An economic analysis of the 160 acre limitation in District One of the Lower Yellowstone Irrigation Project with policy implications
by George Walser Haynes

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AN ECONOMIC ANALYSIS OF THE 160 ACRE LIMITATION IN DISTRICT ONE
OF THE LOWER YELLOWSTONE IRRIGATION PROJECT
WITH POLICY IMPLICATIONS

by

GEORGE WALSER HAYNES

A thesis submitted in partial fulfillment
of the requirements for the degree

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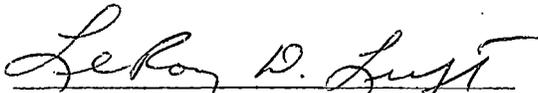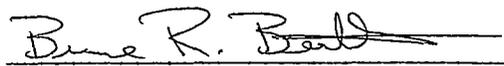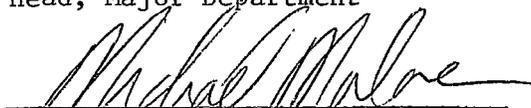
MASTER OF SCIENCE

in

Applied Economics

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MONTANA STATE UNIVERSITY
Bozeman, Montana

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ABSTRACT

Recent litigation in the Federal Courts concerning the enforcement of the Reclamation Act of 1902 and the Omnibus Adjustment Act of 1926 prompted this study to be undertaken. This thesis examines economies of size and the relationship between farm size and net income on irrigated farms in District 1 of the Lower Yellowstone Irrigation Project. Chapters one and two include a brief historical account, a problem statement and a review of relevant economic literature. The economic rationale and mathematical model are presented in chapter three. Chapters four and five contain the conclusions drawn from the linear programming model and subsequent financial analysis in considering various policy scenarios.

CHAPTER 1

INTRODUCTION

Evolution of the 160 Acre Limitation

Settlers of the American West found water to be a very scarce

and consequently precious resource. The pre-Columbian Indians adapted

to the arid environment of the Southwest by capturing storm runoff and

irrigating their crops. Spanish colonialists and Missionaries, in

the 17th and 18th centuries, employed water preservation techniques

practiced in their homeland for centuries.[1] The next several decades

were marked by controversy as land and water were enjoined.

Following the formation of the thirteen colonies, the new govern-

ment was posed with problems of disposing of a vast public domain.

The new government needed money, thus prompting Secretary of the

Treasury Alexander Hamilton to suggest that land be sold to settlers

to raise revenue. Hamilton's notion coupled with Thomas Jefferson's

vision of an agrarian economy, with production in the hands of small

producers, to determine congressional policy. In 1784, a congressional

policy was approved suggesting that an attempt be made to dispose of

this vast public domain.[2] With the adoption of the Constitution,

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[1] Michael G. Robinson, "Water at Work: Reclamation, 1902-1977." 1976 Summary Report, United States Department of the Interior (Bureau of Reclamation). p. 41.

[2] Alan Stanford Kezis, "An Examination of Economies of Size and Net Revenues on Columbia Basin Farms: Implications for Acreage Limita- tion Policy," Unpublished doctoral dissertation, Washington State University, (1978), p. 1.

Congress, via the property clause, had unlimited power over public lands. This clause gave Congress proprietary power to "dispose of and make all needful Rules and Regulations respecting the Territory or other property belonging to the United States."[3]

Federal involvement in the settlement of the western lands was prompted by a goal of rapid growth and development. The fundamental policy involved was that of making western lands capable of supplying their own reclamation. Until 1841 land was disposed of by selling various sized tracts, thus leading to the Preemption Act of 1841. The Preemption Act allowed the head of each household to acquire 160 acres of western land at a price fixed by the government. Squatting on unsurveyed land was illegal. This coupled with no outright land grant made the westerner dissatisfied. Nevertheless, western land policy was about as liberal as it could be, consistent with the demand that the public domain be a continuing source of revenue.

Agitation for free land continued throughout the 1850's, finally leading to the Homestead Act of 1862. This Act allowed the head of a family or anyone over 21 years of age to have 160 acres of public domain by paying a small fee. The only stipulation was that the homesteader either live on or cultivate the land for five years. However, the Homestead Act said nothing about the appropriation or use of the

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[3] U.S. Constitution, Article IV, Section 3, Clause 2.

water. No clear line could be drawn between Federal or State authority at this point because the Federal government chose to stand by, allowing the State and Territorial courts to declare what western water law would be. The Act of July 26, 1866 stated:

> "Whenever, by priority of possession, rights to the use of water for mining, agriculture, manufacturing, and other purposes have vested and accrued, and the same are recognized and acknowledged by the local customs, laws and decisions of courts, then the customary users are recognized as being legally valid."[4]

This Act was followed by the Act of 1870, the Desert Land Act of 1877 and Carey Act of 1894.[5]

The Act of 1870 further defined the Act of July 26, 1866 by subjecting all patented lands and homesteads to "any vested and accrued water rights."[6] The Desert Land Act allowed anyone to purchase 640

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[4] Act of July 26, 1866, Ch. 262, Sect. 9, 14 Stat. 253, Rev. Stat., Sect. 2339, 3 U.S. Cong. 661.

[5] The notion of an acreage limitation for irrigated lands was implemented in Lassen County, California on March 3, 1875. This first acreage limitation attempt also stipulated that land not reclaimed would then be sold back to the government at a nominal price. This information came from the following source: Richard Moss Alston, "Commercial Irrigation Enterprise: The Fear of Water Monopoly and the Genesis of Market Distortion." Unpublished doctoral dissertation Cornell University, January, 1970. p. 161.

[6] Act of July 9, 1870, Ch. 235, Sect. 17, 16 Stat. 218, Rev. Stat., Sect. 2340, 43 U.S. Cong. 661.

acres of land at $1.25 per acre with one stipulation: to irrigate
the land within three years. The Desert Land Act offered too much
land to the small operator to effectively operate and not enough land
to interest large corporations in water supply investments.[7] Congress
continued its encouragement of capitalists investment in reclaiming
the western lands by enacting the Carey Act in 1894. Senator Carey
envisioned the Act as an aid to the public lands states for the re-
clamation, supplementation and cultivation of these lands by small oper-
ators. The Act allowed the states to contract for construction work
on irrigation projects, to fix water prices and to sell land only to
persons owning water rights in the irrigation canal region.[8] While
the Carey Act essentially left irrigation development in the hands
of the states and effectively prevented speculation, the primary goal
of rapid western development wasn't being realized. The Act simply
was unable to (1) guarantee an effective demand for land, (2) guarantee
purchases of water or (3) provide adequate financial arrangements to
repay the construction costs of the irrigation project.

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[7] Elwood Meade, "Rise and Future of Irrigation in the United States,"
Yearbook of the Department of Agriculture, Government Printing
Office, Washington, D.C., 1899, pp. 603 - 604; and Moss, p. 164.

[8] The arrangement between the State and the construction company
allowed the construction company to sell water rights that granted
water purchasers an interest in the project. Moss, op. cit., p. 181.

The apparent failure of the Carey Act, linked with a conservation

movement, pressured Congress into considering direct federal aid to

reclaim the western lands. This movement led to the organization of

the National Irrigation Association, supported by dues from individual

members and large railroad contributions, which pressed for Federal

monies to develop the western lands. Their wishes were satisfied by

the enactment of the Reclamation Act of 1902, providing for the use

of receipts from land sales in the arid western states to finance the

construction of reservoirs and irrigation works, with repayment to

be made by settlers over a period of years.[9] The Federal government

was now directly involved in irrigated agriculture. The policy

objectives are reflected in the Bureau of Reclamation's internal

guidelines which state:

> "The policy of limiting the area of land for which project
> water may be supplied under the Reclamation laws is designed
> to (1) provide opportunity for a maximum number of settlers
> on the land, (2) distribute widely the benefits from public-
> supported reclamation where interest free money is involved,
> and (3) promote the family sized farm as a desirable form
> of rural life."[10]

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[9] At the Montana Irrigation Convention in January of 1892 (Ten
years prior to the Reclamation Act), the delegates to the Salt Lake
convention were criticized for supporting the Salt Lake Convention
platform calling for a cession of all public lands to the states.
They, in turn, adopted a resolution calling for proceeds of land
sales to be allocated for western water development. Moss, op. cit.,
p. 175.

[10] Reclamation Instructions, (Series 210 Land, Part 219 Excess Land),
p. 15.

The above guidelines were based on the following provision contained in the original Reclamation Act of 1902:

> "No right to the use of water for land and private ownership shall be sold for a tract exceeding 160 acres to any one individual landowner, and no such sale shall be made to any landowner unless he be an actual bona fide resident on the land, or occupant thereof residing in the neighborhood."[11]

The acreage limitation provision places an ownership limitation of 160 acres on irrigated land obtainable by an individual. The law has been loosely interpreted to allow 320 acres of land jointly owned by a husband and wife to be allocated water from the irrigation project. Any irrigated land owned over the 160 acre limit (or 320 acres for husband and wife) is called excess land. The owner of excess land is not eligible for project water unless the excess land is placed under recordable contract or the lands are eligible by statute.[12] The provision for disposal of excess lands became law through section 46 of the Omnibus Adjustment Act, passed in 1926.[13]

A general lack of regard for the original Reclamation Act and

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[11] D. Seckler and R. A. Young. "Economic and Policy Implications of the 160 Acre Limitation in Federal Reclamation Law," _American Journal of Agricultural Economics_, November 1978, p. 575.

[12] The recordable contract forces the owner to sell the excess land at a price not including the value added by the irrigation project within five years of the inception of the contract.

[13] The Omnibus Adjustment Act of 1926 also stipulated that all water contracts must be with the irrigation district association, not with individuals.

subsequent amendments was to follow. As suggested by Colorado State University Professor Robert Young, "There are few, if any, examples in American jurisprudence where the gap between de jure and de facto looms so large."[14] The root of the enforcement problem appeared to lie in a 1912 Amendment to the Reclamation Act and two subsequent letters from the Department of the Interior in 1933 and 1947. The 1912 Amendment contained ambiguous language, thus making it unclear whether it was illegal in all cases for an individual to own more than 160 acres or only in cases where the final payments for building charges remain unpaid.[15] A 1933 letter from Secretary of the Interior Wilbur to the Imperial Irrigation District states that the limitation didn't apply to lands "...now cultivated and having a present water right."[16] In 1947, referring back to the 1912 Amendment, Solicitor of the Interior Cohen in a letter to the Commissioner of Reclamation stated the 1912 Amendment meant that the full and final payment of construction charges against excess lands would free the lands of the acreage provision.[17]

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[14] Statement made as a discussant at the Western Agricultural Economics Association meetings at Montana State University in July 1978.

[15] Nancy Jones. "Proposed Rules for Administering the Acreage Limitation of Reclamation Law." Natural Resource Journal, October 1978. p. 934.

[16] Ibid, p. 937.

[17] Ibid, p. 935.

The Cohen letter (1947) and the 1912 Amendment were tested in the courts in the United States v. Tulare Lake Canal Company in 1976, introducing a trend in litigation aimed at enforcement of the Omnibus Act (1926). The Court rejected the Cohen interpretation of the 1912 Amendment and ruled that all excess land owners must come into compliance with Section 46 of the Omnibus Adjustment Act by executing recordable contracts to dispose of the excess land.[18] In August 1977, a three judge panel from the Ninth Circuit Court denied the validity of the 1933 letter by Secretary Wilbur and ruled that the Imperial Irrigation District was subject to the 160 acre limitation.[19]

In 1976, National Land for the People, Inc. filed a suit against the Bureau of Reclamation questioning the approval of excess land sales in the Westlands Irrigation District.[20] An injuction was granted, in favor of National Land for the People, Inc., enjoining the Secretary of the Interior from approving land sales in the Westlands Irrigation District until administrative rules were established.[21] These suits provided the necessary impetus for an

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[18] 535 F2d. 1093 (9th Circuit 1976).

[19] U.S. Department of the Interior Proposed Rules for Enforcement of the Reclamation Act of 1902: An Economic Analysis. Staff report by E.S.C.S., U.S.D.A. February 1978. E.S.C.S. - 04. p. 3

[20] 417 F. Supp. 449 (1976) U.S.D.C. This suit was initiated in 1967.

[21] U.S. Department of the Interior, p. 3.

examination of the 160 acre limitation on United States Bureau of
Reclamation Irrigation Projects.

The Problem

There are nearly 11 million acres of irrigable land under U.S.
Bureau of Reclamation Projects with nearly 393 thousand acres of this
total found in Montana. Nationwide, irrigated agriculture accounted
for 8.9 percent of total livestock production, 22.4 percent of total
crop production and 15.9 percent of total agricultural production in
1977. In Montana, irrigated agriculture accounted for 33 percent of
total value of crop production with around 20 percent of this total
generated by lands irrigated from U.S. Bureau of Reclamation Proj-
ects.[22] Federally funded irrigation projects, under the U.S. Bureau
of Reclamation, represent about 7% of Montana's irrigated agricul-
tural production.

Montana is a land of diversity. There are differences in
soil condition, climate, crop mix and market potential for each of
the 14 irrigation districts under the U.S. Bureau of Reclamation, yet
all the federally funded irrigation projects fall under the 160 acre
limitation. The 160 acre limitation was largely ignored by the

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[22] Montana Agricultural Statistics, Vol. XVII (1976-77), Montana
Department of Agriculture, W. Gordon McOmber, Director, p. 21 and
1976 Summary Report, p. 70.

irrigated farming community as well as the Bureau of Reclamation until recently. According to the Department of the Interior there are 2.3 million acres of land classed as excess land on projects governed by Federal Reclamation law out of eleven million acres served by the Bureau of Reclamation. California has over 80 percent of all excess lands with Texas, Arizona, Nebraska, Montana and Wyoming accounting for a total of 7 percent of the total excess land.[23]

Excess land disposal is the major issue raised by National Land for the People, Inc. The realization by Secretary of the Interior, Cecil Andrus, that enforcement of the 160 acre limitation may be realized, prompted him to propose the following plan in August of 1977:

(1) An individual may own 160 acres of land receiving project water.

(2) An individual can lease up to 160 acres.

(3) In family-related multiple ownerships, each individual may own 160 acres of land receiving project water.

(4) Purchasers of excess land must reside within 50 miles of it.

(5) All land sales must be approved by the Bureau of Reclamation.[24]

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[23] U.S. Department of the Interior, p. IV.

[24] Ibid. p. 2-5.

Current revisions to the August 1977 plan include the following:

(1) Individuals may lease up to 480 acres or own and lease

not more than 480 acres. Multiple ownerships may lease

up to 960 acres or own and lease not more than 960

acres.[25]

The current revision offers significantly larger upper bounds

on irrigated farm ownership and leasing. However, the crucial char-

acteristic to be recognized is the emphasis on farm size, not land

ownership. The critical consideration now becomes economies of size

in a farming operation, rather than economies of size for land owner-

ship.

The Reclamation Act of 1902 provided a significant subsidy to

American irrigated agriculture and led to the controversy over the

distribution of that subsidy. Proponents of rigorous enforcement

of the limitation advocate a more widespread distribution of oppor-

tunities provided by the reclamation program. While opponents of the

limitation, mainly farmers already benefiting from nonenforcement of

the limitation, are demanding freedom to exercise their ingenuity

within the limits of the free enterprise system. In essence the

argument boils down to the "family farm" ideology of the proponents

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[25] These revisions were included in a letter from Dr. C. V. Moore
in September of 1978.

versus the "efficiency" argument posed by the opponents. Political

compromise will require establishing an "adequate farm size" without

eliminating the idea of the family farm. This objective was well

stated by Dr. Roy Huffman in the following:

> "The family farm should remain as a basic objective in the
> expenditure of public funds for irrigation development, but
> it should be a concept consistent with modern agriculture.
> The combination of resources which can be managed efficiently
> by the family farm has changed through the years. If an
> obsolete standard for the family farm is maintained in
> connection with public irrigation development it may result
> in the creation of a segment of agriculture which is at a
> competitive disadvantage not only with highly commercialized
> agriculture, but the other family farms as well."[26]

The goals of efficiency and equity both warrant consideration.

