	584	438	657	511	511	365	511	365	292	219	219	146
(5) Yosu	365	292	511	365	0	730	803	730	365	365	438	876	876	511	876	1349	730	657	584	438	657	292	292	219	292	657	584	438	365	219
(6) Sosa	438	584	657	730	730	0	365	73	438	657	657	219	657	292	292	1653	73	73	219	292	292	438	438	730	584	438	438	511	657	730
(7) Janghang	365	657	730	730	803	365	0	438	511	730	730	511	803	292	511	1505	365	292	219	365	146	511	511	657	657	657	511	584	657	803
(8) Incheon	365	584	730	730	730	73	438	0	511	657	730	219	730	292	365	1580	73	146	219	292	292	511	438	730	584	511	438	511	657	803
(9) Kunsan	584	219	584	584	365	438	511	511	0	292	584	584	803	292	438	1505	438	365	292	219	365	73	73	365	219	584	365	438	511	438
(10) Mokpo	584	146	803	584	365	657	730	657	292	0	657	803	1022	511	657	1200	657	584	511	438	584	292	292	292	146	803	511	657	584	438
(11) Pusan	438	584	146	146	438	657	730	730	584	657	0	803	730	511	511	1419	657	657	511	438	657	584	584	657	584	365	292	219	73	292
(12) Chuncheon	511	730	803	876	876	219	511	219	584	803	803	0	803	438	365	1799	219	219	292	438	438	584	584	803	730	511	584	657	730	876
(13) Kangneung	146	949	657	730	1022	657	876	730	803	1022	730	803	0	584	439	2148	657	730	657	657	730	803	730	876	876	365	511	584	657	803
(14) Cheongju	1870	438	511	511	511	292	292	292	292	511	511	438	584	0	219	1797	292	219	146	146	219	292	219	511	365	365	219	365	438	584
(15) Jecheon	73	584	438	511	876	292	511	365	438	657	511	365	438	219	0	1943	292	365	292	292	365	438	438	657	584	219	292	365	438	657
(16) Jeju	1870	1346	1495	1388	1340	1653	1505	1580	1505	1200	1419	1799	2148	1797	1943	0	1653	1726	1797	1724	1651	1578	1578	1492	1346	1783	1710	1638	1491	1534
(17) Seoul	292	584	657	657	730	73	365	73	438	657	657	219	657	292	292	1653	0	73	146	292	292	438	438	657	584	438	438	511	584	730
(18) Suwon	292	511	584	657	657	73	292	146	365	584	657	219	730	219	365	1726	73	0	146	219	219	365	365	584	511	511	365	438	584	730
(19) Cheonan	219	438	511	584	584	219	219	219	292	511	511	292	657	146	292	1797	146	146	0	146	146	292	292	511	438	438	292	365	438	584
(20) Taejeon	219	365	438	438	438	292	365	292	219	438	438	438	657	146	292	1724	292	219	146	0	219	219	146	438	292	365	146	292	365	511
(21) Hongseong	292	511	657	657	657	292	146	292	365	584	657	438	730	219	365	1651	292	219	146	219	0	365	365	584	511	511	365	511	511	730
(22) Jeonju	365	219	584	511	292	438	511	511	73	292	584	584	803	292	438	1578	438	365	292	219	365	0	73	365	219	584	365	438	511	365
(23) Iri	365	219	584	511	292	438	511	438	73	292	584	584	730	219	438	1578	438	365	292	146	365	73	0	292	219	511	292	365	511	365
(24) Boseong	584	146	657	365	219	730	657	730	365	292	657	803	876	511	657	1492	657	584	511	438	584	365	292	0	146	730	584	657	511	438
(25) Sonjeongri	511	73	657	511	292	584	657	584	219	146	584	730	876	365	584	1346	584	511	438	292	511	219	219	146	0	657	438	511	511	365
(26) Andong	219	657	292	365	657	438	657	511	584	803	365	511	365	365	219	1783	438	511	438	365	511	584	511	730	657	0	292	219	292	511
(27) Kimcheon	365	438	292	292	584	438	511	438	365	511	292	584	511	219	292	1710	438	365	292	146	365	365	292	584	438	292	0	146	219	438
(28) Taegu	438	584	219	219	438	511	584	511	438	657	219	657	584	365	365	1638	511	438	365	292	511	438	365	657	511	219	146	0	146	292
(29) Samrangjin	511	584	219	219	365	657	657	657	511	584	73	730	657	438	438	1491	584	584	438	365	511	511	511	511	511	292	219	146	0	219
(30) Jinju	657	365	365	146	219	730	803	803	438	438	292	876	803	584	657	1534	730	730	584	511	730	365	365	438	365	511	438	292	219	0

