Economic applications of soil survey data in irrigated areas
by John P Doll

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Economics
Montana State University

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Part I introduces the problem and outlines the general methodological procedure to be used. It also notes emperical data sources and their use in this study.

Part II defines the economic requirements which the yield estimates must meet if they are to be of maximum benefit to the farmer in his efforts to maximize net farm income. Also, this section of the study is concluded by a statement of the hypothesis.

Part III contains a description of the budget of a farm which represents the "typical" farm of the sample of farms studied.

Part IV is divided into two sections. First is a description of the procedure used to develop the soil survey information. Second, the soil survey information is listed as it might appear in a soil survey report.

Part V contains an analysis of the problem which is accomplished by substituting yield estimates from the soil productivity chart in the budget of the "typical" farm. The budget method permits the analysis of three types of alternatives (enterprise, resource, and practice alternatives).

Part VI contains the conclusions and implications drawn from this study.

ECONOMIC APPLICATIONS OF SOIL SURVEY DATA IN IRRIGATED AREAS

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Approved:

Head, Major Department

Chairman, Examining Committee

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John P. Doll
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ABSTRACT

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PART I - INTRODUCTION

The Purpose of Soil Survey

Soil scientists often refer to the soil survey as the connecting link between the farm and agricultural research. 1/ This means that the soil survey is not an end in itself but is a means to an end. For instance, as the "connecting link" the soil survey should play a significant role in the farmer's effort to maximize net farm income. Further, the soil survey should be a tool usable by all agricultural researchers as well as farmers. 2/

To be useful, the soil survey must be exact and easily interpreted. Unfortunately, as the science of soil classification has become more exact, it also became more esoteric. The highly technical nature of the survey now excludes interpretation by those not trained in the science. 3/

To facilitate the interpretation of soil survey maps by others, soil scientists now include in the soil survey reports: (1) a description of the physical characteristics of the soils included on the soil map, and (2) a productivity chart listing estimates of yields each soil is capable

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1/ This, however, is not the only use of the soil survey. For a discussion of the uses and purpose of soil survey (including the one listed above) see the U.S.D.A. Handbook No. 18, Soil Survey Manual, August, 1951, pp. 23-41 and 365-367.

2/ For a discussion of the usefulness of the soil survey by agricultural researchers not soil scientists see Huffman, R. E., Irrigation Development and Public Water Policy. The Ronald Press Co., New York, 1953, pp. 65-67; and Renne, R. R., Land Economics, Harper and Bros., New York, 1947, pp. 35-46.

3/ For a consideration of the weaknesses of land classification, including the soil survey, see Renne, R. R., op. cit., pp. 50-53.

of producing when subjected to specified systems of management. Historically, soil scientists have emphasized the former but in recent years the latter has gained in importance. In fact, the Soil Survey Manual says, "The fundamental purpose of a soil survey, like that of any other research, is to make predictions". 4/

The Problem

Stimulated by the increasing realization of the importance of the soil productivity chart, this study was initiated to: (1) test the reliability of the yield estimates of a soil productivity chart, and (2) assuming their reliability, test the usefulness of those yield estimates to the farmer in his efforts to maximize net farm income.

It is hoped that this study will, at least in part, reveal the reliability and usefulness of yield data sources used to synthesize soil productivity charts, and the criteria which the yield estimates must meet to be of most value to the farmer in his efforts to attain maximum net farm income. If weaknesses are found in the soil survey data, this study may suggest improvements and areas in which further research might prove most beneficial.

Methodological Procedure

The Huntley Irrigation Project, which was opened for settlement in 1907 by the Bureau of Reclamation, was picked as the site of this study.

4/ *Op. cit.*, p. 23.

The Project is located in the Yellowstone River Valley and extends about 30 miles downstream from Huntley, Montana, where it begins. The entire Project is situated in Yellowstone County of which Billings is the county seat.

The general methodological procedure of this study is to: (1) develop a soil productivity chart for the Huntley Project, utilizing all available sources of yield data, and test the reliability of that data by analyzing the original data sources; (2) formulate a farm budget describing a farm typical of the area; and (3) substitute yield estimates from the productivity chart into the farm budget to test their usefulness (assuming their reliability) to the farmer where usefulness had been previously defined as the economic criteria which the data must meet if it is to improve the ability of the farmer to maximize net farm income.

Data Sources

Yield data used to formulate the soil productivity chart were obtained from direct interview of a sample of Project farms, from the Huntley Project water user's reports for the same sample of farms, and from the results of experiments carried out at the Huntley Branch Experiment Station.

Also obtained from the farmer interview and the Huntley Project water user's reports were data used to develop, along with additional secondary data, a budget of the "typical" farm.

PART II - THE FARMER'S ECONOMIC OBJECTIVES

It is generally assumed for studies in farm management that the farmer's economic objective is to maximize net farm income. While the motivation for maximization may result from many psychological or social forces which need not be analyzed in detail here, it may be provident to discuss some general objectives at this time.

The time period in which net farm income is maximized will vary with the conditions facing the farmer. When payments on debts come due, the farmer must maximize his immediate income in an effort to meet these obligations. Or, even when not faced by heavy indebtedness, the farmer must have an income of sufficient magnitude to adequately provide for his family and meet farm operating expenses, i.e., to avoid indebtedness which might hinder future efforts to maximize net farm income. Over a long time period, however, the objectives of the maximization of net farm income is, in addition to meeting yearly obligations, to assure family security, raise the family standard of living as high as possible, and attain other goals.

To obtain immediate income, the farmer must grow cash crops rather than forage and feed crops. Also, in the short run, he may be confronted with fixed factors of production which are inefficient or unadaptable to his present needs. Maximization of immediate net farm income can result in inefficient and exploitive resource use in terms of social welfare or long run productivity (to the farmer, however, this may be highly efficient use if his needs are met). The tenant with a short term lease is in a situation comparable to the indebted owner. In this case, however, the tenant attempts to maximize net farm income over the short run because his uncertain tenure does not guarantee him returns on long term practices.

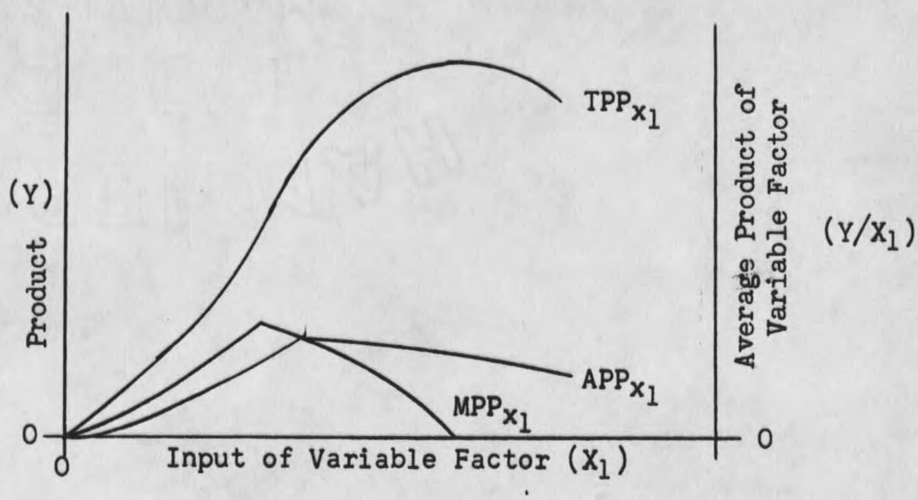
Over a long period of time, resource use leading to maximization of net farm income is different from resource use which will attain that goal in the short run. Because all factors of production become variable through time, the farmer is able to vary these factors to obtain the most efficient combination of productive factors. And, over long time periods of tenure, the farmer is able to obtain maximum benefit from the complementary and supplementary relationships involved in enterprise combinations. Thus, in the long run, the farmer must aim towards optimum resource allocation leading to maintenance and improvement of his farm's resources if he is to maximize net farm income.

For the present study, the livestock enterprise will be held constant as given in Part I. If the farmer has no debt or tenure problems, how can he maximize that portion of net farm income contributed by the cash crop enterprise?

Input - Output Relationships

Let us suppose, to begin with, that the farmer is interested in maximizing net income from a single enterprise on his farm. Further, let us assume that there is but one factor of production which is variable while all other factors of production are fixed or held constant throughout the production process. 5/ The input-output relationship (representing the total amount of product produced by varying quantities of the variable factor) may be expressed as follows: $X_1 = f(X_1 | X_2, X_3, ... X_n)$. This means that the total product (X) is a function of the variable factor (X_1) net of the fixed factors of production ($X_2, X_3, ... X_n$). This function is represented by the TPP_{X_1} curve in Figure I. While this total physical product (TPP_{X_1}) curve represents both increasing and decreasing returns as the input of the variable factor is increased, both do not necessarily need be present. For this production function to be valid, the inputs must be homogeneous,

Figure I. The Production Function[a]



[a] While it is desirable to portray the three functions (TPP_{X_1}, APP_{X_1}, MPP_{X_1}) on the same graph so their relationship can be shown, the three are not measured in the same units. Thus, the TPP_{X_1}, and MPP_{X_1} may be measured on the left ordinate (Y) while the APP_{X_1} is measured on the right ordinate (Y/X_1).

5/ This would be comparable, for instance, to an agronomical experiment which is designed to measure the effects of varying amounts of fertilizer (such as treble super phosphate) upon the yield of a crop (such as sugar beets).

the units of output must be homogeneous and the state of technology must be given. Finally, the production function is related to a specific period of time.

Two other relationships can be derived from the total physical product curve. They are the average physical product curve (APP_{X_1} in Figure I) and the marginal physical product curve (MPP_{X_1} in Figure I). The average physical product curve is obtained by dividing each level of total product by the amount of input needed to produce that product (TPP_{X_1}/no. of X_1). Since the production function in Figure I represents both increasing and decreasing returns, the APP_{X_1} curve rises and then declines. The marginal productivity curve represents the rate of change of the TPP_{X_1} curve. The marginal product refers to the increment in total product produced by each input. Thus, the marginal product of any given input is the increase in total product attributed to that input ($\Delta Y/\Delta X_1$). It can be noted in Figure I that when TPP_{X_1} is at a maximum, MPP_{X_1} is zero.

Given this input-output relationship, how much of the variable factor of production should the farmer use to maximize income from this enterprise? To determine the optimum amount of variable factor to use, value relationships must be used.

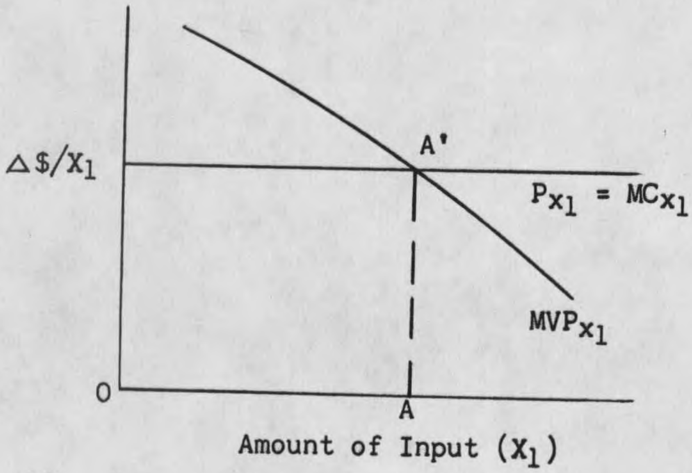
Since the farmer operates under a system of pure competition (at any time, he cannot sell enough product to influence the market price of that product) the price he receives for a product remains constant regardless of the amount of that product which he, as an individual producer, can raise. Thus, the physical production function can be converted to value terms when it is multiplied by the price of the product. When this is done, total physical product becomes total value of product, average physical product becomes average value of product, and marginal physical product becomes marginal value of product.

In general, the farmer also purchases variable inputs in a purely competitive market (if seed costs $2/bu., a farmer can purchase 2 or 2000 bushels of seed at that price). The cost of each unit of input is identical regardless of the total number of inputs used. To return to the marginal concept, the marginal cost of each unit of input is the increment in total cost when an additional unit of input is added. Under purely competitive conditions, the marginal cost equals the price of the input.

To maximize income from the enterprise, the farmer will increase output until the marginal cost of the factor of production equals the marginal value of product. That is, inputs will be added until the increment to total cost (caused by a unit of input) equals the increment to total revenue (produced by that unit of input). In purely competitive conditions, MC_{X_1} equals the price of X_1. Therefore, the farmer will equate P_{X_1} to MVP_{X_1}. This is demonstrated in Figure II. Since the $P_{X_1} = MVP_{X_1}$ at point A', O-A amount of input will be used.

Very seldom, if ever, does a production process involve only one variable factor of production. Usually, there are many variable factors involved in the production of any given product. However, when two or more variable factors of production are utilized in a production process, the same criteria are used to determine economic optima. Output is increased

Figure II. Income Maximization



to the point where the marginal cost of the productive factors equal the marginal value of product.

<u>Resource Substitution</u> 6/

Given the amount of product to be produced, how can the variable factors be combined to produce that product at minimum cost to the farmer? 7/ Let us suppose there are two variable factors of production (X_1 and X_2) and they are substitutable for each other in the production process. That is, various combinations of the two inputs may be used to produce a given amount of product. To determine which combination of factors will minimize production costs, another marginal concept must be utilized: the marginal rate of resource substitution (MRRS). This concept refers to the amount by which one input is decreased when another input is increased by one unit (while total production is held constant). In our example, the marginal

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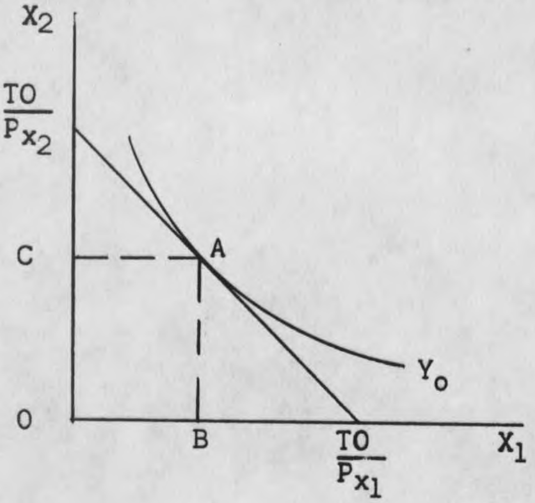
6/ For a more complete discussion of resource substitution and cost minimization, see Heady, Earl O., <u>Economics of Agricultural Production and Resource Use</u>, Prentice-Hall Inc., 1952, Chapters 5 and 6.

7/ Cost minimization as referred to here means that combination of variable factors used in the production of the given product which produces any given amount of product at less cost than any other combination of the same variable factors. This does not take into consideration fixed costs.

rate of substitution of X_1 for X_2 is expressed as the ratio $(\Delta X_2/\Delta X_1)$.

The various combinations of X_1 and X_2 which will produce Y_o amount of product is represented in Figure III by the iso-product curve Y_o. The marginal rate of resource substitution is represented by the slope of the iso-product curve Y_o.

Figure III. Cost Minimization



Value concepts must again be used to determine the minimum cost combination of the two inputs. If the total outlay (TO) available for the purchase of input factors is divided entirely to the purchase of either X_1 or X_2, amount (TO/P_{x_1}) of X_1 can be purchased or amount (TO/P_{x_2}) can be purchased when P_{x_1} is the price per unit of X_1 and P_{x_2} is the price per unit of X_2. If the points (TO/P_{x_1}) and (TO/P_{x_2}) are plotted on Figure III and connected, an iso-cost curve is determined which represents all possible combinations of the two inputs which can be purchased with the total outlay available. The slope of this iso-cost curve (for purely competitive resource markets) is expressed as the ratio (P_{x_1}/P_{x_2}).

The minimum cost combination of resources is obtained where the slope of the iso-product curve equals the slope of the iso-cost curve $(\Delta X_2/\Delta X_1 = P_{x_1}/P_{x_2})$. This is represented by point A of the model presented in Figure III denoting the use of OB amount of X_1 and OC amount of X_2. Costs will be reduced by using more of X_1 and less of X_2 if the price ratio is smaller than the MRRS of X_1 for X_2. The relationship is reversible, of course, and may call for the use of more X_2 and less X_1. 8/

Enterprise Combination 9/

Following the discussion of optimum resource combination within an enterprise, optimum enterprise combination should be considered. To maximize the contribution of the crop enterprise to total net farm income, in what relative amounts should the products of the farm be grown? There are four types of product (enterprise) relationships to be considered here: competitive, complementary, supplementary, and joint products.

Figure IV represents a competitive relationship between products Y_1 and Y_2. Distance OA represents the total amount of Y_2 which can be produced with the available amount of resources and OA' represents the total amount of Y_1 obtainable when the same resources are all allocated to the production

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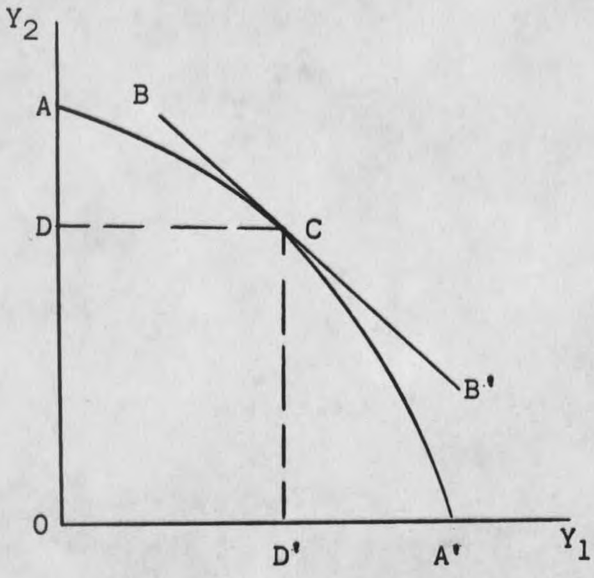
8/ The solutions for optima in resource combination have dealt with two variable resources which have been assumed to substitute for each other at diminishing marginal rates. This analysis may be extended to situations where the resources substitute at constant or increasing marginal rates although the latter situation can be shown to be economically irrelevant. Finally, when more than two variable inputs are utilized in the production process, the same criteria for economic optima are used. The inputs will be used in such quantities that: $MPP_{x_1}/P_{x_1} = MPP_{x_2}/P_{x_2} = ... = MPP_{x_n}/P_{x_n}$.

9/ The following discussion of enterprise combination is a brief outline of the problem. For a complete discussion, see Heady, Earl O., *op. cit.*, Chapters 7 and 8.

Figure IV. Competitive Enterprises



of Y_1. 10/ The curve AA' is an opportunity curve representing the various combinations of the two products which can be produced from the given amount of resources. The marginal rate of product substitution (MRPS) is represented by the slope of the transformation curve. Since the MRPS is increasing, the two products are competitive because unit increases in the production of one product can only be obtained by sacrificing increasing amounts of the other product.

To determine the amount of each product which should be produced, an iso-revenue curve indicating the price ratio of the two products must be used. The iso-revenue curve represents all possible combinations of the two products which will bring an equal amount of revenue to the farm. The slope of the iso-revenue curve is the price ratio (P_{Y_1}/P_{Y_2}) of the products sold in purely competitive markets. In Figure IV, BB' represents an iso-revenue curve.

