Project A-017-IDA.

WATER
for
IDAHO

THE ECONOMIC VALUE OF WATER IN DIFFERENT USES WITHIN AGRICULTURE

A Thesis

in the

University of Idaho Graduate School

by

MATTHEW JOSEPH MAHER

August, 1967

THE ECONOMIC VALUE OF WATER IN DIFFERENT USES WITHIN AGRICULTURE

A Thesis

Presented in Partial Fulfillment of the Requirements for the

DEGREE OF MASTER OF SCIENCE

Major in Agricultural Economics

in the

UNIVERSITY OF IDAHO GRADUATE SCHOOL

by

MATTHEW JOSEPH MAHER

August, 1967

This thesis of Matthew Joseph Maher for the Master of Science degree, "The Economic Value of Water in Different Uses Within Agriculture,"

A. has been reviewed in rough draft form and preparation of the final draft is recommended; permission is granted to proceed with the final examination upon submission of two final draft copies to the Graduate School:

Major Professor Karl Lindeborg Date Aug. 4-1967

Committee Members S L Corey Date Aug 8, 1967

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C. has been granted final acceptance after review by the Graduate Council and after successful completion of the final oral examination:

Dean of the Graduate School Edgar H. Lueker Date November 7, 1967

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Matthew Joseph Maher was born in County Galway, Ireland on April 28, 1941. He attended University College Galway from October, 1958, to June, 1961. In the fall of 1961, he enrolled at University College Dublin where he received his Bachelor of Agricultural Science degree in October, 1963.

Following graduation, he served as Agricultural Instructor in County Galway for one year prior to enrolling in the Graduate School at the University of Idaho in September, 1965. In August, 1967, he completed the requirements for the degree of Master of Science in Agriculture, of which this thesis represents a part.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to the staff in the Department of Agricultural Economics for their assistance during his graduate studies. A special word of thanks goes to Dr. William E. Folz for his guidance and encouragement, and to Dr. Karl Lindeborg whose criticisms and suggestions during all phases of this study were invaluable.

Thanks also goes to Dr. Roger Long and Dr. Gilbert L. Corey for their comments and suggestions.

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ABSTRACT

This study was undertaken in order to determine the economic value of water in alternative uses within agriculture in Idaho. It is important to Idaho farmers and to the economy of Idaho in general to have such estimates available so that maximum economic gains may be derived from the available supply of irrigation water.

Three irrigation areas, Area I, Area II, and Area III, along the Snake River valley were studied. Costs of producing different crops in those areas were already available from previous studies. The author interviewed selected farmers in two of those areas to update available information and to determine the resource supply situations confronting operators.

The analytical tool applied to fulfill the objectives was linear programming. Three representative farms of different sizes were constructed for Area I and one each for Areas II and III. Three analytical models were formulated as steps in attaining the objectives. Changes were made from model to model in order to make the analysis more realistic or to investigate some particular facet of the problem.

The results of the study indicate that the value of water varies from area to area, water being most valuable in Area I and least valuable in Area III. Analysis of different sized farms in Area I indicates that farmers can afford to pay more for water on large farms than on smaller farms.

CHAPTER I

INTRODUCTION

Water is important for the economic development of Idaho, and it is likely to increase in importance in the future. Due to increasing per capita consumption, expansion of long-established industries and development of new ones, the demand for water is steadily increasing while the annual water supply is relatively fixed. The available supply must therefore by allocated to potential users in such a manner that it contributes most to the economic and social welfare of the people of Idaho.

Irrigation farming, which is a major water user in Idaho, makes an important contribution to the economic prosperity of the state. Some of its major exports, for example potatoes, are produced on irrigated farms. Its sugar production and general food processing industries rely on irrigated farms for their raw material. The future prosperity of Idaho seems to be dependent on expanded food processing and food exports which in turn depend on increased agricultural output. Large increases in agricultural output can only be achieved by increased irrigation. However, agriculture must compete with other water uses, such as industry, recreation and urban use, for the available supply. Therefore, some estimate of the value of water in alternative uses must be available so that it can be allocated to the most efficient uses.

When water is allocated to some major use such as agriculture, it should be allocated to the most efficient individual user or use within the main use category. For example, it should be allocated to those farms where the returns are the greatest, and it should be devoted to the highest rewarding enterprises within farms.

VALUE OF WATER

If a free market for water existed such as exists for potatoes, that is if potential users could buy water from potential sellers, the market price of water in its alternative uses would be readily available. The less efficient users would be bid off the market by the more efficient ones, and water would then be employed in its most efficient uses. No such market for water exists in Idaho. For the most part, the allocation of water among the host of users is in the hands of public bodies and organizations. Those public bodies and organizations must have some measure of the value of water in its various uses if they wish to allocate present water supplies and any supplies developed in the future, in an economically efficient manner. We must, therefore, estimate the value of water in its present uses.

Economic theory tells that the value of any scarce commodity is maximized if the marginal value of that commodity in all its alternative uses is equalized. Therefore, the relevant values on which allocation of water is based are the marginal values, that is the value of the marginal unit of water employed in any use.[1] In an open, competitive market, the marginal value would be represented by the price a buyer would be willing to pay for an additional unit of water. In the case of water for which there is no free market, its marginal value can be estimated by the value

[1]Alternatives in Water Management (Publication No. 1408. Washington, D. C.: National Academy of Sciences-National Research Council, 1966), p. 26.

of the increase in output resulting from the final unit of water used in producing that output. If the marginal value of water in all its alternative uses is thus estimated, the water resource allocation authorities will have quantitative figures to guide them in allocating water among various users. Estimating the marginal value of water among uses and users in agriculture lies within the sphere of duty of agricultural economists.

The marginal value of water within agriculture varies for different activities or enterprises. That is, the marginal value of some quantity of water used in producing potatoes will be different from the value of an equal quantity of water used in the production of wheat. The marginal value also varies with soil productivity, climatic conditions, the relative prices of goods produced and the efficiency of production.

The size of farm on which water is used, the managerial ability of the operator, and the level of technology employed on that farm also influence the marginal value of water. The size of the farm limits the size of the activity or activities that may be conducted, and it also limits the level of technology which may be economically employed. For example, it will invariably be uneconomical to employ the most modern and most efficient beet or potato harvesting equipment on a 100-acre farm. The ability of the manager to select the correct combination of activities and production techniques will have a very substantial effect on the marginal value of water on any farm.

MARGINAL VALUE PRODUCT DEFINED

The marginal value product of any factor of production is the value of the increase in output obtained by adding an additional unit of that factor to a fixed amount of other factors used in the production of that product. This concept may be more easily explained by considering a common situation such as adding incremental amounts of fertilizer to a set of fixed factors in the production of wheat.

If a farmer uses 100 pounds of seed, 100 pounds of fertilizer and one acre of land to produce 20 hundred weight of wheat and if by using 101 pounds of fertilizer and the same amount of land and seed he obtains an increase in output of one hundredweight, the marginal value product of the additional unit of fertilizer is one multiplied by the dollar price of wheat. It is profitable to continue increasing the amount of fertilizer in the above example as long as marginal cost, or the cost of the incremental unit of fertilizer, is less than the marginal value product. Profit is at a maximum when marginal cost equals marginal returns.

In the above example only one output is taken into consideration. In real life farmers have the opportunity to produce more than one crop. The optimum combination of crops to produce, when some factors of production are scarce, is obtained by examination of the marginal value of scarce factors in their alternative uses. A simplified situation will be used to demonstrate the procedure. A farmer wished to select the optimum amounts of potatoes and alfalfa to produce while water is the only scarce factor. Assume that the curves in Figures 1 and 2 are schedules of the marginal value product of water used in the production of potatoes and alfalfa respectively. Assume that the amount of water available is represented by OA_1 in Figure 1.

With water supply equal to OA_1, it can be seen that maximum total revenue is obtained when the entire supply is allocated to potato production. The marginal value product of the last unit of water is OQ, Figure 1. Assuming that the value of OQ in Figure 1 is greater than OT in Figure 2, total returns would be reduced by transferring water from potato production to alfalfa production, since the marginal value product of a unit of water used to produce potatoes is greater than if it were used to produce alfalfa. That is, the loss which accompanies the transferring of water from potatoes to alfalfa is greater than the gain.

If a larger supply of water were available, for example OA_2 of Figure 2, it is evident from those two figures that some water would be used to produce both crops. If the entire amount of water is used in producing potatoes, the marginal value product is OR, Figure 1, which is less than the marginal value product of water used in the production of alfalfa. Returns would be increased by transferring water from potato production to alfalfa production. Water should be transferred to alfalfa production until its marginal value product is equal in both uses. In this example this would require using an amount of water OA_o in producing potatoes and OB_o in producing alfalfa.

This is the principle of equimarginal returns. The same principle applies when several products may be produced. Under conditions of perfect competition, profit or net revenue is at a maximum when the marginal value product of water is equal in all its alternative uses, and

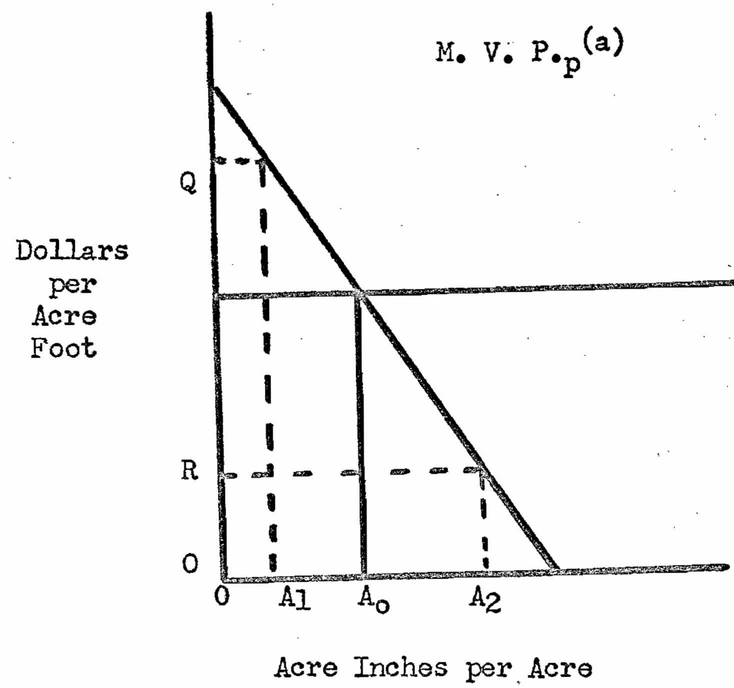

Figure 1. Hypothetical Marginal Value Product Curve for Water in the Production of Potatoes

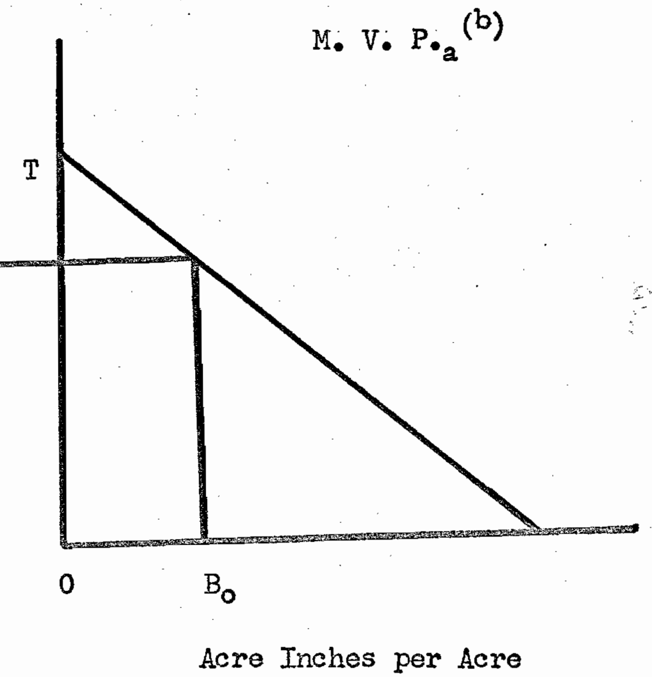

Figure 2. Hypothetical Marginal Value Product Curve for Water in the Production of Alfalfa

(a) $M.\ V.\ P._p$ = The marginal productivity of water in the production of potatoes.

