ECONOMIC ASPECTS OF AGRICULTURAL USE OF COLORADO RIVER WATER IN YUMA COUNTY, ARIZONA

by

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PREFACE

The investigation reported in this dissertation is a portion of a larger effort to determine how allocation of water resources affects the economic and social development of Arizona. The overall study is entitled "Water in Relation to Social and Economic Growth in an Arid Environment" and has been supported by a grant from the Rockefeller Foundation. The project has proceeded in two phases. The first has been the development of an interindustry model for Arizona emphasizing the major agricultural sectors. The second phase is concerned with projecting changes in the output potential of the agricultural sectors which may be expected to occur over time particularly in response to changing water conditions. The present study is one of several investigations of specific sub-regions of Arizona contributing to the second phase and is specifically concerned with western Yuma County. When the corollary studies for other areas of the state are completed, they will be combined to indicate aggregate levels of agricultural production potential and resource use for the state as a whole.

Integration of the two phases may then be accomplished to show the impact of changes in water conditions or other selected variables not only on the agricultural sectors but on the entire economy of the state. The techniques and results of these studies may be used as a guide to resource allocation problems not only by policy makers concerned with Arizona problems but may have application in other areas where similar conditions prevail.

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ABSTRACT

The investigation reported in this dissertation is a portion of a larger effort to determine how allocation of water resources affects economic and social development in an arid environment. The study focuses on irrigated crop agriculture in Western Yuma County, Arizona, where irrigation water supplies are obtained from diversions from the Colorado River. Irrigated agriculture accounts for nearly 95 percent of total water use in this area. Linear programming techniques are used to determine optimum farm output and resource use patterns for five different farm models representing different farm size groups.

The farm models were synthesized from data collected in a survey of 102 farms within the study area in 1964. This sample represented about one-fourth of the total universe.

The linear programming analysis proceeds in four phases. In the first phase solutions are obtained for each model under the assumption that the size structure of agricultural firms and the resource base is fixed at current levels. In the second phase additional activities are added to permit land acquisition or disposal by each model farm. In the third phase the original formulation is modified to permit reclamation of new lands under the assumption that existing water rights will be perfected. The fourth phase combines the individual models analyzed in phase two into an integrated general model in

which resource disposals by one farm size model must be balanced by acquisition in another.

The final stage of the analysis includes estimates of crop output, and resource use under conditions specified in each phase. The marginal value product of selected resources is discussed and demand schedule for additional water is estimated. Land transfer price ranges are also discussed.

CHAPTER I

INTRODUCTION

The economic growth of a region depends on many things. The manner in which development occurs is often an extension of a traditional socio-economic pattern. In highly developed and growing societies such as that of the United States, this tradition depends largely on the available resource base and on the propensity of the people, both individually and collectively to employ these resources in such a manner as to achieve their desired economic goals. How well the society responds to external factors such as the discovery of new knowledge, development or deterioration of markets resulting from socio-economic change elsewhere, or alterations in the institutional parameters, may also affect the manner in which their own social well-being may be enhanced.

One of the major factors which affects the growth and development of a region is the efficiency with which scarce resources are allocated in alternative uses. In an arid region, economic development may be limited or enhanced by how the growing society allocates its water resources.

To the extent that conditions found in Arizona typify those of other arid environs where water supplies are limited and where society is growing, the manner in which the problems of allocating water resources are solved in Arizona will provide a basis for broad generalizations for water policy matters in other arid regions. Thus, Arizona represents an excellent laboratory for the study of the problems to be faced by other developing societies in midlatitude arid regions.

This dissertation is a portion of a larger effort to determine how allocation of water resources affects the economic and social development of Arizona. One of the major phases of this larger effort has been the development of an interindustry model of the Arizona economy.[1] This model has been patterned after the regional input-output models which have been pioneered by Leontief[2] and others.

The specific input-output formulation for this overall project has been designed to give particular emphasis to agricultural sectors. Since a major proportion of Arizona's water resources are used in irrigated crop agriculture an intensive study of agriculture in relation to water allocation is important. As other economic uses for water develop or as present water supplies dwindle it becomes necessary to re-examine current water allocation policies particularly as they impinge on irrigated crop agriculture. Moreover since the agricultural sector is composed of a large number of independent firms each operating within the framework of a price dominated market it can be expected that reallocation of water resources will occur in response to changes in market

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1. Anilkumar G. Tijoriwala, William E. Martin, and Leonard G. Bower, The Structure of the Arizona Economy: Output Interrelationships and Their Effect on Water and Labor Requirements; Part I, The Input-Output Model and Its Interpretation, Arizona Agricultural Experiment Station Technical Bulletin 180, (forthcoming), 1968, and Part II, Statistical Supplement, Department of Agricultural Economics File Report 63-1, The University of Arizona, 1968 (unpublished).

2. Wassily Leontief, The Structure of the American Economy, 1919-1939, Second Edition, New York, Oxford University Press, 1951.

forces. As these reallocations occur, changes in the composition of agricultural output and in the structure of the agricultural sector may likewise be expected.