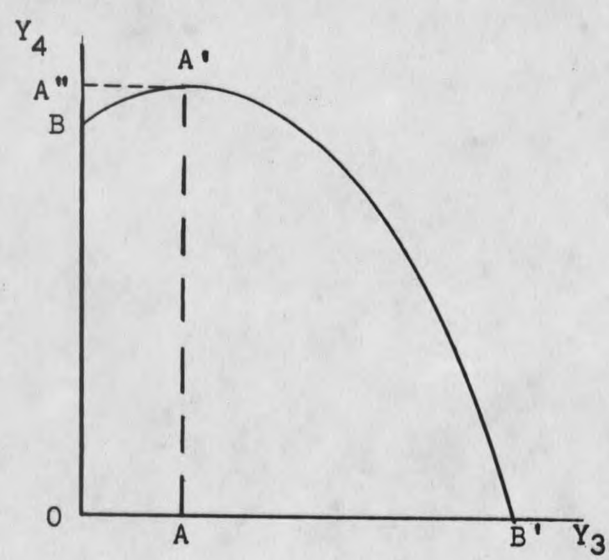
10/ The resources referred to here must be utilizable in the production of either product. Thus, resources not used in common by the two products are not considered in this analysis. The relative mobility of the inputs must also be considered by the farmer. Fixed factors of production will influence the use of the variable factors of production.

Optimum enterprise combination is achieved when the marginal rate of product substitution is inversely equal to the price ratio of the two products ($\Delta Y_2/\Delta Y_1 = P_{y_1}/P_{y_2}$). This is where the slopes of the two curves are equal (point C in Figure IV) and denotes the amounts of the two products to be produced (OD of Y_2 and OD' of Y_1).

In addition to increasing MRPS, competitive enterprises may have either constant or decreasing MRPS. However, because the same criteria may be used to reach economic optima in all cases, the latter phenomena need not be discussed in detail here.

A complementary relationship between two products (Y_3 and Y_4) is depicted in Figure V. The relationship is complementary because production of Y_4 is increased from OB to OA" when production of Y_3 is increased from O to OA. As production of Y_3 is increased beyond OA, the products become competitive.

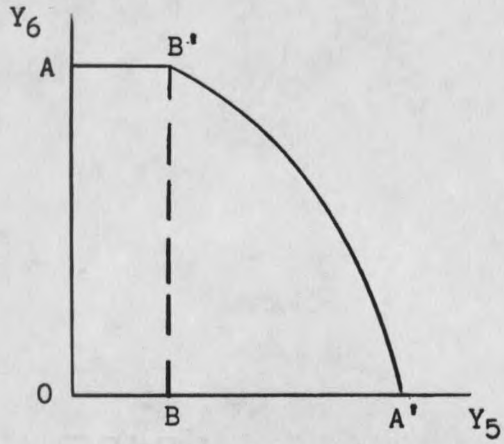
Figure V. Complementary Enterprises



Amount of OA of Y_3 will be produced even if the price of Y_3 is zero, for at that point (OA) maximum production of Y_4 is obtained from the given resources. When the two products become competitive in their use of resources, the quantities to be produced are determined (as described above) by equating the price ratio of the products inversely to the MRPS.

The opportunity curve AA' in Figure VI represents a supplementary relationship between two products (Y_5 and Y_6). The two products are supplementary because OB of Y_5 may be produced without decreasing the total amount of Y_6 (OA) which it is possible to produce when the given amount of resources are all allocated to the production of Y_6. In other words, the production of OB amount of Y_5 can be attained with zero opportunity costs (in terms of Y_6). Thus, OB of Y_5 will be produced even when the price of Y_5 is low (but greater than zero) relative to the price of Y_6. When production of Y_5 is increased beyond OB_1 the products become competitive and the amounts produced will be determined by the price and substitution ratios as described above.

Figure VI. Supplementary Enterprises



Joint products can only be produced in given proportions. There is no MRPS between them. In this case, the problem involves determining the optimum scale of operation rather than the optimum combination of the two products.

When considering the above relationships, it should be remembered that any two products may have differing relationships existing when different factors of production are considered. That is, a crop might be supplementary to another crop in terms of labor but the two might be competitive for a given amount of capital. When enterprise relationships are discussed, the factors of production involved in the relationships should be specified.

Allocation of Limited Resource Among Technical Units

A technical unit is a fixed factor of production within an enterprise. Depending upon the enterprise, a technical unit may be a cow, a laying hen, an acre of land, etc. 11/ When analyzing the cash crop enterprise of a farm, the technical unit involved is an acre of land. The problem is, given a limited amount of resource (for example, fertilizer), how should this resource be allotted to the various technical units within the enterprise to maximize returns from that resource? This problem arises because of a lack of homogeneity between technical units.

The elasticity of the production function of the technical units involved will determine the allocation of the resource among the units. If the production function has an elasticity greater than one (meaning the marginal product is increasing with the addition of each increment of resource), all of the resource will be allocated to the one technical unit. If the elasticity of the production function is one (constant marginal returns to each increment of resource) any allocation of the resources among the technical units will yield the same total product. Finally, if the elasticity of the production function is less than one (each increment of resource yields a smaller marginal product than the preceding increment), the resources will be allocated among the technical units in a manner which

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11/ Heady, Earl O., Ibid., p. 27.

will equalize the marginals products of those technical units ($MPP_{tu(1)} = MPP_{tu(2)} = \ldots = MPP_{tu(n)}$).

Resource Mobility

Fixed factors of production are involved in shortrun time periods. On the farm, these factors may be acres of land, tractors, buildings, etc. Since they must be used for long time periods, the purchase of these factors must be based upon the farmer's expectations of the future.

When purchasing fixed factors of production, the farmer may (1) build a specialized plant which is highly efficient in the production of one product or (2) may build a more versatile plant capable of producing two or more products. The second plant is more flexible than the first but is incapable of highly efficient production of any product. Conversely, while the first plant is highly efficient in the production of one product, it is also highly inefficient in the production of any other product.

The expected variation of the prices of the products will be the criterion on which the farmer bases his future planning decisions.

If he decides that prices of a given product will be steady in the future, he may choose to build the specialized plant. Thus, if the price of that product does remain constant or rise (relative to costs and other prices), the farmer will maximize net farm income from his productive factors. But if the farmer expects prices of (say) two given products to fluctuate widely in relation to each other, he will build a flexible plant which will enable him to produce either product. He will then be able to produce either crop, depending on which has the highest market value. When faced with price uncertainty, the flexible plant will return the maximum net farm income from the farmer's productive factors.

Once purchased, however, the physical plant becomes immobile. The presence of this fixed plant will influence the enterprise combination on the farm.

The Economic Requirements of the Soil Survey Data

The adaptability of the yield estimates to the economic criteria outlined above in this treatise will depend upon their reliability and scope. The reliability of the yield estimates may be tested by analyzing the data sources used in their formulation. And, assuming the yield estimates to be accurate, their scope may be tested by comparing them to the type of data the farmer needs if he is to maximize net farm income.

The scope the yield estimates must have to meet the economic criteria are: (1) for each crop grown on each soil, the production function for each input or combinations of inputs should be given; (2) for each production process, substitutability of inputs, if any, should be measured; and (3) to facilitate enterprise combination, competitive, complementary, and supplementary relationships between enterprises, if any, should be enumerated. 12/

The Hypothesis

The hypothesis as to the adaptability of the yield estimates presented

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12/ The above requirements apply only to those relationships which are within the field of soil science. Examples of this are fertilizer response, number of irrigations, comparisons of various rotations, etc.

in the soil productivity chart to the economic criteria is: while the yield estimates will not satisfy the "ideal" data requirements outlined by the economic theory, it will prove to be very useful to the farmer in his efforts to maximize net farm income.

PART III - THE FARM

Size

The sample studied consisted of 87 Project farms. Although 13 of these farms had dryland supplements, the size of the farm unit for purposes of this study, was measured by the number of irrigated acres in the unit. 13/ A grouping of the sample according to size is given in Table I. Since the Project was originally divided into 40 acre tracts, most farm acreages occurred in multiples of 40.

Table I. Characteristics of Sample Groupings

Group	No. of farms in group	Ave. no. of irrigated acres in group	Mode (acres) of group
0- 80	27	70.5	80
81-160	37	128.4	120
161-240	11	196.1	200
241-320	8	275.6	-
321-400	3	363.3	-
401-480	1	440	440

The most frequently occurring group of farms in the sample (the 81-160 acre group) had an average of 128.4 acres and a mode of 120 acres.

13/ For a discussion of the integration of dryland and irrigated areas see Ward, Ralph E. and Kelso, M. M., Irrigation Farmers Reach Out Into the Dry Land, Bulletin 464, Montana State College Agricultural Experiment Staion, Bozeman, Montana, September, 1949.

Therefore, a 120 acre farm unit was selected as the representative farm size to be used in this study.

The Crop Organization

The budget of crop production is presented in Table II. The acreage devoted to each crop was calculated, by use of percentages, from the acreage each crop occupied on the farms included in the sample. Since the farm has 8.6 acres of beans, 11.6 acres of spring wheat, and 25.0 acres of sugar beets, a total of 45.2 acres are devoted to the cash crop organization.

The yield figures used are the average of the yields found on the farms of the sample for the 1953 seasons.

Table II. Budget of Crop Production

Crop	Acres	Y/A	Total	Crop Disposition			
				Feed	Sale	Price [a]	Gross
Alfalfa (tons)	27.6	2.7	75	72.5	--	--	--
Beans (cwt.)	8.6	18.5	159	--	159	$ 8.04	$1,278
Barley (bu.)	5.6	41.1	230	194	36	1.04	37
Spr. Wheat (bu.)	11.6	33.8	392	75	317	1.95	618
Pasture	26.6	--	--	--	--	--	--
Sugar Beets (tons)	25.0	16.1	403	--	403	14.44	5,819
Waste	15.0	--	--	--	--	--	--
Total							$7,752

[a] 1953 crop prices derived from Montana Federal Ag. Statistical Service for 1953, A.M.S., U.S.D.A., Office of Ag. Statistician, Helena, Montana; $2.44 is added to sugar beet price to account for government payments, sugar beet payments obtained from Myrick, D. C., A.R.S., U.S.D.A., Unpublished Data, Bozeman, Montana, 1955.

The total gross income from the crop organization is $7,789. Of this amount, $1,278 resulted from bean production, $37 from the sale of surplus barley, $618 from spring wheat, and $5,819 from sugar beet production.

Table III is a summary of the direct crop expenses. This includes only those expenses which can be attributed directly to each enterprise.

Table III. Direct Crop Expenses

Sugar Beets	P/A	Total
Seed (4.5#/A. at $.55/lb.)[a]	$ 2.48	$ 62
Contract labor (24 hr./A. at $1.64 bu.)[b]	39.36	984
Fuel, grease, oil, and repairs (11.78 hrs./A. at $.36/hr.)	4.24	106
Harvesting and Hauling	61.50	1,538
Total	$107.58	$2,690

[a] Seeding rate and seed cost from Myrick, D. C., A.R.S., U.S.D.A., Unpublished Data, Bozeman, Montana, 1954.

[b] Contract labor requirements from Farm Budget Standards for Irrigated Farming, U. S. Dept. of Interior, Bureau of Reclamation, prepared by Branch of Operation and Maintenance, Region 6, Billings, Montana, Oct., 1948, p. 5; hourly cost from Jensen, Clarence W., The Economics of Pasture Integration on Irrigated Farms, Mimeo Circular 67, Agricultural Experiment Station, Montana State College, Bozeman, Montana, 1952, p. 55 and adjusted by index from Farm Cost Situation, Ag. Research Service, U.S.D.A., Feb., 1954.

Beans	P/A	Total
Seed (40#/A. at $.09/lb.)[c]	$ 3.60	$ 31
Fuel, grease, oil, and repairs (12.20 hrs./A. at $.36/bu.)	4.39	38
Threshing (.34 cwt.)	6.29	54
Total	$14.28	$123

[c] Price and seeding rate of beans from Myrick, D. C., op. cit.

Barley	P/A	Total
Seed (1.5 bu./A. at $2.08/bu.)[d]	$ 3.12	$ 17
Fuel, grease, oil, and repairs (5.65 hrs./A. at $.36/bu.)	2.03	11
Harvesting (.10/bu.)	4.11	23
Total	$ 9.26	$ 51

[d] Seed cost assumed double that of 1953 market price.

Spring Wheat	P/A	Total
Seed (1 bu./A. at $3.90/bu.)[e]	$ 3.90	$ 45
Fuel, grease, oil, and repairs (5.65 hrs./A. at $.36/hr.)	2.03	24
Threshing (.11/bu.)	3.72	43
Total	$ 9.65	$ 112

[e] Seed cost assumed double 1953 market price.

Pasture	P/A	Total
Seed (16 lbs./A.)[f]	$ 1.17	$ 31
Fuel, grease, oil, and repairs (1.57 hrs./A. at $.36/hr.)	.57	15
Total	$ 1.74	$ 46

[f] Seeding rate and cost from Jensen, Clarence W., op. cit., p. 56, cost adjusted to 1953 price level by index in Farm Cost Situation, op. cit. Seeding costs allocated over a five year period.

Alfalfa	P/A	Total
Seed (8 lbs./A.)[g]	$ 1.08	$ 30
Fuel, grease, oil, and repairs (4.37 hrs./A. at $.36/bu.)	1.57	43
Total	$ 2.79	$ 73

[g] Seeding rate and cost from Jensen, Clarence W., op. cit., p. 56, and cost adjusted to 1953 level by Farm Cost Situation, op. cit., seeding costs allocated over a five year period.

The tractor operating expenses, "fuel, grease, oil, and repairs", are calculated by a method which allows the determination of the hourly cost of tractor operation. 14/ By multiplying the number of hours the tractor is used for each enterprise by the hourly cost of tractor operation ($.36), the direct costs of tractor operation for each enterprise may be calculated. Thus, the total variable costs of tractor operation are proportioned among the enterprises in accordance to the amount of tractor usage required by each enterprise. 15/

The sugar beets, beans, barley, and spring wheat harvest is done by contract labor. Hauling costs for sugar beets are based on a four mile distance. 16/

The total direct crop expenses are $3095. This includes $2690 charged to the sugar beet enterprise, $123 to the bean enterprise, $51 to barley production, $112 cost of production of spring wheat, $46 charged to pasture production, and $73 charged to the production of alfalfa.

The Livestock Organization

The livestock production budget is shown in Table IV. This livestock

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14/ See Scoville, Orlin J., "Fixed and Variable Elements in the Calculation of Machine Depreciation", Agricultural Economics Research, B.A.E., U.S.D.A., Washington D.C., July, 1949, pp. 69-77.

15/ The number of hours of tractor usage required by each enterprise was obtained from Farm Budget Standards for Irrigated Farming, op. cit., pp. 1-34.

16/ Harvesting and hauling costs procured from Farm Budget Standards for Irrigated Farming, op. cit., p. 81, and are adjusted to the 1953 price level by index from Farm Cost Situation, op. cit.

organization represents the average of the livestock organizations found on the farms of the sample.

Table IV. Budget for Livestock Production

ENTERPRISE	NO.	PRODUCTION		DISPOSITION			
				Home	Marketed		
		Kind	Amount	Consumed	Amount	Price	Value
Dairy cows	5	B. F. (lbs.)	975	215	760	$.65	$ 494
		Meat (lbs.)	1,000	-	1,000	.13[a]	130
Beef cows	12	Meat	2,400	-	2,400	.16	384
Calves	15	-	-	-	-	-	-
Yearlings Beef	11	Meat	7,200	-	7,200	.20[a]	1,440
Dairy	4	Meat	2,217	750	1,467	.16	235
Sow	1	Meat	120	-	120	.23	28
Pigs	5	Meat	933	440	493	.23	113
Chickens	100	Eggs (doz.)	933 doz.	145[a]	788	.45	355
		Meat	375	100[a]	275	.27	74
TOTAL							$3,253

[a] Estimated for this study.

Each dairy cow produces 4990 pounds of milk containing 3.9 percent butterfat. Therefore, a cow produces 195 pounds of butterfat each year. 17/ Of the total milk production, 5500 pounds of milk representing 215 pounds of butterfat are consumed by the farm family. 18/ The remaining butterfat

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17/ Milk and butterfat production of dairy cows are statewide averages and derived from: Montana Agricultural Statistics, Montana Dept. of Agriculture, Labor, and Industry, cooperating with the U.S.D.A. Bureau of Ag. Econ., Helena, Montana, Vol. IV, Dec., 1952, p. 30.

18/ Unless otherwise mentioned, all home consumption estimates taken from: Jensen, Clarence W., op. cit., p. 59.

is sold at $.65/lb. 19/

Each cow weights 1200 pounds and is replaced every six years. Prorated, this means 1000 pounds of meat is sold each year. The price of this meat was assumed to be lower than the price received for beef animals.

A death loss of one dairy calf a year was estimated and from the remaining four calves the replacement stock is chosen. Since five cows are replaced every six years, an average of 5/6 of a yearling used each year for replacement purposes. This leaves an average of 3 1/6 dairy yearlings available for marketing each year. If each yearling weighs 700 pounds, dairy yearlings supply a total of 2217 pounds of meat for the market each year.

Beef cows are replaced every six years. Thus, an average of two cows, each weighing 1200 pounds, are replaced each year. A death loss of one calf a year and the use of two yearling heifers for replacement stock leaves nine beef yearlings for the market. The average weight of these yearlings is 800 pounds, so a total of 7200 pounds of beef is marketed each year from this source.

One brood sow weighing 360 pounds is kept on the farm. Prorated, 120 pounds of pork would be sold each year when the sow is replaced every three years. A six-pig litter with a death loss of one leaves five animals available for the market. Since 1/3 of a pig is necessary for replacement purposes,

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19/ Unless otherwise stipulated, all 1953 prices are derived from Montana Federal Ag. Statistical Service for 1953, op. cit.

4 2/3 pigs weighing 200 pounds are available for marketing.

Each hen lays 140 eggs per year. 20/ At any one time, 80 percent of the flock is considered as laying hens. Each year, 20 dozen eggs are set on the farm but due to infertility, death loss, etc., only 150 of the chicks reach maturity. Half of the parent flock is replaced each year so 50 old chickens are available for marketing along with 100 spring chickens. Home consumption was estimated on the basis of a four member family.

The direct expenses of the livestock enterprise is shown in Table V. Home grown feeds are shown as well as purchased feeds to illustrate the feed requirements of the livestock. 21/ The average yields of the feed crops for all farms in the sample were used as guides to amounts of feed available for the livestock.

The artificial insemination fee was estimated at $9.50 per animal. Veterinarian expenses were also an estimate. Depreciation is charged only for buildings and equipment used exclusively by the enterprise to which that depreciation is charged. 22/

Labor

The total amount of labor supplied each month by the farmer and his

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20/ Montana Ag. Statistics, op. cit., p. 29.

21/ Feed requirements for livestock are based on: Committee on Animal Nutrition, Recommended Nutrient Allowances for Domestic Animals, National Research Council, Washington 25, D. C., Nos. I-IV, revised 1950.

22/ Building and equipment values based on figures given in Farm Budget Standards for Irrigated Farming, op. cit., pp. 69-71. Values were adjusted to 1953 level according to indexes in Farm Cost Situation, op. cit.