(b) $M.\ V.\ P._a$ = The marginal productivity of water in the production of alfalfa.

is equal to its marginal cost. This principle also holds in deciding how water should be allocated among different farms and different areas.

CHAPTER II

PURPOSE AND SCOPE

Objectives.

This study has three objectives which are stated below.

1. What is the marginal value product of water in three selected irrigation-farming areas in Southern Idaho.

2. What is the optimum crop combination in each of these areas under present farming conditions.

3. How much can farmers afford to pay for water on different sized farms in one of the study areas. Operators of large farms may be able to pay more for water than operators of small farms due to economies of size.

ASSUMPTIONS

To answer the questions listed above, it is necessary to make certain simplifying assumptions. Some of the more important assumptions are:

1. The managerial abilities of all farm operators included in this study are assumed equal. Management is one of the most important assets on any farm. The farm manager must select the level of technology appropriate to his farm, the activity or combination of activities to be pursued, and the production technique to be followed for each activity. All those decisions must be made under conditions of uncertainty. The farmer must decide at the beginning of the year what crops he is going to produce, basing his decisions on present and expected prices while a

completely different set of prices may exist when he wishes to market his output. He must decide what machinery to purchase without knowledge of future price changes or future developments in production technique.

The conditions under which management makes decisions vary also from farm to farm. For example, one farm may have adequate supplies of capital and labor while such resources will be less than adequate on other farms. Obviously resource supplies will have a big influence on the program selected for any farm. However, on two different farms with equal resource endowments, the selected programs may vary due to personal characteristics and preferences of different managers. One manager may be willing to undertake a big risk program in order to have a chance of making big gains, while another may forego the opportunity of large profits in order to avoid taking any risks. There are no known methods by which such characteristics may be measured. In many cases the success of a program may be attributable to chance more than to wise decision making on the part of the manager. Differentiation of such causes is impossible. For those reasons, this study assumes that managerial ability on all farms is equal, and the managers' only objective is profit maximization. It is also assumed that a plentiful supply of capital is available, each operator employes that production technique which is most efficient and appropriate for the resources at his disposal, and his average production costs are at a minimum.

2. It is assumed that farmers are at present growing the crop combination which maximizes net revenue. This may not be the case. Some farmers, because of some special skill or lack of it, or for personal likes and dislikes, may be conducting less than optimum combination

of enterprises on their farms. Instead of seeking maximum profit, some farmers may prefer less profit and more leisure time. The error which arises from this assumption will be minimized by using the technique of linear programming to analyze the data.

3. The water requirements for the different crops in this analysis are based on the amounts prescribed in published reports.[2] Use of those water requirements is based on the assumption that farmers, by their experience, use the correct amounts. This may not be correct, and in many cases when water supply is plentiful, farmers water their crops to excess. If excessive amounts of water are used, the results of this study will overestimate the value of water. It was necessary to assume constant water requirements per crop because most farmers interviewed did not have accurate estimates of the amount of water they applied to each crop.

4. It is assumed that irrigation efficiency is 60 per cent on all the study farms. This figure is based on studies on the efficiency of irrigation water use in Idaho.[3]

5. It is assumed that each farmer faces a perfectly elastic demand curve for goods sold and a perfectly elastic supply curve for goods purchased. That is, each individual farmer receives constant prices for each unit of product sold, irrespective of the amount of each good he sells, and he pays the same price for every unit of any input he purchases.

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[2] Max C. Jensen and Wayne D. Criddle, Estimated Irrigation Water Requirements for Idaho (Bulletin No. 291. Moscow, Idaho: Idaho Agr. Exp. Station, 1952), pp. 11, 12.

[3] Ibid., p. 6.

6. The study assumes that the same production technique is employed on farms of approximately the same size within individual areas and that this is the optimum technique.

7. Soil productivity and climatic conditions are assumed to be the same on all farms within each area.

8. The only restrictions on production for individual farms are available supplies of land and water and rotation restrictions.

Limitation of the Assumptions

The assumptions stated above could cause a difference between the value of water obtained in this study and the value of water on real farms. The reason is that this study develops representative enterprise budgets for farms with different resource supplies by an aggregation process. Individual enterprise budgets on farms with similar resources are averaged to get a typical budget for a farm that approximates or represents that resource category. Exact replicates of the representative farms may not occur in real life. This study is normative in the sense that it analyzes and makes recommendations about situations that ought to occur, not what actually occurs in reality.

The analysis is static in that it uses one given level of technology on each representative farm and does not consider advances in agriculture technology. The effects of changes in the rate of fertilizer application or improved weed-control chemicals are not considered. The study does not allow for a shift in the demand for agricultural products. With changes in consumer taste, the demand for individual crops may change disproportionately as the demand for new products arises. Therefore, the quantities purchased of some of the more important present-day crops would probably decrease while output of others will increase, and new crops will be introduced in response to consumer demand. However, it is not the purpose of this study to forecast the extent or direction of changes in demand.

Grouping individual farms into various size groups and assuming that all farms within one such group may be represented by one farm also leads to inaccuracies. Such grouping relies on personal judgment, and there is no quantitative method by which farms can be assigned to different size groups. Farms with smaller area and more intensive production methods than a larger farm may have greater total output, and this may lead to difficulties in deciding to what size group such farms belong. Individual farms within a size group will not have identical input-output coefficients due to differences in managerial ability, skills and preferences. Land quality may not be uniform within one farm and will not be uniform within a whole area.

Land and water availability may not and usually are not the only restricting factors on individual farms. Capital supply, and to a lesser extent marketing contracts, may be limiting factors. While farmers may be able to obtain sufficient capital from banks or other credit institutions, such institutions usually require farmers to conduct farm operations which they consider safe.

VALUE OF THE STUDY

The results obtained from this study will be of value to public policy makers, county agents and individual farmers if allowances are made for the assumptions and if the results are applied with discretion to specific situations. Public policy makers may be able to use the results in allocating water among areas and individual farms within an area. County agents may use the results as standards of efficiency and as approximate guides in designing farm programs.

The study may point out problem areas or difficulties in estimating the marginal value product of water and suggest areas where further research would be beneficial. It may detect cases of inefficient use of water, if any exist, and suggest how such inefficiencies may be minimized or eliminated.

The results will only be applicable to situations where the production techniques, market outlets and the overall economic conditions and outlook are comparable with those which exist at the present time. A major agricultural development such as the introduction of Gaines wheat in the past may render the results inaccurate and misleading.

The value of irrigation water obtained in this study only includes the monetary returns accruing to farmers. Those returns may be much less than the total social benefits derived from use of water in irrigation. That is, indirect social benefits are omitted. Examples of indirect benefits derived from employment of water resources in irrigation are readily available in Idaho. For example, the establishment of potato processing plants in Southern Idaho in past years as a result of increased potato output provided rewarding employment for many citizens and led to the evolution of prosperous communities in the neighborhood of those plants. The possibility of such indirect benefits must be taken into account by policy makers, but are beyond the scope of this study.

CHAPTER III

GENERAL PROCEDURE

Statement of Hypotheses

As a basis for procedure, two hypotheses and two alternative hypotheses are formulated.

Hypotheses

1. The value of irrigation water is not equal in the three areas studied.

2. Operators of larger farms can afford to pay more for water than operators of smaller farms.

Alternative Hypotheses

1. The value of water is the same irrespective of the area in which it is used.

2. Operators of small farms and large farms can afford to pay the same amount for water.

Theoretical Basis for the Hypothesis

Hypothesis number two is based on the theory of economies of size. Economies of size means that the average cost of producing one unit of a product decreases as the total volume of output of that product increases. A theoretical farm firm will be used to illustrate this concept.

In examining average costs of a firm it is convenient to classify average cost curves for two different theoretical time periods, (1) short time periods, and (2) long periods, or the so-called long-run and short-run. In the short-run the available quantities of some resources are fixed. For example, a farmer may not be able to change his farm acreage or beet-harvesting equipment in such a short period of time. There is an upper limit to the amount of goods he can produce in the short-run, the fixed resource or resources being the limiting factors. He may produce nothing or he may produce any output up to the upper limit.

With initial expansion of output, average costs per unit of output decrease because the fixed costs, which are involved in any production process, are distributed among more units of output. Average unit costs decline until they reach a minimum at some particular output level. If this level of output is exceeded, average unit costs may begin to increase, because diseconomies begin to set in and outweigh any advantage gained by spreading the fixed costs over more units of output. Diseconomies may set in because management may not be able to give as much attention to each individual phase of the production process as it could with smaller output. Machinery may not be able to perform operations on time which may cause lower yields or loss of a portion of some crops such as potatoes which are very susceptible to frost damage at harvest time.