An apparent tradeoff exists. The equity goal requires that a maximum

number of people realize the project's benefits, while the efficiency

goal requires that farm size be of sufficient size to realize economies

of size and minimize production costs per unit of output. This study

provides some of the essential information necessary for policy forma-

tion concerning the 160 acre limitation in the Lower Yellowstone River

Project in Montana. To illuminate the aforementioned policy considera-

tions, economies of size in farming and the relationship between farm

size and net farm income will be examined.

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[26] Roy E. Huffman, Irrigation Development and Public Water Policy,
Ronald Press Co., New York, 1953. p. 305.

This analysis employs a linear programming model to (1) estimate the long run average cost curve and (2) estimate the net farm income obtained on alternative farm sizes. The estimation of the long run average cost curve will be used to determine the relationship between the costs of production and farm size. At each point along the curve, net farm revenue can be estimated. From this information policymakers can objectively evaluate the tradeoff between efficiency and equity by considering the net farm revenues available on a given farm size and the corresponding efficiencies obtained.

Research Objectives

The objectives of this study are to:

(1) Develop enterprise cost budgets for the major crops grown in District 1 of the Lower Yellowstone Irrigation Project;

(2) Estimate short and long run average total cost curves for irrigated farms in District 1 of the Lower Yellowstone Irrigation Project under specific product price and resource assumptions;

(3) Estimate net farm revenue obtainable on various farm sizes under specific product price and resource assumptions; and

(4) Determine the required payments to land and capital at selected levels of net farm revenue.

CHAPTER 2

LITERATURE REVIEW

The basic methodology reviewed in this study for estimating

long run average cost curves and consequently economies of size

extends from H. O. Carter and G. W. Dean's work in the early 1960's

to the most recent work of A. S. Kezis in the 1970's. Three general

methods are employed in economies of size studies: (1) descriptive,

(2) statistical and (3) economic-engineering or synthetic firm

method.

The descriptive method involves either a direct analysis of actual

firm records or an analysis of composite firm budgets from actual firm

records. The direct analysis of actual firm records requires sampling

records from firms of various sizes. If firm records are readily

available, this procedure is relatively quick and easy. However, this

direct accounting method has some rather severe shortcomings. Records

are not compatible across all firms. Various accounting methods are

employed and the utilization of capacity varies among firms. These

shortcomings confuse attempts to examine the firm size efficiency

relationship and thus provide little useful information about the

affect of firm size on average production costs.

Moran employed the direct analysis of actual records of nonfeed

costs for several Arizona feedlots in 1957. At each of the sampled

feedlots the average cost per ton of feed was calculated. The feeding

operations were grouped according to the tons of feed used per year to establish a relationship between size and efficiency. Moran found that large feedlots had less than one-third of the nonfeed costs per ton of feed fed when compared to the smaller feedlots. The results of the study were clouded by the fact that (1) feedlots employed various percentages of their total capacity and (2) the observed average costs for the feedlots varied with the length of the feeding period, classes of feeders fed and the types and quantities of feed used.[27]

The composite firm budget from actual firm records procedure involves only a slight modification from the direct analysis procedure. Firm records are separated into size classes and a "typical firm" is developed for each firm size using average acreage, investment, acres in each crop, yield, application rates, etc. The size-efficiency relationship is established by comparing costs across each composite or "typical firm". This procedure is quick and easy and it sheds some light on the internal structure of the firm. However, this procedure has some inherent problems: (1) the same basic accounting records are used as in the direct analysis and thus it suffers the same problems with the compatibility of the basic cost data; (2) the classification of firms according to size require making a subjective judgment of

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[27] Leo J. Moran, "Nonfeed Costs of Arizona Cattle Feeding." (Arizona Agricultural Experiment Station Technical Bulletin No. 138, December 1959.)

the width of class intervals, therefore the "typical firm" may not represent the actual average cost of firms in their respective class sizes; and (3) firms operate at various percentages of full capacity and often employ inefficient combinations of resources. Therefore, the size-efficiency relationship does not accurately reflect the potential efficiency attainable by firms of various sizes.

Maier and Loftsgard employed the composite firm procedure in analyzing the costs and practices of potato producers in the Red River Valley of North Dakota. Average costs were calculated per hundred weight of potatoes. The farms analyzed were grouped into three major groups, based on the acres of potatoes cultivated, to compare the costs and practices of potato producers as farm size increased. The larger farms were found to have the lowest average cost. The difference in average costs were attributed to difference in size and cultural practices.[28]

The second method commonly used to estimate the long run average cost curve is the statistical method, i.e. ordinary least squares. Costs are regressed on outputs to estimate the parameters determining the relationship between firm size and cost. This method is employed to compensate for limited cost data available from firms, specifically to account for excess capacity or underutilization of facilities and

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[28] Melvin G. Mayer and Laurel D. Loftsgard. "Potato Production Costs and Practices in the Red River Valley." (North Dakota Agricultural Experiment Station Bulletin, No. 451, September 1964.)

differences in reported costs and prices from firm records. Kezis

cited several problems with this approach: (1) as with the descriptive

method, accounting data from farm records are used and caused some of

the same problems; (2) regression fallacy may arise when costs are

regressed on output and capacity is not considered in the problem

formulation and (3) linear regression is an averaging technique,

therefore the long run average cost curve is an average LRAC curve,

rather than an efficiency frontier as it should be.[29]

Carter and Dean employed this method in analyzing cash crop farms

in the Imperial Valley (1962). In the cash crop farm study, they

compensated for the excess capacity problem by including a degree of

utilization variable in the multiple regression model. By fixing the

utilization variable, each farm size could be evaluated on a comparable

basis. They found that (1) economies of size could be realized up to

around 1500 to 2000 irrigated acres, (2) highly mechanized larger farms

often underutilize their capacity and consequently may have higher per

unit costs than smaller operations better utilizing their capacity; and

(3) farms of any size could operate efficiently and make a reasonable

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[29]
Alan S. Kezis, op. cit., p. 33.

profit under the conditions in 1959.[30]

The third method considered in this literature review is the synthetic firm, or economic engineering method. This method allows the researcher to construct firms from the best estimators available on production parameters and resource requirements. Budgets are generated from available input-output data in an attempt to isolate the firm size - efficiency relationships without interference from the degree of plant utilization, use of obsolete technologies, substandard management practices, etc. When a few alternative choices are considered simple budgeting is adequate, however as the number of input and output options increase mathematical programming becomes appropriate.

A host of studies, including ones authored by H. O. Carter and E. W. Dean, R. Barker, and J. P. Madden and B. Davis have employed synthetic firm budgeting and mathematical programming. A variable capital programming model was employed by Carter and Dean (1961) to calculate the maximum gross income per dollar of capital at various levels of investment. Variable resource and price techniques were employed by Barker in 1960 to estimate average cost curves. Mixed integer programming was employed by Madden and Davis in 1965 to better handle fixed costs in their economies of size analysis.

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[30] Harold O. Carter and Gerald W. Dean, "Cost-Size Relationships for Cash Crop Farms in Imperial Valley, California." (California Agricultural Experiment Station, Giannini Foundation Research Report, No. 253, May 1962.)

The Madden and Davis study of irrigated cotton farms on the Texas High Plains employed synthetic firm budgeting and mathematical programming. Irrigation wells, land, permanent laborers, tractors and machinery complements were available only in discrete units, which was made possible by the use of mixed integer programming. Short run average cost curves were generated by varying output, proxied by total revenue, and thus enabling the firm size-efficiency relationship to be considered by examining the long run average cost curve. They found, given available capital, that a one man farm could be as efficient as any larger farm.

Carter and Dean in a study of California cling peaches (1963) compared two analytical methods, (1) statistical, or regression analysis, and (2) synthetic-firm budgeting. The most significant difference between the two methods is that the synthetic firm budgeting method indicated smaller reductions in average cost as farm size increased. The ability of synthetic firm budgeting to better fit machinery to requirements, and thus reduce excess capacity, enables a more accurate estimation of the potential efficiency attainable by different size firms.

A. S. Kezis in a study of irrigated farms in the Columbia River Basin provided the basic approach employed in this study. Kezis employed a synthetic firm-mathematical programming to approximate the long run average cost curve and net revenues for various farm sizes. In his formulation, the crop mix, machinery complement and irrigation

system are allowed to vary on a given farm size. In this study, Kezis found that (1) economies of size are realized by a 320 acre farm; (2) net revenue is responsive to changes in product prices and the level of land payments; (3) average costs and net revenue vary considerably on a given farm size; (4) net revenue increases at a ratio slightly more than in proportion to farm size and (5) required capital investments are high for all farm sizes considered.[31]

The review of literature highlights the most widely used methods for examining economies of size. These studies, done largely in the 1960's, are the principle works employed on more recent studies addressing the 160 acre limitation.

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[31] Kezis, op. cit., p. v.

CHAPTER 3

THEORY AND METHODS

In this chapter, the theory and methods employed for this study
are reviewed. The theory section reviews the neoclassical price
theory relevant to the study. The methods section outlines the data
collected, major assumptions, the model and subsequent analysis
employed in this study.

Theory

The theoretical framework for viewing efficiency is provided by
neoclassical price theory. The basic relationship in considering
these production efficiencies is the production function which relates
the level of output to the quantity of variable inputs employed. Pro-
duction efficiency is traditionally divided into three categories:
(1) technical efficiency, (2) price efficiency, and (3) scale effi-
ciency.

Technical efficiency results from more adequate utilization of
the resources productive capacity. If a single output is produced
utilizing one variable input with all other variables held constant,
the relationship between the quantity of output produced and the
quantity of the variable input used defines the concept of technical
efficiency. In Figure 1, the area shaded under the production
function represents possible production. Any points below the

output

$q = F(X_1\ X_2\ ,\ldots X_n\ )$

variable input

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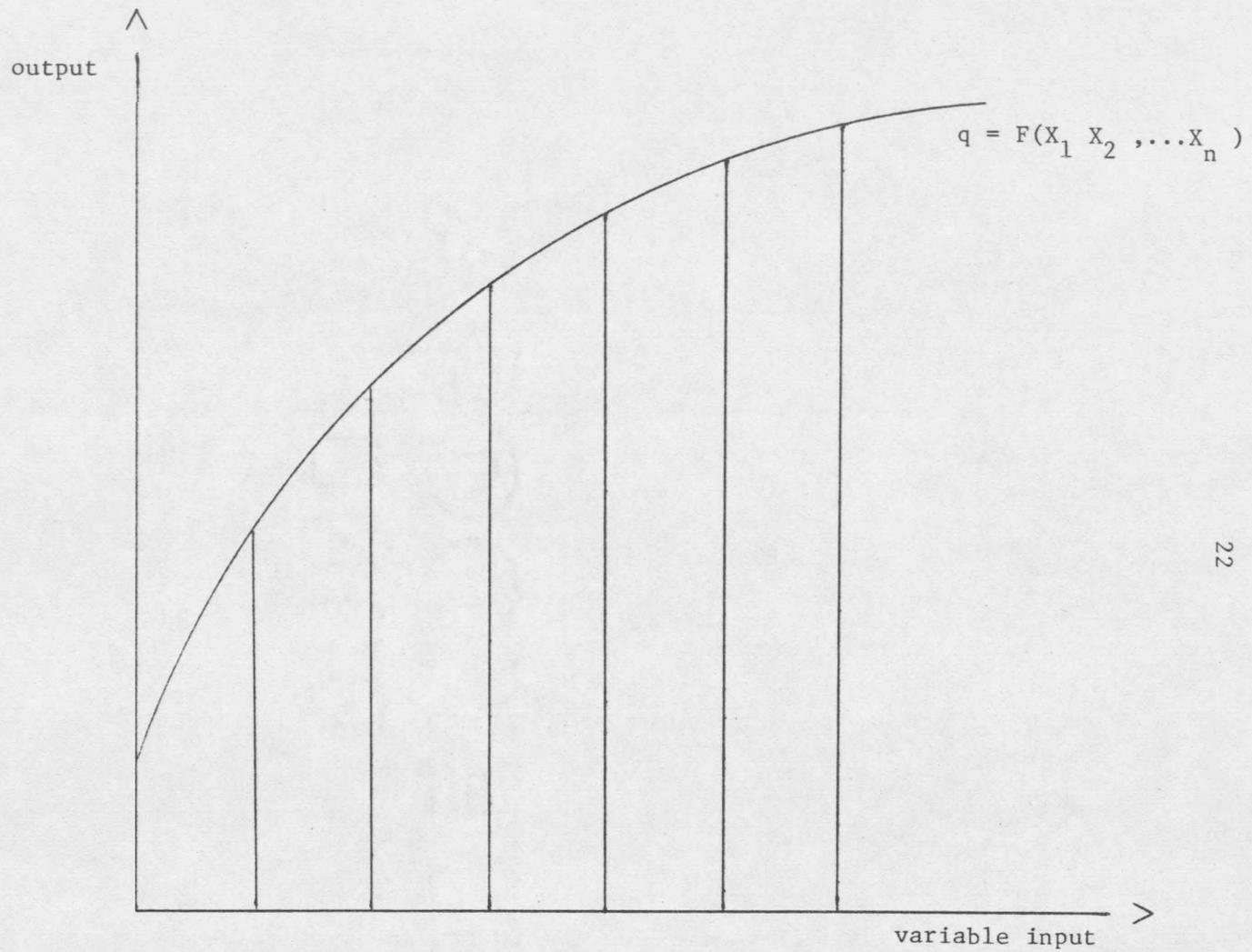
FIGURE 1.   Production Function With One Variable Input.

curve are not technically efficient.[32] Technical efficiency is

increased by moving to a point on the production function, q. If

a single output is produced utilizing more than one variable input,

then isocost and isoquant curves are employed.[33] This situation is

depicted in Figure 2. The isoquant curve q_1 represents different

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[32] This simple production function can also be represented by the following mathematical formulation:

(a) $q^o = F(x_1 | x_2^o)$

where

q^o = level of production

x_1 = variable input

x_2^o = fixed input

[33] For simplicity, only two inputs will be allowed to vary thus refining the original production function to

(b) $q^o = F(x_1, x_2 | y_1, \ldots y_m)$

where

x_1 and x_2 = variable inputs

$y_1, \ldots y_m$ = fixed inputs

By introducing input prices, r_i, associated with each variable input a total cost function for a given level of output can be expressed as follows:

(c) $TC = \sum_{i=1}^{n} r_i x_i + b$

where b = fixed costs.
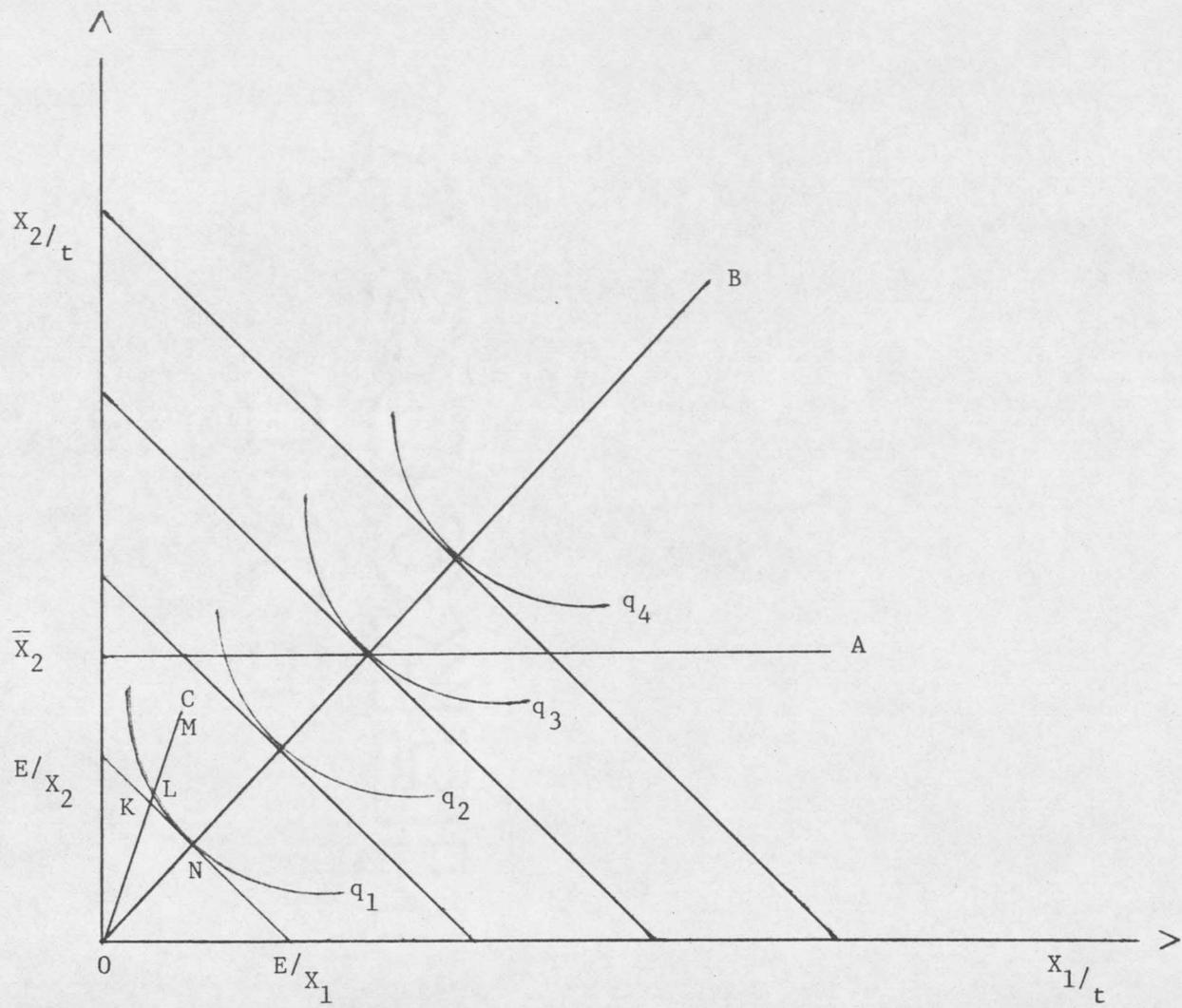
FIGURE 2. Production Function With Two Variable Inputs

combinations of inputs x_1 and x_2 that can be employed to produce a specific level of output, q_1. The isocost curve, E/x_1 E/x_2, represents the ratio of input prices. The concepts of technical and price efficiency can be discussed using these functions.