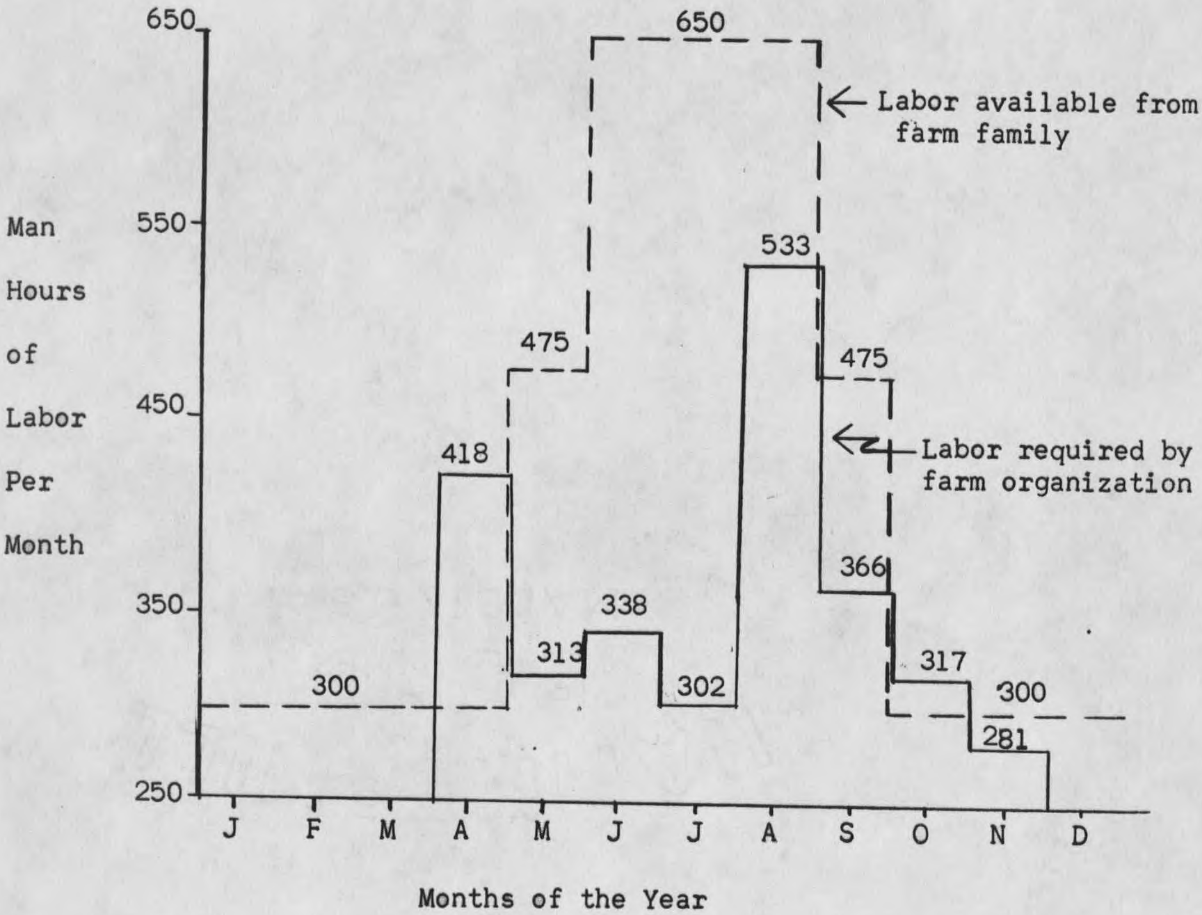
Table V. Direct Livestock Expenses

Enterprise	Type	Required	Home Grown	Purchased	Price ($)	Value ($)
Dairy cows	Alfalfa	7.5 T	7.5 T	x x	x x	x x
	Barley	146 bu.	146 bu.	x x	x x	x x
	Pasture[a]	900	900	x x	x x	x x
	Artificial Insemination	x x	x x	x x	x x	48
	Vet.	x x	x x	x x	x x	50
	Equip. Depr.	x x	x x	x x	x x	61
Beef cows	Alfalfa	22 T	22 T	x x	x x	x x
	Pasture	2160	2160	x x	x x	x x
	Artificial Insemination	x x	x x	x x	x x	95
Yearlings	Alfalfa	25 T	25 T	x x	x x	x x
	Pasture	2700	2700	x x	x x	x x
Calves	Alfalfa	18 T	18 T	x x	x x	x x
	Vet.	x x	x x	x x	x x	x x
Hogs	Milk	4825#	4825#	x x	x x	x x
	Barley	48 bu.	48 bu.	x x	x x	x x
	Vet.	x x	x x	x x	x x	25
	Bldg. Depr.	x x	x x	x x	x x	5
Poultry	Wheat	75 bu.	75 bu.	x x	x x	x x
	Mash	6000#	x x	6000#	2.74/cwt.	164
	Bldg. Depr.	x x	x x	x x	x x	37
Total						$ 535

[a] Pasture requirements are expressed as cow-acre days per season.

family is given in Figure VII. Assuming a family of four including two school age children who are old enough to work, the diagram includes labor devoted to chores as well as field work. The labor available from the farmer and his wife is constant throughout the year, but the total labor supply is increased during the summer months due to the school vacation. It is assumed that the children are able to work part time during May and September. The labor available from the family does not include the time

Figure VII. Labor Requirements of the Farm



<u>Available labor from farm family:</u>

Farmer - 250 hrs./mo. for 12 mos.

Wife - 50 " " " "

Boy - 200 " " 3 " and 100 hrs./mo. for 2 mos.

Boy - 150 " " " " " 75 " " " "

devoted to management, i.e., future planning, supervision of contrast labor and hired labor, etc.

Also depicted in Figure VII are the labor requirements of the farm. This includes labor required by both the crop and livestock organizations. A detailed presentation of the requirements of each enterprise is presented in Appendix (I). 23/ These labor requirements do not include contracted labor. Contract labor is included in direct crop expenses. For the farm, as organized here, 135 hours of hired labor is required.

All labor required over the amount supplied by the farm family is hired at an estimated cost of one dollar per hour. Because this hired labor may be used for any purpose and would be difficult to assign to a particular enterprise, it is listed as an indirect expense.

Machinery Inventory

All machinery used to operate the farm business is listed in Table VI. Except for the tractor, annual repairs of all machinery is estimated to be 2 1/2 percent of the original machinery cost. Annual depreciation is a linear function of time derived by dividing the new cost by the life span measured in years. 24/

23/ The monthly labor requirements for each enterprise are obtained from Farm Budget Standards for Irrigated Farming, op. cit., pp. 2-34.

24/ The cost of repairs for the tractor is included in the direct crop expense "fuel, grease, oil, repairs" as based on a method developed by Scoville, Orlin J., op. cit. This allows direct costs to be assigned to the enterprise for which tractor is used. New cost and annual depreciation of tractor derived from Baker, C. B., Unpublished Data, 1954. (cont. next page)

Table VI. Machinery Inventory

Item	New Cost	Life (yrs.)	Annual Depr.	Annual Repairs	Total
Tractor	$1,775	16	$221	--[a]	$ 265
Plow (2B 2W)	548	18	30	$ 14	44
Spike Tooth Harrow (3-5')	80	20	4	2	6
Level	628	16	39	16	55
Float	77	10	8	2	10
Manure Spreader	438	15	29	11	40
Disc.	249	16	16	6	22
Ditcher	234	15	16	6	22
Cultivator Beets-Beans	345	15	23	9	32
Lifter-Beet	249	18	14	6	20
Drill Beets-Beans	720	15	48	18	66
Mower	253	12	21	6	27
Buck Rake	76	18	4	2	6
Side Del. Rake	345	15	23	9	32
Hydraulic Farmhand	1,034	15	69	26	95
Drill-Grain	709	15	47	18	65
Binder	739	14	53	18	71
Post Hole Digger	364	15	24	9	33
Cream Separator	272	15	--[a]	--	--
Milk Cooler	383	15	--	--	--
Feed Grinder	410	15	27	10	37
Misc. Tools	287	5	57	7	64
Truck	2,530	12	211	602[b]	813
Auto (farm share)	1,240	10	124	255[b]	379
Total	$13,985		$1,108	$1,052	$2,204

[a] Charged to enterprise which has exclusive use of the item.

[b] Auto and truck annual repairs include operating costs.

24/ (cont.) Cost and life span of other machinery as developed in Farm Budget Standards for Irrigated Farming, op. cit., pp. 55-68. Values adjusted according to Farm Cost Situation, op. cit.

Annual depreciation and repairs of equipment is charged directly to an enterprise when that equipment is used exclusively by that enterprise. Because of the variability to be allowed in analyzing the cash crop enterprise and the multi-use characteristics of most machinery, only the highly specialized livestock equipment and the tractor repairs are charged as direct costs.

Building Inventory

The costs, life span, annual depreciation, and repairs of the farm buildings are given in Table VII. 25/

Annual repairs are calculated by the Standard to be 2 percent of the original cost. It also assumes that all labor for repairs is supplied by the farmer.

Annual depreciation is estimated to be a linear function of time. Whenever possible, annual depreciation and repairs are charged to the enterprise which demands exclusive use of the building or structure.

Indirect and Fixed Expenses

Indirect and fixed expenses for the farm are listed in Table VIII.

Indirect expenses include machinery depreciation and repairs (from Table VI, page 30) and hired labor (listed in Figure VII, page 32).

Building and improvements depreciation and repairs (from Table VII,

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25/ Cost, life span, and annual repairs from Farm Budget Standards for Irrigated Farming, op. cit., pp. 69-75. Values adjusted according to Farm Cost Situation, op. cit.

Table VII. Building and Structures Inventory

Item	Cost	Life	Annual Depr.	Annual Repairs	Total
Barn	$1,180	33 yrs.	$36	$24	$60
Granary	420	"	13	8	21
Garage and Shop	846	"	26	17	43
Hog Houses and Equip.	85	"	--[a]	--	--
Poultry House, etc.	740	"	--	--	--
Barbed Wire Fence	1,017	"	31	20	51
Woven Wire Fence	194	"	6	4	10
Electric Fence	67	"	2	1	3
Irrigation Structures	380	"	12	8	20
TOTAL	$4,929		$126	$82	$208

[a] Charged to enterprise by which it is used.

Table VIII. Indirect and Fixed Farm Expenses

Indirect Expenses	Amount
Machinery Depreciation and Repairs	$2,204
Hired labor	135
Total Indirect Expenses	$2,339
Fixed Expenses	**Amount**
Taxes	$ 397
Insurance	60
Building and Improvements Depr. and Repairs	208
Water Charge	300
Total Fixed Expenses	$ 965

page 32), taxes, insurance, and water charge are listed as fixed costs. 26/

Budget Summary

The budget summary for the farm organization described herein is presented in Table IX. Net farm income is calculated by subtracting the total farm expenses from the gross farm income and, for this farm organization, equals $4,521. This amount represents the return to the farmer for his labor, management, risk-bearing, the interest on his investment, and the labor contributed by the family.

Table IX. The Budget Summary

Receipts	Amount	Expenses	Amount
Crop	$7,752	Direct:	
Livestock	3,253	Crop	$3,095
Home consumed products	450	Livestock	535
		Indirect	2,339
		Fixed	965
Total	$11,455		$6,934
NFI			$4,521

The budget described here will be used to analyze the soil survey data. To do so, all parts of the budget will be held constant except the crop organization. Various yield estimates will be substituted into the budget for crop production to determine the suitability of the soil survey data to the economic criteria defined in Part I.

26/ Taxes, insurance, and water charge are from Jensen, Clarence W., *op. cit.*, p. 66, and are adjusted to 1953 price level by indexes from *Farm Cost Situation*, *op. cit.*

PART IV - THE SOIL SURVEY

A. The Development of the Soil Survey Information

The development of the soil survey information began with the synthesis of the soil productivity chart. The discussion of this development includes an anlysis of data sources and a description of the procedures used to derive the yield estimates and productivity groupings given in the chart. Next, the formulation of the soil management groups and management recommendations is discussed. A description of the evaluation of the present agricultural practices of the area concludes this section.

<u>Data Sources</u>

<u>Farm Data</u> - For each farm in the sample, yield data were obtained from two sources: (1) direct farmer interview and (2) the Huntley Project water user's census. Thus, for any given farm field during any cropping year, two yield figures were gathered, one which the farmer reported to the interviewer and one which was reported to the Project.

An illustration of the farmer interview schedule used is given in Appendix II. In addition to recording past crop rotations and yields, questions about fertilizer treatment and response, date of first use of commercial fertilizers, drainage conditions, leveling requirements, cultural practices, etc., were included.

Each fall after all harvesting is completed and crop yields (except for sugar beet yields) are available, the Huntley Project Office conducts a census of water users on the Project. This census includes, for each farm, a description of both the livestock and crop enterprise as well as the total land acreage rented or owned by the farm operator. A description of the schedule used to record this data is given in Appendix III.

The data were obtained from 13 of the most extensive and typical soil types found on the Project. Since some of the soils differed only slightly in physical characteristics relevant to crop production and because some soils are most often found in association with similar type soils, the 13 soil types were aggregated into seven groups consisting of one or more soil types. Thus, when a farm had a field composed of one or more soils of a given group, that farm was included in the sample. In total, data were obtained from 105 fields on 87 farms.

Farm Data, Literature Review - While conceding that farmers are a great potential source of yield information due to their presence on many soil types under varying management levels, other investigators believe them, in general, to be a poor source of information. 27/ Farmer memory, they felt, is not accurate beyond a period of two to three years and, since few farmers keep accurate yield records, the information obtained by farmer interview can be no more accurate than the memory of the farmer.

Little can be found in the literature to suggest the reliability others have placed upon water users census data obtained by irrigation projects.

27/ See Simonson, R. W., and Englehorn, A. J., "Methods of Estimating the Productive Capacities of Soils", Soil Science Society of American Procedings, 3:247-252, 1938 and U.S.D.A. Handbook No. 18, op. cit., pp. 365-395.

The Survey Manual lists census data as a possible source of information but limits its discussion to federal or state census taking. 28/

Farm Data, Evaluation - The yield data obtained from the farmer interview and the Project water users reports are given in Table X. By using the acreage and past cropping sequence of any given field (as obtained from the

Table X. A comparison of Crop Yields Obtained from Farmer Interviews and Project Water Users Reports [a]

Soil Type		Alfalfa (Tons)	Sugar Beets (Tons)	Beans (Cwt.)	Oats (Bu.)	Barley (Bu.)	Spr. Wheat (Bu.)	W. Wheat (Bu.)	Corn (Tons)
153A1	PR[b]	2.5	15.1	2460*	40*	53.7*	30.1		6*
	FI[c]	4.2	16.9	1778*	67.5*	73.8*	41.7		10.7*
314A1	PR	2.7	11.5*	1080*	81.7*	50*			
	FI	3.7	16*	2200*	64.7*	50*			
304A1	PR	2.8	15.3	1650*	80*	63*	35*		
307A1	FI	3.9	15.6	2100*	90*	77.5*	35*		
333A1	PR	2.3	14.6	1800	68.5*	40*	38.8	50*	
352A1	FI	3.0	16.1	2000	69*	40*	42.4	50*	
205A1	PR	2.0	13.1	1692	40.3	50.0	30.6	21.7*	30*bu.
207A1	FI	3.1	13.7	2260	67.8	62.8	38.9	28.8*	43.8*bu.
372A1-374A1	PR	2.1	15.0	2033	42.5*	54.3*	32.2		
362A1-364A1	FI	2.6	15.6	1950	71.3*	56.3*	41.5		
228A1	PR	1.3	10.4		32.8	37.5*	17.3	40*	.5
	FI	2.3	12.0		54.9	45*	28.8	40*	2

a 1953 yield data obtained from farmer interview is not included because 1953 Project report data was not available at the time of this study.

b Project Water User Report.

c Farmer Interview Data.

* Five or less observations.

28/ U.S.D.A. Handbook No. 18 op. cit., pp. 365-395.

farmer interview) as a guide, the past crop yields of that given field were obtained from the Project reports. Thus, the yield data reported annually to the Project census takers could be compared both by field size and by years grown to the yield data gathered directly by the farm interview during the 1953 season.

Yields of the eight most common crops are given for each of the soil groups. The figures given represent the arithmetic mean of all yields reported by the farmers.

It was originally planned to separate the farm data into groups according to management. Thus, for each soil group, it would have been possible to derive crop yields obtained from (say) above average, average, and below average soil management levels. The classification of farmers into these management groups would have to be arbitrarily done by the interviewer, who would refer to data listed on the interview schedule and memory. However, it was decided that the sample was not large enough for this procedure. The mean of all yields of a particular crop on a given soil would, it was felt, be a less refined but more reliable yield estimate.

The Project water user's census is conducted, as mentioned previously, in the fall after all crops are harvested but before the sugar beet yields are available to the farmers. 29/ In order to complete their census, the

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29/ The sugar beet company measures each field and weighs the beets removed from it. They are therefore able to determine accurately the yield of the field. There is necessarily a time elapse before the farmers obtain the yields, however.

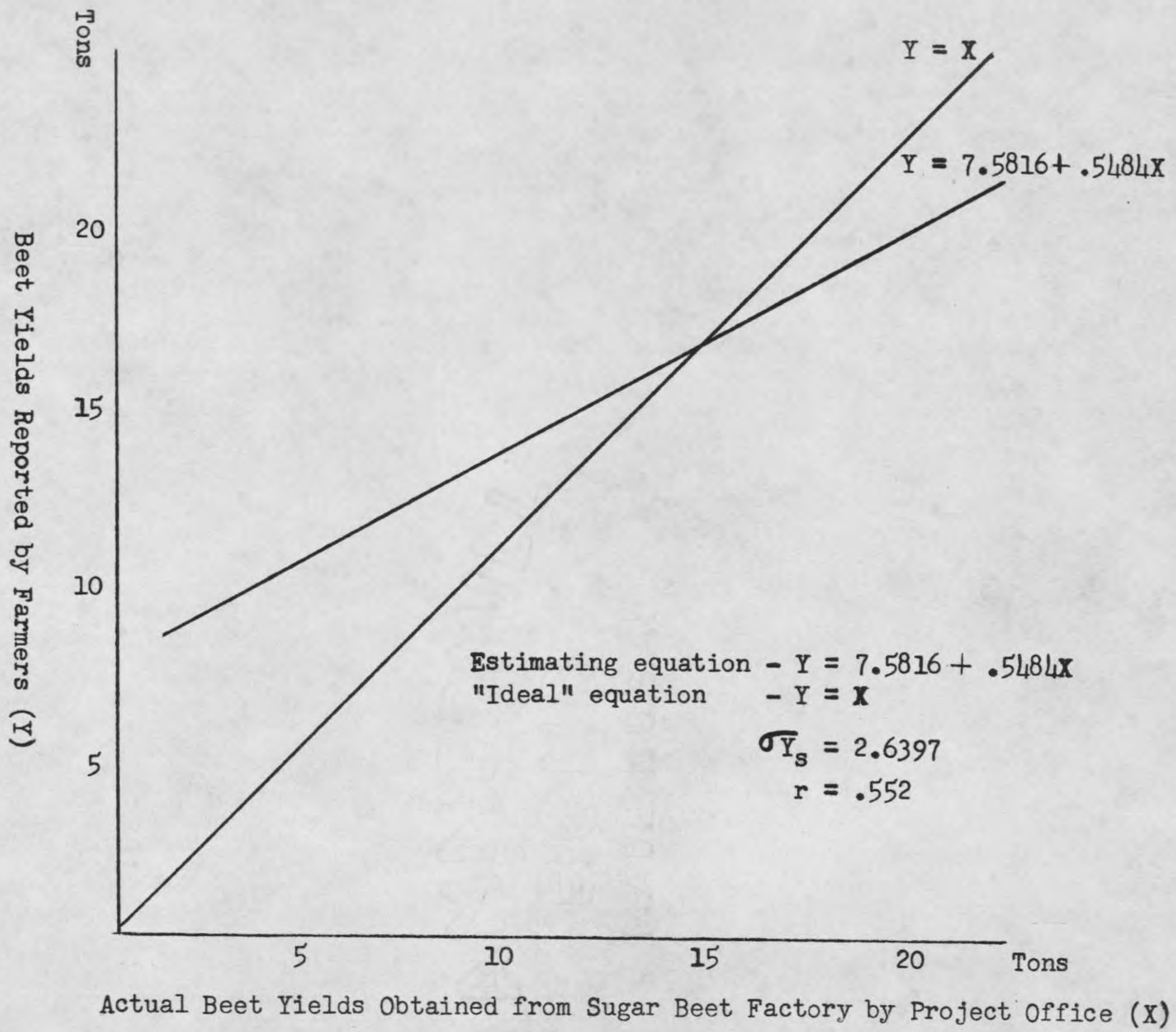
Project office obtains the sugar beet acreages and yields directly from the sugar beet company when that data becomes available. Thus, accurate sugar beet yield data were obtained from the Project reports.