In theory there is one unique level of output which minimizes average costs for a given set of resources. For every possible different combination of resources there is an average cost schedule with its minimum point for some level of output. An array of theoretical short-run average cost schedules is presented in Figure 3. Level of output is represented on the X axis, average cost on the Y axis. The curves are

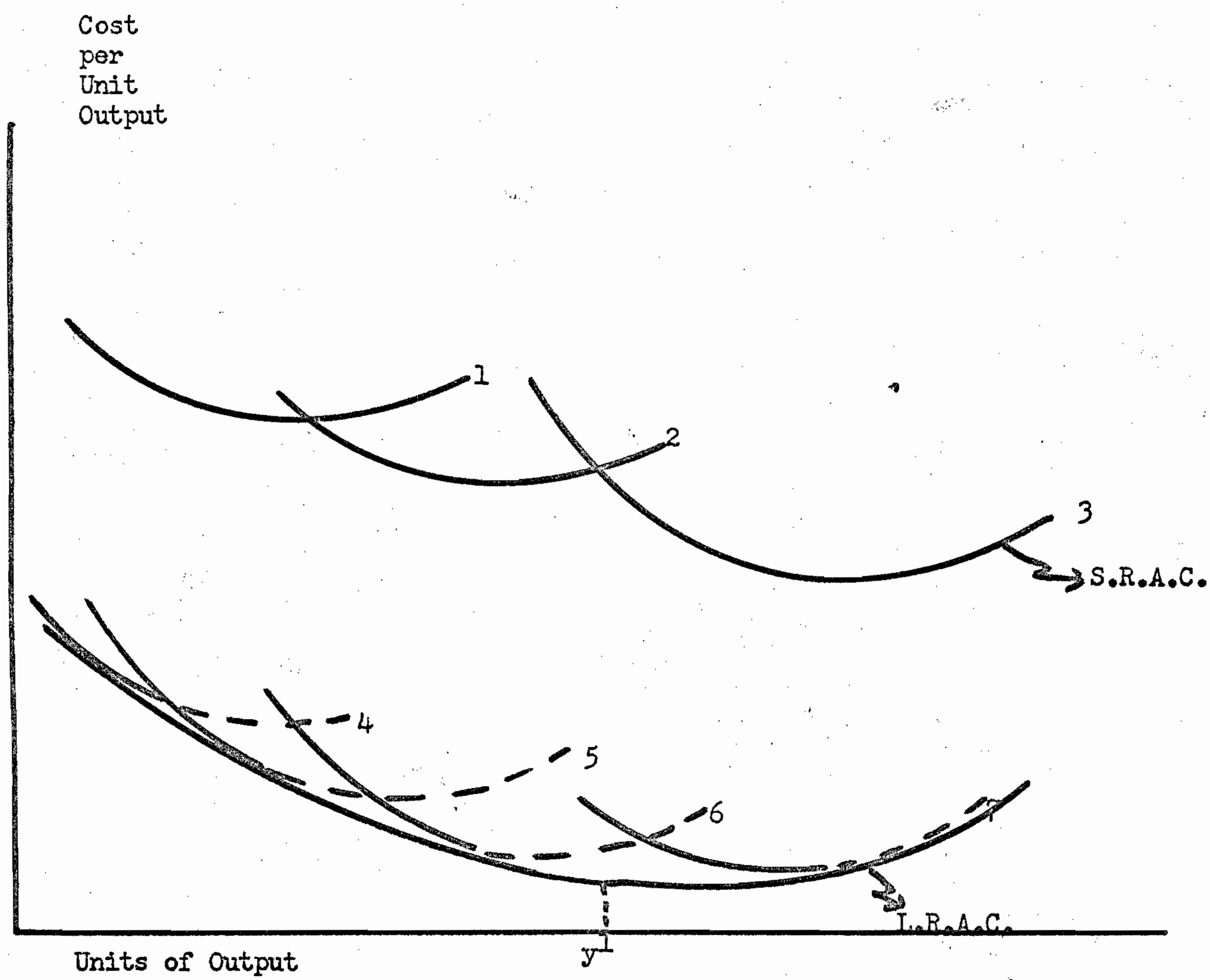

Figure 3. Hypothetical Short-Run Average Cost Curves and Long-Run Average Cost Curve

(a) S.R.A.C. curves 1, 2 and 3 are irrevelant for planning decisions because the same level of output can be produced at a lower per unit cost. The broken parts of curves 4, 5, 6 and 7 are irrevelant for the same reason.

obtained by plotting several cost-output ratios.

In the long-run all resources are variable. A farmer may buy or sell land, machinery or any resource. The long-run average cost curve is obtained by drawing a curve tangential to the short-run average cost curves at their lowest points. In the long-run a farm operator could produce at any point along this average cost curve. For each level of output there is one resource combination which gives the lowest average cost per unit of output. A long-run average cost curve LRAC is drawn on Figure 3.

The LRAC curve drawn above indicates that in the long-run average costs per unit of output increase beyond the output indicated by Y'. This may or may not be the case. Average costs may not increase as output is expanded beyond Y'.

Rationale Behind Cost Analysis

If the average cost per unit of output decreases as farm size increases, it follows that the net revenue increases (ceteris paribus). This net revenue may be regarded as the residual, or the amount of money available to remunerate those factors (such as the management factor) which were not included in estimating the average cost per unit of output. All factors cannot readily be included in estimating production costs because no market price exists for those goods. Management services and water would be examples. The residual available after paying the assumed marginal value for all other factors may be regarded as the returns earned by those excluded factors of production such as water and management. If the residual increases as farm size increases, it follows that the returns to water and management in the above example increase. Therefore, one of the major tasks of this study is to estimate the average costs of producing a unit of various products on different sized farms to estimate what farmers can afford to pay for water.

TESTING THE HYPOTHESIS

The following is the procedure employed to test the hypotheses: (1) Three irrigation areas in Southern Idaho were selected for analyses. (2) A number of farms were selected within each area for detailed analyses. (3) Costs of producing various crops on individual farms were then estimated by budgeting. (4) Farms within each area were then grouped according to size when possible and per unit production costs for different activities on each farm computed. (5) Representative enterprise budgets were constructed for each farm size group, by averaging the individual farm budgets already computed. (6) The linear programming technique was then used to analyze the data for different resource supply situations to obtain the optimum solution to the study problem.

THE LOGIC OF LINEAR PROGRAMMING

A linear programming problem exists when some resources are scarce, alternative production possibilities exist and there must be an objective. The problem which this study wishes to solve fits into this class: land and water resources limit the total output quantities, a farmer may produce alternative crop activities, and the objective is to maximize net revenue.

Linear programming is based on the same information as budgeting but has many advantages over the latter. It is an easy, rapid method of computing the optimum resource combination when the objective is profit maximization. It is possible to take many resource restrictions and many production alternatives into consideration when this method is applied, and a unique optimum solution is obtained on all occasions. It gives the marginal value product of all scarce resources and presents the unique combination of enterprises which maximize the income from those scarce resources.

Before a problem can be solved by linear programming, it must be expressed in mathematical form. Such a problem may be expressed mathematically by simultaneous linear equations which represent the conditions of the problem, such as restrictions on production activities, input-output coefficients, net revenue per unit of activity, and a linear function which expresses the objective of the problem. A problem thus stated can then be quickly solved by an electronic computer. Mathematically, the problem is stated as follows:

<u>Objective Function</u>:

$$Z = \sum_{j=1}^{n} C_j X_j \qquad (j = 1, 2, \ldots n)$$

subject to restraints of the form

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad (i = 1, 2, \ldots m)$$

and

$$X_j \geq 0$$

where:

X_j = the quantity of the j^{th} variable of interest to the decision-maker, where there are <u>n</u> variables being considered;

C_j = the per unit contribution to the objective function of the j^{th} variable where there are n variables;

Z = the objective function to be maximized;

b_i = the i^{th} requirement where there are m requirements in all;

a_{ij} = the exchange coefficient of the j^{th} variable in the i^{th} restraint where there are m restraints and n variables.

To obtain accurate solutions to problems by the method of linear programming, all data and coefficients used must be estimated as accurately as possible. However, it may not always be possible to obtain completely accurate information, or some variables may vary over time. Therefore, it is often desirable to study linear programming solutions while allowing some of the programming parameters to vary. This may be done by parametric linear programming which is closely related to linear programming.

The solution to a linear programming problem includes the marginal value product of all scarce resources used. The marginal value product of a scarce resource thus obtained is different to the marginal value product concept explained in Chapter I. Linear programming assumes that all inputs vary proportionately until the supply of the scarce resource is exhausted and production then ceases. Therefore, the marginal value obtained by linear programming is the average value product of the total supply of the scarce resource. However, if a range of scarce resource supply quantities are taken, the marginal value product of those quantities may be estimated by linear programming and are practically as useful as the marginal value product of each additional unit of scarce resource used. Three analytical models were formulated as steps in attaining the objectives outlined. These are described in Chapter IV.

ESTIMATING PROGRAMMING COEFFICIENTS

Description of Areas Studied

Three areas were selected for inclusion in this study. These areas are situated along the Snake River Valley, one area in Southwest Idaho and two areas in Southcentral Idaho. Their location is shown in the accompanying map.

The study area in Southwest Idaho is known as the Dry Lake Area. It shall be identified as Area I henceforth. Area I is a relatively new irrigation project, most of the farmland in the farms studied having been reclaimed from sagebrush since 1962. Part of the irrigation water is obtained directly from the Snake River, pumped to a height of 500 feet, and the remainder is obtained from farm wells. The topography of the area is gently rolling and necessitates the use of sprinkler irrigation on most farms.

The soil is very productive, judging by crop yields reported by interviewed farmers. The length of growing season and average seasonal temperature make the area ideally suited to the production of most agricultural crops. The average length of growing season is 144 days. The amount of precipitation occurring during the growing season is negligible; therefore, the water requirements of crops grown must be supplied by irrigation. Farms in this area were larger than in the other areas studied, and the farming was highly mechanized. Farm size