For example, assume the individual is at point M producing output q_1.[34] Clearly this is technically inefficient because the same level of output could be produced by employing fewer resources at point L. Technical efficiency is measured by the ratio OL/OM.

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[34] This relationship can be expressed mathematically by minimizing costs subject to a given

$$\text{Min } Z = r_1 x_1 + r_2 x_2 + b + \lambda \left[q^o - F(x_1, x_2 | y_1, \ldots y_m) \right]$$

Setting the partial derivatives of Z with respect to the x_i's and λ equal to 0, the first order conditions can be expressed as follows:

(d) $\alpha Z / \alpha x_1 = r_1 - \lambda F_1 = 0$

(e) $\alpha Z / \alpha x_2 = r_2 - \lambda F_2 = 0$

$\alpha Z / \alpha \lambda = q^o - F(x_1, x_2 | y_1, \ldots y_m) = 0$

where r_1 and r_2 is the marginal cost of the x_ith input, F_1 and F_2 is the marginal product of the x_ith input and λ is the derivative of cost with respect to a given output level.

By setting equation (d) and (e) equal to each other it can be shown that $r_1/r_2 = F_1/F_2$ or that the ratio of input prices is equal to the ratio of the respective marginal products, i.e. the marginal rate of technical substitution. For this to be a MINIMUM the relevant Bordered-Hessian determinant must be negative to satisfy the second order conditions.

While production at point M is technically inefficient in relation to point L, point L is price inefficient in relation to point N. Price efficiency is attained at that point where the input price ratio equals the marginal rate of technical substitution. Graphically, the tangency point between the isocost and isoquant represents the least cost combination of variable inputs employed to produce a given output. In Figure 2, price efficiency is measured by the ratio $OK_{/OL}$.

The product of technical efficiency (TE) and price efficiency (PE) defines economic efficiency (EE).

(1) $EE = TE \times PE$

$$EE = OL_{/OM} \times OK_{/OL} = OK_{/OM}$$

Referring back to Figure 2, in the short-run, x_2 is fixed at $\bar{x}_2$, thus the relevant short-run expansion path becomes $\bar{x}_2 A$.[35] In the long-run x_2 is allowed to vary and the relevant long-run expansion path

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[35] James M. Henderson and Richard E. Quandt in <u>Microeconomics Theory: A Mathematical Approach</u> (McGraw-Hill Book Company, New York, 2 ed.) p. 55. Define the short-run subject of the three restrictions: (1) It must be sufficiently short so that the entrepreneur is unable to alter the levels of his fixed inputs, (2) sufficiently short so that the shape of the production function is not altered through technological improvements and (3) sufficiently long to allow the completion of the necessary technical processes.

becomes OB.[36]

To this point, scale has been held constant as technical and price efficiency have been considered. When scale is allowed to vary, economic scale (or size) efficiency is considered. David Holland summarized the concepts of technical, price and scale efficiency as follows:

> "Economic scale efficiency is the product of technical scale efficiency and price scale efficiency, and is an overall measure of the relative efficiency of alternative scales of operation. Economic efficiency is now redefined to be the product of both economic efficiency given scale and economic scale efficiency, with each of these measures embodying measures of both price and technical efficiency."[37]

The graphic device employed in considering economies of size is the long run average cost curve. The long run average cost curve is generated graphically as an envelope curve encompassing short run average cost (SRAC) curves. The shape of the SRAC curve is dependent upon the shape of the average variable and fixed cost curves. The shape of the average variable cost curve is dependent upon the shape of the average physical product (APP) curve which can be shown as follows:

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[36] Referring back to the first order conditions and putting it in implicit function form it can be shown that the expansion path can be represented by a linear equation.

[37] David Holland, "Production Efficiency and Economies of Size in Agriculture," Unpublished Scientific Paper No. 5266, Washington State University, p. 3.

$$AVC = TC_{/Q} = rx_{/Q}$$

where AVC = average variable cost

TC = total cost

Q = output level

r = input price

x = input quantity

we know $APP = Q_{/X}$

therefore $AVC = r \left(1_{/APP}\right)$

The AVC curve is the mirror image of the APP curve, therefore, as the average physical product curve increases, reaches a maximum, then decreases; the AVC curve decreases, reaches a minimum, then increases. Since total fixed costs are constant, average fixed costs decreases as output is increased, eventually becoming asymptotic to the output axis. Thus the increasing and decreasing returns of the APP curve determine the shape of the short-run average cost curve. In Figure 3, the initial farm was represented by curve SAC_1, the farmer is restricted to a given farm size in the short run and is able only to alter the variable inputs. Efficiencies realized in the short run are those associated with better resource utilization, and in this study is defined as better utilization of machinery and land resources.

In the long run the farmer is able to vary all inputs in the production process. If the farmer exists in a perfectly competitive economy, farm size will approach the tangency point between minimum
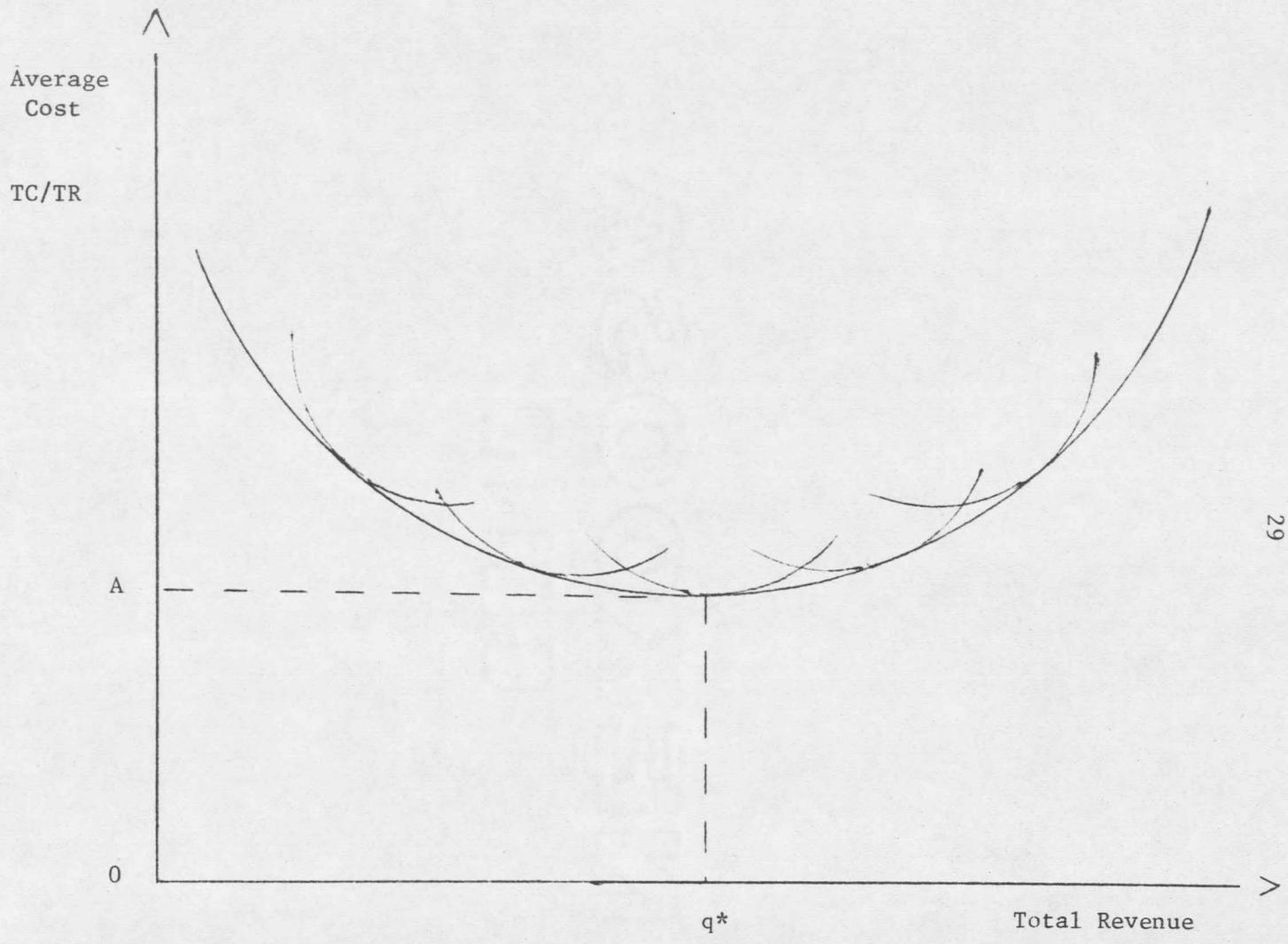
Figure 3. Short and Long Run Average Cost Curves

short and long run average cost curves, with this point representing
the competitive optimum Oq*, in Figure 3. If economies of size do exist
in irrigated agriculture, then one would hypothesize that irrigated
farms will approach that optimum size. Efficiencies realized in the
long run are associated with economies realized from adjustments to
farm size to better utilize available machinery and resources.

This theoretical development outlined above is concerned with a
single product firm. Treatment of a multi-product firm is presented by
Ralph F. Pfouts and well outlined in Alan S. Kezis' unpublished disser-
tation. The complexity of Pfouts' work need not be employed in this
study, thus further inquiry is referred to Pfouts original work in "The
Theory of Cost and Production in the Multi-product Firm," and Kezis dis-
sertation entitled, "An Examination of Size and Net Revenues on Columbia
Basin Farms: Implications for Acreage Limitation Policy."[38]

Model

The theory and methods discussed above are combined to devise a
model to analyze short and long run average costs and net farm revenue.
This section will discuss the procedures employed in generating the
data and the specifications of the model employed.

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[38] Ralph F. Pfouts, "The Theory of Cost and Production in the Multi-
product Firm", *Econometrica* 29 (4), (1961) pp. 650-658, and Kezis
pp. 24-30.

Data Sources

Data on irrigated farms in the state of Montana, and more specifi-
cally in the Lower Yellowstone River Valley, have been generated by the
Montana Cooperative Extension Service over the past few years. The most
recent data collection exercise occurred in July and August of 1978.
The primary data used in this study was generated from interviews with
the farmers in 1978. Farmers were organized into groups of six or more,
representing a variety of farm sizes and types. The farmers were chosen
by the local County Agricultural Extension Agent and Irrigation District
Manager. The timing of the data collection effort and the limited num-
ber of very small (160 acre) and very large (1280 + acre) irrigated
farms required using those farmers willing to take time to participate
in the study. The procedures used in the primary data collection effort
are as follows:

1. Available published and unpublished crop and farm information
was supplied by the Montana Cooperative Extension Service, regional of-
fice of the Bureau of Reclamation and Economic Reporting Service of the
United States Department of Agriculture. Additional information on out-
put prices and yields was provided by the Montana State Crop and Live-
stock Reporting Service.

2. Develop a calendar of operations for each major crop in the
district. The calendars of operation were prepared from the published
and unpublished information with the assistance of University and

Montana Cooperative Extension Service personnel.

3. Collect data on input costs and machinery performance. This information was collected from machinery dealers and the farmers in the survey.

4. Prepare a preliminary crop budget for each crop and review them with University, United States Bureau of Reclamation and local Cooperative Extension personnel. The review was accomplished by meetings in Sidney, Billings and Bozeman with interested personnel from the aforementioned institutions.

5. Form a panel of farmers representing a wide range of farm sizes to review the preliminary crop budgets and help specify typical machinery compliments and crop mixes to represent 160, 320, 640 and 1,280 acre farms for the case study district. Farmers were chosen by the local Agricultural Extension Agent and the Irrigation District Manager. The farmers, representing a variety of farm sizes from 160 acres to 640 acres, assisted in the review and development of the crop and total farm budget.

6. Develop total farm budgets for each farm size. The aforementioned information was organized into individual crop budgets which were processed using the Montana State University version of the Oklahoma State Budget Generator. The assumptions utilized are summarized in Appendix A. The Budget Generator utilizes the information to generate a summary of the timing and sequence of operations, the

machinery complement utilized, the gross revenue generated, variable and fixed costs, the break-even price and the labor and fuel requirements.

7. Present typical farm budgets to farmer panels for review and revision. The crop budgets were reviewed with the farm panels and other interested Extension personnel, farmers and businessmen.

Separate budget runs are made for each crop (sugar beets, spring wheat, barley and alfalfa hay) on each farm size (160, 320, 640 and 1280 acres) utilizing each of three machinery complements. These four crops were chosen because they represented the largest percentage of total acres planted in the Lower Yellowstone as reported by the U.S. Bureau of Reclamation in 1978. The four farm sizes represent the present law, allowing no individual to farm more than 160 acres and proposed regulations, suggesting acreage limitations of 320, 640 and 1280 acres of owned and leased land per farm.

As with the farm size specification, the three machinery lists represent the present and a possible situation. The present, or "typical", machinery list was generated from suggestions provided by the farmer panel. This list incorporated new and used machinery with all rates of performance and machinery specification provided by the panel participants. The second machinery list employed the same suggestions for all tillage and planting activities, but specified all harvesting to be done by custom operators. These custom rates were

generated by utilizing three machinery programs provided by the Montana

Agricultural Computer Network, AGNET.

The first of these machinery programs, entitled FIXEDCOST, cal-

culates annual fixed costs as a percentage of purchase price by input-

ing (1) the purchase cost, (2) salvage value, (3) years of life, (4)

interest rate on the average value and (5) the local mill levy. Annual

ownership costs are calculated by using the following assumptions:

(1) Straight line depreciation.

(2) Interest on average investment.

(3) Housing costs = .006 x average investment.

(4) Insurance costs = .01 x average investment.

(5) Taxes = mill levy x average investment.

The resulting percentage is then entered into program 2, entitled

MACHINE. MACHINE calculates fixed and variable costs for field

machines on a per acre or per hour basis by inputing the (1) machine

size, (2) list price, (3) annual acres used, (4) miscellaneous costs,

(5) fuel consumption, (6) fuel cost and (7) labor cost. Field machine

ownership and operating costs are calculated by using the following

assumptions:

(1) Rate of accomplishment, in acres per hour, is based

on field efficiency, speed and size.