Since the yield data obtained from the two sources were from the same fields during the same period of years, the known accuracy of the sugar beet data obtained from the Project reports made possible a check upon the accuracy of the information obtained by the farmer interview. A linear regression equation was computed using the sugar beet yields of known accuracy as the independent variable and the sugar beet yield data obtained from the farmer interview as the dependent variable. This equation is illustrated in Figure VIII. The slope of the estimating equation ($Y = 7.5816 + .5484X$) is significantly different from that of the "ideal" equation ($Y = X$).

Some error may have been introduced from the yields obtained from the Project reports. Occasionally fields are combined or separated by farmers thus causing acreage changes which make it difficult to trace the field's history through past Project reports. Also, sugar beet yields are sometimes computed as an average of several small fields present within a 40 acre unit (the unit size used for census taking) and while the Project report would contain only an average yield figure for the aggregate of these fields, the farmer could report a more accurate figure on the basis of his knowledge of the relative productivity of the field.

The estimating equation illustrates a tendency of farmers to report towards the average. While it might be expected that low yields would be

Figure VIII. Comparison of Sugar Beet Yields Obtained from Two Sources



reported high, it probably would not be foreseen that high yields might be reported low.

The mean of all actual sugar beet yields (derived from the Project reports) was 14.14T/A while the farmers reported an average of 15.33 T/A. This represents a 1.19 T/A average discrepancy between the two sources. This would indicate that, on the average, the interview data possesses a moderate degree of reliability.

In general, the Project water users census was concluded to be a less reliable source of yield information (for crops other than sugar beets) than the farmer interview. On some irrigation projects water taxes are levied according to the relative level of crop yields. While this is not true of the Huntley Project, it could be a factor influencing the farmer, through mis-information or distrust, to report yields low. Also, as noted above, it is often difficult to accurately trace a field's history back through the Project records.

Although farmer memory is not an important consideration because the census is conducted annually, the reports are taken by several different interviewers who may use varying techniques. There is no way of knowing which farmers cooperated "actively" or "passively" with the interviewers. And, although the Project reports are a source of yield data for many years back, it is difficult if not impossible to trace a field's history beyond the limits of the past cropping sequence as obtained from the farmer by direct interview. Thus, farmer memory becomes a limiting factor to the usefulness of Project reports as well as direct farmer interviews.

Finally, there are criticisms which apply to both sources of data. Yields obtained from farmers are difficult to evaluate because they result from present and past levels of soil management which is vague and can be only arbitrarily estimated. Because the level of soil management varies between farmers, it becomes difficult to evaluate yield differences if a given crop is grown on different soils. Many yields, especially those of feed crops, are never measured accurately by farmers and so a true yield figure is impossible to obtain. Finally, both sources of information are subject to human error on the part of both the interviewer and the respondent.

In summary, the farmer interview data obtained in this study were judged to possess a moderate degree of reliability. The Project census was considered to be less reliable than the farmer interview for crops other than sugar beets because, in addition to being subject to the farmer interview weaknesses of farmer memory and the "human element", the Project census was limited by additional considerations.

If yield data of known reliability could be obtained by the farm interview method, it would be of great use. Data obtained by farm interview represents yields obtained under many soil management and crop rotation systems. Also, the farm yield data is obtained from the entire range of variation allowed with a given soil type by soil surveyors.

<u>Experimental Data</u> - Five years after the Huntley Project was opened for settlement the Huntley Experiment Station was established. That same year, 1912, a series of irrigated crop rotations were begun in the Station.

The original rotations were added to until, in 1941, the entire series included 15 continuously cropped plots, 11 two-year rotations, 7 three-year rotations, 6 four-year rotations, and 5 six-year rotations. 30/ The rotations included alfalfa, sugar beets, oats, wheat, potatoes, corn, flax, and beans. Barnyard manure was applied to some of the rotations so its effect on soil fertility could be determined. The rotations were continued with little change until 1941 when extensive revisions, including the use of commercial fertilizers, were made. Twelve rotations were still in existance in 1953.

Cultural practices, seeding dates, etc., were held as constant as possible throughout the entire period. 31/ However, some variation was encountered due to varying year to year environmental conditions.

Experimental Data, Literature Review - Other investigators have found experimental data to be amoung the most accurate sources of data available for soil survey purposes. 32/ They have concluded that the data is valuable when determining the effects of soil management practices upon soil yields. Furthermore they believed the long time nature of such data to be extremely helpful.

30/ Hansen, Dan, and Post, A. H., Irrigated Crop Rotations, Huntley Branch Station, Huntley, Montana, Montana State College Ag. Exp. Sta. Bull., Bozeman, Montana, May, 1943.

31/ For a more complete description of cultural practices see Hansen, D. and Post, A. H., Ibid., pp. 6-7.

32/ Simonson, R. W. and Englehorn, A. J., op. cit., pp. 247-252, and U.S.D.A. Handbook No. 18, op. cit., pp. 373-374.

However, they recommend caution be used when interpolating such data because experimental results are usually obtained under higher soil management levels than are achieved by the average farmer. 33/

Experimental Data, Evaluation - The rotation data obtained from the Branch Station were an invaluable source of yield information. Because data were available from many rotations of varying length and crop sequence, the most efficient crop rotations could be selected.

Long-time crop responses to barnyard manure were calculated by the comparison of "manured" rotations to "non-manured" rotations. To a lesser extent, the response to commercial fertilizers were similarly derived. A "maximum production" rotation served to illustrate the crop yields actually obtainable when fertilizers (N.P.M.) are applied at heavy rates.

Because of the length of time the rotations were carried on, it was possible to estimate yields obtainable from the soils of the area over long periods of crop production. Thus, long-time yields estimates were incorporated into the productivity chart which would have been unattainable from the other sources used. Finally, all yield figures from the Branch Station were obtained from fields subjected to known systems of management.

Almost all of the rotations were carried out on two soil types which are not found extensively on the Project. Many assumptions were required to apply yield and response data obtained from these soils to other soils of the area. Some rotations, which were laid out in transition zones

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33/ U.S.D.A. Handbook No. 18, *op. cit.*, p. 374.

between the soil types present could not be used without qualification.

Statistical analysis was made difficult because the rotations were not replicated, comparable rotations were placed on different soil types, and varying cultural practices were used on the rotations (such as fall or spring seeding of alfalfa).

As new crop varieties became available, they were introduced into the rotations. Some distortion of crop yields may have been caused by this practice.

Although commercial fertilizers were introduced in 1941, (other than the maximum production rotation which was begun in 1929) the fertilization trials were conducted on plots with varying crop history so that comparisons of resulting crop responses between soils and rotations were made difficult. Finally, most of these fertilized experiments were discontinued before usable data was obtained.

In summary, despite the above shortcomings, the experimental data obtained from the Huntley Branch Station was judged to be the most usable and reliable information available. It provided (1) data to judge the relative merits of different crop rotation, (2) crop yield responses to fertilizers over short and long time periods, and (3) estimates of soil depletion over long time periods from fields subjected to known cropping history and soil management levels.

Chart Synthesis

Type of Chart - From the outset of the chart development, it was desired to synthesize a productivity chart which would give yield predictions for three levels of soil treatment. Because this would require extensive yield data, the predictions were limited to the most typical crops of the area: alfalfa, sugar beets, beans, oats, barley, spring and winter wheat, corn, and pasture.

In order to fully utilize the yield information obtained from the Huntley Branch Experiment Station, all yield predictions given in the chart were defined to be the yields obtained when the crops are grown in a six year, one-half time legume rotation.

Finally, while it was realized that farm management efficiency, in general, rises with or before crop yields increase, it was assumed that, even under the lowest soil treatment level, farm cultural practices were never limiting to crop yields. Therefore, the yield differences between soil fertilization treatments used on a given soil would be due, as much as possible, to the variations in fertilization.

Yield Syntheses - The initial productivity chart included only the seven soil groups on which yield data were obtained. As previously mentioned, the farmer interview data were summarized in terms of arithmetic means. These means are an average of individual crop yields which resulted from soil fertilization treatments varying from high to low. And, the farmer interview data is also representative of the variation of crop yields resulting from the variation within a given soil type. By regarding the interview information as average yields obtained by the farmers of the Project, "benchmark" yields were established for each of the eight crops when grown on each of the seven groups of soil.

Next, a study of the experimental rotation data was made to ascertain, as near as possible, the exact increment in crop yields which could be expected when manure, commercial fertilizers, or both, were applied to a rotation. These yield increases due to fertilization could be applied directly to one soil group but had to be tempered according to the relative merits of the soils involved when applied to the other six soil groups.

From the study of the experimental data, it was decided that the average of the yield data obtained from the farmer interview could most nearly be equaled (given the management conditions generally found on most farms in the area) by barnyard manure applications to the soil. The soil fertilization treatments were then established to be: A. no treatment; B. barnyard manure applied at the rate of 15 T/A once during the rotation period; C. barnyard manure applied at the rate of 15 T/A, nitrogen (NH_4OH) applied at 100#/A and phosphorus (TSP) applied 100#/A, all applied once during the rotation period. These soil fertilization treatments corresponded to similar soil treatments found on rotation data from the Experiment Station.

The initial chart, then was formed using the farm data to establish benchmarks with yield variations which result from increased or decreased fertilization derived from the experimental data. The soil treatment levels defined for the productivity chart were similar to soil treatment levels used on the experimental rotations. This facilitated the use of the experimental data.

<u>Grouping vs. Individual Ratings</u> - When the intial chart was enlarged

to include all soils of the project, the problem of group estimates versus individual soil estimates arose. Grouping involves selection of soils with similar productive capacities and calculating yield estimates for the group as a whole. Individual soil estimates involves deriving a yield estimate for each soil in the Project. It was decided to formulate a productivity chart by each method and the two could then be compared.

For grouping purposes, all soils which were estimated (by use of data or field observation) to have nearly equal or equal productivities were grouped together. To keep the groups as homogeneous as possible, soils of similar productivities but which differed widely in physical characteristics were split into separate groups. Finally, a productivity chart, based upon the intial chart of seven soil groups, was formulated for all groups using field observation as a guide. (This chart is on page 78).

To establish individual ratings, the original seven soil groups were used as benchmarks and field observations and experience were used to calculate yield estimates for each soil. (This chart is presented on page 80).

Soil Management Groups

In addition to giving productivity ratings on the Project soils, soil management recommendations were made. To facilitate management recommendations the Project soils were classified into management groups according to the physical characteristics of the soil. These characteristics were depth to gravel, salinity, drainage, and substrata texture. On this basis, the soils were classified into 15 management groups.

Fertilization, crop rotation, irrigation, drainage, and reclamation practices are discussed in relation to each management group. However, any of these factors considered not relevant to the group being discussed is omitted. Recommended management practices are based upon field observation.

Integration of Productivity and Management Groups - When the productivity groups and the management groups were compared, they were found to be almost identical. There were 12 productivity groups and 15 management groups. In order to simplify the study, the productivity groupings were enlarged and made comparable to the management groupings.

This integration would probably not be feasible when many soils are involved. In such a case the discrepancy between the number of productivity groupings and the number of management groupings might be too large to permit effective integration. The present study, however, included only 53 soil types which were ultimately divided into 15 groups.

Agricultural Practices

The section of the Soils Chapter dealing with agricultural practices accomplishes a dual purpose. First, it describes the present agricultural practices of the area and, secondly, it discusses each practice and suggests general procedures which pertain to each practice. The information given is based upon field observation and general experience in the area.

B. The Soil Survey Information: Use, Management, and Productivity of Huntley Project Soils

Discussion of the use, management and yield of Huntley Project soils is divided into three parts. First is a description of the agricultural practices commonly followed on the Project coupled with a discussion of these practices. Tillage and irrigation practices, drainage facilities, crop rotation, and fertilizers are considered in this first part. Secondly, soil management practices are discussed. To facilitate this, the Project soils have been divided into management groups consisting of soils with similar management characteristics. Management practices salient to each group are described. Finally, the included charts are described and their use is explained. Along with this, soil treatment levels and assumptions necessary for the use of charts are stated.

Agricultural Practices

Tillage Practices - Fall plowing of cropland is a common practice on the Huntley Project. Because of the high clay content of many of the Project soils, plowing with a moldboard plow will often form large clods. When the soils are plowed in the fall, climatic weathering agents effectively break down these clods during the winter months. Seedbed preparations in the spring are thereby simplified. Seedbeds are prepared by alternate disking and leveling until the field is level and optimum soil tilth is reached.

Weeds - Control of weeds is accomplished by crop rotations, tillage of row crops, and use of weed sprays upon small grains.

Discussion: Noxious weeds have become a problem of considerable proportion in the Huntley Project in recent years despite the development and widespread use of herbicides. Canal and ditch banks, roadsides, and permanent pastures provide ample space for noxious weeds to grow and irrigation water is a ready means of transportation for weed seeds so produced. Weed seeds, then, are spread directly on the croplands by irrigation water. Irradication of the weed problem will come, not with effective control of weeds within the farm fields alone, but with elimination of noxious weeds wherever found on the Project.

Irrigation - Water for irrigation is diverted from the Yellowstone River. It is plentiful in supply and of a good quality for irrigation. Because the topography of the valley is nearly level and further leveling may be satisfactorily accomplished, flood irrigation is commonly practiced. Border dikes are used for water control on small grains, pasture and hay crops. Furrow irrigation is used on row crops. Soil slope steep enough to cause erosion is not a common problem on the Project.

Discussion: Irrigation is one of the most important problems on the Huntley Project. Excessive application of irrigation water coupled with seepage from canals and inadequate drainage facilities has caused seeped or saline conditions to limit the agricultural usefulness of many soil areas. This is because the water table, saline from soil minerals leached into it, is raised into the plant root zone by over irrigation. Seeped and usually saline soils result.

Proper irrigation (plus improved drainage which is discussed next) involves consideration of slope, soil infiltration rates, plant water requirements, depth of water table and weather conditions.

Soil slope should be such that irrigation waters will cover a field with a minimum of erosion but yet provide the desired amount of water. Slope should be considered along with the infiltration rate of water into the soil. Ideally, soils that take water slowly should be irrigated on a slight slope so that the water will remain on the soil surface long enough to permit sufficient penetration without excessive runoff, and, as soil infiltration rates increase, soil slope should be increased. However, soil slope is often not ideal or easily varied and other irrigation practices must often be used to gain the desired result. The use of small heads of water and short water runs will reduce erosion and the amount of water infiltration into light textured soils while long water runs and large heads of water will increase the water infiltration rate into heavy textured soils (and also increase the amount of erosion).

As discussed previously, depth of water table is important to proper irrigation. A high water table requires light water applications to prevent raising the water table into the root zone.

Irrigation practices should be varied with crops. Hay and pasture crops root deeper and should be irrigated to a lower depth than other crops. In general, a three-foot depth is satisfactory for row crops and small grains while five feet should be sufficient for other crops.

Current weather conditions should be considered when irrigating. Factors which affect evaporation rates, i.e., temperature, humidity, air movement, should affect rates of water application. Rapid drying will result from high temperatures, low humidity, and rapid air movement.

Drainage - Drainage facilities of the Project consist of tile and open ditch drains. In some localities the system is inadequate in terms of the amount of water requiring disposal under the present conditions. In addition to the excess of water from irrigation, losses from irrigation ditches due to seepage (and some evaporation) have been estimated to be as high as 60 percent of the diverted water. Drainage problems are accentuated by large areas of soils with low permeability which hamper water movement and soil drainage.

Discussion: Enlargement of drainage facilities is needed on the Project and care should be taken to insure that all drains, whether open or tile, are deep enough to adequately drain the entire soil profile instead of removing the surface water only. Ditches should have sufficient slope to carry water away rapidly.

Improved drainage along with controlled irrigation will improve soil aeration, increase the plant rooting zone, warm the soil and permit leaching of excessive salts from soils by providing a means of disposal for these salts.

Crop Rotation - No definite crop rotation is used universally throughout the Project. In general, legume crops, when planted, are allowed to remain as long as yields remain satisfactory. Small grains are almost universally used as hay and pasture nurse crops while other crops are grown according to the farm operator's needs and desires.

Discussion: While it would be illogical for a farmer to follow specific rotation, beneficial results may be obtained by following a proper sequence of crops. Alfalfa, clovers, or pasture should be followed by row crops to provide for maximum use of the nitrogen left in the soil by these crops. Small grains should be last in the rotation because in addition to their moderate plant nutrient requirements they serve as nurse crops for hay and pasture seedings.

Rotations help to control weeds. Mowing of hay, cultivation of row crops and spraying of grains provide an effective defense for the farmer against weeds. Likewise, disease can be controlled by a sequence of crops. A host crop, once grown, will not be grown again for several years. Thus, the disease organisms will perish for lack of proper environment.

A rotation should, for most soils, be at least half-time legume. That is, a six-year rotation should have three years of legume. This will provide for maintenance of nitrogen and organic matter but is not protection against soil depletion. Phosphorus is used heavily by legumes and row crops and if not replaced its deficiency will cause declining yields.

Fertilization - Barnyard manure, green manure, commercial nitrogen and phosphorus fertilizers are all used on the Huntley Project. The type and rate of fertilization varies with the farmer, soil, and crop.

Barnyard manures are commonly applied in the fall preceding row crop growth. The following spring, commercial nitrogen and phosphorus fertilizers are drilled as the crop is seeded and additional nitrogen is often sidedressed later in the season. When row crops are not grown, fertilization is carried out on either the cash grain crop or the hay crop.

Green manuring practices are not as easily described. One common practice is to plow under the last hay crop of the season. Another is to raise an annual clover, either alone or with a small grain nurse crop, and turn it under in the fall. If a nurse crop is used, the green manure crop is irrigated once after the grain is harvested.

Discussion: Commerical fertilizers increase soil fertility by adding plant nutrients in a form usable by plants. Nitrogen and phosphorus will often become depleted in a soil even when good farming practices are followed but fertilizers are not used. Green manuring legumes will maintain (possibly increase) the nitrogen content of the soil but does not add phosphorus, which is heavily utilized by many crops including alfalfa and sugar beets. Since barnyard manure is also low in phosphorus, commercial fertilizers are the only available source of phosphorus. Commercial nitrogen may be used in rotations where nitrogen consumption is high.

Barnyard manure and green manure, besides supplying plant nutrients, add organic matter to the soil. Organic matter will combine with elemental nitrogen and prevent its (nitrogen) rapid removal by leaching. Organic matter improves the physical condition of the soil, i.e., permeability, water holding capacity, aeration, and drainage of excess water, etc. Improvement of permeability is especially beneficial to clay soils.

Fertilizers may be combined in many ways to produce the result desired by the farmer. For example, legumes or non-legumes in the form of green manure can effectively replace barnyard manure if equal amounts of organic matter are added and supplemental plant nutrients are supplied by use of commercial fertilizers. Or if a rotation that maintains soil organic matter is used, complete fertilization may be accomplished by use of commercial fertilizers.

Fertilization procedures will depend upon the nutrient requirements of the crops grown and the inherent or present fertility of the soil type on which they are grown. For example, the crops in some rotations flourish with barnyard manure applications while others will need manure plus commercial fertilizer. Similarly, an inherently fertile soil will require less fertilizer for the same rotation than an inherently infertile or a depleted soil.

Soil Management Practices for Huntley Project Soils 34/

GROUP I -- Highly productive silt loam to silty clay loam soils.

153A1 - Harlem-Havre silt loam, nearly level
155A1 - Harlem silty clay loam, nearly level
333A1 - Fort Collins silt loam, nearly level
334A1 - Fort Collins clay loam, nearly level
352A1 - Fort Collins silt loam, moderately deep, nearly level
354A1 - Fort Collins clay loam, moderately deep, nearly level
312A1 - Fly Creek loam, nearly level
314A1 - Fly Creek clay loam, nearly level

These are well drained, non-saline, deep soils with weakly to moderately well developed profiles and stratified loamy to clay substrata. They are well suited for cultivation.

34/ Crop rotation, fertilization, irrigation and drainage practices are all discussed here only in relation to each soil group. Any or all of these practices are not discussed if they are considered irrevelant. For a complete discussion and understanding of each practice, refer to the section which describes and discusses agricultural practices of the Huntley Project. The contents of this section of soil management is presented briefly in Table XI, page 72.