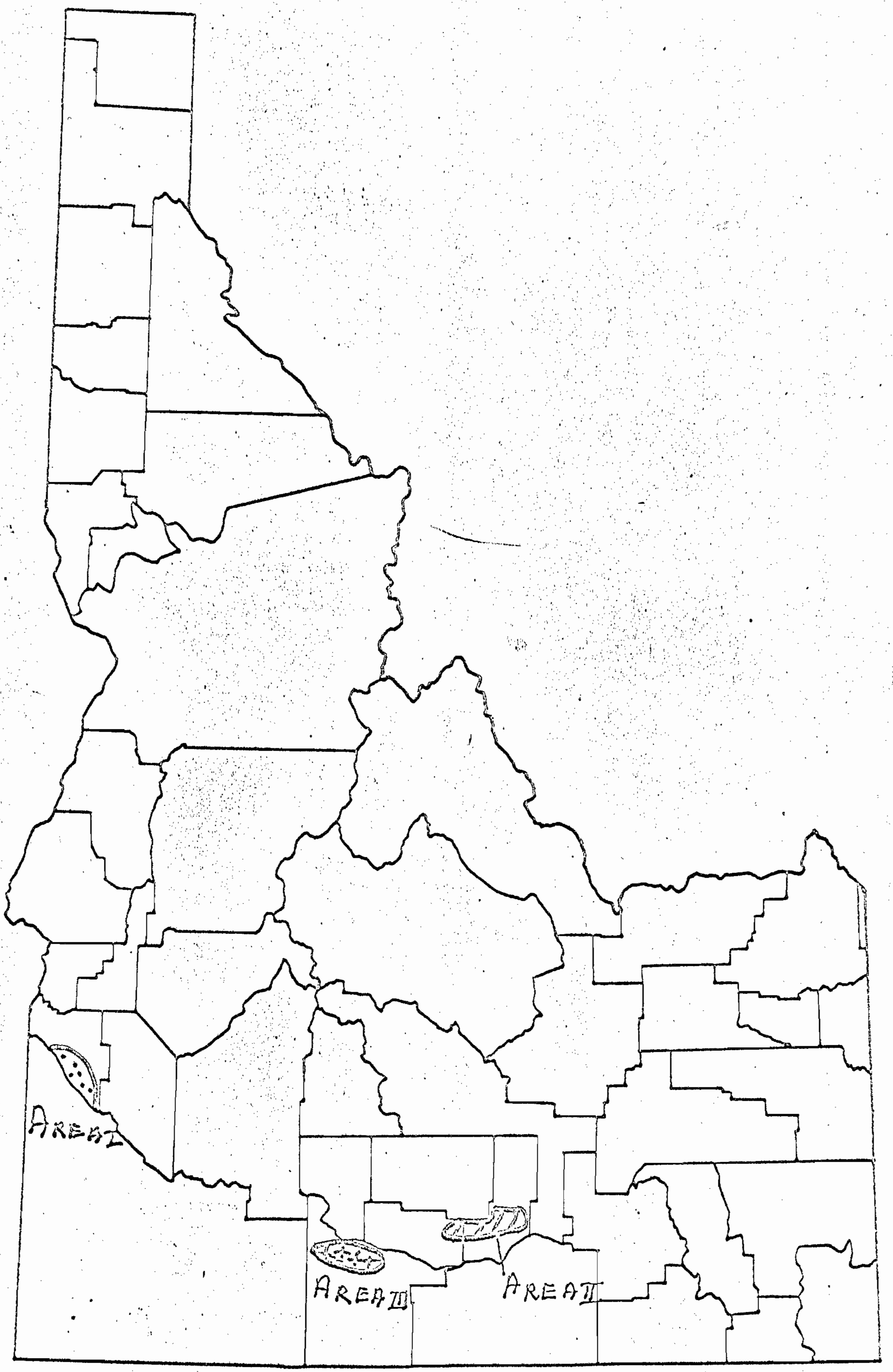

Figure 4: Location of the Study Areas in Southern Idaho

distribution is presented in Table 1.

The two irrigation areas studied in Southcentral Idaho are known as Minidoka and Twin Falls irrigation areas and shall be identified as Area II and Area III respectively for the remainder of this study.

For Area II the sample farms have been in operation from 10 to 15 years. The majority of farms in this area are smaller than in Area I. They range in size from 80 to 900 acres, the predominant size being below 320 acres and only two sample farms were greater than 640 acres in size.

Most of the land is perfectly flat and lends itself admirably to gravity flow irrigation. The average length of the growing season is 133 days, and precipitation during this period is negligible.[4] The soil is a fertile silt loam, but crop yields are not as high as in Area I.

Area III is on the south side of the Snake River in Twin Falls County. The land is flat except for a few hillocks, and gravity flow irrigation can easily be conducted. The soil in this area is a fertile silt loam. At present water supply is insufficient. Much of the planted acreage is never harvested. The main crops grown are alfalfa hay, beans, grain and sugar beets, peas and potatoes. The net revenue per unit of activity was estimated during an earlier study of Area III.

Source of Data

The type of information necessary to fulfill the objectives of the study may be summarized as follows:

1. The size of farms within each area.

2. The net revenue per unit of activity produced on farms of

[4]Climate and Man. Yearbook of Agriculture 1961. United States Department of Agriculture. (Washington D.C.: United States Government Printing Office), pp. 720, 746.

TABLE 1

SIZE DISTRIBUTION OF SAMPLE FARMS WITHIN EACH STUDY AREA IN 1964

	Number of Farms	Irrigable Acres	Per Cent of Irrigable Acres
Area I[a]			
Group 1, Farms Less Than 320 Acres	1	200.00	.03
Group 2, Farms Between 320 and 640 Acres	4	2,223.00	32.77
Group 3, Farms Greater Than 640 Acres	3	4,540.00	67.20
Total	8	6,963.00	100.00
Area II[b]			
Farms Less Than 320 Acres in Size	47	5,797.10	66.29
Farms Between 320 and 640 Acres	3	1,275.00	14.58
Farms Greater Than 640 Acres	2	1,673.00	19.13
Total	52	8,745.10	100.00
Area III[b]			
Farms Less Than 320 Acres in Size	16	2,738.50	31.58

TABLE 1 (Continued)

SIZE DISTRIBUTION OF SAMPLE FARMS WITHIN EACH STUDY AREA IN 1964

	Number of Farms	Irrigable Acres	Per Cent of Irrigable Acres
Area III[b]			
Farms Between 320 and 640 Acres	6	2,255.00	26.00
Farms Greater Than 640 Acres in Size	4	3,678.65	42.42
Total	26	8,672.15	100.00

[a]Source: Arthur Lee Coffing, "The Relationship of Farm Size to Ability to Pay for Irrigation Water in the Dry Lake Area of Canyon County, Idaho" (Unpublished Master's Thesis, University of Idaho, 1965), p. 64.

[b]Source: From data collected in previous studies of the area.

different sizes in each area.

3. The alternative crop enterprises which may be produced in each area.

Much of this information was obtained from earlier studies of these areas. The information concerning Area I was obtained from A. L. Coffing's thesis.[5] Data for Areas II and III were available from data collected in a survey in 1963 and 1964 by a staff member of the Department of Agriculture Economics at the University of Idaho. The author also conducted a survey of Area II in June, 1966, to update the information available for that area.

The farms studied in each area were grouped according to size when possible. From the data available for Area I, it was possible to divide the farms into three size groups. In Areas II and III it was not possible to divide the farms into different size groups from available data. For each farm size group a farm was constructed which was assumed to be representative of all farms within the respective farm groups. Unit production costs and net revenue obtained from producing one unit of crop enterprise on each representative farm was then obtained from the data sources mentioned above. Detailed budgets for Area II and III are presented in Appendix A. Average costs, total revenue and net revenue per unit of activity in each area are presented in Table 2. An area of crop produced is taken as the unit of activity.

Enterprise Budgets

The following section is presented as an example of the content

[5] Arthur Lee Coffing, "The Relationship of Farm Size to Ability to Pay for Irrigation Water in the Dry Lake Area of Canyon County, Idaho." Unpublished Master's Thesis, University of Idaho, Moscow, Idaho, 1965.

TABLE 2

AVERAGE COSTS[a], TOTAL REVENUE AND NET REVENUE[b] EXPRESSED IN DOLLARS PER UNIT OF ENTERPRISE IN AREA I[c], II[d], AND III[e]

	Enterprise					
	Potatoes	Sugar Beets	Grain	Alfalfa Hay	Beans	Peas
Area I						
A. Farms Less Than 320 Acres						
Costs/Ac.	250.66	189.70	51.84	71.65	---	
Total Rev./Ac.	325.00	363.40	150.45	89.23	---	
Net. Rev./Ac.	74.30	173.70	98.61	17.58	---	
B. Farms Between 320 to 640 Acres in Size						
Costs/Ac.	220.10	185.00	50.69	70.65	87.85	
Total Rev./Ac.	325.00	363.40	150.45	89.23	170.96	
Net. Rev./Ac.	104.90	178.40	99.77	18.58	83.11	
C. Farms Greater Than 640 Acres in Size						
Costs/Ac.	188.99	180.53	58.27	69.99	56.80	
Total Rev./Ac.	325.00	363.40	150.45	89.23	170.96	
Net. Rev./Ac.	136.00	182.87	92.18	19.24	114.16	
Area II						
Costs/Ac.	215.28	174.96	68.24	83.80	73.64	78.75
Total Rev./Ac.	319.80	233.31	164.61	99.15	143.96	144.86
Net. Rev./Ac.	104.52	58.35	96.37	15.35	70.32	66.11
Area III						
Costs/Ac.	215.28	173.66	61.68	73.94	80.33	78.75
Total Rev./Ac.	319.80	233.31	164.61	99.15	143.96	144.86
Net. Rev./Ac.	104.52	59.65	102.93	25.21	63.63	66.11

[a]Costs per acre do not include water, management, or land costs.

[b]Net revenue is the residual money available to reward land, management, and water.

[c]Costs per acre were derived from enterprise costs reported by Coffing, p. 65, and land and management costs excluded.

[d]Net revenue for Area II was obtained from a 1964 study confirmed by a survey by the author in 1966.

[e]Net revenue for Area III was obtained from a 1964 study of the area.

and method of estimating enterprise budgets on individual farms. This was the method used by the author in computing enterprise budgets for those farms which he analyzed in Area II. In the course of interviews conducted with farmers, complete information on farm resources, the number of acres of each enterprise conducted on the farm, the quantities of physical inputs used in producing each crop, the method of performing each farm operation--that is whether it was done by manual labor, by machinery owned by the farmer, or if an agricultural contractor was hired to do it--and yield per acre of each crop was obtained.

Prices

Average prices paid by Idaho farmers for input factors and average prices received for products, in the years 1956-66, were used to estimate the net revenue for each unit of activity. It is assumed that all seed used to produce the crops was purchased. Prices of seed inputs and products, which are assumed to be the same in all areas, are presented in Table 3.

Yields Per Acre

The yields per acre vary between the different areas studied. The yields per acre of each crop in the different areas were computed by averaging the yields reported by farmers in those areas over the previous 10 years. Yields per acre in the different areas are presented in Table 4.

Land, Management, and Water Costs

Land, management, and water costs were not included in the

TABLE 3

AVERAGE PRICES RECEIVED BY IDAHO FARMERS FOR AGRICULTURAL PRODUCTS BETWEEN THE YEARS 1956 AND 1966[a], AND PRICES PAID BY FARMERS IN SOUTHERN IDAHO FOR SEED USED IN PRODUCING THOSE PRODUCTS[b]

	Input (seed)		Product	
	Price in Dollars	Unit	Price in Dollars	Unit
Potatoes	3.65	Hundredweight	1.30	Cwt.
Sugar Beets	.55	Pound	14.14	Ton
Beans	.09	Pound	7.05	Cwt.
Grain	.05	Pound	1.77	Bushel
Alfalfa Hay	.50	Pound	19.83	Ton
Peas	5.60	Cwt.	4.35	Cwt.

[a]Source: United States Bureau of the Census, Statistical Abstract of the United States 1958, 1960, 1962, 1964, 1966. (Washington: Government Printing Office). 1967.

[b]Source: From farmers own estimates and dealers in the areas studied.

TABLE 4

AVERAGE OUTPUT PER UNIT OF ACTIVITY IN EACH STUDY AREA IN SOUTHERN IDAHO AS REPORTED BY INTERVIEWED FARMERS IN 1964

Crop	Yield Per Acre Area I	Area II	Area III
Potatoes	250 hundredweight	246 hundredweight	246 hundredweight
Sugar Beets	25.7 tons	16.5 tons	16.5 tons
Grain	85 bushels	93 bushels	93 bushels
Alfalfa Hay	4.5 tons	5.0 tons	5.0 tons
Beans	2,425 pounds	2,042 pounds	2,042 pounds
Peas		33.3 hundredweight	33.3 hundredweight

computed enterprise budgets. Land costs were not included because it was impossible to get a true value of land in each area. Very few farms come on the market, and when they do, they are usually bought at excessive prices, more because of their strategic value or as an investment opportunity rather than their income producing capacity. Farmers would be willing to pay prices for land in excess of its real value if it were adjacent or close to farmers' own property, in order to turn this property into an economic sized unit.