(2) Field efficiency, the efficiency of accomplishing the

field operation, is less than 100 percent due to turning,

overlap, refilling seed boxes, etc.

(3) A labor factor is included to account for labor beyond

the actual field operation. This labor would include

machine preparation, travel to and from the field, etc.

(4) Labor and miscellaneous costs are summarized as part of

the implement operating cost.

(5) Investment credit or income tax savings are not included.

(6) For self-propelled machines fuel and oil become part of the

implement operating cost.

This information provided by MACHINE on fixed and variable costs is

then entered into program 3, CUSTOM, to calculate a custom rate for

field work performed on a per hour basis. The rates generated were

compared with custom rates reported by farmers and found to be repre-

sentative.

The first two machinery lists represent typical machinery comple-

ments. The third list represents a possible machinery complement gen-

erated by utilizing draught requirement formulas provided by Agricul-

tural Engineers and an AGNET program entitled SIZEMACH. The Agricul-

tural Engineering Yearbook of 1976 provided a procedure to generate

the horsepower required per foot of implement. Assuming a soil type,

a slippage rate, a field speed and efficiency, the PTO horsepower (or

drawbar horsepower) and required tractor weight was determined for

each implement. The SIZEMACH program required inputing the (1) number

of acres to be covered during the critical time period, (2) the minimum number of work days in the critical time period, (3) the hours per usual work day, and (4) field speed and efficiency to generate the size of machinery to accomplish critical tasks in a specified period of time.[39] In short this procedure generated a "recommended" implement and "recommended" draught power and weight. This procedure enables the researcher to construct a farm budget and better isolate the farm size – efficiency relationship without interferences caused by the degree of plant utilization, use of obsolete technologies, etc.

Major Assumptions

Combining the four crop enterprises, four farm sizes and three machinery lists, 48 separate enterprise costs were generated comprising 12 separate farms. The 12 separate farms were modelled in a linear programming framework to provide a method of generating a least cost crop mix and machinery complement, thus generating a SRAC curve for each farm size and consequently a LRAC curve over all farm sizes. The following assumptions were incorporated into the linear programming model:

1. Only sugar beets, spring wheat, feed barley and alfalfa hay could be grown.

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[39] The critical days for a given task was generated from information provided by the Huntley Project and Sidney Agricultural Experiment Stations. The suitable days available for field were taken from R. C. Greer and W. A. Yaeger's publication entitled, "Estimated Days Suitable for Fieldwork." (Montana State Agricultural Experiment Station Research Report No. 67, December 1974).

2. Sugar beets could be grown on no more than 50 percent of the irrigable acreage. This approximates the actual situation, since the maximum sugar beet acreages are set by the sugar beet processor.

3. Spring wheat, feed barley and alfalfa hay could be 100 percent of the irrigable acreage.

4. Total water supplied was constrained at 25.44 acre inches per irrigable acre per year. This figure represents the average water supply available to farmers on the project over the past five years.

5. The water price is $.445 per acre-inch. This water price is not representative of current water charges, since at present, water is charged on a per acre basis of $9.50 per acre. Assuming that water demanded equals water supplied, the $.445 acre is a weighted average price with the relative weights being the percent of irrigable acres typically planted into sugar beets, spring wheat, barley and alfalfa hay.

6. An unlimited supply of labor is availalbe at $5.00 per hour. This labor price is reflective of the wage demanded by hired labor in the area and the opportunity cost of the operators time engaged in working as a laborer.

7. Irrigable land is limited to the farm size designated minus land set aside for ditches, roads, etc. Five percent of the total acreage on each farm size is set aside for ditches, roads, etc.

8. All irrigable land must be planted into a crop. No acres will be allowed to remain fallow.

9. All land is flood, or surface irrigated, with an irrigation efficiency of 70 percent.

10. Capital is unlimited at an interest rate of 10.3 percent which was the Production Credit Association rate on July 1, 1978.

11. All soil is homogeneous and capable of growing each of the crops.

12. Either all or none of the harvesting is done with custom operators.

13. All new machinery and input prices are reflective of July 1978 prices. All new and used machinery prices were taken from estimates provided by machinery dealers.

14. Farm operators have average management abilities. Management cost is estimated as 7 percent of gross revenue.

The cost minimization objective coupled with the above assumptions allows a model to be specified.

Model Specification

This linear programming model offers a divergence from neoclassical price theory. In neoclassical theory the shape of the SRAC curve is determined by the increasing and decreasing marginal productivity of the variable inputs and by the spreading out of the fixed costs associated with the fixed inputs. In this formulation, all variable inputs (fertilizer, seed, etc.) are determined in the crop budgets. The linear programming model chooses the least cost combinations of crops and machinery complements, thus making the variable factors the crop mix and machinery complement. Therefore, the shape of the SRAC curve derived from this data set must be due to (1) the crop combination and/or (2) the lumpiness of the fixed inputs, in this case the machinery utilized. This formulation allows the following linear programming model specification:

Minimize Total Cost = Production costs + labor cost + water

cost + ownership costs of specialized machinery.

Subject to:

a. total water used $\leq$ 25.44 acre-inches per irrigable acre.

b. total land irrigable = total acreage minus waste.

c. total sugar beet acreage $\leq$ 50 percent of total irrigable acres.

d. spring wheat, barley and alfalfa hay can be 100 percent of total irrigated acreage.

e. total revenue = constant (selected levels of total

revenue).

f. ownership costs of specialized machinery are included,

utilizing the capacity of a given machinery complement.

Each is specified as:

objective function: $F_jZ_j + V_jX_j$

reference row: $-$ capacity $+ \alpha X_j$

Where $F_j =$ fixed cost

$Z_j =$ integer, o or 1

$V_j =$ variable cost

$X_j =$ service activity

The mathematical programming chooses a crop mix and machinery

complement, thus a priori total fixed costs for a farm are not known.

For each crop a machinery complement specific to that crop was deter-

mined. The total fixed costs for each enterprise were attributed to

that specific enterprise and included via integer programming. This

"either-or" formulation allows a lump sum to be entered into the

solution and simplifies the procedure for inclusion of fixed costs.

This model allows several different crop mixes to enter the

solution, therefore a method had to be devised to measure output in

terms common to each of these crops. This convention, employed by

Carter and Dean, is to express output in terms of total revenue,

price times quantity, and in turn express average cost as total cost

divided by total revenue. Utilizing these proxies for output and aver-
age cost allows the model to consider multiple products, rather than
a single product in the solution.

As mentioned above, 12 model farms representing the four farm
sizes and three machinery lists were formulated in a linear programming
format. The input coefficient for the matrices are summarized in the
tables of Appendix B. The matrices and an explanation appear in Appen-
dix C. For each farm size, an optimal, or least cost, solution is
derived for specific levels of total revenue. The line connecting
these discrete points is the SRAC curve for a given farm size specified
in acres.

The envelope curve formed by the SRAC curve generates the curve of
most interest for this study, the LRAC curve. Prices were increased and
decreased by 25 percent to form a band around the SRAC curve and LRAC
curve to simulate possible price fluctuations.

The model, as specified, allows only an analysis of technical effi-
ciency in the short run and that portion of economic scale efficiency
attributed to technical scale efficiency in the long run. A note of
caution is warranted in interpreting these results as measures of eco-
nomic efficiency in the short run and economic scale efficiency in the
long run as defined by Holland. The information collected to estimate
price efficiency and thus price scale efficiency was not complete,

therefore the results of this study include only the technical com-

ponent. It will be left to further data collection and research to

provide the information needed to capture economic scale efficiency as

defined by Dr. Holland.

CHAPTER 4

RESULTS

Economies of size and net revenue relationships are presented in
this chapter for 160, 320, 640 and 1280 acre farms in District 1 of the
Lower Yellowstone River Irrigation Project. Economies of size are ana-
lyzed by examining average cost curves, where average cost is the total
cost per dollar of physical output. When multiple physical outputs are
considered, output must be presented in common terms. In this study,
output is proxied by total revenue, product price times the quantity
produced; and average cost is proxied by total cost divided by total
revenue as was justified in Chapter 3. The resulting short run average
cost curve is a locus of points depicting optimal farm types, defined
by a crop mix and machinery complement, on a given farm size at various
levels of total revenue. The variability in climate, soil conditions
and cultural patterns throughout Montana prevents the extension of
these results as representative of all irrigated agriculture in Montana.

The price, yield and cost of production data are summarized in Ap-
pendices A and B. The levels of total revenue were selected between the
minimum and maximum levels of total revenue attainable on a given farm
size. In Section I, net revenue is defined as the return to management
and land. In Sections II and III, land and capital payment schemes are
examined and the net return to operator management is considered.

I. <u>SRAC and Net Revenue Relationships</u>

160 Acre Farm

The SRAC and net revenue curves for the 160 acre farm are summarized in Table 1 and the SRAC and net revenue curves with a 25 percent increase and decrease in product prices are summarized in Table 2. The SRAC curve is depicted graphically in Figure 4 by line segment AA'.

Table 1 indicates that efficiency, measured by TC/TR, and NR vary considerably at various levels of farm output. A farm growing only barley has an average cost of 1.19 while a sugar beet and wheat farm has an average cost of 0.88. Net revenue varies from $-3,717.53 on the barley farm to $6,984.01 on the sugar beet and spring wheat farm

The only change taking place as one moves along the SRAC curve for a 160 acre farm is in the crop mix. At low levels of total revenue, barley is the predominate crop while at higher levels of total revenue, sugar beets become the most prominant crop. Machinery list one is employed on all 160 acre farms. This machinery list contains the smallest equipment available from local implement dealers with all harvesting accomplished by custom operators. Custom harvesting offered a significant savings because the farmer did not incur the relatively high fixed costs of owning harvesting equipment.

The use of custom services hinges on their availability. In this survey few custom operators were identified, therefore producers were often not faced with the option of employing a custom operator. The

Table 1

Short Run Average Cost and Net Revenue Curves
for a 160 Acre Farm in District 1 of the
Lower Yellowstone Irrigation Project

Case	Total Revenue	Total Cost[1]	TC/TR	Net Revenue	Optimal Solution Acreage[2]	Crop	Machinery List
1.	$19374.00	$23091.53 (39960.79)	1.19 (2.06)	$- 3717.53 (-20586.79)	152.0	Barley	1
2.	31200.00	32000.40 (49760.44)	1.02 (1.59)	- 800.40 (-18560.44)	27.5 124.5	Sugar Beets Barley	1
3.	38470.00	36459.70 (54665.67)	.95 (1.42)	2010.30 (-16195.67)	41.3 110.7	Sugar Beets Barley	1
4.	44830.00	40911.97 (59563.17)	.91 (1.33)	3918.03 (-14733.17)	55.1 96.9	Sugar Beets Barley	1
5.	56117.00	49132.99 (68606.29)	.88 (1.22)	6984.01 (-12489.29)	76.0 76.0	Sugar Beets Spring Wheat	1

[1] The total cost calculation in parentheses includes a 7% opportunity cost for land value and a management charge equal to (TC - opportunity cost of land) times .10%. This calculation is included for a comparison across other states in western region in the original U.S.D.A. - U.S.B.R. project supervised by Dr. C.V. Moore and Mr. David Wilson.

[2] Five percent of the total acreage is classified as nonirrigable land for ditches, roads, etc.

Table 2

160 Acre SRAC and Net Revenue Curves Assuming a 25 Percent
Increase and a 25 Percent Decrease in Product Price

Case	Total Revenue	Total Cost	Total Cost/ Total Revenue	Net Revenue
		25% Increase in Product Price		
1.	$24217.50	$23091.53 (39960.79)	.95 (1.65)	$1125.97 (−15743.29)
2.	39000.00	32000.40 (49760.44)	.82 (1.28)	6999.60 (−10760.44)
3.	48087.50	36459.70 (54665.67)	.76 (1.14)	11627.80 (−6578.17)
4.	56037.50	40911.97 (59563.17)	.73 (1.06)	15125.53 (−3525.67)
5.	70146.25	49132.99 (68606.29)	.70 (.97)	21013.26 (1539.96)
		25% Decrease in Product Price		
1.	$14530.50	$23091.53 (39960.79)	1.59 (2.75)	$−8561.03 (−25430.29)
2.	23400.00	32000.40 (49760.44)	1.37 (2.13)	−8600.40 (−26360.44)
3.	28853.00	36459.70 (54665.67)	1.26 (1.89)	−7606.70 (−25812.67)
4.	33623.00	40911.97 (59563.17)	1.22 (1.77)	−7288.97 (−25940.17)
5.	42087.80	49132.99 (68606.29)	1.17 (1.63)	−7045.19 (−26518.49)

Figure 4. Short and Long Run Average Cost Curves Considering Base Prices and a 25 Percent Increase and Decrease in Product Prices

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most efficient and maximum net revenue generating farm types were the same in this case. They were attained on a sugar beet and spring wheat farm utilizing machinery list 1.

Changes in product price have rather significant effects on farm efficiency and net revenue (Table 2). Case Five is the most efficient and net revenue maximizing farm. An increase in product price of 25 percent decreases average cost from 0.88 to 0.70 and increases maximum net revenue from $6,984.01 to $21,013.26. A decrease in product price of 25 percent increases average cost from 0.88 to 1.17 and decreases maximum net revenue from $6,984.01 to $-7,945.19. The change in product price does not change the optimal solution because product price relationships remain the same.

320 Acre Farm

The SRAC and net revenue curves for the 160 acre farm are summarized in Table 3 and the SRAC and net revenue curves with a 25 percent increase and decrease in product prices are summarized in Table 4. The SRAC curve is depicted graphically in Figure 4 by line segment BB'.

The SRAC and net revenue curves are similar to those for the 160 acre farm. Table 3 indicates that efficiency and net revenue vary considerably as total revenue changes. Average costs decrease from 1.01, for a barley only farm, to 0.78 for a sugar beet and spring wheat farm. Net revenue ranges between $-578.94 and $24,948.26 for these farms.

Table 3

Short Run Average Cost and Net Revenue Curves
for a 320 Acre Farm in District 1 of the
Lower Yellowstone Irrigation Project

Case	Total Revenue	Total Cost[1]	TC/TR	Net Revenue	Optimal Solution Acreage[2]	Crop	Machinery List
1.	$38748.00	$39326.94 (72379.63)	1.01 (1.87)	$- 578.94 (-33631.63)	304.0	Barley	1
2.	64200.00	56040.39 (90764.43)	.87 (1.41)	8159.61 (-26564.43)	55.0 249.0	Sugar Beets Barley	1
3.	76940.00	64406.30 (99966.93)	.83 (1.30)	12533.70 (-23026.93)	82.6 221.0	Sugar Beets Barley	1
4.	89660.00	72759.08 (109155.00)	.81 (1.22)	16900.92 (-19495.00)	110.0 194.0	Sugar Beets Barley	1
5.	112234.00	87285.74 (125134.31)	.78 (1.11)	24948.26 (-12900.31)	152.0 152.0	Sugar Beets Spring Wheat	3

[1] The total cost calculation in parentheses includes a 7% opportunity cost for land value and a management charge equal to (TC - opportunity cost of land) times 10%. This calculation is included for a comparison across other states in western region in the original U.S.D.A. - U.S.B.R. project supervised by Dr. C.V. Moore and Mr. David Wilson.

[2] Five percent of the total acreage is classified as nonirrigable land for ditches, roads, etc.

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The crop mix and machinery complement change as one moves along the SRAC curve. At low levels of total revenue barley is the predominant crop and machinery complement one is employed. At the higher levels of total revenue, sugar beets and wheat are the prominant crops and machinery list three is employed.

The primary difference between machinery lists one and three is that machinery list one assumes all harvesting is accomplished by custom operators while machinery list three contains harvesting equipment. On the farm type depicted by Case Five, the custom harvesting charges exceed the costs of owning and operating the harvesting equipment.

Product price changes of 25 percent above and below average product price are summarized in Table 4. An increase in product price of 25 percent decreases average cost from 0.78 to 0.62 and maximum net revenue increases from $24,948.26 to $53,006.76. A decrease in product prices by 25 percent increases average cost from 0.78 to 1.04 and maximum net revenue decreases from $24,948.26 to $-3,110.24.