APPENDIX B

Problem

There are three kinds of mixed fertilizer types. They are 22-22-11, 18-18-18, and 14-37-12. We want plant nutrient N-P-K components of 19-22-12 as an aggregate. What would be the quantity ratio of each mixed fertilizer type to the total mixed fertilizer quantity?

Let X_1 denote 22-22-11

X_2 denote 18-18-18

X_3 denote 14-37-12

Then, solution matrix takes the form of:

$$\begin{bmatrix} 22 & 18 & 14 \\ 22 & 18 & 37 \\ 11 & 18 & 12 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} 19 \\ 22 \\ 12 \end{bmatrix}$$

The answer to the problem is:

$X_1 = 0.613$

$X_2 = 0.205$

$X_3 = 0.130$

We can convert this result into percentage terms to total:

22-22-11	0.613	64.7
18-18-18	0.205	21.6
14-37-12	0.130	13.7
Total	0.948	100.0

APPENDIX C

Questionnaire for Fertilizer Distribution of 123 county cooperatives

A. General Situation

1. What were the size of the following purchasing businesses in 1972?

Fertilizer ________ wons Ag. chemical ______ wons
Feed ________ wons
Total purchasing ______ wons

2. How much fertilizer did you supply in 1971 and 1972?

1971 total ______ ton
1972 total ______ ton

Tendency

1) Same increase as in the previous year
2) Tend to use more fertilizer compared with previous year
3) Increase in use due to introduction of new variety
4) More fertilizer was allocated to farmers
5) Increase in use due to a lower price of fertilizer

3. What is the number of farms to which your coop distributes fertilizer?

1971 ______ farms
1972 ______ farms

4. How many times did you distribute fertilizer in the last year? ________ times

5. What are the types of farms to whom you distribute fertilizer?

Rice farm ______	Rice and upland farm ______
Upland farm ______	
Vegetable farm ______	Others ______________

6. What is the total area of farms to which your coop distributes fertilizer?

Paddy land ______ ha.   Upland ______ ha.

7. Can you tell me the quantity of fertilizer by size of farms served by your coop?

	Total	N	P	K
	-----------(kg)--------			
0.3--0.5 ha.				
0.5--1.0 ha.				
1.0--2.0 ha.				
2.0--3.0 ha.				
more than 3.0 ha.				
Total				

8. What is the purchasing tendency of fertilizer by large farm compared with that by small farm?

1) Use more fertilizer per 10 ha. than the small farms
2) Use less fertilizer per 10 ha. than the small farms
3) Same proportion to land size
4) Purchase fertilizer less frequently

9. Balance of fertilizer at the end of 1972.

Fertilizer	Transportation Distance	Transportation Cost (per kg)	Price (per kg)	Inventory
Ammonium sulfate				
Urea				
Potassium chloride				
Triple super-phosphate				
Calcium cynamide				
Mixed fertilizer				
Compound fertilizer				
Ag. lime				

10. Quantity of fertilizer transported under your coop control from pick-up point.

Distance	Quantity	Number of farms	Facilities	
			Train	Truck
less than 4 km				
4 -- 7.9 km				
8 -- 11.9 km				
12 -- 15.9 km				
16 km or more				

11. Transportation cost of fertilizer from county coop to Myon or Ri coop.

Truck	Cost	Distance
Transportation	____ wons	_____ km
Loading and unloading	____	
Other	____	

Truck	Cost	Distance
Transportation	____ wons	_____ km
Loading and unloading	____	
Other	____	

12. Fertilizer sales by month

	Ammonium sulphate	Fused phosphate	Potassium chloride	Mixed	Other
	-----------	-----------	(kg)	-----------	-----------
Jan					
Feb					
Mar					
Apr					
May					
June					
July					
Aug					
Sept					
Oct					
Nov					
Dec					
Total					

13. Do you think that the nutrient of fertilizer distributed by your coop is consistent with what the farmers want to buy?