Farm managers were usually the farm operators and did not allow themselves a fixed salary. Rather, they appropriated any residual after total farm costs had been paid. For this reason, managers' salaries are not included in budget costs.

Since the object of this study is to estimate the value of water in different situations, water is assumed to be delivered free at the headgate. The residual net revenue is then the amount that is available to pay management, land, and water costs.

Programming Restrictions

The only factors of production which restrict total output on each representative farm are acres of land and water supply. The extent to which any one crop can be produced on a farm is limited by rotation requirements. Some rotation pattern must be followed by each farmer in order to maintain soil fertility and productivity in the long run.

Potato production was the most profitable single enterprise in Areas II and III, but it rapidly depletes soil fertility, and for this and other reasons it may not be extended over the whole farm area. Specialization in the production of one crop would also cause weed and disease problems on a farm and would increase the chance of very large losses due to low prices or yields in some years. Production of one crop alone or a few crops with similar production patterns would make excessive demands on labor and machinery at certain periods of the year and leave resources idle for the remainder of the year. Therefore, in analyzing the data, restrictions are placed on the level of individual activities. Those restrictions are presented in the following chapter. Non-use of land is regarded as an activity for programming purposes.

The number of alternative activities which may be produced on the representative farms are those crops which were extensively produced in the area which each farm represents. Speciality crops, such as onion seed, returned large profits to those who grew them, but the demand for such crops is limited and they were not produced by sufficient numbers of farmers to warrant inclusion in the rotation. The major crops produced in each area and which are included in this study are presented in Table 5.

Water Requirements

The water requirements, or water coefficients, of each crop were computed from a study conducted by Jensen and Criddle.[6] The water requirements of each crop in each area are presented in Table 6.

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[6]Max C. Jensen and Wayne D. Criddle, Estimated Irrigation Water Requirements for Idaho (Bull. No. 291, Moscow, Idaho, Agr. Exper. Station, 1952), pp. 11, 12.

TABLE 5

MAJOR CROPS GROWN IN EACH STUDY AREA, EXPRESSED IN ACRES, AND AS A PERCENTAGE OF TOTAL CROPPED ACRES IN EACH AREA

	Area I[a]		Area II[a]		Area III[b]	
	Acres	% of Total Cropped Acres	Acres	% of Total Cropped Acres	Acres	As a % of Irrigated Acres
Potatoes	1517.00	21.80	1499.00	22.20	5864.00	3.40
S. Beets	2207.00	31.70	485.50	7.19	10736.00	6.25
Grain	1849.00	26.60	1890.00	28.00	37201.00	21.67
Beans	50.00	.70	840.10	12.44	54456.00	31.72
A. A. Hay	120.00	1.17	1411.00	20.90	57837.00	33.69
Peas	——	——	624.10	9.25	5569.00	3.24
Total	5743.00	81.97[c]	6749.70	99.98[c]	171663.00	99.97[c]

[a]Source: The figures for Area I and Area II were obtained from operators of the farms included in the study, for the years 1963 to 1966.

[b]Source: U. S. Bureau of the Census, Census of Agriculture 1964, "Statistics for the State and Counties, Idaho," (Washington, D. C., U. S. Government Printing Office 1967), pp. 286, 292, 298.

[c]The sum of the percentages in each column does not add to 100 because small quantities of crops not included in the table are produced.

TABLE 6

IRRIGATION WATER REQUIREMENTS, IN ACRE FEET, OF CROPS GROWN IN THREE STUDY AREAS[c]

	A. A. Hay		Potatoes		S. Beets		Grain		Beans		Peas	
	CU[a]	TIR[b]	CU	TIR	CU	TIR	CU	TIR	CU	TIR	CU	TIR
Area I	2.3	3.83	1.67	2.88	2.03	3.47	1.36	2.26	1.19	1.98	.85	1.42
Areas II and III	1.94	3.33	1.63	2.78	1.72	2.86	1.36	2.23	1.19	1.99	.86	1.37

[a]CU = Consumptive use, and is the amount of water used by the crop plus water lost through evaporation.

[b]TIR = Total irrigation water requirements and includes consumptive use plus application losses due to seepage. It is assumed that consumptive use equals 60 per cent of total irrigation water requirements. That is, irrigation efficiency is 60 per cent. It is assumed that all water necessary for crop production is provided by irrigation.

CHAPTER IV

ANALYSIS OF DATA

Three linear programming models were formulated as steps in attaining the objectives outlined. Structural changes are made from model to model in order to add greater realism to the analysis or to investigate some particular portion of the problem. The structure of each model and programming results shall be presented in the following sections.

Model I: With Fixed Water Supply

Three representative farms of equal size were developed, one for each study area. Each farm is restricted in size to 320 acres, all of which are irrigable. The crop enterprises for the three farms are given in Table 7.

TABLE 7

CROPS WHICH MAY BE GROWN ON THE REPRESENTATIVE FARM FOR EACH AREA IN MODEL I

Area I	Area II	Area III
Potatoes	Potatoes	Potatoes
Beets	Beets	Beets
Grain	Grain	Grain
Hay	Hay	Hay
	Peas	Peas
	Beans	Beans

All the possible crop enterprises in each area are required in the optimum solution. An upper and lower limit is placed on the level at which individual crop enterprises may be included on each farm. These limits were placed on the level of activities to meet rotation requirements. The lower limits in Area I are higher than in Areas II and III because the farms in Area I are more highly mechanized, and it would not be economical to handle small acreages with the type of machinery available. The levels at which each enterprise may be included in the farm programs are included in Table 1, Appendix A.

The linear programming matrix for Model I is presented in Table 1, Appendix B. The top or C row contains the net revenue per unit of activity. The second row contains the activities which may be conducted on each representative farm. The left hand column presents the program restrictions and rows of technical coefficients are included in the matrix body proper. The identity matrix is omitted.

The objective function of the model is net profit maximization for the three areas combined. The net revenue for each area can be computed from the linear programming solution by simple arithmetic. The solution also gives the marginal value product of water when total net revenue is at a maximum.

The net revenue per acre of crop enterprise for each study area has been presented in Table 2, Chapter III. The irrigation water requirements for acre of each crop enterprise can be found in Table 6, Chapter III.

The total quantity of water available for use on the three representative farms is 2,600 acre feet. It was calculated on the desk calculator that this would be the quantity of water required by those farms. The total quantity of water could be allocated in any proportion among the three areas.

Results from Model I

The unique solution to the combination of crop enterprises which maximize net revenue on the representative farms is presented in Table 8. This solution was calculated on the electric computer.

TABLE 8

OPTIMUM CROP COMBINATION AND TOTAL NET REVENUE ON EACH OF THE REPRESENTATIVE FARMS (320 ACRES)

Crop Enterprise	Farm (Area I) Acres	Farm (Area II) Acres	Farm (Area III) Acres
Potatoes	40	120.90	55
Beets	180	20	20
Grain	60	104.91	180
Hay	40	25	25
Beans	0	25	25
Peas	0	15	15
Net Revenue	$40,859.00	$28,007.60	$28,681.65

The marginal value product of water in this program is $14.82 per acre-foot. This value is common for the three areas, because the assumption was that irrigation water could be transferred between the areas according to the most economically beneficial use.

It should be remembered that included in this value are the fixed rewards to the input factors land and management. The net revenue on the farm representative of Area I was considerably larger than on the other two farms as is shown in Table 11. This indicates that if water supply was less than adequate to meet the demands of all three areas, farmer's net revenue and returns to water would be maximized by supplying Area I with water prior to Area II or III.

Stability of the Solution

The stability of this solution may be evaluated by examining the variation in the price of individual crops which may occur before a change in the optimum solution takes place. The price of only one crop at a time is allowed to vary and all other prices are constant. The range over which prices may vary before the solution becomes sub-optimum is presented in Table 9. The price ranges are obtained from the program solution in two steps:

1. The range over which net revenue for individual activities may vary is calculated first;
2. The change in the price per unit of output necessary to cause those changes in net revenue for each activity is calculated.

Interpretation

The figure $ .134 at the top of column 7 in Table 9 means that if the price of 1 hundredweight of potatoes increased by $ .134, potato production would be increased on the farm representative of Area I. The figure $ .07 at the top of column 8 means that potato production would decrease in Area II if the price per hundredweight of potatoes decreased by $ .07.

TABLE 9

RANGE IN DOLLARS OVER WHICH PRICE PER UNIT OF OUTPUT MAY VARY BEFORE THE SOLUTION BECOMES SUB-OPTIMUM

Activity	Programmed Net Revenue	Programmed Price Per Unit of Output		Net Revenue Limits Within Which Solution is Optimum		Price Change Per Unit of Output	
		Price	Unit	High	Low	Increase	Decrease
Potatoes							
Area I	74.33	1.30	Cwt.	107.8	*	.134	--
Area II	104.52	1.30	Cwt.	111.35	97.96	.028	.027
Area III	104.52	1.30	Cwt.	111.08	87.003	.027	.07
Beets							
Area I	173.7	14.14	Ton	*	116.54	--	2.22
Area II	58.35	14.14	Ton	105.70	*	2.87	--
Area III	59.65	14.14	Ton	105.70	*	2.79	--
Beans							
Area II	70.32	7.05	Cwt.	92.81	*	1.2	--
Area III	63.63	7.05	Cwt.	92.81	*	1.43	--
Grain							
Area I	98.61	1.77	Bushel	155.77	65.14	.67	.39
Area II	96.37	1.77	Bushel	102.93	89.54	.07	.07
Area III	102.93	1.77	Bushel	*	96.37	--	.07
Hay							
Area I	17.58	19.83	Ton	121.87	*	23.18	--
Area II	15.35	19.83	Ton	112.67	*	19.46	--
Area III	25.21	19.83	Ton	112.67	*	17.49	--
Peas							
Area II	66.11	4.35	Cwt.	83.63	*	.52	--
Area III	66.11	4.35	Cwt.	83.63	*	.52	--

*No Limit.

--The original solution is not affected.

Model II: With Variable Water Resource

The objective of this model is to determine the marginal value product of different quantities of water on farms of equal size in each of the study areas. In this model the marginal value product includes returns to water land and management.

Total acreage per farm, activities which may be conducted on each farm, water requirements per unit of activity and net revenue per unit of activity are the same as in Model I.

The water supply is assumed to be variable in this model, that is, that each farm can use as much water as the crop enterprises require for the optimum solution. Water is still considered a scarce resource, but the difference between this model and Model I is that all optimum plans can be determined as the supply of water varies from zero to an amount sufficient to satisfy the requirements for the crop enterprises in the optimum solution. Each step in the continuous solution reveals the opportunity cost of water in alternative uses among the crop enterprises.