The economies gained by moving from the 160 to 320 acre farm are attributed to fuller utilization of available machinery capacity. The machine lists for the 160 and 320 acre farms are essentially the same, thus indicating that excess machine capacity exists on the 160 acre farm. The distribution of the fixed costs over more acres accounts for the economies achieved.

Table 4

320 Acre Farm SRAC and Net Revenue Curves Assuming a 25 Percent
Increase and a 25 Percent Decrease in Product Price

Case	Total Revenue	Total Cost	Total Cost/ Total Revenue	Net Revenue
		25% Increase in Product Price		
1.	$48435.00	$39326.94 (72379.63)	.81 (1.49)	$9108.06 (-23944.63)
2.	80250.00	56040.39 (90764.43)	.70 (1.13)	24209.61 (-10514.43)
3.	96175.00	64406.30 (99966.93)	.67 (1.04)	31768.70 (-3791.93)
4.	112075.00	72759.08 (109155.00)	.65 (.97)	39315.92 (2920.00)
5.	140292.50	87285.74 (125134.31)	.62 (.89)	53006.76 (15158.19)
		25% Decrease in Product Price		
1.	$29061.00	$39326.94 (72379.63)	1.35 (2.49)	$-10265.94 (-43318.63)
2.	48150.00	56040.39 (90764.43)	1.16 (1.89)	-7890.39 (-42614.43)
3.	57705.00	64406.30 (99966.93)	1.12 (1.73)	-6701.30 (-42261.93)
4.	67245.00	72759.08 (109155.00)	1.08 (1.62)	-5514.08 (-41910.00)
5.	84175.50	87285.74 (125134.31)	1.04 (1.49)	-3110.24 (-40958.81)

640 Acre Farm

The SRAC and net revenue curves for the 640 acre farm are summarized in Table 5 and the SRAC and net revenue curves with a 25 percent increase and decrease in product prices are summarized in Table 6. The SRAC curve is depicted graphically in Figure 4 by line segment CC'.

The shapes of the SRAC and net revenue curves are similar to those of the previous farm sizes. The average costs for the barley only farm are 0.89 while the average cost for the sugar beet and wheat farm is 0.66. Note, the corresponding average costs for the 160 acre farm are 1.19 and 0.88 and for the 320 acre farm are 1.01 and 0.78. In this study, all economies of size are realized by the 640 acre farm. Net revenue varies between $8,528.05 and $75,826.28 across optimal farm types at a given production level.

The machinery lists employed on the 640 acre farm required the inclusion of larger machinery, than that employed on the 320 acre farm, in order to accomplish the required task in the time available. Machinery list three is employed on all optimal solution farms except the barley farm. This machinery list includes the smallest machine capable of accomplishing a task in time, consequently this machinery complement is utilized closest to capacity.

Table 6 indicates that price fluctuation remains an important source of variation in average cost and net revenue. When product

Table 5

Short Run Average Cost and Net Revenue Curves
for a 640 Acre Farm in District 1 of the
Lower Yellowstone Irrigation Project

Case	Total Revenue	Total Cost[1]	TC/TR	Net Revenue	Optimal Solution Acreage[2]	Crop	Machinery List
1.	$77496.00	$68967.95 (134104.75)	.89 (1.73)	$8528.05 (−56608.75)	608.0	Barley	1
2.	128400.00	100595.39 (168894.93)	.78 (1.32)	27804.61 (−40494.93)	110.0 498.0	Sugar Beets Barley	3
3.	153880.00	112698.17 (182207.99)	.73 (1.18)	41181.83 (−28327.99)	165.0 443.0	Sugar Beets Barley	3
4.	179320.00	124781.97 (195500.17)	.70 (1.09)	54538.03 (−16180.17)	220.0 388.0	Sugar Beets Barley	3
5.	224468.00	148641.72 (221745.89)	.66 (.99)	75826.28 (2722.11)	304.0 304.0	Sugar Beets Spring Wheat	3

[1] The total cost calculation in parentheses includes a 7% opportunity cost for land value and a management charge equal to (TC − opportunity cost of land) times 10%. This calculation is included for a comparison across other states in western region in the original U.S.D.A. − U.S.B.R. project supervised by Dr. D.V. Moore and Mr. David Wilson.

[2] Five percent of the total acreage is classified as nonirrigable land for ditches, roads, etc.

Table 6

640 Acre Farm SRAC and Net Revenue Curve Assuming a 25 Percent
Increase and a 25 Percent Decrease in Product Price

Case	Total Revenue	Total Cost	Total Cost/ Total Revenue	Net Revenue
		25% Increase in Product Price		
1.	$96870.00	$68967.95 (134104.75)	.71 (1.38)	$27902.05 (-37234.75)
2.	160500.00	100595.39 (168894.93)	.63 (1.05)	59904.61 (-8394.93)
3.	192350.00	112698.17 (182207.99)	.59 (.95)	79561.83 (10142.01)
4.	224150.00	124781.97 (195500.17)	.56 (.87)	99368.03 (28649.83)
5.	280585.00	148641.72 (221745.89)	.53 (.79)	131943.28 (58839.11)
		25% Decrease in Product Price		
1.	$58122.00	$68967.95 (134104.75)	1.19 (2.31)	$-10845.93 (-75982.75)
2.	96300.00	100595.39 (168894.93)	1.04 (1.75)	-4295.38 (-72594.93)
3.	115410.00	112698.17 (182207.99)	.98 (1.58)	2711.83 (-66797.99)
4.	134490.00	124781.97 (195500.17)	.93 (1.45)	9708.03 (-61010.17)
5.	168351.00	148641.72 (221745.89)	.88 (1.32)	19709.28 (-53394.89)

prices are increased by 25 percent, average cost decreases from 0.66 to 0.53 and net revenue increases from $75,826.28 to $131,943.28. When product prices are decreased by 25 percent, average costs increase from 0.66 to 0.88 and net revenue decreases from $75,826.28 to $19,709.28.

1280 Acre Farm

SRAC and net revenue curves are summarized in Table 7 and the SRAC and net revenue curves with a 25 percent increase and decrease in product price are summarized in Table 8. The SRAC curve is depicted graphically in Figure 4 by line segment DD'.

Once again, the shape of the SRAC and net revenue curves are similar to those of the other farm sizes. Efficiency, measured by average cost, decreased from 0.83 on the barley only farm to 0.70 on the sugar beet and spring wheat farm. Net revenue increases from $27,067.02 to $135,030.30 as one moves along the SRAC curve. The increase in average cost, and hence decrease in efficiency, from the 640 to 1280 acre farm is the result of fuller utilization of farm machinery on the 640 acre farm. In order to satisfy the timeliness constraints on the 1280 acre farm, some farm machinery, i.e. sugar beet equipment, was duplicated. The additional machinery created excess capacity, as the additional machinery was underutilized.

Machinery list three is employed on all farm types except for the barley only farm. In this machinery list, excess machinery capacity

Table 7

Short Run Average Cost and Net Revenue Curves
for a 1280 Acre Farm in District 1 of the
Lower Yellowstone Irrigation Project

Case	Total Revenue	Total Cost[1]	TC/TR	Net Revenue	Optimal Acreage[2]	Solution Crop	Machinery List
1.	$154992.00	$127924.98 (257197.48)	.83 (1.66)	$27067.02 (−102205.48)	1216.0	Barley	1
2.	$256800.00	194140.54 (330034.59)	.76 (1.29)	62659.46 (−73234.59)	220.0 996.0	Sugar Beets Barley	3
3.	$307760.00	225105.68 (364096.25)	.73 (1.18)	82654.32 (−56336.25)	330.0 886.0	Sugar Beets Barley	3
4.	$358640.00	256022.21 (398104.43)	.71 (1.11)	102617.79 (−39464.43)	440.0 776.0	Sugar Beets Barley	3
5.	$448936.00	313905.70 (461776.27)	.70 (1.03)	135030.30 (−12840.27)	608.0 608.0	Sugar Beets Spring Wheat	3

[1] The total cost calculation in parentheses includes a 7% opportunity cost for land value and a management charge equal to (TC − opportunity cost of land) times 10%. This calculation is included for a comparison across other states in western region in the original U.S.D.A. − U.S.B.R. project supervised by Dr. D.V. Moore and Mr. David Wilson.

[2] Five percent of the total acreage is classified as nonirrigable land for ditches, roads, etc.

is minimized and hence it is employed instead of machinery lists one and two, which contain larger land preparation and grain harvesting equipment.

Table 8 indicates that a change in product price is an important source of variation in average cost and net revenue. When product price is increased by 25 percent, average costs decrease from 0.70 to 0.56 and net revenue increases from $135,030.30 to $246,589.30. When product prices are decreased by 25 percent, average costs increase from 0.70 to 0.93 and net revenue decreases from $135,030 to $22,796.30.

Long Run Average Cost Curve

A long run average cost curve is formed by sketching an envelope tangent to the SRAC curves. The relevant consideration is where most significant economies of size are attained and over what range of output, total revenue, they are increasing or decreasing. The sources of economies of size along the SRAC curve are the lumpiness of the typical fixed inputs (i.e. machinery) and the optimal crop mix selected. The source of economies of size along the LRAC, and among SRAC curves depicting optimal farm types on a given land area, are the spreading out of fixed cost, i.e. machinery fixed costs, over more acres, and the use of more efficient machinery.

The LRAC curve is depicted graphically in Figure 1. The bold lines are the SRAC and LRAC at the base prices while the dashed lines

Table 8

1280 Acre Farm SRAC and Net Revenue Curves Assuming a 25 Percent
Increase and a 25 Percent Decrease in Product Price

Case	Total Revenue	Total Cost	Total Cost/ Total Revenue	Net Revenue
		25% Increase in Product Price		
1.	$193740.00	$127924.98 (257197.48)	.66 (1.33)	$65815.02 (-63457.48)
2.	321000.00	194140.54 (330034.59)	.60 (1.02)	126859.46 (-9034.59)
3.	384700.00	225105.68 (364096.25)	.59 (.95)	159594.32 (20603.75)
4.	448300.00	256022.21 (398104.43)	.57 (.89)	192277.79 (50195.57)
5.	560495.00	313905.70 (461275.40)	.56 (.82)	246589.30 (99219.6)
		25% Decrease in Product Price		
1.	$116244.00	$127924.98 (257197.48)	1.1 (2.21)	$-11680.99 (-140953.48)
2.	192600.00	194140.54 (330034.59)	1.0 (1.71)	-1540.54 (-137434.59)
3.	230820.00	225105.68 (364096.25)	.98 (1.58)	5714.32 (-133276.25)
4.	268980.00	256022.21 (398104.43)	.95 (1.48)	12957.79 (-129124.43)
5.	336702.00	313905.70 (461275.40)	.93 (1.37)	22796.30 (-124573.4)

represent the hypothetical 25 percent product price variations around the base product prices. Among the SRAC curves average cost decreases from 0.88 to 0.78 from the 160 to 320 acre farm, 0.78 to 0.66 from the 320 to 640 acre farm and increases from 0.66 to 0.70 from the 640 to 1280 acre farm. The LRAC curve would indicate that all technical scale economies are realized by the 640 acre farm with slight technical scale diseconomies, and increases in net revenue, realized in moving to the 1280 acre farm. Net revenue ranges between $6,984.01 and $135,030.30 along the LRAC curve.

Changes in product price contribute to more substantial changes in average cost than do economies of size. Average costs, on the most efficient farms decrease 0.22 from 9.88 to 9.66 across all farm sizes. When product prices are allowed to vary in the 25 percent range, average costs may vary as much as 0.47 from 9.70 to 1.17 on a 160 acre farm, 0.42 from 0.62 to 1.04 on a 320 acre farm, 0.35 from 0.53 to 0.88 on a 640 acre farm and 0.37 from 0.56 to 0.93 on a 1280 acre farm.

For the most efficient and maximum net revenue generating farms, Case Five, net revenue per acre increased by $74.83 from 43.65 to 118.48 per acre across all farm sizes.

II. Land Payments

The primary issue posed by the National Land for the People, Inc.
was concerning the disposal of excess lands. The results reported in
Section I, enabled the policymaker to evaluate possible acreage limita-
tions based on economic efficiency only and hence determine which land
should be classified as excess land. In this section, the role of land
and capital investments will be examined with regard to their effect
on farm viability.

To this juncture, net revenue has been defined as the return to
operator management and land. In this section, net revenue is defined
as the return to operator management only as various land payment
schemes are considered. The land payment arrangements are typical sit-
uations faced by the Federal Land Bank (F.L.B.), Farmers Home Adminis-
tration (Fm.H.A.) and local banks near the Irrigation District in July
of 1978. They are as follows:

1. $8\frac{1}{2}$ percent interest rate, 25 year mortgage, 50 percent
   equity (Federal Land Bank, July 1978);

2. 5 percent interest rate, 40 year mortgage, 25 percent
   equity (Farmers Home Administration, July 1978); and

3. $9\frac{1}{2}$ percent interest rate, 15 year mortgage, 40 percent
   equity (Local Banks, July 1978).

The three land payment options typify two situations. Options one and
three typify the established farmer interested in enlarging his present

land holdings by borrowing from the Federal Land Bank or the local

bank. Option two typifies the beginning farmer purchasing a parcel of

land to establish a viable farming operation.

Two land prices will be considered: (1) a post-project price of

$1,300 reflecting the improvements offered by the irrigation project

and (2) a pre-project price of $700 not reflecting the benefits of the

irrigation project.[40] These two prices represent two proposals for the

disposal of excess land. The first proposal would simply allow excess

land owners to sell the land at whatever price they could capture in

the market. The second proposal would require the land to be sold at

a pre-project, or unimproved price, by the Secretary of the Interior.

160 Acre Farm

Table 9 summarizes the possible net revenue obtainable on the most

efficient 160 acre farm at a post-project land price of $1,300 per acre.

Table 10 summarizes the possible net revenue obtainable on the most ef-

ficient 160 acre farm at a pre-project land price of $700 per acre. At

a land price of $1,300 per acre, annual land payments range from $9,091

to $15,942 and, in turn, net revenue may vary from $11,921.87 to

$-22,987.60 (Table 9). At a land price of $700 per acre, annual land

payments range from $4,895 to $8,584 and, in turn, net revenue may vary

from $16,117.89 to $-15,629.57 (Table 10).

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[40] These figures were generated by Mr. Russell H. Murray, a staff
appraiser for the Bureau of Reclamation in August of 1978.

Table 9

Net Revenue After Land Payment Assuming the
Post Project Land Price of $1300 Per Acre

| Farm Size and Type | Prices | Possible NR – Options[a] | | |
		1	2	3
160 Most efficient	basic	$ -3178.00	$ -2107.38	$ -8958.40
"	25% Inc.	10851.25	11921.87	5070.85
"	25% Dec.	-17207.20	-16136.58	-22987.60
320 Most efficient	basic	4624.23	6765.47	-6936.57
"	25% Inc.	32682.73	34823.97	21121.93
	25% Dec.	-23434.27	-21293.03	-34995.07
640 Most efficient	basic	35178.28	39460.71	12056.63
	25% Inc.	91295.22	95577.71	68173.63
	25% Dec.	-20938.78	-16656.29	-44060.37
1280 Most efficient	basic	53734.18	62299.15	7490.99
	25% Inc.	165293.18	173858.15	119049.99
	25% Dec.	-58499.82	-49934.85	-104743.01

[a]The three options represent three possible land payment situations and
they are as follows:

1. 8 1/2 percent interest, 25 year mortgage, 50 percent equity
    (F.L.B., July 1978).
2. 5 percent interest rate, 40 year mortgage, 25 percent equity
    (Fm.H.A., July 1978).
3. 9 1/2 percent interest rate, 15 year mortgage, 40 percent equity
    (Local bank, July 1978).