The soils of this group comprise much of the finest farmland of the Huntley Project. They are highly productive of all crops grown in the area including sugar beets, beans, wheat, corn, oats, barley, alfalfa, and grass and legume pasture crops.

Crop rotation: Hay or pasture crops (preferably legumes) should be grown at least one-third of the rotation period; for instance, two years out of a six-year rotation should be alfalfa.

Fertilization: Substantial crop increases may be obtained from use of barnyard manure and commercial fertilizers (see Productivity Chart). Because the high crop yields these soils are capable of producing draw heavily on plant nutrients, heavy fertilization is needed to maintain their inherently high fertility level.

Irrigation: Light and frequent irrigations using short water runs is recommended. Care should be taken to prevent over-irrigation and consequently, excessive leaching and erosion of these highly permeable soils.

GROUP II -- Highly productive clay soils.

304A1 - Nunn clay loam, nearly level
307A1 - Nunn silty clay loam, nearly level

The soils of this group have clay substrata, are well drained and non-saline. They have moderately well developed profiles and are very deep and well suited for cultivation.

These soils are highly productive of all crops commonly grown on the Project including sugar beets, beans, wheat, barley, oats, corn, alfalfa, and pasture mixtures.

Crop rotation: Rotations should include at least one-half time hay or pasture crops (preferably legumes). Power and breakage expenses are high on these soils, due to their clay texture, so crops which require a minimum of plowing and cultivation are recommended (hay, pasture and small grain) although all crops grow well.

Fertilization: Large yield increases are obtainable with full fertilization (see Productivity Chart). To improve their physical condition large amounts of organic matter should be supplied to these soils by either green manuring or applying coarse barnyard manure. Nitrogen fertilizers will increase crop production while phosphorus fertilization usually, but not always, is beneficial.

Irrigation: Long water runs may be desirable to permit a longer period for water to infiltrate into these slowly permeable clay soils without excessive water loss due to runoff.

GROUP III -- Highly productive loam to fine sandy loam soils.

102A1 - Havre loam, nearly level
101A1 - Havre fine sandy loam, nearly level

These soils have stratified sandy to loamy substrata, are non-saline and well drained but lack any readily apparent profile development. They are very deep and well-suited for cultivation.

This group is highly productive of all crops grown in this area. Sugar beets, wheat, barley, oats, beans, corn alfalfa and pasture mixtures are all commonly found on this soil.

Crop rotation: Hay or pasture crops (if possible, legumes) should be grown on these soils at least 50 percent of the rotation period.

Fertilization: This group of soils is inherently low in plant nutrients and organic matter. Therefore, complete fertilization (manure, nitrogen and phosphorus fertilizers) can increase yields markedly (see Productivity Chart). Frequent green manuring or heavy applications of barnyard manure should be made to add organic matter to these soils. Similarly, nitrogen and phosphorus fertilizers should be used to raise the productivity of these soils.

Irrigation: Leaching and erosion are the principal hazards when irrigating these soils. Therefore, irrigations should be light and frequent over a short water run.

GROUP IV -- Productive, slightly saline, loamy soils.

109A1 - Havre loam, slightly saline, nearly level

Stratified loamy to sandy substrata typify this group of slightly saline soils. These soils are moderately well drained and have no readily apparent profile development. They are very deep and easily cultivated.

This group of soils is productive of all crops common to the area. Yields are slightly below those of Group III due to spotiness caused by salinity.

Crop rotation: Rotations should be more than 50 percent hay or pasture. While beans may be grown with some success, other crops which are more salt tolerant (sugar beets, small grains) should be grown on these soils.

Fertilization: Sizeable crop increases are obtained from complete fertilization of these soils (see Productivity Chart). To improve the physical properties and aid in reclamation of these soils, organic matter should be added by frequent green manuring or heavy applications of barnyard manure. Also, heavy applications of nitrogen and phosphorus fertilizers will increase yields markedly.

Irrigation: Light, frequent irrigations with short water runs will prevent excessive erosion and leaching of plant nutrients from these soils.

Drainage and/or reclamation: These soils vary from Group III soils in salinity only. These salts may be removed by improving the drainage where necessary and leaching with irrigation water. Applications of large amounts of organic matter are also beneficial (as stated above).

GROUP V -- Productive, moderately well developed, moderately deep, loam to clay loam soils.

364A1 - Fort Collins clay loam, moderately deep, nearly level
362A1 - Fort Collins loam, moderately deep, nearly level

Soils in this group have loam to clay loam subsoils overlying gravelly substrata at depths of 20 to 36 inches. They are well drained and non-saline with moderately well developed profiles. Although of moderate depth they are suitable for cultivation.

These soils are productive of all crops commonly grown in the area.

Crop rotations: Hay or pasture crops should comprise at least half of any rotation used on these soils.

Fertilization: Yield increases of sizeable amounts will result from complete fertilization (see Productivity Chart). To insure maximum water holding capacity in these moderately deep soils, organic matter should be added either from frequent green manuring or heavy barnyard manure applications. Nitrogen and phosphorus fertilizers are both needed to obtain maximum yields from these soils.

Irrigation: Irrigations should be light to prevent leaching in these moderately deep (20-36") soils but frequent enough to prevent crops from suffering for lack of water. (Droughtiness due to excessive drainage may occur because of the soils' depth to gravel.) Short water runs will also help prevent leaching due to over-irrigation.

GROUP VI -- Productive, moderately deep, silty clay loam to very fine sandy loam soils with little or no development.

145A1 - Harlem silty clay loam, moderately deep, nearly level
122A1 - Havre loam, moderately deep, nearly level
121A1 - Havre fine sandy loam, moderately deep, nearly level

These soils have stratified sandy loam to clay loam subsoils which grade into loose sand gravel between depths of 20 to 36 inches. They are suitable for cultivation even though they are of moderate depth.

This group of soils is productive of all crops commonly grown in the area including sugar beets, beans, wheat, corn, oats, barley, alfalfa, grass and legume pasture mixtures.

Crop rotation: Hay or pasture crops should occupy more than half of the rotation. All other crops may be grown as desired.

Fertilization: Green manuring or barnyard manure plus nitrogen and phosphorus fertilizers can increase crop yields sizeable amounts on these soils (see Productivity Chart). Heavy use of barnyard or green manure is essential to create optimum water holding capacity in these moderately deep, light textured soils.

Irrigation: Because of their moderate depth, these soils are susceptible to leaching and droughtiness. Irrigations should be light and frequent to prevent leaching. Water runs should be short and, if possible, on slopes which are level enough to prevent erosion and still provide for rapid water coverage.

GROUP VII -- Productive, slightly saline, clay to silty clay loam soils.

235A1 - Ballantine silty clay loam, nearly level
237A1 - Ballantine silty clay, nearly level
247A1 - Pryor silty clay, moderately deep, nearly level
205A1 - Pryor silty clay loam, nearly level
207A1 - Pryor silty clay, nearly level
209A1 - Pryor clay, moderately deep, nearly level
239A1 - Ballantine clay, deep, nearly level

These are very deep to moderately deep soils which are slightly saline, moderately well drained and have clay and stratified clay to sandy loam substrata. All soils are deep enough to allow satisfactory cultivation and all soils show slight profile development.

This group of soils is productive of all crops commonly found in the area including sugar beets, wheat, barley, oats, corn, legume and grass pasture mixtures. Beans may be grown but are not as well adapted as the crops previously mentioned.

Crop rotation: To supply organic matter needed in these soils, hay or pasture crops should comprise up to 75 percent of any rotation used. Because their heavy texture causes high power and breakage expenses when plowing or cultivating it is desirable to keep these soils in hay and pasture as much as possible. Also, beans should not be included in any rotation because they lack salt tolerance.

Fertilization: Sizeable crop increases can be obtained from heavy applications of green or barnyard manures along with nitrogen and phosphorus fertilizers (see Productivity

Chart). Organic matter is badly needed in these soils to improve their physical condition. Coarse organic material which decomposes slowly (sweet clover, straw) should be used in preference to green, succulent material. Manure (green or barnyard) should be applied often.

Irrigation: Long water runs may be used on this group of soils for they have slow infiltration rates. Light irrigations should be practiced to prevent over-irrigation of these naturally wet soils. Also because of their wetness, they should not be irrigated as frequently as lighter textured, better drained soils.

Drainage: Improved drainage is often needed on these soils. The slow internal drainage of these soils limits the value of drains but does not render them useless. Drains should be deep and carefully laid out. However, careful irrigation is important even when good drainage is available for these soils.

GROUP VIII -- Productive, clay loam soils with scattered "slick spots".

264A1 - Fort Collins-Arvada clay loam, nearly level
269A1 - Fort Collins-Arvada clay loam, deep, nearly level

The soils in this group have stratified sandy loam to clay loam substrata. They are slightly saline, moderately well drained, and exhibit moderately well developed profiles. They are deep enough to allow satisfactory cultivation. Spots of plastic clayey soils difficult to manage are scattered throughout these soils.

All crops are produced moderately well by these soils. Crops commonly grown are sugar beets, wheat, oats, barley, beans, corn, alfalfa and legume and/or grass pasture mixtures.

Crop rotation: One-half (50%) of any rotation used on these soils should be hay or pasture. Other crops all grow well enough to be used as desired in the rotation.

Fertilization: Moderate increases in crop yields can be obtained with complete fertilization practices (see Productivity Chart). Green manure or barnyard manure should be applied frequently to add organic matter to the solonetic areas (slick spots) in these soils. This group responds well to commercial nitrogen and phosphorus fertilizer treatments.

Irrigation: Frequent and light irrigations over short water runs will help prevent these moderately well drained soils from becoming seepy.

Drainage: Drainage is not a serious problem on these soils but may frequently be improved by deep tile drains or open ditches.

GROUP IX -- Moderately productive, moderately saline, silty clay loam and clay soils with scattered slick spots.

225A1 - Pryor-Nibbe silty clay loam, nearly level
227A1 - Pryor-Nibbe silty clay, nearly level

These soils have silty clay substratum, are moderately saline with scattered "slick" spots, are moderately well drained and exhibit slight profile development. They are very deep and may be cultivated.

These soils are moderately productive of all crops commonly found on the Huntley Project with the exception of beans.

Crop rotation: Hay and pasture crops should comprise at least 75 percent of any rotation used on these soils. Since power and breakage costs are high on these clay soils, it is desirable to keep plowing and cultivating costs to a minimum by growing hay crops, pasture or small grains. If row crops are grown, beans are not recommended for they are intolerant to salts.

Fertilization: Crop increases of moderate amount can be obtained from fertilization of these soils (see Productivity Chart). Because organic matter will improve the physical conditions of these soils, heavy applications of manure (barnyard or green) will benefit crop yields more than commercial fertilizer applications. The latter are beneficial, however.

Irrigation: Irrigations should be light and over long water runs. Because these soils are naturally wet, care should be taken not to apply water too often in excess amounts.

Drainage: Although the permeability of these soils is low, deep open ditch or tile drains are usually beneficial to them.

GROUP X -- Moderately productive, very shallow soils.

374A1 - Larimer clay loam, nearly level
372A1 - Larimer loam, nearly level

This group of soils is shallow (sometimes gravelly to the surface), non-saline, excessively drained, and has moderately well developed profiles. The shallowness causes plowing and cultivation to be difficult but not impossible.

These soils are moderately productive of crops commonly found in the area including sugar beets, beans, corn, oats, barley, wheat, alfalfa and legume and/or grass pasture mixtures.

Crop rotation: It is recommended that these soils be kept in hay and pasture crops. Other crops are not usually recommended (but sometimes grow very well) because the gravel in these soils makes plowing and cultivation difficult.

Fertilization: Complete fertilization of these soils may increase yields moderately (see Productivity Chart). Green manure and barnyard manure will add organic matter which will increase the water holding capacity of these soils and reduce leaching of plant nutrients. Since these soils are easily leached, commercial fertilizers usually give beneficial (if short lived) results.

Irrigation: Short water runs coupled with very light, frequent irrigations are recommended for these excessively drained soils. Care must be taken not to leach plant nutrients from the soil.

GROUP XI -- Moderately productive, imperfectly drained, loam to silty clay loam soils.

158A1 - Harlem silt loam, moderately saline, nearly level
159A1 - Harlem silty clay loam, moderately saline, nearly level
252A1 - Ballantine loam, seeped, nearly level
255A1 - Ballantine silty clay loam, seeped, nearly level

The soils in this group have stratified light loamy to clay substrata, are moderately saline and imperfectly drained, and have no readily apparent profile development. They are deep and suitable for cultivation.

Alfalfa, sugar beets, wheat, barley, oats, corn and pasture crops are all moderately well suited to these soils. Beans do not have enough salt tolerance to grow well in these soils.

Crop rotation: Rotations on these soils should include up to 75 percent hay or pasture crops. Beans are not recommended because they are not tolerant to salts.

Fertilization: Complete fertilization (commercial fertilizers, green or barnyard manure) will increase crop yields moderately. Manure (green or barnyard) will improve these soils and should be used generously on them. Commercial fertilizers (without manure) are not as beneficial to these soils as manuring (without commercial fertilizer).

Irrigation: Light and frequent irrigations over short water runs are recommended for this group. Excess water may be applied if drainage conditions will permit leaching operations to reclaim these soils.

Drainage and reclamation: Drainage of these soils can usually be improved by deep open ditch or tile drains. Once drainage is improved, leaching will remove the salts from the soil.

GROUP XII -- Moderately productive, moderately saline, imperfectly drained, clay and silty clay soils.

217A1 - Pryor silty clay, seeped, nearly level
228A1 - Pryor-Nibbe clay, nearly level

These soils have clay substrata, are imperfectly drained, are moderately saline, and have slightly developed profiles. They are deep and may be cultivated.

This group is moderately productive of legume and grass pasture or hay crops. Small grains sometimes attain fair yields but cultivated crops are not recommended.

Crop rotation: It is recommended that hay and pasture crops be grown exclusively on these soils. Cultivated crops are difficult and expensive to raise because power and breakage costs are high and yields are low on these heavy, saline, poorly drained soils. Fair small grain crops may be grown if they are preceded by green manuring with a heavy, coarse legume or grass crop.

Fertilization: Heavy applications of barnyard or green manure are beneficial to these soils. Commercial fertilizers will increase yields little, if any, when used alone on these soils but are moderately beneficial when applied in conjunction with manures. When green manuring is practiced, coarse materials which provide more aeration and decompose slowly are preferable to fine succulent growths.

Irrigation: Irrigation should be light on these naturally wet soils. Using small heads of water over long water runs will allow water penetration without excessive runoff loss.

Drainage and reclamation: Drainage improvement is limited because of the slow internal drainage of these soils. They can be benefited somewhat by proper drainage facilities, however. Since unsatisfactory physical conditions are responsible for much of this group's low productivity, large quantities of coarse organic matter should be used on these soils.

GROUP XIII -- Shallow soils, poorly suited to cultivation.

370A1 - Larimer gravelly loam and sandy loam, nearly level
10A1 - Havre gravelly loamy fine sand, shallow, nearly level

These are very shallow, excessively drained soils which are frequently gravelly to the surface. They are droughty, too gravelly for satisfactory cultivation, and poorly suited to crop growth.

This group of soils is cultivated only because of its association with arable soils. When found in sizeable areas it is left in native vegetation; thus, management practices are not discussed for it. Because these soils are present as small inclusions within arable soils, productivity ratings are given for them.

GROUP XIV -- Alluvial soils, not suited to cultivation.

- 2A1 - Alluvial soils, loamy, nearly level
- 3A1 - Alluvial soils, loamy, saline, nearly level
- 4A1 - Alluvial soils, loamy, seeped, nearly level
- 8A1 - Alluvial soils, clayey, nearly level
- 9A1 - Alluvial soils, clayey, saline, nearly level
- 11A1 - Banks soils undifferentiated, nearly level

These soils are sandy to clayey alluvials found bordering rivers, streams and low, marshy areas. They may be saline and/or seeped and have extreme fluctuations in depth. They have no sizeable areas suitable for cultivation.

Because cultivation of these soils is impractical, they are commonly left in native vegetation and used for pasture.

GROUP XV -- Saline and alkali soils, not suited to cultivation.

- 407A1 - Nibbe silty clay, nearly level
- 422A1 - Mossmain loam, nearly level
- 425A1 - Mossmain silty clay loam, nearly level
- 429A1 - Mossmain clay loam, nearly level
- 432A1 - Mossmain loam, very poorly drained, level
- 452A1 - Arvada-Mossmain loam, nearly level
- 455A1 - Arvada-Mossmain silty clay loam, nearly level
- 458A1 - Arvada silty clay loam, nearly level

These soils have stratified loam to clay substrata, are strongly saline and/or alkali and imperfectly drained. They are unsuitable for cultivation.

Even when found in areas large enough to warrant individual treatment, these soils are best left in natural vegetation and used for pasture. Crop growth is erratic but very poor.

Reclamation of these soils is very expensive, if possible, and probably would not be feasible. Improved drainage, extensive leaching with heavy organic matter and gypsum applications will improve these soils.

Table XI. Groups of Soils with Common Management Characteristics, Huntley Project, Montana

Group No.	Soil Characteristics Affecting Management				Adaptable Crops	Remarks	Soil Types Included in Group	
	Depth	Salinity	Drainage	Substrata			Number	Name
I	deep to very deep as indicated in type name	none	well drained	stratified loam to clay	highly productive of all crops grown in the area including alfalfa sugar beets, beans, wheat, corn, oats, barley, grass and legume pasture mixtures		153A1	Harlem-Havre silt loam, nearly level
							155A1	Harlem silty clay loam, nearly level
							333A1	Fort Collins silt loam, nearly level
							334A1	Fort Collins clay loam, nearly level
							352A1	Fort Collins silt loam, mod. deep, nearly level
							354A1	Fort Collins clay loam, mod. deep, nearly level
							312A1	Fly Creek loam, nearly level
							314A1	Fly Creek clay loam, nearly level
II	very deep	none	well drained	clay	Do		304A1	Nunn clay loam, nearly level
							307A1	Nunn silty clay, nearly level
III	very deep	none	well drained	stratified loamy to sandy	Do		102A1	Havre loam, nearly level
							101A1	Havre fine sandy loam, nearly level
IV	very deep	slightly	moderately well drained	Do	Productive of all crops commonly grown in the area including alfalfa sugar beets, beans, wheat, corn oats, barley, grass and legume pasture mixtures	These soils produce slightly less than those in Group III due to spotiness caused by salinity.	109A1	Havre loam, slightly saline, nearly level

Table XI. (cont.)

Group No.	Soil Characteristics Affecting Management				Adaptable Crops	Remarks	Soil Types Included in Group	
	Depth	Salinity	Drainage	Substrata			Number	Name
V	mod. deep	none	well drained	stratified clay loam to sandy loam	Productive of all crops commonly grown in the area including alf-alfa, sugar beets beans, wheat, corn, oats, barley, grass and legume pasture mixtures	These soils are less productive than those in Group I be-cause of their shal-lower depth.	364Al 362Al	Fort Collins clay loam, mod. deep, nearly level Fort Collins loam, mod. deep, nearly level
VI	Do	Do	Do	Do	Do		145Al 122Al 121Al	Harlem silty clay loam, mod. deep, nearly level Havre loam, mod. deep, nearly level Havre fine sandy loam, mod. deep, nearly level
VII	very deep to mod. deep(as indi-cated in type name)	slightly	moder-ately well drained	clay and stratified clay loam to sandy loam	Productive of all commonly grown crops in the area including alfalfa sugar beets, beans, wheat, corn, oats, barley, grass, and legume pasture mixtures. Beans may be grown but are not as well adapted.	Becasue of their heavy texture, power and breakage costs incurred while plowing and cultivating these soils are high. It is desirable to keep these soils in pasture and hay as much as possible	235Al 237Al 247Al 205Al 207Al 209Al 239Al	Ballantine silty clay loam, nearly level Ballantine silty clay, nearly level Pryor silty clay, mod. deep, nearly level Pryor silty clay loam, nearly level Pryor silty clay, nearly level Pryor clay, mod. deep, nearly level Ballantine clay, deep, nearly level

Table XI. (cont.)