The rotation restrictions are given in Table 10. The difference

TABLE 10

UPPER AND LOWER LIMITS IN ACRES OF THE LEVEL OF EACH ACTIVITY IN MODEL II

	Area I		Area II		Area III	
Activity	U.L.[a]	L.L.[b]	U.L.	L.L.	U.L.	L.L.
Potatoes	180	0	180	0	180	0
Beets	180	0	160	0	160	0
Beans	0	0	120	0	120	0
Grain	180	0	180	0	180	0
Hay	0	40	0	20	0	20
Peas	0	0	80	0	80	0

[a] Upper Limit.
[b] Lower Limit.

between the rotation restrictions in this model and Model I is that it is not necessary to include all possible activities in the optimum solution for each farm in Model II. Hay is the only activity which must be included on all farms in Model II. It seemed desirable to make this change because in practice many farmers in areas studied do not include all possible activities on their farms, and they can still maintain soil fertility and avoid disease and weed problems. However, all farmers do include hay in their rotations, and this model demands that a minimum quantity of hay be included in each farm program. The linear programming matrix for Model II is similar to the linear programming matrix for Model I in all aspects except water availability and rotation restrictions. Water supply is variable, and rotation restrictions are presented in tabular form in Table 10.

Program Results for Model II

The crop combination which maximizes net revenue on each of the three representative farms in Model II is presented in Table 11.

The net income is maximized in each area when water is available in unlimited amounts. The marginal value product of water listed in Table 11 is for Area I - $25.81; Area II - $14.82; and for Area III - $2.89. This means that if the water supply was slightly less than the water requirements listed in Table 11, then the farmer would be willing to pay the prices indicated by the marginal value products for an additional acre-foot of water.

The value of an additional acre-foot of water is not fixed for the three areas. The values depend upon the degree of water scarcity and

TABLE 11

OPTIMUM SOLUTION ON EACH REPRESENTATIVE FARM IN THE THREE AREAS WHEN WATER IS NOT A LIMITING FACTOR

Activity	Area I 320-Acre Farm	Area II 320-Acre Farm	Area III 320-Acre Farm
Potatoes	0	180	180
Beets	180	0	0
Grain	100	120	120
Beans	0	0	0
Hay	40	20	20
Net Income	$41,830.2	$30,685	$31,669.4
Water Requirements, acre-feet	1,003.8	834.6	834.6
Marginal Value Product of Water	$ 25.81	$ 14.82	$ 2.89

upon the crop enterprises of the areas. When the water supply is scarce, the marginal value product is high, and as the supply increases, the marginal value product decreases. The reason is that high valued crops are grown under scarcity situations, and as the supply increases, less profitable crops are grown.

The relationships of varying supply of water to the marginal value products in the three areas are shown in Table 12 on the following page.

TABLE 12

MARGINAL VALUE PRODUCT OF DIFFERENT QUANTITIES
OF WATER IN EACH AREA

Area	Quantity of Water Available (Acre Feet)	Marginal Value Product (Dollars Per Acre Foot)
I	0 - 624.6	50.10
	624.6 - 760.2	32.89
	760.2 - 1028.6	25.81
	1028.6 and Over	0
II	0 - 109.6	48.26
	109.6 - 511.0	43.22
	511.0 - 622.2	37.6
	622.2 - 735.0	27.24
	735.0 - 834.6	14.82
	834.6 and Over	0
III	0 - 109.6	48.26
	109.6 - 511.0	46.11
	511.0 - 622.0	37.6
	622.2 - 735.0	27.24
	735.0 - 834.6	2.89
	834.6 and Over	0

Model III: With Variable Water Resource

The objectives of this model are: 1) to determine how much operators of different sized farms can afford to pay for an acre-foot of water at different supply levels, and 2) to compare those results with the results obtained by Coffing in his study of the area.[7] From the data available for Areas II and III it was not possible to estimate the cost of producing each activity on farms of different sizes, and the two areas are therefore excluded from this model.

Farms in Area I were divided into three size groups and a representative farm constructed for each group. Those three farms which shall be identified as Farm I, Farm II, and Farm III were 320, 640, and 1,280 acres in size respectively. The only crops which may be grown on each farm are potatoes, beets, grain, and alfalfa hay. The rotation restrictions for this model are given in Table 13.

TABLE 13

UPPER AND LOWER LIMITS IN ACRES ON THE LEVEL OF EACH ACTIVITY ON THE THREE DIFFERENT SIZED FARMS OF MODEL III

Activity	Farm I (320 acres)		Farm II (640 acres)		Farm III (1280 acres)	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Potatoes	180	40	360	80	720	160
Beets	180	50	200	80	400	160
Grain	180	50	360	120	720	240
Hay	*	40	*	80	*	160

* No Limit.

[7]Arthur Lee Coffing, op. cit. pp. 88, 89.

The rotation restrictions for this model are similar to the rotation restrictions for Area I in Model I. The main difference is that the maximum beet acreage that may be included in the farm program is reduced from 180 acres to 100 acres on a 320 acre farm and the minimum beet acreage is decreased from 50 to 40 acres. Those changes were made because farmers in Area I expressed the opinion that the present high beet acreage may reduce the fertility of the soil. As farm size increases in this model, the rotation requirements increase in the same ratio. For example, a 640 acre farm may produce twice as much potatoes as a 320 acre farm.

The water requirements per acre of activity are: Potatoes - 2.88 acre-feet; Beets - 3.47 acre-feet; Grain - 2.66 acre-feet; Alfalfa hay - 3.83 acre-feet.

Net revenue per unit of activity on each farm in this model is the amount available to pay for water alone. The net revenue per unit of activity on different size farms in Area I as presented in Table 14 below

TABLE 14

NET REVENUE IN DOLLARS PER UNIT OF ACTIVITY ON DIFFERENT SIZED FARMS IN AREA I[a]

Activity	Farm I	Farm II	Farm III
Potatoes	42.89	45.49	55.57
Beets	121.98	123.03	124.42
Grain	16.00	17.23	16.85
Hay	26.11	26.11	26.11

[a]Source: Progress Report No. 112, University of Idaho Agricultural Experiment Station (Moscow, Idaho, 1966), pp. 22-24.

differs from the values presented in Table 2 for two reasons. These are:

1. Management and land costs are included in the production costs in computing Table 14, and

2. Prices per unit of output of grain and beets used in computing Table 14 are lower than the output prices used in computing Table 2.

The prices per unit of output used in estimating those net revenues are as follows: Potatoes, $1.30 per hundredweight; Beets, $13.60 per ton; Grain, $1.12 per bushel; Hay, $20.90 per ton. The results from this model may still be compared with previous results on an ordinal basis.

The linear programming matrix for Model III is presented in Table 2, Appendix B.

Program Results for Model III

The combination of enterprises which maximize net revenue on each farm, subject to the program restrictions, are given in Table 15. Also

TABLE 15

THE NUMBER OF ACRES OF EACH ACTIVITY, TOTAL WATER REQUIREMENTS IN ACRE-FEET, AND MARGINAL VALUE PRODUCT OF WATER ON FARMS OF DIFFERENT SIZES

Activity	Farm I	Farm II	Farm III
Beets	100	200	400
Potatoes	120	240	480
Grain	60	120	240
Hay	40		
Price Payable for an Acre-foot of Water	6.82	6.82	6.82
Total Water Requirements	981.4	1962.8	3925.6

given in Table 15 are the quantities of water required and the amount farmers can afford to pay for water on each farm.

Because of rotation requirements, grain and hay were forced into the final solution in that order. Since hay production was the final activity entered in the program for all farms and it uses the final unit of water, it determines the price payable for the final unit of water on each farm. This price of $6.82 per acre-foot was the same on all farms.

If it were not compulsory to include grain and hay in the farm programs, beets and potatoes alone would be produced. Beets being the single most profitable enterprise would be produced on all farms up to the maximum levels allowed by the programming restrictions. If beets were the only activity conducted on each farm, the price which farmers could pay for water would be: $35.15 on Farm I; $35.46 on Farm II; and $35.86 on Farm III.

Potatoes would be the next activity included in the farm programs, and the price payable per acre-foot of water on each farm would be: $14.89 on Farm I; $15.80 on Farm II; and $19.30 on Farm III. If additional amounts of water were available, net revenue would be maximized by including grain in the farm programs. The price payable for water would then be $7.08, $7.62, and $7.46 on Farms I, II, and III respectively.

From the preceding discussion it can be seen that as the quantity of water used per farm increases initially, the price which farmers can afford to pay for water decreases. This is due to the fact that there is a limit to the quantities of the most profitable crops which may be produced; and, therefore, less profitable crops must be included in each farm program. The price payable for different quantities of water on each farm is presented in Table 16 on the following page.

The average prices which farmers can afford to pay for the total amount of water used on each farm are: $19.71 per acre-foot on Farm I; $20.22 per acre-foot on Farm II; and $21.57 per acre-foot on Farm III. This indicates that as farm size increases, the price which farmers can afford to pay for an acre-foot of water increases.

Those average prices are close to the results obtained by Coffing in his study, and do not add anything new to his results with respect to economies of size. However, they do show that the results obtained by Coffing are the average price which farmers can afford to pay for the total amount of water used on farms of different sizes and not the price which may be paid for incremental units of water.

TABLE 16

MARGINAL VALUE PRODUCT OF DIFFERENT QUANTITIES OF WATER AND AVERAGE MARGINAL VALUE PER ACRE-FOOT OF WATER ON DIFFERENT SIZED FARMS IN AREA I

	Quantity of Water Used	Marginal Value Product Per Acre-Foot in Dollars	Average Marginal Value Product Per Acre-Foot in Dollars	Average[a] Marginal Value Product of Water
Farm I	0 - 347.0	35.15		
	347 - 692.6	14.89		
	692.6 - 828.2	7.08		
	828.2 - 981.4	6.82		
	981.4 and over	0	19.71	16.64
Farm II	0 - 694.0	35.46		
	694.0 - 1385.2	15.8		
	1385.2 - 1656.4	7.62		
	1656.4 - 1962.8	6.82		
	1962.8 and over		20.22	17.03
Farm III	0 - 1388.0	35.86		
	1388.0 - 2770.4	19.3		
	2770.4 - 3312.8	7.46		
	3312.8 - 3925.6	6.82		
	3925.6 and over		21.57	18.48

[a]Determined by Coffing. Progress Report No. 112, University of Idaho Agricultural Experimental Station (Moscow, Idaho, 1966), pp. 22-24.

CHAPTER V

SUMMARY AND CONCLUSIONS

The study was undertaken in order to determine the marginal value product of water in alternative uses within agriculture in Southern Idaho. The results may be a guide so that water allocation bodies may be able to decide how much of Idaho's total water supply should be allocated to irrigation uses, and how this irrigation water may be distributed among its various uses.