Table 10

Net Revenue After Land Payment Assuming the
Pre-project Land Price of $700 per Acre

Farm Size/Type	Prices	Possible NR Options[a]		
		1	2	3
160 Most efficient	basic	$1512.16	$2088.64	$-1600.37
	25% Inc.	15541.41	16117.89	12428.88
	25% Dec.	-12517.04	-11940.56	-15629.57
320 Most efficient	basic	14004.55	15157.53	7779.51
	25% Inc.	42063.05	43216.03	35838.01
	25% Dec.	-14053.95	-12900.97	-20278.99
640 Most efficient	basic	53938.86	56244.82	41488.77
	25% Inc.	110055.86	112361.82	97605.77
	25% Dec.	-2178.14	127.82	-14628.23
1280 Most efficient	basic	91255.47	95867.38	66355.29
	25% Inc.	202814.47	207426.38	177914.29
	25% Dec.	-20978.53	-16366.62	-45878.71

[a] The three options represent three possible land payment situations and
they are as follows:

1. 8 1/2 percent interest rate, 25 year mortgage, 50 percent equity
   (F.L.B., July 1978).
2. 5 percent interest rate, 40 year mortgage, 25 percent equity
   (Fm.H.A., July 1978).
3. 9 1/2 percent interest rate, 15 year mortgage, 40 percent equity
   (Local bank, July 1978).

The farmer considering a land purchase faces a wide variation in possible returns to management even under the smallest annual land payment arrangement, option 2. At a land price of $1,300 per acre, net revenue varies from $11,921.87 to $-16,136.58 (Table 9). At a land price of $700 per acre, net revenue varies from $16,117.89 to $-11,940.56 (Table 10). Under the assumption of basic product prices, net revenue is $-2,107.38 and $2,088.64 with land prices of $1,300 and $700 per acre, respectively. Net revenue per acre, at the land prices of $1,300 and $700 per acre, are $-13.17 and $13.05, respectively.

320 Acre Farm

Annual land payments range from $18,183 to $31,885 and, in turn, net revenue varies from $34,823.97 to $-34,995.07 at a land price of $1,300 per acre under the specified product price variation (Table 9). At a land price of $700 per acre, under a specified product price variation, annual land payments range from $9,791 to $17,169 and, in turn, net revenue varies between $43,216.03 and $-20,278.99 (Table 10).

The lowest annual land payment is afforded by option 2. Under this option and at a land price of $1,300 per acre, net revenue varies between $34,823.97 and $-21,293.03 (Table 9). At land price of $700 per acre, net revenue varies between $43,216.03 and $-12,900.97 (Table 10). Using the basic product prices, net revenue is $6,765.47 and $15,157.53 with land prices of $1,300 and $700 per acre, respectively. The net revenue per acre obtainable at a land price of $1,300 increases

from $-13.17 to $21.14 when moving from the 160 to the 320 acre farm. At a land price of $700, the net revenue per acre increases over three-fold from $13.05 to $47.37.

640 Acre Farm

A wide variation in annual land payments and net revenues are evident when pre- and post-project land price and product price variations are considered. At a land price of $1,300 per acre, (Table 9) annual land payments range from $36,366 to $63,770 and net revenue varies between $95,577.71 and $-44,060.37 (Table 9). At a land price of $700 per acre, annual land payments range from $19,581 to $34,338 and net revenue varies from $112,361.82 to $-14,628.23 (Table 10).

Considering the lowest annual land payment option, net revenue varies between $-16,656.29 and $95,577.71 at a land price of $1,300 per acre and between $127.82 and $112,361.82 at a land price of $700 per acre. When only the basic product prices are considered, the net revenue per acre at the post-project land prices increases from $21.14 to $61.66 and at pre-project land prices, net revenue per acre increases from $47.37 to $87.88, as the farm size increases from 320 to 640 acres.

1280 Acre Farm

The 1280 acre farm follows the same pattern established by the other farm sizes. Annual land payments vary from $72,731 to $127,539 and net revenue varies from $173,858.15 to $-104,743.01 at the

post-project land price of $1,300 per acre (Table 9). At the pre-project land price of $700 per acre, annual land payments vary from $39,163 to $68,675 and net revenue varies from $207,426.38 to $-45,878.71 (Table 10).

Once again, considering the lowest annual land payment option, net revenue varies between $173,858.15 and $-49,934.85 at the post-project land price and between $207,426.38 and $-16,366.62 at the pre-project land price. When only base product prices are considered, the net revenue per acre at the post-project land price decreases from $61.66 to $48.67 and at the pre-project land price decreases from $87.88 to $74.90 as the farm size increases from 640 to 1280 acres.

The subjective evaluation of an adequate return to management is left to the reader. The return to management on a per acre basis increased over six-fold as farm size increased from 160 to 640 acres, and decreased slightly as farm size increased from 640 to 1280 acres. When comparing the effects of annual land payments versus product prices, product prices appear to be relatively more important. For example on the 320 acre farm, the maximum change in net revenue from changes in land payment is $22,094, while the maximum change in net revenue from variation in product prices of 25 percent is $56,117. The variation resulting from changes in land payments and product prices increases as farm size increases, consequently the largest variation occurs on the 1280 acre farm.

III. Capital Requirements

The previous sections have addressed farm efficiency and viability with and without payments to land considered. Under various conditions, farms in each farm size classification would appear to generate a positive net return to operator management and hence appear to be viable. However, all farm sizes require substantial investments in land and capital. This section reviews the total capital requirements, for land and machinery, and the resource required to meet the initial down payments and the annual payments.

Table 11 summarizes the total land and capital investments for each farm size and type. In all cases, the machinery investments are substantial, ranging from $59,440 for a 160 acre barley farm with custom harvesting to $446,805 for a 1280 acre sugar beet and wheat farm. For the most efficient farm types, the machinery investment per acre varies from $733 to $349 across all farm sizes. Land prices are assumed to be $1,300 per acre across all farm sizes. The total investment in land and machinery varies only slightly between machinery lists on a given farm size, however in each case a substantial investment in land and capital is required.

Table 12 summarizes the initial and annual capital payments for the machinery and land required on each farm size. The machinery payments assume 25 percent equity, 9.5 percent rate of interest and a five year repayment period. The land payments assume a land price of $1,300

Table 11

Total Land and Capital Investment for Various Farm Sizes,
District 1, Lower Yellowstone Irrigation Project

Acreage and Crops Grown	Machinery List	Machinery Investment	Land Investment[a]	Total Investment
160 Acre Farm				
Barley	1	$59440	$208000	$267440
Sugar Beets Barley	1	83140	208000	291140
Sugar Beets Wheat	1	83140	208000	291140
320 Acre Farm				
Barley	1	63740	416000	105340
Sugar Beets Barley	1	131610	416000	547610
Sugar Beets Wheat	3	234570	416000	650570
640 Acre Farm				
Barley	1	96875	832000	928875
Sugar Beets Barley	3	293300	832000	1125300
Sugar Beets Wheat	3	293000	832000	1125300
1280 Acre Farm				
Barley	1	106175	1664000	1770175
Sugar Beets Barley	3	446805	1664000	2110805
Sugar Beets Wheat	3	446805	1664000	2110805

[a] The land price is assumed to be $1300 per acre.

Table 12

Initial Capital Investment and Annual Payments for Machinery and Land
for Various Farm Sizes in District 1 of the
Lower Yellowstone Irrigation Project

| | | Initial Capital Investment | | |
Farm Size	Machinery List	Land Down Payment[a]	Machinery Down Payment[b]	Total Capital Investment
160	1	52,000	20,785	72,785
320	3	104,000	58,645	162,645
640	3	208,000	73,325	281,325
1280	3	416,000	111,700	527,700

| | | Annual Payments | | |
		Land Payment	Machinery Payment	Total Capital Payments
160	1	9,091	16,239	25,330
320	3	18,182	45,817	63,999
640	3	36,366	57,289	93,655
1280	3	72,731	87,274	160,005

[a] Land payments calculations assume a land price of $1,300 per acre, 5 percent rate of interest, 25 percent equity and a 40 year mortgage.

[b] Machinery payment calculations assume 25 percent equity, 9.5 percent rate of interest and a 5 year repayment period.

per acre, 5 percent rate of interest, 25 percent equity and a 40 year

mortgage. Total initial investments in capital are $72,785, $162,645,

$281,325 and $527,700 for the 160, 320, 640 and 1280 acre farms, re-

spectively. Total annual payments for capital are $25,330, $63,999,

$93,655 and $160,005 for the 160, 320, 640 and 1280 acre farms, respec-

tively. These figures indicate that substantial amounts of capital

must be available, which would suggest that capital may be a barrier to

entry into irrigated farming.

Summary

This chapter has considered farm efficiency and viability under a

host of conditions. The most significant factor causing variations in

net revenue, i.e. return to operator management, is the change in prod-

uct price. However, it is evident that changes in crop mix, machinery

complement and land and capital payments cause substantial variation in

net revenue. The results of this study are summarized well in this

statement of A. S. Kezis with regard to his economies of size study in

the Columbia River Basin:

> "In general, one can conclude that, with today's
> technology, credit and financial conditions, it
> requires more than just subsidized water to make
> irrigated agriculture, as developed by the Bureau
> of Reclamation, a "settlers" program.[41]

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[41] Kezis, op. cit., p. 87.

CHAPTER 5

SUMMARY AND CONCLUSIONS

This project began as a component in a United States Department of Agriculture (U.S.D.A.) - United States Bureau of Reclamation (U.S.B.R.) project to assess the Department of the Interior's 1977 Proposed Rules and Regulations with respect to the Reclamation Act of 1902. This thesis project utilized the data generated by the U.S.D.A - U.S.B.R. project in an analysis of economies of size in District 1 of the Lower Yellowstone River Irrigation Project.

The data gathering procedures employed in this study are summarized below:

1. Collect available published and unpublished crop and farm budget information for the study district.

2. Develop a calendar of operations for each major crop in the District.

3. Collect 1978 data on input costs and machinery performance from available sources.

4. Prepare a preliminary crop budget for each crop and review them with University, U.S.B.R. and local Cooperative Extension personnel.

5. Form a panel of farmers representing a wide range of farm sizes to review the preliminary crop budgets and help specify typical machinery complements and crop mixes to represent 160, 320, 640 and 1280 acre farms for each case study district.

6. Develop total farm budgets for each farm size.

7. Present typical farm budgets to farmer panels for review and revision.

These data were modelled in a linear programming framework to generate long run average cost curves and hence examine economies of size in irrigated farming. In this formulation, the irrigable land area was designated as the resource fixed in the short run. Therefore, the SRAC curves in Figure 4 represent the average cost per unit of output, assuming a fixed land area, with the machinery complement and crop mix allowed to vary. In an attempt to consider trends in farm size and farm survival the long run average cost curve (LRAC) is the most relevant. The LRAC is an envelope curve tangent to the short run average cost curves and it represents the minimum cost of producing a given level of output. If the farmer has sufficient funds, he theoretically could choose any point along the LRAC curve in his long range planning horizon. However, once the farmer has chosen a land area onwhich to farm, the LRAC curve is no longer relevant as he is constrained to the SRAC curve corresponding to a given land area.

This model considered multiple products, therefore a common output denomination was required. In this study, total revenue, quantity of output times price, was employed as a proxy for output. The points along the resulting short run average cost curve represented total cost per dollar of physical output. The break-even point for the farmer

would be a ratio of TC to TR equal to 1, or where the farmer receives

a dollar in revenue for each dollar of cost.

This economies of size study focused on technical economies, asso-

ciated with the spreading out of the fixed plant over more units of

output. No cost or price economies associated with volume purchases or

sales were considered.

Conclusions

The major conclusions of this study are as follows:

1. Essentially all relevant economies of size are realized
   by the 640 acre farm, as compared to the other farm
   sizes considered in the study, with a level of total
   revenue equal to $225,000.

2. The most efficient and maximum net revenue generating
   farms had a crop mix of sugar beets and wheat.

3. Net revenue is most responsive to changes in product
   price with some response to changes in land payments.

4. Average costs, TC/TR, and net revenue vary widely
   between farms with the same acreage, given a different crop
   mix.

5. Net revenue increases as farm size increases to the 1280
   acre farm.

6. Substantial investments in capital and land are required
   across all farm sizes.

Sugar beet acreages are contracted and are closely tied to Holly Sugar Company in Sidney. Rumors of the company's closure are ever present and tend to add to the long-run uncertainty of irrigated farmers. If the company were to close, sugar beets, the highest net return crop, would not be produced. The sugar beet processor in Billings contracts its sugar beets locally and has been holding its production constant. The option of lower Yellowstone producers shipping to the Billings area is virtually nonexistent.

With no alternative market, the sugar beet producer is faced with producing a substitute crop. The crop yielding the next highest net return is wheat. Substituting wheat for sugar beets will increase the average cost per dollar of output and thus shift the LRAC curve upward. This shift indicates that the potential efficiency of the individual farmer, and the irrigation project, is decreased.

A host of cropping alternatives exist beyond the four major crops considered in this study. The Eastern Agricultural Research Center and other state and Federal organizations have been considering alternatives for the sugar beet farmer. The most promising alternative as suggested by the Research Center, were short season legumes, i.e., faba beans, soybeans and kidney beans. The consideration of these alternatives is left to further research.

While the efficiency goal requires that farm size be sufficient to realize economies of size and minimize production costs, the equity

goal requires that a maximum number of people be given the opportunity

to realize the projects' benefits.

The equity goal, in essence, gives everyone with the desire the

opportunity to farm. The compassion for human beings with physical and

financial hardships results in additional government assistance pro-

grams. Young, and new, farmers possess low equity capital and hence

are considered very high credit risks by traditional lending institu-

tions. Government programs, specifically the Farmers Home Administra-

tion, assist these farmers in establishing and operating a farm unit.

The favorable interest rate, mortgage length, and downpayment for these

high risk borrowers is part of the cost to society to assist the dis-

advantaged young or new operator.

A substantial subsidy to the agricultural sector resulted from

the construction of the original irrigation project. The farmers of

today realized very little of the original subsidy as the benefits of

the project were internalized into the price of the land at the time

they either purchased or inherited it.

The low equity position and large capital expenditures required

by the new farmer would indicate there are barriers to entry in irri-

gated farming. These same barriers exist for young or new farmers

waiting to enter into nonirrigated farming or ranching.

If the goals were to be satisfied under the literal interpretation

of the 160 acres limitation, then society would be faced with the

policy question of adding another subsidy, i.e., subsidized interest rate in addition to the present water development subsidy.

These subsidy programs can and do lead to production efficiencies such as over capitalization. These inefficiencies represent the trade off the general public appears to be willing to make.

Further Research

This study considered technical size economies on only one irrigation project in Montana. This analytical framework could be applied to any irrigation project with slight modifications to consider various cultural patterns. The policy decisions on the immediate horizon will require further analysis of all irrigation projects under the 1902 Reclamation Act, to assist policymakers in future discussion of the "160 acre limitation".

Montana has adequate baseline data for additional descriptive work on technical economies of size. Additional work needs to be done on price economies across all farm sizes and types.

At the time of this data collection effort, very little information was available on land tenure, off farm employment and land ownership in the Lower Yellowstone Project. Additional analysis should include a consideration of these parameters.

LITERATURE CITED

Alston, Richard Moss, "Commercial Irrigation Enterprize: The Fear of Water Monopoly and the Genesis of Market Distortion," Unpublished doctoral dissertation, Cornell University, 1970.

Bass, Peter L., and Edward M. Kirshner, "Demographic, Economic, and Fiscal Impacts of Alternative Westlands Reclamation Act Enforcement Scenarios," American Journal of Agricultural Economics. 60 (1978): 935-940.

Bressler, Raymond G., and Benjamin French, Efficiency in Fruit Marketing: Grading Costs for Apples and Pears. California Agricultural Experiment Station, Giannini Foundation. Mimeographed Report No. 128, June 1952.

Brewer, Michael F., Economics of Public Water Pricing. California Agricultural Experiment Station, Giannini Foundation Research Report No. 224, May 1961.

Eidman, Vernon R., Gerald W. Dean, and Harold O. Carter, Economies of Scale in California Turkey Production. California Agricultural Experiment Station, Giannini Foundation Research Report No. 298, August 1968.

Faris, J. Edwin, and David L. Armstrong, Economies Associated with Site, Kern County Cash-Crop Farms. California Agricultural Experiment Station. Giannini Foundation Research Report No. 269, December 1963.