Group No.	Soil Characteristics Affecting Management				Adaptable Crops	Remarks	Soil Types Included in Group	
	Depth	Salinity	Drainage	Substrata			Number	Name
VIII	deep and very deep(as indicated in type name)	slightly	mod. well drained	stratified sandy loam to clay loam	Productive of all commonly grown crops in the area including alfalfa sugar beets, beans wheat, corn, oats, barley, grass and legume pasture mixtures.	Scattered solonetz spots are difficult to manage and cause crop spotiness.	264A1 269A1	Fort Collins-Arvada clay loam, nearly 1 level Fort Collins-Arvada clay loam, deep nearly level
IX	very deep	moderately	Do	silty clay	Moderately productive of most crops grown in the area including alfalfa, sugar beets, wheat, corn oats, barley, grass and legume mixtures. Beans not highly adaptable.	Do	225A1 227A1	Pryor-Nibbe silty clay loams, nearly level Pryor-Nibbe silty clay, nearly level
X	very shallow	none	excessively		Do	Use of these soils may be limited by droughtiness and cultivation difficulties caused by gravel.	374A1 372A1	Larimer clay loam, nearly level Larimer loam, nearly level
XI	very deep	moderately	imperfectly	stratified light loam to clay	Poorly to moderately productive of some crops grown in area including sugar beets, barley, mixed legume-grass hays and pastures. Beans not adaptable.	These soils should be used for pasture and hay crops; imperfect drainage and salinity make other crops, especially beans respond poorly.	158A1 159A1 252A1 255A1	Harlem silt loam, mod. saline, nearly level Harlem silty clay loam, mod. saline, nearly level Ballantine loam, seeped, nearly level Ballantine silty clay loam, seeped, nearly level

Table XI. (cont.)

Group	Soil Characteristics Affecting Management				Adaptable Crops	Remarks	Soil Types Included in Group	
	Depth	Salinty	Drainage	Substrata			Number	Name
XII	Do	Do	Do	clay	Moderately productive of mixed legume-grass pastures and hays. Not well suited to the production of cultivated crops.		217A1	Pryor silty clay, seeped, nearly level
							228A1	Pryor-Nibbe clay, nearly level
XIII	very shallow	none	very excessively drained		Poorly suited to cultivation.	Cultivated only because of their associations with arable soils.	370A1	Larimer gravelly loam and sandy loams, nearly level
							10A1	Havre gravelly loamy fine sand, shallow, nearly level
XIV	highly variable	non-saline and saline (as indicated in type names)	well-drained to imperfectly drained (as indicated)	sandy to clayey stratified materials	Not suitable for cultivation	Commonly utilized as natural grass pastures	2A1	Alluvial soils, loamy, nearly level
							3A1	Alluvial soils, loamy, saline, nearly level
							4A1	Alluvial soils, loamy, seeped, nearly level
							8A1	Alluvial soils, clayey nearly level
							9A1	Alluvial soils, clayey saline, nearly level
							11A1	Banks soils undifferentiated, nearly level
XV	very deep	strongly	imperfectly drained	stratified loam to clay	Do	Do	407A1	Nibbe silty clay, nearly level
							422A1	Mossmain loam, nearly level
							425A1	Mossmain silty clay loam, nearly level
							429A1	Mossmain clay loam, mod. deep, nearly level
							432AA1	Mossmain loam, very poorly drained, level
							452A1	Arvada-Mossmain loam, nearly level
							455A1	Arvada-Mossmain silty clay loam, nearly level
							458A1	Arvada silty clay loam, nearly level

Soil Productivity Ratings

Soil productivity ratings are estimates of the crop yields to be expected from specified soils under given management practices. Through them, the user of the soil survey report may evaluate, in terms of crop yields, the soils in which he is interested. To simplify that task, soils with like management and production characteristics have been grouped together in Chart II.

Chart I lists the soil types included in each group. It also states the soil characteristics which determine the best use and management practices for each group. (On the Project, these are depth, salinity, drainage and substrata texture.) Finally, adapted crops and special remarks on management are included in this chart.

Chart II is the soil productivity chart. For each soil group, the productivity chart lists estimated crop yields obtainable under each soil fertilization treatment. Thus, response to fertilization between soil groups may be compared as well as response between crops within a soil group.

Chart III presents the yield estimates of each individual soil type. This chart presents estimated crop yields obtained under each fertilization treatment.

There are four soil fertilization treatments under which crop yields are defined on the productivity charts. The first three (A, B, and C) are used for arable soils while the fourth (D), which in reality denotes a lack of fertilization, is applied to soils not recommended for cultivation. All crops are grown in a six-year, half-time legume rotation in which the legume is followed by a cash row crop. Such a rotation might be alfalfa, alfalfa, alfalfa, sugar beets, corn, oats, or alfalfa, alfalfa, alfalfa, beans, corn, wheat.

The four fertilization treatments are:

A. No green manure, barnyard manure, no commercial fertilizers applied.

B. Barnyard manure on cash row crop at the rate of 15 tons per acre once during the rotation; no commercial fertilizers used.

C. Barnyard manure on the cash row crop at the rate of 15 tons per acre once during the rotation period; TSP and NH_4NO_3 applied on cash row crop at the rate of 100 pounds each once during the rotation period.

D. This "fertility" treatment applies to non-arable soils which should be left in native vegetation. Rotations, manures, and commercial fertilizers have not been shown to be profitable on these soils.

The fertility treatments described above are not specific recommendations but are used to illustrate yields which may be obtained from the Huntley Project soils.

It is realized that in practice the relative level of crop yields varies with the efficiency of farm management. However, since soil management practices other than fertilization are also capable of limiting crop yields when improperly done, it is assumed that all management and cultural practices are carried out satisfactorly and are not a limiting factor in crop production no matter which fertilization treatment is used.

Table XII. Estimated Soil Productivity Under Specified Systems of Fertilization by Soil Management Groups, Huntley Project, Montana

Group No.	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Natural[a] Pasture
I	A[b]	3.0	11	30	35	40	13	25	210	
	B[b]	4.5	15	45	55	60	18	45	330	
	C[b]	6.5	19	55	80	95	25	60	450	
II	A	2.5	7	30	35	40	12	20	210	
	B	4.0	14	40	50	55	16	40	330	
	C	6.0	18	50	75	90	23	50	450	
III	A	2.5	10	25	30	35	14	20	140	
	B	4.0	14	35	45	50	17	40	270	
	C	6.0	18	50	75	90	23	50	425	
IV	A	2.0	9	23	28	32	12	15	140	
	B	3.0	12	30	40	42	14	30	270	
	C	5.0	16	45	70	80	18	40	400	
V	A	2.5	9	20	25	30	14	20	140	
	B	4.0	13	30	45	50	17	40	270	
	C	5.5	17	45	65	80	22	50	325	
VI	A	2.0	8	18	23	25	12	14	140	
	B	3.0	12	27	41	44	15	28	270	
	C	4.5	16	42	60	70	20	35	425	
VII	A	1.5	5	20	20	30	8	15	120	
	B	3.5	12	30	45	50	11	30	250	
	C	5.0	16	45	65	80	15	40	400	
VIII	A	2.5	7	20	25	30	9	15	110	
	B	4.0	12	30	45	50	12	30	200	
	C	5.5	16	40	60	70	15	40	270	

Table XII. (cont.)

Group No.	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Natural[a] Pasture
IX	A	1.5	3	15	20	20	8	12	70	
	B	3.0	10	25	30	45	13	23	140	
	C	5.0	15	40	50	70	15	30	200	
X	A	1.5	5	15	20	20	10	12	70	
	B	2.5	9	25	30	43	13	24	140	
	C	3.5	12	35	42	62	16	30	200	
XI	A	1.5	4	12	17	17	6	10	70	
	B	2.0	8	20	25	35	10	15	140	
	C	3.0	11	25	35	50	12	20	200	
XII	A	1.0	2	10	15	15	4	7	40	
	B	2.0	7	15	20	30	8	12	70	
	C	2.5	9	18	25	40	9	16	110	
XIII	A	0.5	2	6	10	12	2	5	50	
	B	1.0	5	10	15	25	6	10	80	
	C	1.5	6	12	18	30	7	12	120	
XIV	D									30
XV	D[c]									30

[a] Pasture ratings expressed in cow-acre-days per season (a typical grazing season is 180 days).

[b] All crops are grown in a six-year crop rotation consisting of three years of alfalfa, a cash row crop, a feed crop and a small grain nurse crop. The fertilization levels applied to this rotation are: A. None; B. 15 T/A of manure on the cash row crop; C. 15 T/A of manure, 100#/NH_4NO_3, and 100# TSP per acre on the cash row crop.

[c] These soils are non-arable and should be left in native vegetation and used for pasture.

Table XIII. Estimated Soil Productivity Under Specified Systems of Fertilization by Mapping Units, Huntley Project, Montana

Soil	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Native[a] Pasture
1A1[b]										
2A1[b]	D									30
3A1[b]	D									30
4A1[b]	D									30
8A1[b]	D									30
9A1[b]	D									30
10A1	A[c]	.5	2	6	10	12	2	5	50	
	B[c]	1.0	5	10	15	25	6	10	80	
	C[c]	1.5	6	12	18	30	7	12	120	
	D									40
11A1[b]	D									30
101A1	A	2.0	9	23	28	32	12	18	140	
	B	3.5	13	32	42	45	15	37	270	
	C	5.5	17	47	72	85	21	47	425	
102A1	A	2.5	10	25	30	35	14	20	140	
	B	4.0	14	35	45	50	17	40	270	
	C	6.0	18	50	75	40	23	50	425	
109A1	A	2.0	9	23	28	32	12	15	140	
	B	3.0	12	30	40	42	14	30	270	
	C	5.0	16	45	70	80	18	40	400	
121A1	A	2.0	8	18	23	25	12	14	140	
	B	3.0	12	27	41	44	15	28	270	
	C	4.5	16	42	60	70	20	35	425	

Table XIII. (cont.)

Soil	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Native[a] Pasture
122A1	A	2.0	8	18	23	25	12	14	140	
	B	3.0	12	27	41	44	15	28	270	
	C	4.5	16	42	60	70	20	35	425	
145A1	A	2.5	9	20	25	30	14	16	140	
	B	3.5	13	30	45	50	17	30	270	
	C	5.0	17	45	65	80	22	40	425	
153A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.5	19	55	80	95	25	60	450	
155A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.5	19	55	80	95	25	60	450	
158A1	A	1.5	4	12	17	17	6	10	70	
	B	2.0	8	20	25	35	10	15	140	
	C	3.0	11	25	35	50	12	20	200	
159A1	A	1.5	4	12	17	17	6	10	70	
	B	2.0	8	20	25	35	10	15	140	
	C	3.0	11	25	35	50	12	20	200	
205A1	A	1.5	7	20	25	30	9	15	120	
	B	3.5	13	30	45	50	14	30	250	
	C	5.0	17	45	65	80	18	40	400	
207A1	A	1.5	7	20	25	30	9	15	120	
	B	3.5	12	30	45	50	13	30	250	
	C	5.0	16	45	65	80	17	40	400	
209A1	A	1.0	5	15	18	20	7	12	100	
	B	3.0	10	25	30	40	10	25	200	
	C	4.0	14	37	55	65	14	35	350	

Table XIII. (cont.)

Soil	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Native[a] Pasture
217A1	A	1.0	2	10	15	15	4	7	40	
	B	2.0	7	15	20	30	8	12	70	
	C	2.5	9	20	27	42	9	16	110	
225A1	A	1.5	3	15	20	20	8	12	70	
	B	3.0	11	25	30	45	13	23	140	
	C	5.0	15	40	50	70	15	30	200	
227A1	A	1.5	3	15	20	20	7	12	70	
	B	3.0	9	25	30	45	12	23	140	
	C	4.5	13	37	45	65	14	30	200	
228A1	A	1.0	2	10	15	15	4	7	40	
	B	2.0	7	15	20	30	8	12	70	
	C	2.5	8	18	25	40	9	15	110	
235A1	A	1.5	7	20	25	30	9	15	120	
	B	3.5	12	30	45	50	13	30	250	
	C	5.0	16	45	65	80	17	40	400	
237A1	A	1.5	7	20	25	30	9	15	120	
	B	3.5	12	30	45	50	13	30	250	
	C	5.0	16	45	65	80	17	40	400	
239A1	A	1.0	5	18	20	25	7	12	110	
	B	3.0	9	28	40	45	10	25	225	
	C	4.0	13	41	60	70	15	35	375	
247A1	A	1.5	7	20	25	30	9	15	120	
	B	3.5	12	30	45	50	13	30	250	
	C	5.0	16	45	65	80	17	40	400	
252A1	A	1.5	4	12	17	17	6	10	70	
	B	2.0	8	20	25	35	10	15	140	
	C	3.0	11	25	35	50	12	20	200	

Table XIII. (cont.)

Soil	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Native[a] Pasture
255A1	A	1.5	4	12	17	17	6	10	70	
	B	2.0	8	20	25	35	10	15	140	
	C	3.0	11	25	35	50	12	20	200	
264A1	A	2.5	7	20	25	30	9	15	110	
	B	4.0	12	30	45	50	12	30	200	
	C	5.5	16	40	60	70	15	40	270	
269A1	A	2.5	7	20	25	30	9	15	110	
	B	4.0	12	30	45	50	12	30	200	
	C	5.5	16	40	60	70	15	40	270	
304A1	A	2.5	7	30	35	40	12	20	210	
	B	4.0	14	40	50	55	16	40	330	
	C	6.0	18	50	75	90	23	50	450	
307A1	A	2.5	7	30	35	40	12	20	210	
	B	4.0	13	40	50	55	16	40	330	
	C	6.0	17	50	75	90	23	50	450	
312A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.0	18	52	77	92	24	55	450	
314A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.0	18	52	77	92	24	55	450	
333A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.5	19	55	80	95	25	60	450	
334A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.5	19	55	80	95	25	60	450	

Table XIII. (cont.)

Soil	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Native[a] Pasture
352A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.5	19	55	80	95	25	60	450	
354A1	A	3.0	11	30	35	40	13	25	210	
	B	4.5	15	45	55	60	18	45	330	
	C	6.5	19	55	80	95	25	60	450	
362A1	A	2.5	9	20	25	30	14	20	140	
	B	4.0	13	30	45	50	17	40	270	
	C	5.5	17	45	65	80	22	50	325	
364A1	A	2.5	9	20	25	30	14	20	140	
	B	4.0	13	30	45	50	17	40	270	
	C	5.5	17	45	65	80	22	50	325	
370A1	A	.5	2	6	10	12	2	5	50	
	B	1.0	5	10	15	25	6	10	80	
	C	1.5	6	12	18	30	7	12	120	
	D									40
372A1	A	1.5	5	15	20	20	10	12	70	
	B	2.5	9	25	28	43	13	24	140	
	C	3.5	12	35	43	62	16	30	210	
374A1	A	1.5	5	15	20	20	10	12	70	
	B	2.5	9	25	28	43	13	24	140	
	C	3.5	12	35	43	62	16	30	210	
407A1[b]	D									30
422A1[b]	D									30
425A1[b]	D									30
429A1[b]	D									30

Table XIII. (cont.)

Soil	Fertilization Treatment	Alfalfa tons	Sugar Beets tons	Wheat (Spr. & W) bushels	Barley bushels	Oats bushels	Beans cwt.	Corn bushels	Seeded[a] Pasture	Native[a] Pasture
432AA1[b]	D									30
452A1[b]	D									30
455A1[b] 458A1[b]	D									30

[a] Pasture ratings expressed in cow-acre days per season (a typical season is 180 days).

[b] These soils are non-arable and should be left in native vegetation and used for pasture.

[c] All crops are grown in a six-year crop rotation consisting of three years of alfalfa, a cash row crop, a feed crop and a small grain nurse crop. The fertilization levels applied to this rotation are: A. None; B. 15 T/A of manure on the cash row crop; C. 15 T/A of manure, 100#/A of ammonium nitrate, and 100#/A of treble super phosphate on the cash row crop.

PART V - ANALYSIS OF SOIL SURVEY DATA

The applicability of the soil survey data to the above defined criteria of economic optima will be tested by substituting that data into the farm budget described in Part III. Assuming the livestock enterprise constant, the alternative methods of cash crop production facing the farmer may, for the purposes of budget analysis, be classified into three categories: (1) enterprise alternatives, (2) resource alternatives, and (3) practice alternatives.

Enterprise Alternatives

Enterprise alternatives are concerned with the optimum combination of the products which the farmer is able to produce. Sugar beets, beans, and spring wheat are the cash crops listed in the Productivity Chart on page 78. Various combinations of these crops will be substituted into the farm budget to determine which combination will result in maximum net farm income. The budget, then, will be used to outline tenative production procedures to which the farmer has recourse. The complementary, supplementary, and competitive relationships of the enterprises, if any, will be represented by the change in net farm income. These relationships will be expressed in terms of all relevant factors of production.

There are many ways the 45.2 acres available for the production of cash crops may be divided between the three cash crops. 35/ Five

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35/ For a delineation of acreage available for cash crop production, see the crop organization, page 20, Part III.

combinations have been chosen for analysis here. These combinations are: (1) 45.2 acres of sugar beets, (2) 22.6 acres of sugar beets and 22.6 acres of beans, (3) 45.2 acres of beans, (4) 45.2 acres of spring wheat, and (5) 22.6 acres of spring wheat and 22.6 acres of beans. Further, it is assumed that the 45.2 acres of land on which the cash crops are grown are composed of soils found in Group I of the productivity chart and all other arable soils are those found in Group VII. Finally, the yield estimates used for analyzing enterprise alternatives will be those obtained from soil fertilization treatment B of the productivity chart.

The budget summary of each of the five enterprise alternatives is presented in Table V. The receipts and expenditures for the alternatives were determined in the manner described in Part III. Only the crop receipts and expenditures varied between alternatives.

Table XIV. The Budget Summaries for Enterprise Alternatives

	Receipts	Amount	Expenses	Amount
Alternative I : 45.2 Acres of Sugar Beets	Crop	$10,388	Direct:	
	Livestock	3,253	Crop	$4,878
	Home Consumed products	450	Livestock	535
			Indirect	2,903
			Fixed	965
	TOTAL	$14,091	TOTAL	$9,281
NFI - Alternative I				$4,810

Table XIV. (cont.)

	Receipts	Amount	Expenses	Amount
Alternative II : 22.6 Acres of Beans and 22.6 Acres of Sugar Beets	Crop	$8,765	Direct:	
	Livestock	3,253	Crop	$2,862
	Home Consumed Products	450	Livestock	535
			Indirect	2,589
			Fixed	965
	TOTAL	$12,468	TOTAL	$6,951
NFI - Alternative II				$5,517

	Receipts	Amount	Expenses	Amount
Alternative III : 45.2 Acres of Beans	Crop	$7,143	Direct:	
	Livestock	3,253	Crop	$ 847
	Home Consumed Products	450	Livestock	535
			Indirect	2,535
			Fixed	965
	TOTAL	$10,846	TOTAL	$4,882
NFI - Alternative III				$5,964

	Receipts	Amount	Expenses	Amount
Alternative IV : 45.2 Acres of Spring Wheat	Crop	$4,564	Direct:	
	Livestock	3,253	Crop	$ 681
	Home Consumed Products	450	Livestock	535
			Indirect	2,393
			Fixed	965
	TOTAL	$8,267	TOTAL	$4,574
NFI - Alternative IV				$3,693

	Receipts	Amount	Expenses	Amount
Alternative V : 22.6 Acres of Spr. Wheat and 22.6 Acres of beans	Crop	$5,853	Direct:	
	Livestock	3,253	Crop	$ 763
	Home Consumed Products	450	Livestock	535
			Indirect	2,419
			Fixed	965
	TOTAL	$9,556	TOTAL	$4,682
NFI - Alternative V				$4,874

Alternative III (45.2 acres of beans) provided the highest NFI while Alternative IV (45.2 acres of spring wheat) returned the lowest NFI. The highest gross income was provided by Alternative I (45.2 acres of sugar beets) but this system also incurred the highest operating expenses. The high operating expense of Alternative I can be attributed mostly to the cost of contract labor need to block, thin, hoe, and harvest the sugar beets. Alternative III utilized contract labor only for threshing and needed much less hired labor than Alternative I (Alternative III - 142 hrs.; Alternative I - 510 hrs.). Thus, the farmer is able to grow beans using mostly family labor and machinery while sugar beets require both high amounts of contract labor and hired labor.