Three irrigation areas in Southern Idaho were chosen for analysis purposes. These three areas which may be identified as Area I, Area II, and Area III, are situated along the Snake River valley. In these areas crop production, by use of irrigation water, is the major source of income.

The cost of producing different crops in each area was obtained from earlier studies conducted in the same areas. Those farms in Areas I and II which had been included in earlier studies were visited by the author and the farm operator interviewed. The purpose of those interviews was to supplement already available data and to determine representative resource supply situations for each area. Three representative farms were developed for Area I, and one each for Areas II and III. The representative farms for Areas II and III were each 320 acres in size. The size of the representative farms for Area I were 320, 640, and 1280 acres.

The objective of the study was to determine the marginal value product of water in each area. Three linear programming models were constructed to obtain the objective of the study. For each model water was treated as a limiting resource. There were two additional groups of restrictions--total acreage and rotation requirements on each farm. Labor, management, and capital supply were assumed adequate.

RESULTS

In Model I a fixed quantity of water, 2,600 acre-feet, was available for the three farms and could be transferred between areas according to the most economically beneficial use. This quantity of water which was just adequate to permit the optimum production program on each farm was arrived at by trial and error. The marginal value product of an acre foot of water in this model was $14.82.

Model II was constructed in order to determine the marginal value product of different quantities of water in each of the study areas subject to the restrictions of the model. The results of this model indicate that the value of water in each area is as follows: Area I - $25.81 per acre-foot; Area II - $14.82 per acre-foot; Area III - $2.89 per acre-foot. Those values are the amounts operators of 320-acre farms could pay for the final unit of water in each area. The value of different quantities of water in Area I varies from $50.10 to zero. The value of the initial quantity of water is high because profitable crops can be grown. As the quantity of water increases, less profitable crops must be included in the rotation; and, therefore, the marginal value product of water declines. The value of water varies from $48.26 to zero in Area II and from $46.11 to zero in Area III. The marginal value product of water obtained in Models I and II includes fixed returns to land and management.

Model III was designed to determine the amount payable for water on different sized farms in Area I. In this model the net revenue per unit of activity is the returns to water alone. The price which farmers would be willing to pay for the final unit of water on all farms was the same at $6.82. The average price per acre-foot of water on each farm was as follows: on a 320 acre farm, $19.71 per acre foot; $20.22 per acre foot on 640-acre farms; and $21.57 per acre foot on 1280-acre farms.

CONCLUSIONS

The value of water is greatest in Area I, and its value is greater in Area II than in Area III. Therefore, greater economic benefits are derived from a limited supply of irrigation water if it is used in Area I rather than in Areas II or III. The price farmers can afford to pay for water increases as farm size increases.

Results of Model III are based on a small number of farms, and it may be useful to do a similar study of Area I including a greater number of sample farms of all sizes. Such a study could also be expanded to include such activities as onion-seed production, and hay-seed production which are acquiring a more prominent position in farm programs in this area.

BIBLIOGRAPHY

Alternatives in Water Management (Publication No. 1408, Washington D.C.: National Academy of Sciences, National Research Council, 1966), p. 26.

Climate and Man Yearbook of Agriculture, 1941 (U. S. Department of Agriculture).

Arthur Lee Coffing, "The Relationship of Farm Size to Ability to Pay for Irrigation Water in the Dry Lake Area of Canyon County, Idaho" (Unpublished Master's Thesis, The University of Idaho, Moscow, Idaho, 1965).

Max C. Jensen and Wayne D. Criddle, *Estimated Irrigation Water Requirements for Idaho* (Bulletin No. 291, Moscow, Idaho: Idaho Agr. Experiment Station, 1952), pp. 11, 12.

United States Bureau of the Census, *Statistical Abstract of the United States* 1958, 1960, 1962, 1964, 1966. (Washington: Government Printing Office), 1967.

APPENDIX A

PRODUCTION COSTS, TOTAL REVENUE AND NET REVENUE FOR UNIT OF ACTIVITY IN AREAS II AND III

TABLE 1

AREA II
MINIDOKA PEAS

	Unit	Price Per Unit	Quantity	Value
Production:				
Peas	Cwt.	$ 4.35	33.30	$144.86
Inputs:				
Tractor	Hour	2.17	3.63	7.88
Implements	Hour	Varied	3.63	5.80
Labor	Hour	1.50	5.75	8.63
Harvesting		10.00	1.00	10.00
Hauling				.99
Seed	Lbs.	0.056 ~~5.60~~	225.00	12.60
Fertilizer	Lbs.	.04	245.00	9.44
Spraying	Acre	4.50	1.00	4.50
Farm Supplies and Travel				5.00
Total Variable Costs				$64.84
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land and Building Taxes				6.00
Insurance and License				.56
Total Fixed Costs				$13.91
Total Cost				$78.75
Net Revenue				$66.11

TABLE 2

AREA II
POTATOES PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Potatoes	Cwt.	$ 1.30	246.00	$319.80
Inputs:				
Tractor	Hour	2.17	6.20	13.45
Implements	Hour	Varied	6.20	5.47
Labor	Hour	1.50	8.79	13.19
Spraying - Hired				2.75
Harvesting	Cwt.	0.25	246.00	61.50
Hauling to Cellar	Cwt.	0.07	246.00	17.22
Seed	Cwt.	3.65	14.10	51.46
Fertilizer	Lbs.	.05	560.00	30.98
Farm Supplies and Travel				5.00
Total Variable Costs				$201.52
Fixed Costs:				
Building Depreciation				1.71
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land & Building Taxes				6.00
Insurance				1.05
Total Fixed Costs				$ ~~8.76~~ 13.76
Total Cost				$215.28
Net Revenue				$104.52

TABLE 3

AREA II
SUGAR BEETS PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Sugar Beets	Ton	$ 14.14	16.50	$233.31
Inputs:				
Tractor	Hour	2.17	7.31	15.86
Implements	Hour		7.31	5.96
Labor	Hour	1.50	10.27	15.41
Hoeing and Thinning	Acre	29.00	1.00	29.~~10~~
Harvesting	Ton	2.50	16.50	41.25
Hauling	Ton	1.00	16.50	16.50
Seed	Lbs.	.55	7.00	3.85
Fertilizer	Lbs.	.05	587.00	31.11
Farm Supplies and Travel				5.00
Total Variable Costs				$163.94
Fixed Costs:				
Building Depreciation				1.71
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land and Building Taxes				3.75
Insurance				.56
Total Fixed Costs				$ 11.02
Total Cost				$174.96
Net Revenue				$ 58.35

TABLE 4

AREA II
ALFALFA HAY PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Alfalfa Hay	Ton	$ 19.83	5.00	$99.15
Inputs:				
Tractor	Hour	2.17	5.66	12.28
Implements	Hour	Varied	5.66	8.99
Stacking and Hauling	Bales	.10	165.00	16.50
Total Labor	Hour	1.50	8.50	12.75
Seed	Lbs.	.50	12.00	6.00
Fertilizer	Lbs.	.04	200.00	8.87
Insecticide	Hired			1.50
Farm Supplies and Travel				5.00
Total Variable Costs				$71.89
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land and Building Taxes				3.75
Insurance				.81
Total Fixed Costs				$11.91
Total Costs				$83.80
Net Revenue				$15.35

TABLE 5

AREA II
WHEAT PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Wheat	Bushel	$ 1.77	93.00	$164.61
Inputs:				
Tractor	Hour	2.17	3.04	6.60
Implements	Hour	Varied	3.04	2.61
Labor	Hour	1.50	6.28	9.42
Spray				2.50
Combine				7.00
Haul				1.97
Seed	Lbs.	.05	110.00	5.50
Fertilizer	Lbs.	.086	160.00	13.73
Farm Supplies and Travel				5.00
Total Variable Costs				$54.33
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land and Building Taxes				6.00
Insurance and License				.56
Total Fixed Costs				$13.91
Total Costs				$68.24
Net Revenue				$96.37

TABLE 6

AREA II
BEANS PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Beans	Cwt.	$ 7.05	20.42	$143.96
Inputs:				
Tractor	Hour	2.17	6.10	13.25
Labor	Hour	1.50	8.83	13.25
Implements		Varied	6.10	5.80
Harvesting	Acre	10.00	1.00	10.00
Haul				.80
Hoeing	Hour	1.50	1.76	2.63
Farm Supplies and Travel				5.00
Seed	Lbs.	~~9.00~~ 0.09	100.00	9.00
Total Variable Costs				$59.73
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land and Building Taxes				6.00
Insurance and License				.56
Total Fixed Costs				$13.91
Total Costs				$73.64
Net Revenue				$70.32

TABLE 7

AREA III
POTATOES PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Potatoes	Cwt.	$ 1.30	246.00	$319.80
Inputs:				
Tractor	Hour	2.17	6.20	13.45
Implements	Hour	Varied	6.20	5.97
Labor	Hour	1.50	8.79	13.19
Spraying - Hired				2.75
Harvesting	Cwt.	.25	246.00	61.50
Hauling to Cellar	Cwt.	.07	246.00	17.22
Seed	Cwt.	3.65	14.10	51.46
Fertilizer	Lbs.	.05	589.00	30.98
Farm Supplies and Travel				5.00
Total Variable Costs				$201.52
Fixed Costs:				
Building Depreciation				1.71
Irrigation Equipment Repairs, Depreciation, Taxes and Interest				5.00
Lands and Building Taxes				6.00
Insurance				1.05
Total Fixed Costs				$ 13.76
Total Costs				$215.28
Net Revenue				$104.52

TABLE 8

AREA III
WHEAT PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Wheat	Bushel	$ 1.77	93.00	$164.61
Inputs:				
Tractor	Hour	2.17	2.32	5.05
Implements	Hour	Varied	2.32	2.09
Labor	Hour	1.50	4.57	6.86
Combine Hire	Acre	7.00	1.00	7.00
Haul				4.65
Farm Supplies and Travel				5.00
Seed	Lbs.	.05	110.00	5.50
Fertilizer	Lbs.	.05	160.00	9.12
Spraying Hire	Acre			2.50
Total Variable Costs				$47.77
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment, Repairs and Interest				5.00
Land and Building Taxes				6.00
Insurance and License				.56
Total Fixed Costs				$ 13.91
Total Costs				$ 61.68
Net Revenue				$ 102.93

TABLE 9

AREA III
SUGAR BEETS PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Sugar Beets	Ton	$ 14.14	16.50	$233.31
Inputs:				
Tractor	Hour	2.17	8.58	18.63
Implements	Hour	Varied	8.58	6.51
Labor	Hour	1.50	12.63	18.95
Hoeing and Thinning	Acre	29.00	1.00	29.00
Harvesting	Ton	2.50	16.50	41.25
Hauling	Ton	1.00	16.50	16.50
Seed	Lbs.	.55	7.00	3.85
Fertilizer	Lbs.	.05	500.00	22.95
Farm Supplies and Travel				5.00
Total Variable Costs				$162.64
Fixed Costs:				
Building Depreciation				1.71
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land and Building Taxes				3.75
Insurance				.56
Total Fixed Costs				$ 11.02
Total Costs				$173.66
Net Revenue				$ 59.65