Hall, Bruce F., and E. Phillip LeVeen, "Farm Size and Economic Efficiency: The Case of California," American Journal of Agricultural Economics. 60(1978): 589-600.

Hedges, Trimble R., Water Supplies and Cost in Relation to Farm Resource Use Decisions and Profits on Sacramento Valley Farms. California Agricultural Experiment Station, Giannini Foundation Research Report No. 320, March 1974.

Hedges, Trimble R.; and C. V. Moore, Economics of On-Farm Irrigation Water Availability and Cost, and Related Farm Adjustments. 4: Intra-Valley Variations in Relation to Resource Use, Earnings, and Adjustments in the San Joaquin Valley Cotton Area. California Agricultural Experiment Station. Giannini Foundation Research Report No. 286, June 1963.

Holland, David, "Production Efficiency and Economics of Size in Agriculture. Washington State University Scientific Paper No. 5266, 1978.

Huffman, Roy E., Irrigation Development and Public Water Policy. (Ronald Press Co., New York), 1953.

Jacobs, James J., "Economic Analysis and Federal Irrigation Policy: A Reappraisal: Discussion," Western Journal of Agricultural Economics. December 1978, pp. 269-271.

Johnson, Roger G., and Steven C. Hvinden, "Labor and Management Components in Economies of Farm Size Studies," Western Journal of Agricultural Economics. December 1978, pp. 205-210.

Johnston, Warren E., Economies of Size and Imputed Values of Farmland in the Imperial Valley of California. California Agricultural Experiment Station, Giannini Foundation Research Report No. 314, July 1971.

Jones, Hancy, "Proposed Rules for Administering the Acreage Limitation of Reclamation Law," Natural Resources Journal. October 1978, pp. 933-940.

Kezis, Alan Stanford, "An Examination of Economies of Size and Net Revenues on Columbia Basin Farms: Implications for Acreage Limitation Policy." Unpublished Ph.D. dissertation, Washington State University, 1978.

Kletke, Darrell D., Operations Manual for the Oklahoma State University Enterprise Budget Generator. Oklahoma State University Agriculture Experiment Station Research Report P-179, 1975.

Kraenzel, Carl Frederick, The Great Plains in Transition. (University of Oklahoma Press, Norman, Oklahoma), 1955.

Lackman, Christopher, "Reclamation Act of 1902: After 75 Years 160 Acre Limitation Held Valid," Natural Resources Journal. October 1977.

LeVeen, E. Phillip, and George E. Goldman, "Reclamation Policy and the Water Subsidy: An Analysis of the Distributional Consequences of Emerging Policy Choices," American Journal of Agricultural Economics. 60(1978): 929-934.

Madden, J. Patrick, <u>Economies of Size in Farming</u>. Agricultural Economic Report No. 107, Economic Research Service, U.S.D.A., 1967.

Maier, Melvin G., and Laurel Loftsgard, <u>Potato Production Costs and Practices in the Red River Valley</u>. North Dakota Agricultural Experiment Station Bulletin No. 451, 1964.

Martin, William E., "Economies of Size and the 160-Acre Limitation: Fact and Fancy," <u>American Journal of Agricultral Economics</u>. 60(1978): 923-927.

Matulich, Scott C., Hoy F. Carman, and Harold O. Carter, <u>Cost-Site Relationships for Large Scale Dairies with Emphasis on Waste Management</u>. California Agricultural Experiment Station. Giannini Foundation Research Report No. 324, October 1977.

Mead, Elwood, "Rise and Future of Irrigation in the United States," <u>Yearbook of the Department of Agriculture</u>. Government Printing Office, Washington, D.C., 1899, pp. 603-604.

<u>Montana Agricultural Statistics</u>, Vol. XVII (1976-77), Montana Department of Agriculture, W. Gordon McOmber, Director, 1978.

Moore, C. V., Economies Associated with Size, Fresno County Cotton Farms. California Agricultural Experiment Station, Giannini Foundation Research Report No. 285, November 1965.

Moore, C. V., and Trimble R. Hedges, <u>Economies of On-Farm Irrigation Water Availability and Costs, and Related Farm Adjustments. 2. Farm Size in Relation to Resource Use, Earnings, and Adjustments on the San Joaquin Valley Eastside</u>. California Agricultural Experiment Station, Giannini Foundation Research Report No. 263, June 1963.

Moore, C. V., and Trimble R. Hedges, <u>Some Characteristics of Farm Irrigation Water Supplies in the San Joaquin Valley</u>. California Agricultural Experiment Station, Giannini Foundation Research Report No. 258, September 1962.

Moran, Leo J., <u>Nonfeed Costs of Arizona Cattle Feeding</u>. Arizona Agricultural Experimental Station Technical Bulletin No. 138, 1959.

Niles, James H. and Ben C. French, A Simulation Model of Grower-Processor Coordination in the Beet Sugar Industry. California Agricultural Experiment Station, Giannini Foundation Research Report No. 321, May 1974.

Penson, John B. Jr., and David A. Lins, Agricultural Finance. (Prentice-Hall, Englewood Cliffs, New Jersey), 1980.

Reclamation Instruction, United States Bureau of Reclamation, Series 210 Land, Part 219 Excess Land, 1978.

Robinson, Michael G., "Water at Work: Reclamation, 1902-1977." 1976 Summary Report, United States Department of the Interior (Bureau of Reclamation).

Scitovsky, Tibor, Welfare and Competition. (Richard D. Irwin, Inc., Chicago, Illinois) 1951.

Seckler, David, and Robert A. Young, "Economic and Policy Implications of the 160-Acre Limitation in Federal Reclamation Law," American Journal of Agricultural Economics. 60(1978): 575-588.

Shumway, C. Richard, and Harold M. Stalks, Production Costs and Yields of California Field Crops and Vegetables by Area, Average 1961-65 and Projected 1980. California Agricultural Experiment Station, Giannini Foundation Mimeographed Report No. 307, March 1970.

Tweeton, Lather, Foundations of Farm Policy. (University of Nebraska Press, Lincoln, Nebraska), 1970.

U.S. Department of the Interior, "Proposed Rules for Enforcement of the Reclamation Act of 1902: An Economic Analysis." E.S.C.S., U.S.D.A., February 1978.

Webb, Walter Prescott, The Great Plains. (Blaisdell Publsihing Company, Waltham, Massachusetts), 1931.

Young, Robert A., "Economic Analysis and Federal Irrigation Policy: A Reappraisal," Western Journal on Agricultural Economics, December 1978, pp. 257-267.

APPENDICES

APPENDIX A

Budget Generator Assumptions

Table a-1

Machinery Lists for 160 Acre Farm

Custom List I	Typical List II	Economic-Engineering List III
6 row sugar beet topper	6 row sugar beet topper	6 row sugar beet topper
2 row sugar beet digger	2 row sugar beet digger	2 row sugar beet digger
4 row sugar beet planter &	4 row sugar beet planter &	12' thinner
incorporator	incorporator	4 row sugar beet planter &
12' beet cultivator	12' beet cultivator	incorporator
		12' beet cultivator
custom combine	14' combine (used)	14' combine (used)
12' grain drill	12' grain drill	12' grain drill
custom swath, bale, load &	10' swather (used)	12' swather
stack	1 6-ton round baler	1 16x18" cube baler
	1 farmhand	1 PTO bale wagon
	1 wagon	
12' field cultivator	12' field cultivator	12' field cultivator
24' harrow	24' harrow	16' harrow
30' sprayer	30' sprayer	30' sprayer
3-16 moldboard plow	3-16 moldboard plow	2-16 moldboard plow
10' mulcher	10' mulcher	10' mulcher
12' landplane	12' landplane	12' landplane
12' tandem disk	12' tandem disk	12' tandem disk
90 h.p. tractor	90 h.p. tractor	125 h.p. tractor
70 h.p. tractor	70 h.p. tractor	90 h.p. tractor
1 custom haul	2 trucks, 2 ton	2 trucks, 2 ton

The following implements are the same throughout the budgets:

12' ditcher
12' closer
14' border dike

Machinery Lists for 320 Acre Farm

List I	List II	List III
6 row sugar beet topper	6 row sugar beet topper	6 row sugar beet topper
2 row sugar beet digger	2 row sugar beet digger	2 row sugar beet digger
4 row sugar beet planter & incorporator	4 row sugar beet planter & incorporator	12' thinner
12' beet cultivator	12' beet cultivator	4 row sugar beet planter & incorporator
		12' beet cultivator
custom combine	14' combine (used)	14' combine (used)
12' grain drill	12' grain drill	12' grain drill
custom swath, bale, load & stack	14' swather (used)	12' swather
	1 6-ton round baler	1 16x18" cube baler
	1 farmhand	1 PTO bale wagon
	1 wagon	
12' field cultivator	12' field cultivator	12' field cultivator
24' harrow	24' harrow	16' harrow
40' sprayer	40' sprayer	30' sprayer
3-16 moldboard plow	3-16 moldboard plow	3-16 moldboard plow
12' mulcher	12' mulcher	12' mulcher
15' landplane	15' landplane	12' landplane
12' tandem disk	12' tandem disk	12' tandem disk
100 h.p. tractor	100 h.p. tractor	125 h.p. tractor
90 h.p. tractor	90 h.p. tractor	90 h.p. tractor
70 h.p. tractor	70 h.p. tractor	70 h.p. tractor
1 custom haul	3 trucks, 2 ton	3 trucks, 2 ton

Table a-3

Machinery Lists for 640 Acre Farm

List I	List II	List III
6 row sugar beet topper	6 row sugar beet topper	6 row sugar beet topper
2 row sugar beet digger	2 row sugar beet digger	2 row sugar beet digger
6 row sugar beet planter & incorporator	6 row sugar beet planter & incorporator	4 row sugar beet planter & incorporator
18' sugar beet cultivator	18' sugar beet cultivator	12' sugar beet cultivator
		12' thinner
custom combine	14' combine (new)	14' combine
14' grain drill	14' grain drill	12' grain drill
custom swath, bale, stack	14' swather (new)	12' swather
	1 6-ton round baler	1 16x18" cube baler
	1 farmhand	1 PTO bale wagon
	1 wagon	
12' field cultivator	12' field cultivator	12' field cultivator
28' harrow	28' harrow	16' harrow
40' sprayer	40' sprayer	30' sprayer
5-16 moldboard	5-16 moldboard	5-16 moldboard plow
16' mulcher	16' mulcher	24' mulcher
15' landplane	15' landplane	15' landplane
18' tandem disk	18' tandem disk	12' tandem disk
150 h.p. tractor	150 h.p. tractor	160 h.p. tractor
125 h.p. tractor	125 h.p. tractor	125 h.p. tractor
90 h.p. tractor	90 h.p. tractor	90 h.p. tractor
70 h.p. tractor	70 h.p. tractor	70 h.p. tractor
1 custom haul	3 trucks, 2 ton	3 trucks, 2 ton

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Table a-4

Machinery Lists for 1280 Acre Farm

List I	List II	List III
6 row sugar beet topper	6 row sugar beet topper	2-6 row sugar beet toppers
2-3 row sugar beet diggers	2-3 row sugar beet diggers	2-2 row sugar beet diggers
8 row sugar beet planter & incorporator	8 row sugar beet planter & incorporator	8 row sugar beet planter & incorporator
2-24' sugar beet cultivators	2-24' sugar beet cultivators	2-24' sugar beet cultivators
		12' thinner
custom combine	16' combine	14' combine
16' grain drill	16' grain drill	12' grain drill
custom swath, bale & stack	14' swather	12' swather
	1 6-ton round baler	1 18x16" cube baler
	1 farmhand	1 PTO bale wagon
	1 wagon	
18' field cultivator	18' field cultivator	12' field cultivator
28' harrow	28' harrow	28' harrow
50' sprayer	50' sprayer	30' sprayer
2 6-16' moldboard plows	2 6-16' moldboard plows	2 6-16' moldboard plows
2-20' mulchers	2-20' mulchers	2-20' mulchers
2-15' landplanes	2-15' landplanes	2-20' landplanes
24' tandem disk	24' tandem disk	18' tandem disk
175 h.p. FWD tractor	175 h.p. FWD tractor	175 h.p. FWD tractor
150 h.p. tractor	150 h.p. tractor	150 h.p. tractor
125 h.p. tractor	125 h.p. tractor	125 h.p. tractor
100 h.p. tractor	100 h.p. tractor	100 h.p. tractor
2-90 h.p. tractors	2-90 h.p. tractors	2-90 h.p. tractors
70 h.p. tractor	70 h.p. tractor	70 h.p. tractor
4 custom haul	4 trucks, 2 ton	4 trucks, 2 ton

Table a-5

Operations Schedule for Sugar Beets

Month	Operation
November	Disk
	Plow
	Mulch, twice
	Landplane, twice
	Custom fertilize
	Cultivate, field
April	Custom fertilize
	Mulch
	Cultivate, field
May	Ditch
	Plant
	Apply herbicides
June	Irrigate (4 acre inches)[1]
	Custom hoeing
	Cultivate, beet
July	Irrigate (8 acre inches)
	Custom thinning
August	Irrigate (8 acre inches)
September	Close ditches
October	Top
	Dig
	Haul

[1] The acre inches specified is the net water supplied to the crop. A 70% irrigation efficiency is assumed in these budgets.

Table a-6

Operations Schedule for Spring Wheat

Month	Operation
November	Dike fields
April	Custom fertilize Cultivate, field
May	Ditch Harrow Plant
June	Irrigate (4 acre inches) Spray herbicides
July	Irrigate (4 acre inches)
August	Close ditch Swath Combine Haul

Table a-7

Operations Schedule for Feed Barley

Month	Operation
November	Dike fields
April	Cultivate, field Harrow Plant
June	Ditch Spray herbicides Irrigate (4 acre inches)
July	Irrigate (4 acre inches)
August	Close ditches Swath Combine Haul

Table a-8

Operations Schedule for Alfalfa Hay

Month	Operation
May	Custom fertilize
	Ditch
June	Custom spray herbicide
	Irrigate (6 acre inches)
July	Swath
	Bale
	Load
	Haul
	Irrigate (6 acre inches)
August	Swath
	Bale
	Load
	Haul

Table a-9

Prices for Inputs and Custom Operations
for Sugar Beets

Input or Operation	Price/Acre
Fertilizer (100 N, 90 P_2O_5)[1]	$38.64
Custom fertilizer application	2.00
Sugar beet seed (12 lbs./acre @ $1.50/lb.)	18.00
Weed and insect control (Roneet and Dyfonate)	9.88
Custom hoeing and thinning	45.00
Custom topping	15.32
Custom digging	31.19
Custom hauling ($2.00/T + fuel)	39.00
Water (operation and maintenance)	9.50
Irrigation labor (seasonal)	5.00

[1] Nitrogen – .228/lb.

P_2O_5 – .176/lb.

Table a-10

Prices for Inputs and Custom Operations
for Spring Wheat

Input or Operation	Price/Acre
Fertilizer (60 N)[1]	$13.68
Custom fertilizer application	2.00
Seed (90 lbs./acre @ $.05/lb.)	4.50
Herbicide (2,4-D - 1 pint/acre @ $1.00/pint)	1.00
Custom swath	5.89
Custom combine	18.65
Custom haul (.10/bu.)	4.57
Water (operation and maintenance)	9.50
Irrigation labor (seasonal)	5.00

[1] Nitrogen = $.228/lb. No P_2O_5 is included because spring wheat traditionally follows sugar beets in the crop rotation.

Table a-11

Prices for Inputs and Custom Operations
for Feed Barley

Input or Operation[1]	Price/Acre
Seed (100 lbs./acre at .04/lb.)	$ 4.00
Herbicide (2, 4-D - 1 pint/acre @ $1.00/pint)	1.00
Custom swath	5.89
Custom combine	18.65
Custom haul ($.10/bu.)	5.69
Water	9.50
Irrigation labor (seasonal)	5.00

[1] No nitrogen or phosphorus is included as barley follows sugar beets
in the crop rotation.

Table a-12

Prices for Inputs and Custom Operations
for Alfalfa Hay

Input or Operation	Price/Acre
Fertilizer (90 lbs. P_2O_5)[1]	$15.84
Custom fertilizer application	2.00
Custom spraying (Furaden)[2]	2.40
Stand establishment (15 lbs. of alfalfa seed @ $2.25/lb. amortized over 6 years)	4.34
Custom swath	6.39
Custom bale	12.54
Custom stack	7.10
Irrigation labor (seasonal)	5.00

[1] P_2O_5 - .176/lb.