Resource Alternatives - Resource alternatives are the alternative methods of resource allocation within an enterprise. They determine, ideally, optimum combinations and amounts of factors of production which should be used. In the cash crop enterprise this would include such factors of production as labor, fertilizer, machinery, etc.

Of the cash crop alternatives analyzed, 45.2 acres of beans proved to be the most profitable. Given this enterprise combination (of beans and feed crops), what amounts of fertilizer should be applied to the enterprises to maximize their contribution to NFI? To test this, the yields obtainable from soil fertilization treatments A, B, and C will be substituted into the budget.

Table IV presents the budget summary for each of the soil fertilization treatments available from the soil productivity chart. Since one of the assumptions behind the productivity chart is that labor, etc., should never be limiting to crop yields and also because fertilizer applications should not require much more labor or expense, direct crop expenses have been held constant for each alternative. Direct livestock expenses were increased for Alternative I because the production of feed crops was not sufficient to support the livestock enterprise. Similarly, indirect expenses increased in Alternatives II and III because of fertilizer costs. Livestock receipts and home consumption were held constant throughout, but gross income for Alternative I was increased by the sale of manure not used on the farm.

Total expenses for Alternative II were lower than total expenses for Alternative I. Thus, the farmer can more profitably purchase manure with which to raise his soil fertilization treatment from A to B and raise the additional feed he needs rather than purchase that feed. Because gross income appears increasing at a higher rate than total expenses, it would appear that the farmer has not, even in Alternative III, reached the point where the marginal value of the product of fertilizer equals the marginal cost of the fertilizer. Therefore, it would probably be profitable to the farmer to apply more fertilizer than used in Alternative III.

The above alternatives have been analyzed under the assumption that the farmer will hold the cash crop acreage (45.2 acres of Group I soils) constant and also hold the acreage devoted to livestock (59.8 acres of Group VII soils) constant. However, the farmer may choose to meet the feed requirements of his livestock enterprise first and then devote the remainder of his acreage to cash crops. In other words, he will grow enough

Table XV. Budget Summaries for First Set of Resource Alternatives

	Receipts	Amount	Expenses	Amount
Resource Alternative I : Soil Treatment Level A	Crop	$4,724	Direct:	
	Livestock	3,253	Crop	$ 847
	Home Consumed Products	450	Livestock	1,362
	Manure	600	Indirect	2,346
			Fixed	965
	TOTAL	$9,027	TOTAL	$5,520
NFI - Alternative I				$3,507

	Receipts	Amount	Expenses	Amount
Resource Alternative II : Soil Treatment Level B	Crop	$7,143	Direct:	
	Livestock	3,253	Crop	$ 847
	Home Consumed Product	450	Livestock	535
			Indirect	2,535
			Fixed	965
	TOTAL	$10,846	TOTAL	$4,882
NFI - Alternative II				$5,964

	Receipts	Amount	Expenses	Amount
Resource Alternative III : Soil Treatment Level C	Crop	$10,806	Direct:	
	Livestock	3,253	Crop	$ 847
	Home Consumed Product	450	Livestock	535
			Indirect	3,495
			Fixed	965
	TOTAL	$14,509	TOTAL	$5,842
NFI - Alternative III				$8,667

feed crops to adequately feed his livestock before he allocates any acreage to cash crops. Using these assumptions, the budget analysis for each soil fertilization treatment is presented in Table VII.

In Table VII, the direct crop expense varies between alternatives because the proportionate acreage allocated to each crop varies between

Table XVI. Budget Summaries for Second Set of Resource Alternatives

	Receipts	Amount	Expenses	Amount
Alternative IV : Soil Treatment Level A	Crop	$2,122	Direct:	
	Livestock	3,253	Crop	$ 558
	Home Consumed Products	450	Livestock	535
	Manure	600	Indirect	2,346
			Fixed	965
	TOTAL	$6,425	TOTAL	$4,404
NFI - Alternative IV				$2,021

	Receipts	Amount	Expenses	Amount
Alternative V : Soil Treatment Level B	Crop	$ 7,576	Direct:	
	Livestock	3,253	Crop	$ 952
	Home Consumed Products	450	Livestock	535
			Indirect	2,535
			Fixed	965
	TOTAL	$11,279	TOTAL	$4,987
NFI - Alternative V				$6,292

	Receipt	Amount	Expenses	Amount
Alternative VI : Soil Treatment Level C	Crop	$12,450	Direct:	
	Livestock	3,253	Crop	$1,105
	Home Consumed Products	450	Livestock	535
			Indirect	3,495
			Fixed	965
	TOTAL	$16,153	TOTAL	$6,100
NFI - Alternative VI				$10,053

alternatives. These acreage variations, however, enabled the direct livestock expense to be held constant throughout all alternatives. Again, the indirect expense increased as more fertilizer was used, and the fixed costs, livestock receipts, and value of the home consumed products stayed constant.

Alternative IV yields a lower NFI than Alternative I. Thus, when the farmer used Group I soils (which are the highest producing soils on the productivity chart) to grow feed crops, he gave up a portion of his NFI. Under soil fertilization treatment A, it is more profitable for the farmer to raise cash crops (beans in this instance) and buy the extra feed he needs. The NFI of Alternative V and VI was increased over the NFI of Alternative II and III respectively due to the contribution to the income brought about by growing cash crops on the Group VII soils not needed for feed crops, i.e., the value of the cash crops which can be grown on the Group VII soils is greater than the value of the feed crops when the latter are sold on the market.

The difference between gross income of Alternatives V and VI when compared to the difference between total expenses of the two alternatives would indicate that the farmer has not yet reached, in terms of fertilization, the point where the marginal value of product equals the marginal cost of the input. This is implied here by the relatively large change in gross income as compared to total expenses. Actually, there is no way of knowing whether Alternative VI (or III) represents the exact position where MVP of fertilizers equals the MC of fertilizer or some position on either side of that equality.

Practice Alternatives - Practice alternatives are related to the methods of resource application. For instance, how should fertilizers be applied; drilled with the seed, sidedressed, applied in irrigation water, etc.? Analysis of practices alternatives will tell which practices will maximize product from a given amount of input or how a specific amount of product can be produced with a minimum amount of input.

Practice alternatives will not be analyzed in this study because, while the soil survey information discusses practice alternatives qualitatively, quantitative measures of the relative values of such practices are not derivable from that data.

Part VI - Conclusions and Implications

Limitations of this Study

At the outset of this study, it was assumed that the goal of the farmer is to maximize net farm income. All of the analysis and implications of this study have been based on this assumption. And, since maximizing net farm income may not be a goal of all farmers, this basic premise should be realized when interpeting the results of this study.

The budget analysis has introduced certain limitations in this study. Static prices, techniques, etc., which were used removed the element of uncertainty and limited the quantitative results of the budget analysis (NFI estimates) to the organization of the budget and the 1953 price level. Also, when organizing the budget, the farm was assumed to be debt free.

When analyzing the soil survey data, the study was limited to one year of the rotation period. As the rotation sequence progresses, shifts in fields (soil types) and crops would cause changes in NFI to occur. Also, as resource alternatives were analyzed, the time periods necessary to increase soil fertility levels from (say) fertilizer treatment A to fertilizer treatment B were not taken into consideration. Finally, because the livestock organization was held constant, surplus feed crops were assumed to be marketed. Actually, the farmer might chose to vary the livestock organization to utilize available feed.

Yield Data Sources

Conclusion - The experimental data obtained from the Huntley Branch

Station was the most reliable and useable information utilized in this study. Despite its limitations, it was relied upon more than either of the other sources of information. Experimental data, however, are not always obtainable where needed. In such areas, other sources of data must be utilized.

Of the other sources of yield data used here, the farmer interview was judged to be more reliable than the Project water user's reports (for crops other than sugar beets). Other than assuming that the farmers interviewed reported the yields of other crops with the same degree of accuracy with which they reported sugar beet yields, there is no way of comparing the accuracy of the farmer interview and water user's reports for crops other than sugar beets. Because the farmer obtains accurate sugar beet yield information from the sugar beet company, he would be able to report accurate sugar beet yields. Contrariwise, because the farmer may never accurately measure the yields of other crops, especially feed and forage crops, the Project water user's reports could be as accurate as the farmer interview for those crops.

Also, judgement was used throughout the formulation of the productivity chart. Judgement was used to adapt the farmer interview data to the role of benchmarks. Further judgement was used to adapt the yield responses obtained from the experimental data to these benchmarks. Finally, judgement was used to estimate yields for soils other than the seven groups of soils for which empirical data were gathered.

Implications - While an experienced soil scientist might be able to give yield estimates which are more accurate than could be derived from a small empirical sample, there are dangers in the use of judgement. For instance, soils might be prejudged on the basis of their productivity in other areas or by the efficiency of the farmers who manage them. Or, judgement might allow the soil scientist to place emphasis on certain soil characteristics rather than objectively viewing each soil in situ. Also, the use of judgement in estimating yields eliminates the possibility of calculating error estimates for those yield estimates.

The extensive use made of judgement in synthesizing the soil productivity chart implies an important need for more accurate sources of yield data. For while judgement will probably never be completely removed from the formulation of yield estimates minimization of its use would eliminate, as much as possible, the distortion it could cause in the yield estimates.

Suggested Areas for Further Research - Assuming the yield estimates given in the productivity chart to be the average of yields obtainable by the farmer over long time periods, it would be useful to know the expected variations around that mean. As mentioned before, the judgement involved in formulating the yield estimates used in this study made error estimate calculations impossible. Since this will be true of soil productivity data as long as judgement is used, other methods might be used to illustrate the variability of crop yields in the area.

Table XVII is an example of such a method. In it are calculated the arithmetic mean, the standard deviation, and the coefficient of variation for two crops grown extensively on the Huntley Project. The yield figures from which the information was derived are the average of all yields reported to the Project office each year by all the Project farmers who grew that crop.

Table XVII. Yield Variations [a]

Year	Beans (bu./A)	Sugar Beets (T./A)
1930	29.08	14.13
1931	24.43	11.53
1932	22.62	14.24
1933	23.92	14.86
----	----	----
----	----	----
----	----	----
1946	22.05	15.32
1947	24.37	14.50
1948	22.90	13.30
1949	24.71	14.25
1950	30.58	13.71
$\bar{X}$ [b]	23.73	13.37
σ [c]	2.8245	1.2318
C.V. [d]	11.9%	9.2%

[a] Yield data gathered by Huntley Project office and represent average of all yields reported annually by farmers.

[b] Arithmetic mean.

[c] Standard deviation.

[d] Coefficient of variation.

By using the standard deviation, the chart user can determine the amount of variation to expect, i.e., for beans 68.27 percent of the yields will fall within 23.73 bu. $\pm$ 2.8245 bu.; or 95.45 percent of the bean yields will fall within 23.73 bu. $\pm$ 5.6490 bu. etc. The user could also calculate the dollar value of these deviations. Using 1953 prices, the value of the standard deviation of beans is $13.63 and for sugar beets, $17.42.

The coefficient of variation is perhaps the most useful concept in Table XVII. By using the C. V., the relative variation in crop yields may be compared. In this example, the difference between the variations found in beans and sugar beets yields is not statistically significant. While the yield variations would vary absolutely between farmers, soil types, and systems of management, the coefficient of variation, as calculated here, would serve as a general indicator of crop variations to be expected.

Although the accuracy of the data obtained by farmer interview has been questioned, the farmer is a potentially valuable source of information. An interview system more closely controlled might obtain more accurate data. For instance, as the field work of a soil survey progresses, the soil scientists could compile and continually expand, through direct contact, etc., a list of farmers willing to cooperate with them in their efforts to obtain yield data. The purpose and requirement of such data should be explained to the farmers in order to increase the degree of accuracy of the data. Since the field work of a soil survey for a given area usually requires several years, a substantial backlog of yield observations might be collected in this manner. This technique may be particularly applicable since the recent merger of all the soil survey systems into the Soil Conservation Service. 36/

36/ This suggestion is similar to a method suggested by A. R. Aandal, Senior Soil Correlator, Soil Conservation Service, U.S.D.A., by personal communication, 1954.

Another potential source of yield data, suggested widely in soil survey literature, is field sampling. This would involve measurement of crop yields by sampling yields in fields of known soil types. These yields could then be directly correlated to the soil profiles present in the field sampled. This would provide yield data of known accuracy from known soil types.

Each of the above suggestions have limitations as well as advantages. But because the reliability and scope of the soil productivity data will depend, to a large degree, upon the reliability and scope of the yield data sources, further research in this area is recommended.

Group Yield Ratings vs. Individual Yield Ratings

A problem encountered during this study was: should soils of similar productivity be grouped together and assigned a common set of yield estimates or, should each soil be assigned individual yield estimates (see page 46). Although this problem was not within the defined scope of this study, perhaps a discussion of certain aspects of the problem encountered during this study will serve as a guide to planning future research designed to resolve the problem.

The reliability and extensiveness of the empirical yield data available for the formulation of yield estimates may determine whether or not grouping is used. If the available yield data, because of a lack of reliability or scope, do not present a basis for differentiating between the yields of two soil types, the soil scientist may feel justified in grouping those soils. This type of grouping could occur either because there is no yield differential between the soil types or because there are no data to substantiate any yield differences, where there is a yield difference. However, the chart user might prefer to have the judgement of the soil scientist rather than use his own judgement or a grouped yield estimate which does not represent the productivity of the soil.

Assuming the yield estimates to be reliable, these are still problems in grouping. Classifying soils into groups on the basis of productivity involves the establishment of an arbitrary level of significance. Or, stated differently, accepting the yields estimated for the group of soils as the mean of the yields of all the soils within that group, how widely can the actual yields of the soils vary from the mean without becoming significant to the uses of the chart?

The limits of variation allowed within a grouping of soils will depend upon the users of the chart. While an irrigation farmer might prefer to know relatively small yield differentials, the dryland farmer or rancher might allow wide variation limits. In this sense, the variation acceptable within a grouping would depend upon the yearly yield variations caused by factors of production not controllable by the farmer. Thus, the standard deviation of the crop yields in an area might present an arbitrary limit of variation. For instance, using the yield variation for beans as presented in Table XVII all soils with long time average bean yields falling within 23.73 ± 2.82 bu./A. might be grouped together. The danger here is that the yields of soils on the extremes would fall within the limits of variation only 50% of the time.

Another statistical method of establishing criteria for grouping soils would be the use of tests of significance. Using empirical yield data, analysis of variance could be used to determine if the yield differentials between soils, for given crops and management systems, are significant at the .05, .01, or .001 levels of significance (one of which could be accepted as the limit of variation). This method would require extensive empirical data.

Still another method of calculating yield variation limits allowable in grouping would be by using deviations in yields which would not cause optimum enterprise combinations to change. For instance, of the enterprise alternatives analyzed in this study, the most profitable crop which could be grown on Group I soils is beans. Given the limiatations of the study, this should be true of all Group I soils. So, using beans yields as an example, this method would pose the question: "How much drop can be allowed in per acre bean yields (b), given the per acre yield of sugar beets (s), as well as the prices (P_B, P_S) and costs (c_B, c_S) of producing sugar beets and beans, and still allow beans to yield a higher NFI than sugar beets"? This has been worked out, as an example, using the following equation:

$$b = \frac{sP_S \text{ (acres in beets)} - (c_S - c_B)}{P_B \text{ (acres in beans)}}$$

Solving this equation, using yields obtained from Group I soils subjected to fertilization treatment B, and costs and prices used in the budget formulation, shows that the yield of beans may drop to as low as 14.0

cwt./A. before the NFI from the two enterprises are equal. Thus, given a sugar beet yield of 15 T/A for Group I soils subjected to fertilization treatment B, all soils in Group I must yield more than 14 cwt./A (under fertilization treatment B).

There are difficulties in this method of establishing arbitrary limits of yield variation,however. First, the formula was derived from the budget used in this study and so is limited to the farm as organized here. Other farm organizations would probably give use to different yield variation limits. Secondly, the farmer must consider price variations. Using the above formula, it was calculated that the price of beans need to fall $1.81/cwt. to equalize NFI from the two enterprises. Third, the limits of yield variation vary with the fertilization treatments. In the above example, for fertilization treatment B, bean yields could vary up to a maximum of slightly less than -4 cwt./A from the yield of the group, but the comparable figure for fertilization treatment A is -6.2 cwt./A, and for fertilization treatment C is -3.8 cwt./A. Finally, one crop, in this example, sugar beets, must be chosen to represent a "benchmark" around which other soils are allowed to vary. The chart user, however, might prefer the use of a different crop for a benchmark.

The scale of farm operations must be considered in attempts to define levels of significance in yield variations. As an example of this, suppose a Huntley Project farmer has on his farm, two Group VII soils which represent the yield extremes of the group (235A1, Ballantine silty clay loam, nearly level, and 209A1, Ballantine clay, deep, nearly level). While the sugar beet yield of Group VII soils is estimated to be 16 T/A under fertilization treatment C, the individual sugar beet yield estimates for 235A1 and 209A1 are 16 T/A and 14 T/A, respectively, for the same fertilization treatment. If the farmer raises 6.3 acres of sugar beets a year, he would receive $178.16 (1953 price level) less from growing the sugar beets on 239A1 than if he grew them on 235A1. But if he grew 58.4 acres of sugar beets, the difference would amount to $1651.55. While $178.16 might not be significant to the farmer, the chances that $1651.55 would be insignificant are small. The grouped ratings, however, would indicate no difference between the yields of the soils. 37/

Grouping of soils, as referred to herein, is actually the classification of soils using yield estimates as differentiating characteristics. 38/ The problem of grouping has been discussed in terms of defining the yield limits allowable in the individuals within the group. Further, the groupings attempted in this study, and discussed above, refer to grouping soils on the estimates of their yield capabilities for eight crops (sugar beets, spring and winter wheat, barley, oats, beans, corn, and seeded pasture). Thus, this grouping involves the use of eight differentiating characteristics

37/ This same example could be used to demonstrate the effects of scale upon grouping soils with different yield responses, i.e., production functions with different elasticities.

38/ While soil scientists usually refer to this type of classification as "technical" or "artificial" in contrast to the "natural" classification based upon morphological features of the soil, these terms are not used here because of their conotative implications. Grouping soils for productivity is an interpetive classification which is no more "artificial" or "technical" than any other classification.

and has eight objectives. However, there are other ways to group soils to meet these eight objectives. 39/ Table XVIII illustrates two possible methods of grouping soils on the basis of productivity which could be included in a soil survey report along with a chart giving individual yield estimates for each soil type.