Yes________ No________

If "no," what kind of nutrient do they want to buy more?

N ________%
P ________%
K ________%

14. Would you tell me the warehouse facilities owned by your coop?

Total building area ____pyungs Rent area ____ pyungs
Condition of the warehouse
bad____ not bad____ good____
Capacity ____ bags of fertilizer
or ____ bags of grains
Proportion of capacity used for storage of fertilizer per year ____%
Shortage or excess capacity
Need ____ pyungs
Excess ____ pyungs
No excess or no shortage ____ pyungs

15. How do you inform the farmers of time, quantity, and method of fertilizer application?

___ follow the direction of use tagged at bag
___ through extension worker
___ through chief of Ri coop
___ through journal or prints

16. Distribution method to Ri coop

___ distributed by order of Ri coop
___ distributed by allocation decided by central coop
___ distributed by allocation decided by county coop

17. Does your coop order the fertilizer quantity needed to the central coop?

Yes ____ No ____

If "yes", when ______________________________
How many times per year? ____________

18. When the central coop allocates the quantity of fertilizer to your coop, what do you think the basis for this allocation procedure is?

___ based on total cultivated land
___ based on area of paddy land and upland
___ based on cultivated land of various crops
___ based on inventory
___ based not on nutrients but on physical quantity
___ based on production of fertilizer plant located near the coop
___ don't know

19. Would you tell me the credit sale of fertilizer in 197

Total sale on credit __________ wons
__________ % to total sale
Proportion of payment to total sale on credit
in due time _____%
Percentage of cash payment of sale on credit _____%
Payment by grain
Rice ____% Barley ____% Other ____%
Can you sell total fertilizer on credit to particular
farmers? Yes_____ No _____
If "no,"
proportion of cash sale _____%
interest on credit _____%
Deferred interest rate _____% per month
Guarantee for sale on credit
government liability on guarantee _____
no guarantee _____

20. Percent of time spent for sale of fertilizer to total time needed for total business of your coop ______%

21. How many people are involved in the sale of fertilizer?

	Clerk	Labor
Full time	______	______
Part time	______	______
Average	______	______

22. Did you use temporary labor in the peak period of the fertilizer sale?

Yes ____ No ____

If "yes," When____ How long ____ How many ____
For what ____

23. What kind of facilities does your coop have for sale of fertilizer?

	Number	Size
Truck	______	______
Loading facilities	______	______
Unloading facilities	______	______
Other	______	______

24. About price of fertilizer

-- Is there any difference in the price of fertilizer between county coop, Myon coop and Ri coop?

Yes ____ No ____

If "yes,"

due to the transportation cost from county coop to Ri coop ____

due to extra distance of transportation beyond some limit ____

24. (continued)

Do you have shortage of administration costs established by central coop?

No ____ Yes____

If "yes," how much more did you need? ________%

Would you tell me the gross return from fertilizer business in 1972? ________wons

25. Investment for fertilizer business and present value?

Facilities	Number	Investment	Present value
Warehouse	____pyungs	____wons	____wons
Truck	____cars	____	____
Office	____pyungs	____	____
Loading facilities	____	____	____

Operation cost

Total ______ wons

Source of funds		Interest value
Self-oriented funds	______wons	______%
Borrow from bank	______	______%
Borrow from government	______	______%
Other	______	______%

26. Expenditures for fertilizer business

Administration	Employee No. full or part time	Expenditure per year (wons)
Cost		
Manager		
Clerk		
Treasurer		
Other		
Sale cost		
personnel cost		
other		

26. (continued)

Wage

____

____

Transportation cost
  Transportation
  Loading
  Unloading
  Other
Warehouse cost
Interest on loan
Other

27. Can you tell me the outlook for the fertilizer business?

Increase in sale per year in the near future ______%

Can you expect that there will be some difference in the kind of fertilizer the farmer wants to buy in the future?