[2] Aerial application - 60% of all acres at $4.00/acre.

Table a-13

Prices and Yields for Each Crop[1]

Crop	(Unit)	Yield	Price/Unit	TR/Acre
Sugar beets	(tons)	18.9	31.21	589.87
Spring wheat	(bu)	45.7	3.25	148.53
Feed barley	(bu)	56.9	2.24	127.46
Alfalfa hay	(tons)	2.6	55.07	143.18

[1] Yields and prices were normalized over 5 years, 1973-1977. This information was generated from yields and prices for Richland County provided by Montana State Crop and Livestock reporting service.

Table a-14

Storage Improvements Assumed for Each Farm Size

Farm Size	Machine Storage			Grain Storage	
	f+2	Value		bu.	Value
160	2000	$10,000		4000	$2,600
320	2650	13,250		5800	3,770
640	4450	22,250		14000	9,100
1280	4500	22,250		24000	15,600

Table a-15

Interest Rates Used for Land Value[1]

Farm Size	Interest Rate
160	7.72
320	7.49
640	7.44
1280	7.27

[1] Interest rate for operating capital and machinery purchases is 10.3% and for real estate 7%. The interest rates in the table include a 7% return on land investment with the fraction of a percentage point above 7% for the remaining costs of liability and extended insurance coverage on the farm, and depreciation and interest on improvements.

APPENDIX B

Coefficients For Programming Matrices

Table b-1

Total Costs per Acre, Excluding Water, Labor, Capital and
Ownership Costs of Machinery, for Crops Grown on a
160 Acre Farm

	Machinery List[1]		
Crop	1	2	3
Sugar beets	290.39	248.56	196.48
Spring wheat	75.37	57.05	57.35
Barley	56.42	36.98	37.27
Alfalfa hay	89.64	63.83	65.71

[1] The machinery lists are summarized in Tables a-1 through a-4. List 1 is "typical" machinery with all harvesting done by custom operators. List 2 is "typical" machinery as suggested by producers. List 3 is a "possible" machinery complement with a few different items added. The machinery sizes in list 3 were generated using the Agricultural Engineers Handbook of 1976 and an Agnet program entitled SIZEMACH. The procedure is defined in the text.

Table b-2

Total Cost per Acre, Excluding Water, Labor, Capital and
Ownership Costs of Machinery, for Crops Grown on a
320 Acre Farm

| Crop | Machinery List[1] | | |
	1	2	3
Sugar beets	288.45	250.62	191.32
Spring wheat	69.52	52.41	52.06
Barley	54.78	34.70	34.20
Alfalfa hay	84.12	59.71	61.97

[1] See footnote Table b-1.

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Table b-3

Total Cost per Acre, Excluding Water, Labor, Capital and
Ownership Costs of Machinery, for Crops Grown on a
640 Acre Farm

	Machinery List[1]		
Crop	1	2	3
Sugar beets	279.24	229.87	183.17
Spring wheat	68.98	50.47	51.13
Barley	53.51	32.85	33.18
Alfalfa hay	82.36	60.10	62.14

[1] See footnote Table b-1.

Table b-4

Total Cost per Acre, Excluding Water, Labor, Capital and
Ownership Costs of Machinery, for Crops Grown on a
1280 Acre Farm

Crop	Machinery List[1]		
	1	2	3
Sugar beets	308.87	255.93	209.08
Spring wheat	71.16	52.71	52.10
Barley	54.57	35.00	34.34
Alfalfa hay	81.66	61.07	60.54

[1] See footnote Table b-1.

Table b-5

Total Capital and Ownership Costs of Machinery
Specific to Each Crop on 160 Acre Farms

Crop	Machinery List[1]		
	1	2	3
Sugar beets	3991.50	8099.69	10114.80
Spring wheat and barley	941.53	2535.13	2692.10
Alfalfa hay	0	1987.87	3265.97
Swather services	0	1063.40	2933.02

[1] If spring wheat, barley or hay is chosen the fixed costs of a swather
are included. This is accomplished with mixed integer programming.

Table b-6

Total Capital and Ownership Costs of Machinery
Specific to Each Crop on 320 Acre Farms

	Machinery List[1]		
Crop	1	2	3
Sugar beets	4365.68	8420.68	10297.58
Spring wheat and barley	1064.12	3559.11	2704.75
Alfalfa hay	0	2064.85	3217.92
Swather services	0	2618.39	2932.98

[1] See footnote, Table b-5.

Table b-7

Total Capital and Ownership Costs of Machinery
Specific to Each Crop on 640 Acre Farms

Machinery List[1]

Crop	1	2	3
Sugar beets	5784.15	11339.12	16339.04
Spring wheat and barley	1018.86	7771.00	4877.90
Alfalfa hay	0	2610.70	3217.87
Swather services	0	4190.17	2933.06

[1] See footnote, Table b-5.

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Table b-8

Total Capital and Ownership Costs of Machinery
Specific to Each Crop on 1280 Acre Farms

<u>Machinery List's</u>[1]

Crop	<u>1</u>	<u>2</u>	<u>3</u>
Sugar beets	18931.93	38895.16	43461.72
Spring wheat and barley	1366.62	12169.38	8823.44
Alfalfa hay	0	2618.22	3217.61
Swather services	0	4189.75	2932.87

[1] See footnote, Table b-5.

Table b-9

Total Fixed Costs for Machinery: Taxes, Insurance, Depreciation,
Interest on Improvements, and Return on Land Investment

	Machinery List		
Farm Size	1	2	3
160	25740.53	28347.37	30021.67
320	46686.23	54129.86	53634.49
640	85372.76	125850.57	94286.97
1280	160098.85	169180.68	170649.99

Table b-10

Labor Requirements per Acre for Each Farm Size and Machinery List

Farm Size/Crop	Machinery Lists		
	1	2	3
160:			
Sugar beets	9.291	13.820	9.713
Wheat	2.133	4.179	3.878
Barley	2.133	4.179	3.878
Alfalfa hay	.122	3.670	2.46
320:			
Sugar beets	9.069	13.447	9.484
Wheat	1.643	3.674	3.428
Barley	1.643	3.674	3.428
Alfalfa hay	.122	3.639	2.46
640:			
Sugar beets	6.054	8.414	7.242
Wheat	1.707	2.891	2.963
Barley	1.707	2.891	2.963
Alfalfa hay	.122	3.639	2.46
1280:			
Sugar beets	8.89	11.219	10.383
Wheat	1.71	2.619	2.981
Barley	1.71	2.619	2.981
Alfalfa hay	.081	3.599	2.46

APPENDIX C

Linear Program Matrices

This study used twelve linear programming matrices. The row and column titles do not change in the twelve matrices. The row and column titles are as follows:

Row Titles

1	Objective function, constrained cost minimization case
2	Water balance
3	Water supply constraint
4	Land supply constraint
5	Sugar beet production
6	Grain, i.e., barley and wheat, production
7	Alfalfa hay production
8	Swather services
9	Total Revenue constraint
10	Labor balance
11	Labor supply constraint
12	Maximum sugar beet production

Column Titles

1	Right hand side
2	Sugar beet fixed costs, integered
3	Grain, i.e., barley and wheat, fixed costs, integered
4	Swather fixed costs, integered
5	Alfalfa hay fixed costs, integered
6	Sugar beet production activity
7	Wheat production activity
8	Barley production activity
9	Alfalfa hay production activity
10	Water purchase activity
11	Labor purchase activity

Table c-1. Linear Programming Matrix for 160 Acre Farm
Utilizing Machinery Complement 1.

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	25740.5	3991.5	941.53	0	0	290.39	75.37	56.42	89.64	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	3100									1	
Lnd Supply	E	152					1	1	1	1		
BTS Prod	<	0	-76				1					
Grn Prod	<	0	-1.52					1	1			
Hay Prod	<	0				-152				1		
Swath Service	<	0			-152			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					9.291	2.133	2.133	.122		-1
Labor Supply	<	2080										1
BTS Land	<	76					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 19374;   2 k = 32100;   3 k = 38470;   4 k = 44830;   5 k = 56117.

Table c-2. Linear Programming Matrix for 160 Acre Farm
Utilizing Machinery Complement 3

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	30021.7	10114.8	2692.1	3266	2933	196.48	57.35	37.27	65.71	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	3100									1	
Lnd Supply	E	152					1	1	1	1		
BTS Prod	<	0	-76				1					
Grn Prod	<	0		-152				1	1			
Hay Prod	<	0				-152				1		
Swath Service	<	0			-152			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					9.713	3.878	3.878	2.46		-1
Labor Supply	<	2080										1
BTS Land	<	76					1					

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[1] The program is run with total revenue at each of the following levels:

1 k = 19374;   2 k = 32100;   3 k = 38470;   4 k = 44830;   5 k = 56117.

Table c-3. Linear Programming Matrix for 160 Acre Farm Utilizing Machinery Complement 2

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Wheat Buy	Labor Buy
Min Z	<	28347.4	8099.69	2535.13	1987.9	1063.4	248.56	57.05	36.98	63.83	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	3100									1	
Lnd Supply	E	152					1	1	1	1		
BTS Prod	<	0	-76				1					
Grn Prod	<	0		-152				1	1			
Hay Prod	<	0				-152				1		
Swath Service	<	0			-152			1	1	1		
TR [1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					13.82	4.179	4.179	3.67		-1
Labor Supply	<	2080										1
BTS Land	<	76					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 19374; 2 k = 32100; 3 k = 38470; 4 k = 44830; 5 k = 56117.

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Table c-4.   Linear Programming Matrix for 320 Acre Farm
Utilizing Machinery Complement 1

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	46686.2	4365.7	1064.1	0	0	288.45	69.52	54.78	84.12	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	6200									1	
Lnd Supply	E	304					1	1	1	1		
BTS Prod	<	0	-152				1					
Grn Prod	<	0.		-304				1	1			
Hay Prod	<	0				-304				1		
Swath Service	<	0			-304			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					9.069	1.643	1.643	.122		-1
Labor Supply	<	4160										1
BTS Land	<	152					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 38748;   2 k = 64200;   3 k = 76940;   4 k = 89660;   5 k = 112234.

Table c-5. Linear Programming Matrix for 320 Acre Farm Utilizing Machinery Complement 2

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	54129.9	8420.7	3559.1	2064.9	2618.4	250.6	52.4	34.7	59.7		
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	6200									1	
Lnd Supply	E	304					1	1	1	1		
BTS Prod	<	0	-152				1					
Grn Prod	<	0		-304				1	1			
Hay Prod	<	0				-304				1		
Swath Service	<	0			-304			1	1	1		
TR [1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					13.447	3.674	3.674	3.639		-1
Labor Supply	<	4160										1
BTS Land	<	152					1					

[1] The program is run with total revenue at each of the following levels:

  1 k = 38748;   2 k = 64200;   3 k = 76940;   4 k = 89660;   5 k = 112234.

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Table c-6. Linear Programming Matrix for 320 Acre Farm
Utilizing Machinery Complement 3

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	53634.5	10297.6	2704.8	3217.9	2933	191.32	52.06	34.2	61.97		
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	6200									1	
Lnd Supply	E	304					1	1	1	1		
BTS Prod	<	0	-152				1					
Grn Prod	<	0		-304				1	1			
Hay Prod	<	0				-304				1		
Swath Service	<	0			-304			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					9.484	3.428	3.428	2.46		-1
Labor Supply	<	4160										1
BTS Land	<	152					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 38748;   2 k = 64200;   3 k = 76940;   4 k = 89660;   5 k = 112234.

Table c-7. Linear Programming Matrix for 640 Acre Farm
Utilizing Machinery Complement 1

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	85372.8	5784.2	1018.9	0	0	279.24	68.98	53.51	82.36	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	12400									1	
Lnd Supply	E	608					1	1	1	1		
BTS Prod	<	0	-304				1					
Grn Prod	<	0		-608				1	1			
Hay Prod	<	0				-608				1		
Swath Service	<	0			-608			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					6.054	1.707	1.707	.122		-1
Labor Supply	<	8320										1
BTS Land	<	304					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 77496;   2 k = 128400;   3 k = 153880;   4 k = 179320;   5 k = 224468.

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Table c-8. Linear Programming Matrix for 640 Acre Farm
Utilizing Machinery Complement 2

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	125850	11399.1	7771.0	2610.7	4190.2	229.87	50.47	32.05	60.10	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	12400									1	
Lnd Supply	E	608					1	1	1	1		
BTS Prod	<	0	-304				1					
Grn Prod	<	0		-608				.1	1			
Hay Prod	<	0				-608				1		
Swath Service	<	0			-608			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					8.414	2.891	2.891	3.639		-1
Labor Supply	<	8320										1
BTS Land	<	304					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 77496;   2 k = 128400;   3 k = 153880;   4 k = 179320;   5 k = 224468.

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Table c-9. Linear Programming Matrix for 640 Acre Farm
Utilizing Machinery Complement 3

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	94287.0	16399.0	4877.9	3217.9	2933.1	183.17	51.13	33.18	62.14	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	12400									1	
Lnd Supply	E	608					1	1	1	1		
BTS Prod	<	0					1					
Grn Prod	<	0						1	1			
Hay Prod	<	0								1		
Swath Service	<	0						1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					7.242	2.963	2.963	2.46		-1
Labor Supply	<	8320										1
BTS Land	<	304					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 77496;   2 k = 128400;   3 k = 153880;   4 k = 179320;   5 k = 224468.

Table c-10. Linear Programming Matrix for 1280 Acre Farm
Utilizing Machinery Complement 1

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	160099	18932	1366.6	0	0	308.87	76.16	54.57	81.66	.445	5.00
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	24800									1	
Lnd Supply	E	1216					1	1	1	1		
BTS Prod	<	0	-608				1					
Grn Prod	<	0		-1216				1	1			
Hay Prod	<	0				-1216				1		
Swath Service	<	0			-1216			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					8.89	1.71	1.71	.081		-1
Labor Supply	<	16640										1
BTS Land	<	608					1					

[1] The program is run with total revenue at each of the following levels:

    1 k = 154992;   2 k = 256800;   3 k = 307760;   4 k = 358640;   5 k = 448936.

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Table c-11. Linear Programming Matrix for 1280 Acre Farm
Utilizing Machinery Complement 2

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	169181	38895	12169.4	2618.2	4189.8	255.9	52.71	35.00	61.07		
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	24800									1	
Lnd Supply	E	1216					1	1	1	1		
BTS Prod	<	0	-608				1					
Grn Prod	<	0		-1216				1	1			
Hay Prod	<	0				-1216				1		
Swath Service	<	0			-1216			1	1	1		
TR[1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					11.219	2.619	2.619	3.599		-1
Labor Supply	<	16640										1
BTS Land	<	608					1					

[1] The program is run with total revenue at each of the following levels:

    1 k = 154992;   2 k = 256800;   3 k = 307760;   4 k = 358640;   5 k = 448936.

Table c-12. Linear Programming Matrix for 1280 Acre Farm
Utilizing Machinery Complement 3

	Sign	RHS	BTS FC	Grn FC	Swath FC	Hay FC	BTS VC	Wht VC	Bar VC	Hay VC	Water Buy	Labor Buy
Min Z	<	170650	43461.7	8823.4	3217.6	2932.9	209.1	52.1	34.34	60.54		
Water Bal	<	0					28.57	11.43	11.43	17.14	-1	
Water Supply	<	24800									1	
Lnd Supply	E	1216					1	1	1	1		
BTS Prod	<	0	-608				1					
Grn Prod	<	0		-1216				1	1			
Hay Prod	<	0				-1216				1		
Swath Service	<	0			-1216			1	1	1		
TR [1]	E	K					589.87	148.52	127.46	143.18		
Labor Bal	<	0					10.383	2.981	2.981	2.46		-1
Labor Supply	<	16640										1
BTS Land	<	608					1					

[1] The program is run with total revenue at each of the following levels:

1 k = 154992;　2 k = 256800;　3 k = 307760;　4 k = 358640;　5 k = 448936.

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