Table XVIII. Grouping Soils on the Basis of Productivity [a]

A. Suitability of Soils for the Production of Sugar Beets when Soils are Subjected to Fertilization Treatment C[c]

Suitability Group	Soil Type [b]
Very Good (17-19 T/A)	153A1 - Harlem-Havre silt loam, nearly level
	334A1 - Fort Collins clay loam, nearly level
	304A1 - Nunn clay loam, nearly level
	101A1 - Havre fine sandy loam, nearly level
Good (14-16 T/A)	109A1 - Havre loam, slightly saline, nearly level
	205A1 - Pryor silty clay loam, nearly level
	225A1 - Pryor-Nibbe clay loams, nearly level
	239A1 - Ballantine clay, deep, nearly level
Fair (11-13 T/A)	227A1 - Pryor-Nibbe silty clay, nearly level
	374A1 - Larimer clay loam, nearly level
	255A1 - Ballantine silty clay loam, seeped, nearly level
Poor (-10 T/A)	217A1 - Pryor silty clay, seeped, nearly level
	228A1 - Pryor, Nibbe clay, nearly level
	370A1 - Larimer gravelly loam and sandy loam, nearly level
	10A1 - Havre gravelly loamy fine sand, shallow, nearly level

39/ For a discussion of interpetive groupings see Ornedal, A. C., and Edwards, M. J., "General Principles of Technical Groupings of Soils", Soil Sci. Soc. of Amer. Pro., 6:386-391, 1941. These authors recommend grouping soils for interpetive purposes on only one differentiating characteristic or for only one objective.

Table XVIII. (cont.)

B. Response to Fertilizer (100#A of NH_4NO_3, 100#/A of TSP)[c]

Response of Sugar Beets (T/A)	Soil Type
4	153A1 - Harlem-Havre silt loam, nearly level 109A1 - Havre loam, slightly saline, nearly level 101A1 - Havre fine sandy loam, nearly level 227A1 - Pryor-Nibbe silty clay, nearly level 334A1 - Fort Collins clay loam, nearly level
3	255A1 - Balantine silty clay loam, seeped, nearly level 374A1 - Larimer clay loam, nearly level 314A1 - Fly Creek clay loam, nearly level 158A1 - Harlem silt loam, mod. saline, nearly level
2	217A1 - Pryor silty clay, seeped, nearly level 228A1 - Pryor-Nibbe clay, nearly level
1	370A1 - Larimer gravelly loam and sandy loam, nearly level 10A1 - Havre Gravelly loamy fine sand, shallow, nearly level

[a] No attempt has been made to include all Huntley Project soils in this table. It is used here only as an illustration.

[b] Soils are ranked from the top according to productivity, for instance, 153A1 will produce 19 T/A of sugar beets while 101A1 produces 17 T/A of sugar beets.

[c] The same assumptions underlie these groupings as those given in the productivity chart, i.e., a six year rotation which is half-time alfalfa, fertilizers applied to the cash crop, etc. The responses obtained in Chart II-B are when the fertilizers are applied to soils already subjected to Fertilization Treatment B.

On the basis of their productivity of sugar beets under fertilization treatment C, soils have been grouped in Table XVIII according to their "suitability" for sugar beet production. The sugar beet yield estimates which determined the groupings were procured from the chart which lists individual yield estimates. This table (XVIII) will permit the user to

(1) compare the productivity of a given soil with other soils for the same crop, and (2) compare the relative ability of a soil to produce different crops.

Table XVIII gives the amount of sugar beet response which can be obtained from soils when the fertilization treatment is varied from B to C. This table is useful in demonstrating which soils yield the largest responses to fertilizer and would prove valuable to a farmer who wishes to know how to allocate a limited amount of fertilizer (see page 15 for an explanation of this in terms of economic theory).

An important attribute of these charts is that the limits are defined in the charts and the user is free to disagree with the limits or refer to the individual ratings. Further, each grouping has but one specific objective for which the classification is formulated.

The foregoing discussion presents some methods of grouping soils for the purpose of assigning yield estimates to the group. Since this subject is important to the interpetation of soil survey maps, it is hoped that the above will provide some ideas for future research on the subject.

<u>The Adaptability of the Soil Survey Data to the Farmers Economic Objectives</u>

<u>Conclusions</u> - While the soil productivity chart did not meet the criteria for the maximization of NFI as defined in Part III, it did prove very useful to the farmer in his attempts to attain that objective.

When used for analyzing enterprise alternatives, the data from the soil productivity chart illustrated that, of the alternatives analyzed, 45.2 acres of beans maximized the cash crop contribution to NFI. Further, the number of enterprise alternatives analyzed was not limited by the soil productivity data but by the budget method of analysis. This is true if it is assumed that the farmer wishes to use a six year rotation which is half-time legume. Since this assumption may not always be valid, it would be useful if the soil productivity chart included yield estimates obtainable when other types of rotations are used. This would permit an estimation of the competitive, complementary, and supplementary relationships between enterprises. For instance, in a six year rotation which is half-time legume, what competitive effects, if any, would be created in the yields of other crops if one year of alfalfa were replaced by (say) spring wheat or sugar beets, or what complementary effects, if any, would a fourth year of alfalfa have on the yields of other crops in the rotation? Or, in a given rotation, how will the yields of other crops be effected if sugar beets are grown in place of beans? Further, what yields might be expected from a two year rotation of (say) sugar beets and beans when subjected to various fertilization treatments. There are an almost infinite number of fertilization rates, crop sequences, and rotation lengths which could be included in a soil productivity chart. To present all possible combinations might prove to be an insurmountable task, but it would be useful to enumerate the combinations most commonly found in the area.

Assuming beans to be the most profitable cash crop enterprise available to the farmer, resource alternatives were analyzed to determine the effects of fertilizer upon the contribution of the cash crop enterprise to the total NFI. Again the soil productivity chart proved useful, for it demonstrated, through the budget, how NFI could be increased from $2,021 to $10,053 by the use of fertilizers. But, the productivity chart does not tell the farmer if the use of more fertilizers than utilized by fertilization treatment C would be profitable. Conversely, the change in NFI between the fertilization treatments seems to indicate that the use of fertilizers would increase NFI. 40/ Further, the productivity chart does not separate the effects of each fertilizer on crop yields or indicate to the farmer which fertilizers could be used most profitably on a given soil when funds available for purchasing fertilizers are limited. This situation would be clarified had the productivity chart presented the production function for each type of fertilizer (assuming other variable inputs are held constant) thus enabling the farmer to (1) equate the marginal costs of fertilizer to the value of the marginal product of fertilizer or (2) maximize income from the available resources by using them on soils which yield the highest VMP per unit of input. While it would probably be impossible to formulate production functions for all crops, soils, and combinations of fertilizers, it would be useful to present the combinations of the three most common to the area.

Practice alternatives are the third type of production alternatives which may be analyzed by the budget method. While the soil survey data

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40/ The change in NFI between fertilization treatments A and B was $4271 while the change in NFI between fertilization treatment B and C was $3457. As mentioned previously, from the yield information given there is no way of knowning whether the yields obtained from fertilization treatment C represent the maximum yields obtainable or some point on either side of the maximum.

did discuss practice alternatives, the discussion was qualitative rather than quantitative and so could not be analyzed by the budget method. Comparisons, in terms of crop yields, of practice alternatives would prove useful to the farmer. For instance, how will the different methods of applying fertilizer (side-dressed, drilled with the seed, etc.) effect the yield of beans or sugar beets? Or, how much do alfalfa yields vary when fall seeded rather than spring seeded and how does a nurse crop effect alfalfa yields? Or, how many times during a "typical" growing season should a crop on a given soil be irrigated. Again, as with the other alternatives to eliminate the countless possibilities only the most important and common practices should be evaluated.

In summary, due to variation in soil and soil management, comparison of the alternatives presented to the farmer (enterprise, resource, and practice alternatives) in terms of crop yields would probably not be exactly similar on all farms. In most cases, however, the comparisons would indicate the optimum enterprise combinations and resource allocation which the farmer could utilize. And, when comparing alternatives, only those alternatives which are relevant to soil management in the area should be discussed.

Implications - The economic requirements of the soil survey data seemingly indicate a complex array of yield estimates. Yet, most of the relationships needed to satisfy these requirements need not be calculated by soil scientists but may be derived from the yield estimates by the users of the chart. Table XIX will be used to illustrate this. The sugar beet yields in Table XIX represent the amount of response obtained by applying various combinations of nitrogen and phosphate fertilizers to a Huntley Project soil.

Table XIX. Sugar Beet Yield Response to Fertilization[a]

#$(NH_4)_2NO_3$ / #TSP	0	40	80	120	160	200	
0	<u>14.4</u>	16.0	<u>16.9</u>	17.1	17.3	17.2	T/A
40	14.4	16.1	17.0	17.2	17.5	17.4	of
80	14.5	16.2	<u>17.1</u>	17.4	17.7	17.6	Sugar
120	14.6	16.4	17.2	17.5	17.8	17.7	Beets
160	<u>14.3</u>	<u>16.2</u>	<u>17.0</u>	17.4	<u>17.7</u>	17.5	
200	14.1	15.9	16.9	17.2	17.4	17.3	
	T/A of Sugar Beets						

[a] The underlined yield figures are actual yields obtained on a Fort Collins silt loam on the Huntley Project as part of an experiment conducted by: Larson, W. E., "Fertilizer Studies with Sugar Beets in South Central Montana", reprinted from <u>1952 Proceedings American Society of Sugar Beet Technologists</u>. The rest of the yield figures are hypothetical.

By holding the amount of one type of fertilizer constant at any level, the yields caused by varying amounts of the other fertilizer represent a partial production function. These relationships permit the calculation of the optimum amounts of fertilizer to be used, or the optimum allocation of a given amount of fertilizers. For example, assuming the cost of ammonium nitrate to be $1.64/140# and the cost of applying varying rates of fertilizer negligible, how much ammonium nitrate should be applied when sugar beets sell for $14.44/T and no phosphate fertilizer is used? The marginal analysis presented in Table XX shows that to equate VMP_n to MC_n, the farmer

Table XX. A Demonstration of Marginal Analysis of Sugar Beet Yields

#$(NH_4)_2NO_3$/A	TPP (T/A)	MPP_n (T/A)	VMP_n ($)	MC_n ($)
0	14.4	---	---	---
40	16.0	1.6	$23.10	$1.64
80	16.9	.9	13.00	1.64
120	17.1	.2	2.89	1.64
160	17.3	.2	2.89	1.64
200	17.2	-.1	-1.44	1.64

must use the nitrogen fertilizer at a rate somewhere between 160#/A and 200#/A when no TSP is used. This example also illustrates optimum allocation of a limited amount of resource, for the farmer would receive more return from 200# of the nitrogen fertilizer by applying 40#/A to five acres rather than applying 200#/A to one acre. Notice, in Table XIX, that since a response of more than .1 of a ton of sugar beets (value: $1.44) is needed to pay the cost of 40 lbs. of TSP (value: $1.70), that TSP should not be applied until at least 160#/A of ammonium nitrate is used.

From the same yield figures given in Table XIX, resource substitution rates can be calculated. For example, 17.2 T/A of sugar beets may be produced by several combinations of TSP - $(NH_4)_2$ NO_3: 0-(80-120)#, 0-200#, 40#-120#, 80#-(80-120)#, 120#-80#, 160#-(80-120)#, and 200#-120#. These combinations could be evaluated to determine which of the economically relevant combinations would minimize the fertilization costs of producing

17.2 T/A of sugar beets. 41/

Finally, the type of yield data presented in Chart III, when available for different soils and crops, could be used to: (1) analyze enterprise alternatives given the resource limitations of the farmer, and (2) calculate, in addition to the resource analysis on a given soil type illustrated above, the optimum allocation of a limited amount of fertilizer between soil types. And it should be noted from Chart IV that at least four rates of fertilization (resource) applications are needed for a satisfactory marginal analysis.

Suggested Areas For Future Research - The economic requirements of the soil productivity chart suggest a definite need for improved sources of primary yield data. The extensiveness and accuracy which would be desirable

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41/ This evaluation would involve determining the marginal rates of substitution between the nitrogen and phosphorus fertilizers and equating that MRS to the inverse price ratio of the two fertilizers (as explained in Part II, pp. 9-11). Expressing sugar beet output (Q) as a function of the quantities of phosphorus (P) and nitrogen (N), we have

$$Q = f(P_1, N \mid X_1, \ldots, X_n),$$

from which the marginal products of phosphorus and nitrogen are given by $\frac{\partial Q}{\partial P}$ and $\frac{\partial Q}{\partial N}$, respectively. The marginal rate at which nitrogen substitutes for phosphorus, at a given value for Q_1 is the ratio of the two marginal products: MRS_N for $P = \frac{\partial Q}{\partial P} \Big| \frac{\partial Q}{\partial N}$.
Finally, the optimum (cost minimizing) combination of N and P is given where the marginal rate of substitution of N for P equals their inverse price ratio; i.e.: $\frac{\partial Q}{\partial P} \Big| \frac{\partial Q}{\partial N} = \frac{P_N}{P_P}$
where P_N and P_P refers to the price of nitrogen and the price of phosphorus, respectively. For a more detailed discussion of this procedure see R. G. D. Allen, Mathematical Analysis For Economists, Macmillan and Co., Limited, 1942, pp. 340-343.

in a soil productivity chart cannot be formulated without extensive and accurate yield data which is, for the most part, unavailable today. Thus, many of the improvements suggested for the soil productivity chart in this treatise must come after enough primary yield data is available to formulate such yield estimates. Also, the extensiveness of the yield estimates requirements for economic objectives magnifies the usefulness of soil grouping if future research can formulate a satisfactory method of grouping.

This study has indicated the potential usefulness of the present soil productivity charts and has suggested ways by which the chart might be made even more useful (to those who wish to help the farmer maximize NFI). It is important to remember that if the soil productivity chart is to be useful, the criteria for usefulness must be defined by those who use the chart rather than those who formulate the chart. In this sense, future research should be carried on not only by those who wish to improve the soil productivity chart for economic uses but by all others who would find the productivity chart of value when the yield estimates are presented in a manner useful to them.

APPENDIX

APPENDIX I[a]

Labor Requirements - Crop & Livestock

Operation	No.	Hours /Acre	Total Hrs.	Yearly Distribution											
				J	F	M	A	M	J	J	A	S	O	N	D
Sugar Beets	25														
Land Prep.		5.5	137.5				71.3						33.1	33.1	
Planting		1.5	37.5				37.5								
Cultivating		4.6	115.0				17	49	49						
Irrigation		8.6	215.0				15	40	40	40	40				
Harvest		8.5	212.5										150	62.5	
Beans	8.6														
Land Prep.		4.8	41.3				20.6	20.7							
Planting		1.6	13.8					13.8							
Cultivation		3.6	31.0					11	20						
Irrigation		7.5	64.5					21.9	12.9	12.9	12.9	12.9			
Harvesting		30.4	261.4								130.7	130.7			
Barley	5.6														
Land Prep.		3.8	21.3			4.1	17.2								
Planting		1.7	9.5				9.5								
Irrigation		4.8	26.9					8.9	9.0	9.0					
Harvesting		7.5	42.0								42				
Spr. Wheat	11.6														
Land Prep.		3.6	41.8			30	11.8								
Planting		1.6	18.6				18.6								
Irrigation		4.6	53.4					17.8	17.8	17.8					
Harvesting		7.1	82.4								82.4				
Alfalfa	27.6														
Cultivation		.7	19.4				19.4								
Irrigation		5.7	157.3					17.3	35	35	35	35			
Harvest		6.3	173.9						26.9	60	60	27			
Pasture	26.6														
Cultivation		.9	23.9						7	7	9.9				
Irrigation		7.5	202.2					22.2	45	45	45	45			

APPENDIX I[a]
(cont.)

Labor Requirements - Crop & Livestock

Operation	No.	Hours/ Head	Total Hrs.	Yearly Distribution											
				J	F	M	A	M	J	J	A	S	O	N	D
Dairy Cows	5	140	700	70	70	70	70	56	42	42	42	42	56	70	70
Beef Cows	12	18	216	21.6	21.6	25.9	28.8	15.1	10.8	10.8	10.8	10.8	15.1	25.9	19.4
Calves	15	15	225	33.8	33.8	33.8	33.8						22.5	33.8	33.8
Yearlings	15	10	150	27	27	27							15	27	27
Sow	1	30	30	1.8	1.8	3.0	5.1	3.6	1.8	1.8	1.8	1.8	1.8	3.9	1.8
Pigs	5	2.5	12.5	.8	.8	1.3	2.1	1.5	.8	.8	.8	.8	.8	1.6	.8
Chickens	125[b]	2.3	287.5	23	23	28.8	40.3	23	20.1	20.1	20.1	20.1	23	23	23
Grand Total				178	178	224	418	313	338	302	533	366	317	381	176

[a] Labor requirements calculated from: Farm Budget Standards for Irrigation Farming, op. cit., pp. 1-34.

[b] Chickens: bought 150; sold 100; average number: 125 @ 2.3 hours per head.

APPENDIX II

FARM NO.__________

ECONOMIC APPLICATIONS OF SOIL SURVEY DATA IN IRRIGATED AREAS

MAP NO.__________

DATE__________ OPERATOR__________

OWNER__________ YEARS ON FARM (Operator)__________

FORTY LOCATION F____,Sc.____,S____,T____,R____

SIZE AND TENURE:

FIELD LOCATION:

Total Acres

	Owned	Rented	Total
Dry			
Irrigated			
Total			

Crop Acres

	Owned	Rented	Total
Dry			
Irrigated			
Total			

SOIL TYPE__________

DATA SOURCE__________

DOES THIS FIELD HAVE (NEED) ARTIFICIAL DRAINS?__________

IF SO, WHAT EFFECT DID THEY HAVE?

____

____

____

____

HAS THIS FIELD BEEN LEVELED (Heavy)?__________ WHEN?__________

WHEN WAS COMMERCIAL FERTILIZER FIRST USED ON THIS FIELD? (N)______(P)_____

CULTURAL PRACTICES			IRRIGATION			PLANTING AND HARVESTING		
Operation	Implement	Times Over	Date	Rate	Length of time	Operation	Seeding Rate	Date

FIELD RECORD

YEAR	CROPS	ACRES	YIELD	MANURE				FERTILIZER			Increase Attributed to Fertilizer	REMARKS (Livestock-Suitable Crops)
				Green		Barnyard						
				Kind	Time	Rate	Time	Kind	Rate	Time Applied		
1953												
1952												
1951												
1950												
1949												
1948												
1947												
1946												
1945												
1944												
1943												
1942												
1941												
1940												
1939												
1938												
1937												
1936												
1935												

APPENDIX III

I

Farm No.____

Economic Applications of Soil Survey Data in Irrigated Areas

Operator________________________ Owner________________________

Address________________________ Address________________________

Size and Tenure:

1.

Total Acres	Owned	Rented	Total
Irrigated			
Dry			
Total			

Crop Acres	Owned	Rented	Total
Irrigated			
Dry			
Total			

2. For rented land

$______________ per acre

or ______________ total

or ______________ % of ______________

or ______________ % of ______________

Machinery and Equipment:

Item	Value
Tractor, size____ age____	
Tractor, size____ age____	
Tractor, size____ age____	
Truck, size______ age____	
Truck, size______ age____	
Car, model______ age____	

II Crops: Organization, Production, Disposition

			Produced		Disposition								Inventory			
					Landlord		Sold		Bought		Used		1/1/53		1/1/54	
Crop	Unit	Acres	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Value	Qty.	Value
1	2	3	4	5	6	7	8	9								
Alfalfa Hay Seed																

III Livestock Inventory

Kind	1/1/53 Inventory		Purchased		Sold		1/1/54 Inventory		Used in Household		Landlord	
	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Val.
Dairy cows												

FARM NO. ____________________

FARMER ____________________

ECONOMIC APPLICATIONS OF SOIL SURVEY DATA IN IRRIGATED AREAS (PROJECT DATA)

YEAR	S. BEETS		BEANS		OATS		SPRING WHEAT		WINTER WHEAT		BARLEY		CORN		ALFALFA		OTHER HAY		PASTURE	LIVESTOCK				
	A	Y	A	Y	A	Y	A	Y	A	Y	A	Y	A	Y	A	Y	A	Y	A	Horse	Hog	Sheep	Beef	Dairy
1953																								
1952																								
1935																								

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