TABLE 10

AREA III
BEANS PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Beans	Cwt.	$ 7.05	20.42	$143.96
Inputs:				
Tractor	Hour	2.17	8.15	17.70
Labor	Hour	1.50	11.49	17.24
Implements	Hour	Varied	8.15	5.78
Combine	Acre	10.00	1.00	10.00
Haul				1.70
Farm Supplies and Travel				5.00
Seed	Lbs.	.09	100.00	9.00
Total Variable Costs				$66.42
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment Repairs and Interest				5.00
Land and Building Taxes				6.00
Insurance and License				.56
Total Fixed Costs				$13.91
Total Costs				$80.33
Net Revenue				$63.63

TABLE 11

AREA III
ALFALFA PER ACRE

	Unit	Price Per Unit	Quantity	Value
Output:				
Hay	Ton	$ 19.83	5.00	$99.15
Inputs:				
Tractor	Hour	2.17	4.42	9.60
Implements	Hour	Varied	4.42	7.13
Stacking and Handling	Bale	.10	165.00	16.50
Total Labor	Hour	1.50	6.04	9.06
Seed	Lbs.	.50	12.00	6.00
Fertilizer	Lbs.	.04	178.00	7.24
Spraying - Hired				1.50
Farm Supplies and Travel				5.00
Total Variable Costs				$62.03
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment Depreciation and Interest				5.00
Land and Building Taxes				3.75
Insurance				.81
Total Fixed Costs				$11.91
Total Costs				$73.94
Net Revenue				$25.21

TABLE 12

AREA III
PEAS PER ACRE

	Unit	Price Per Unit	Quantity	Value
Production:				
Peas	Cwt.	$ 4.35	33.30	$144.86
Inputs:				
Tractor	Hour	2.17	3.63	7.88
Implements	Hour	Varied	3.63	5.80
Labor	Hour	1.50	5.75	8.63
Harvesting		10.00	1.00	10.00
Hauling				.99
Seed	Lbs.	0.056 ~~5.60~~	225.00	12.60
Fertilizer	Lbs.	.04	245.00	9.44
Spraying	Acre	4.50	1.00	4.50
Farm Supplies and Travel				5.00
Total Variable Costs				$64.84
Fixed Costs:				
Building Depreciation				2.35
Irrigation Equipment Depreciation, Repairs and Interest				5.00
Land and Building Taxes				6.00
Insurance and License				.56
Total Fixed Costs				$13.91
Total Costs				$78.75
Net Revenue				$66.11

APPENDIX B

LINEAR PROGRAMMING CODE AND MATRIX

TABLE 1

LINEAR PROGRAMMING MATRIX FOR MODEL I. THE IDENTITY MATRIX IS OMITTED.

C. Activities / Restrictions	74.33 Potatoes A_1	104.52 Potatoes A_2	104.52 Potatoes A_3	173.7 Beets A_1	58.35 Beets A_2	59.65 Beets A_3	70.32 Beans A_2	63.63 Beans A_3	98.61 Grain A_1	96.37 Grain A_2	102.93 Grain A_3	17.58 Hay A_1	15.35 Hay A_2	25.21 Hay A_3	66.11 Peas A_2	66.11 Peas A_3
Total Land $A_1=320$	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0
Total Land $A_2=320$	0	1	0	0	1	0	1	0	0	1	0	0	1	0	1	0
Total Land $A_3=320$	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0	1
Total Water = 2600	2.88	2.78	2.78	3.47	2.86	2.86	1.99	1.99	2.26	2.23	2.23	3.83	3.33	3.33	1.37	1.37
Potato Land $A_1<180$	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potato Land $A_1>40$	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potato Land $A_2<180$	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potato Land $A_2>25$	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potato Land $A_3<180$	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Potato Land $A_3>25$	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Beet Land $A_1<180$	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Beet Land $A_1>50$	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Beet Land $A_2<160$	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Beet Land $A_2>20$	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Beet Land $A_3<160$	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Beet Land $A_3>20$	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Bean Land $A_2<120$	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Bean Land $A_2>25$	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Bean Land $A_3<120$	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Bean Land $A_3>25$	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Grain Land $A_1<180$	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Grain Land $A_1>50$	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Grain Land $A_2<180$	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Grain Land $A_2>30$	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

TABLE 1 (Continued)

LINEAR PROGRAMMING MATRIX FOR MODEL I. THE IDENTITY MATRIX IS OMITTED.

C. Activities / Restrictions		74.33 Potatoes A_1	104.52 Potatoes A_2	104.52 Potatoes A_3	173.7 Beets A_1	58.35 Beets A_2	59.65 Beets A_3	70.32 Beans A_2	63.63 Beans A_3	98.61 Grain A_1	96.37 Grain A_2	10293 Grain A_3	17.58 Hay A_1	15.35 Hay A_2	25.21 Hay A_3	66.11 Peas A_2	66.11 Peas A_3
Grain Land	$A_3 < 180$	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Grain Land	$A_3 > 30$	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hay Land	$A_1 > 40$	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hay Land	$A_2 > 25$	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Hay Land	$A_3 > 25$	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Pea Land	$A_2 < 80$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pea Land	$A_2 > 15$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pea Land	$A_3 < 80$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pea Land	$A_3 > 15$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

LINEAR PROGRAMMING CODE FOR MODEL I

A_1 = Area I

A_2 = Area II

A_3 = Area III

Activities: There are 16 possible activities described as follows:

Potatoes A_1 = Potatoe Production Activity in Area I.

Potatoes A_2 = Potatoe Production Activity in Area II.

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Peas A_3 = Pea Production Activity in Area III.

C Row: The figures in this row are the net revenues, in dollars, per unit of activity.

Restrictions:

Total land A_1 = the number of acres in the representative farm for Area I.

Total land A_2 = the number of acres in the representative farm for Area II.

Total land A_3 = the number of acres in the representative farm for Area III.

Total water = this is the total amount of water available on the three farms.

There are two limits on the level of each activity, except hay, an upper and a lower limit. Those restrictions are included to satisfy rotation requirements. By including a positive coefficient on the appropriate row of the identity matrix, it can be assured that the upper limit will not be exceeded. A negative coefficient on the appropriate row of the identity matrix ensures that a minimum of each activity is included. There is only a lower limit of the number of acres of hay which may be included on each farm.

Potato land $A_1 < 180$ = The maximum number of acres of potatoes which may be included in Area I is 180.

Potato land $A_1 > 40$ = At least 40 acres of potatoes must be grown on the representative farm for Area I.

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Pea Land $A_3 < 80$ = The number of acres of peas grown on the representative farm for Area III may not exceed 80.

Pea Land $A_3 > 15$ = At least 15 acres of peas must be grown in Area III.

TABLE 2

LINEAR PROGRAMMING MATRIX FOR MODEL III. THE IDENTITY MATRIX IS OMITTED.

C. Activity Restrictions		42.89 Potatoes F_1	121.98 Beets F_1	16 Grain F_1	26.11 Hay F_1	45.49 Potatoes F_2	123.03 Beets F_2	17.23 Grain F_2	26.11 Hay F_2	55.57 Potatoes F_3	124.42 Beets F_3	16.85 Grain F_3	26.11 Hay F_3
Total Land	$F_1 = 320$	1	1	1	1	0	0	0	0	0	0	0	0
Total Land	$F_2 = 640$	0	0	0	0	1	1	1	1	0	0	0	0
Total Land	$F_3 = 1280$	0	0	0	0	0	0	0	0	1	1	1	1
Total Water	0	2.88	3.47	2.66	3.83	2.88	3.47	2.66	3.83	2.88	3.47	2.66	3.83
Potato Land	$F_1 < 180$	1	0	0	0	0	0	0	0	0	0	0	0
Potato Land	$F_1 > 40$	1	0	0	0	0	0	0	0	0	0	0	0
Beets Land	$F_1 < 100$	0	1	0	0	0	0	0	0	0	0	0	0
Beets Land	$F_1 > 40$	0	1	0	0	0	0	0	0	0	0	0	0
Grain Land	$F_1 < 180$	0	0	1	0	0	0	0	0	0	0	0	0
Grain Land	$F_1 > 60$	0	0	1	0	0	0	0	0	0	0	0	0
Hay Land	$F_1 > 40$	0	0	0	1	0	0	0	0	0	0	0	0
Potato Land	$F_2 < 360$	0	0	0	0	1	0	0	0	0	0	0	0
Potato Land	$F_2 > 80$	0	0	0	0	1	0	0	0	0	0	0	0
Beets Land	$F_2 < 200$	0	0	0	0	0	1	0	0	0	0	0	0
Beets Land	$F_2 > 80$	0	0	0	0	0	1	0	0	0	0	0	0
Grain Land	$F_2 < 360$	0	0	0	0	0	0	1	0	0	0	0	0
Grain Land	$F_2 > 120$	0	0	0	0	0	0	1	0	0	0	0	0
Hay Land	$F_2 > 80$	0	0	0	0	0	0	0	1	0	0	0	0
Potato Land	$F_3 < 720$	0	0	0	0	0	0	0	0	1	0	0	0
Potato Land	$F_3 > 160$	0	0	0	0	0	0	0	0	1	0	0	0
Beet Land	$F_3 < 400$	0	0	0	0	0	0	0	0	0	1	0	0
Beet Land	$F_3 > 160$	0	0	0	0	0	0	0	0	0	1	0	0
Grain Land	$F_3 < 720$	0	0	0	0	0	0	0	0	0	0	1	0
Grain Land	$F_3 > 240$	0	0	0	0	0	0	0	0	0	0	1	0
Hay Land	$F_3 > 160$	0	0	0	0	0	0	0	0	0	0	0	1

LINEAR PROGRAMMING CODE FOR MODEL III

C Row:

The figures in the C row are the net revenues, in dollars, or returns to water alone, for the activities immediately under them.

Activities:

There are a total of 12 activities.

Potatoes F_1 = Potato production on Farm I.

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Hay F_3 = Hay production on Farm III.

Restrictions:

Total land F_1 320 = the number of acres in Farm I is 320.

Total land F_2 640 = there are 640 acres in Farm II.

Total land F_3 1280 = there are 1280 acres in Farm III.

Water supply is permitted to vary in order to determine the value of water under alternative supply situations.

The restrictions on the number of acres of one crop which may be grown on one farm are rotation restrictions. There is an upper and lower limit on the level of all activities except hay. There is only a lower limit on the amount of hay which must be included.

Potato land $F_1 < 180$ = Not more than 180 acres of potatoes may be produced on Farm I.

Potato Land $F_1 > 40$ = At least 40 acres of potatoes must be produced on Farm I.

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Hay Land $F_3 > 160$ = At least 160 acres of hay must be produced on Farm III.