No difference ______

They will use more N____ P____ K____

They will use less ____ ____ ____

Can you expect that the farmers will use more fertilizer due to improvement of farming methods? ______% increase in use

Can you expect an increase in use of fertilizer due to the introduction of SR-667? ______% increase in use

Which method of fertilizer sales do you prefer?

Coop distribution ______

Free market ______

APPENDIX D: The survey questionnaire for 300 sample farms, 1972, Korea.

Survey for Fertilizer Use by Farmers

1. Family information

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 the farm (year around)	____	____		
	____	____		

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

	Sex	Age	Days worked
Operator	MF	____	____
Wife	MF	____	____
	MF	____	____
	MF	____	____

3. Farm Operator

1) Farming experience ______ years
2) No. of years at present ______ years
3) Educational background
   - No schooling ______
   - Elementary school ______
   - Junior high ______
   - Senior high ______
   - College agri. ______
   - Other college ______

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

Duration	Date	Kind	Sponsor

4. Size of farm

1) Area of land

	Paddy field	No. of pieces	Dry field	No. of pieces	Others (forest)
Owned	____pyungs		____pyungs		____pyungs
Rented					

2) Well irrigated land ________ pyungs

3) No. of livestock

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

4) Size of greenhouse

No. of houses	Pyungs	What kind
		vinyl, glass, oth

5) Pyungs of Orchard or Mulberry field

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 (wons)
Rice	________pyungs	________	________	________
Barley	________	________	________	________
Wheat	________	________	________	________
Soybean	________	________	________	________
Potatoes	________	________	________	________

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

Varieties	Area planted 1972	1971	1970
________________	____	____	____
________________	____	____	____
________________	____	____	____

1) Do you plan to expand anyone of the above rice varieties next year?

Name of strains	Total area planted
____________	____________pyungs
____________	____________

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

Year	Size paddy field
____________	____________pyungs

7. Livestocks you have (include income from work cattle)

Kinds	Number	Total amount from sale of them
______	______	________________wons
______	______	________________

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 year	How often
____	________	____________ wons	________
____	________	____________	________
____	________	____________	________

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

New barn	________ wons
Tool or machine	________
Seeds	________
Insecticides and fungicides	________
Commercial feed	________
Other farming materials	________
Hired labor	________
Taxes and charges for farming	________
Interest on farm debts	________
Other (specify)	________

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

Handcart ________ Bicycle ________

Ox-cart ________ Tractor ________

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

Date	Amount	Type of creditors	What for	Interest rate
____	______	____________	______	________ %
____	______	____________	______	________

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

Date	Kind	Quantity (kg)	Official (wons)	Trans. (wons)	Cost Other (wons)	Charge total (wons)

Form of payments		Village	Where did you buy?			Distance
Cash	Credit	co-op	Myun coop	Private dealers	Neigh-bor	from your home

Method of transportation from place where farmer purchased?

Shoulder	Hand-cart	Ox-cart	Truck	Rail	Water	Kgs damaged in moving

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	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 fertilizer leftover at the end of the year?

What kinds	How much
Urea	____kg
Ammonium sulfate	____
Ammonium chloride	____
Triple Sup. Phos.	____
Compound	____
________	____

18. What is the reason for such fertilizer leftover?

- I bought more than I could use ______
- was distributed at the wrong time ______
- wrong type of fertilizer ______
- 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:

Date	To whom (occupation)	At what price (wons)	How: For cash	How: In kind	How: 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 is better for me ____

If you want to use more than this year, how many kilograms 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)

27. (continued)

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, phosphorus and nitrogen in the mixture ________
2) The relative amounts of nitrogen, phosphorus 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 ________
Phosphorus ________
Potassium ________
Don't know ________

32. Barnyard manures contain mostly which elements?

Nitrogen ________
Phosphorus ________
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 ______