These changes within agriculture will have important implications for the non-agricultural sectors as well, and their impact on the economy as a whole can be traced with the use of the interindustry model. Thus the effect of a reallocation of existing water supplies or of posited water resource changes on various sectors of the economy (whether they be major water users or not) may be assessed by linking water to agriculture and agriculture to the non-agricultural sectors. It is important then to determine what changes are likely to occur in the agricultural sector.

Because of the broad range of climatic and geomorphic conditions existing in Arizona, the character of irrigated agriculture differs widely throughout the state. Some areas rely entirely on ground water supplies for irrigation purposes. Others obtain irrigation water by storage and diversion of surface water. In many areas water is obtained from both sources.

Differences in elevation and other climatic factors result in mild winter temperature in some areas which are conducive to the husbandry of temperature-sensitive fruit and vegetable crops. In other areas cotton, alfalfa and small grains are the mainstays of the crop rotation patterns.

Because of these differences it is difficult to generalize about changes which may occur in the agricultural sector of the state as a whole in response to any given changes in the water resource base. It becomes appropriate then to examine several sub-regions each having fairly homogenous characteristics. Accordingly, the investigation reported here is limited geographically to those areas of Yuma County which are presently or potentially irrigable from surface water supplies drawn from the Colorado River. Similar studies of other agricultural areas of the state which are characterized by rather different water resource conditions, climate, and cropping practices have also been undertaken.[3]

The broad purpose of these studies is to determine what changes in water use and availability are likely to occur in each sub-region and how these changes will affect agriculture within the area. The results of all these studies may then be integrated to determine changes in the agricultural sector of the state as a whole and subsequently used to predict changes in the entire economy.

The Problem Setting

Present Pattern of Yuma County Agriculture

Income per farm in Yuma County is among the highest in the nation.[4] Climatic factors favor the husbanding of high-return specialty

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3. See particularly Harold M. Stults, "Predicting Farmer Response to A Falling Water Table: An Arizona Case Study", unpublished Ph.D. dissertation, The University of Arizona, Tucson, 1968. Additional studies are also under way by Lawrence E. Mack and Kenneth Hock, Department of Agricultural Economics, The University of Arizona.

4. U. S. Bureau of the Census, 1964 United States Census of Agriculture, Preliminary Report, Washington, D. C., August 1966.

crops such as citrus, melons, and winter vegetables; short, mild winters and long, hot summers contribute to high yields in such crops as cotton and alfalfa. In 1960 average gross return per cropland acre was $335 in Yuma County compared with $226 in Arizona and $123 for the United States as a whole.[5]

In spite of the fact that this area averages less than four inches of rainfall per year, abundant supplies of water for irrigation are available from the Colorado River at relatively low cost. Farm labor costs are low compared to other areas of the United States due to the advantage of being located near a large pool of unskilled labor which has its roots in a relatively immobile Mexican-American culture. Marketing facilities are well developed. As a result of these favorable conditions and in spite of any locational disadvantages, Yuma County farmers enjoy a strong competitive position with other areas and are able to realize net returns which rank them among the highest in the nation.

The major portion of farm income in Yuma County is from the sale of crops. The 1964 Census of Agriculture indicates that 77 percent of the $76.5 million gross farm income for the county was derived from the sale of crops, the remainder being from livestock and livestock products.[6]

Major field crops in descending order of acreage are alfalfa, short staple cotton, lettuce, cantaloupes and other melons, grain

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5. Ibid.

6. Ibid.

sorghum, barley, bermuda grass seed, and wheat.[7] Other field crops which are grown in lesser amounts are sudan grass and other miscellaneous hays and grasses for pasture, and various types of winter vegetables. Small acreages of seed crops, particularly lettuce, beets, onions, sugar beets, and carrots are also raised. In the past, safflower, long staple cotton, and flax have been grown successfully.

Because of the generally mild winters and the rapid maturity of many of the crops to which the area is suited, there is a considerable amount of double-cropping in Yuma County and occasionally three crops can be harvested from the same land within a year. Barley or wheat and grain sorghum, and lettuce and cantaloupe are often double-cropped in this way.

In addition to field crops, there is a substantial amount of citrus acreage within the county. Much of this has been developed within the past seven or eight years, and has not yet achieved its full productive potential. Estimates for 1965 indicated about 24,000 acres of citrus in Yuma County with about 60 percent of this producing harvestable fruit.[8]

Origin and Availability of Water Supply

The major portion of Yuma County cropland is irrigated from surface waters of the Colorado River. A complex of six irrigation districts in the southwest corner of the county encompass approximately

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7. Arizona Agriculture, 1967, Bulletin A50, The University of Arizona, Cooperative Extension Service and Agricultural Experiment Station, Tucson, Arizona, February 1967.

8. Robert L. Grounds, "Arizona Notes," Citrograph, April 1965, p. 18.

145,000 acres of irrigable land. In one of these districts a small amount of irrigation water is obtained from shallow wells. Some of this is reclaimed percolating water which is diluted with surface water in order to maintain the salinity content within tolerable limits. In each of the other five districts all water supplies are obtained by surface diversions from the Colorado River. These districts contract with the U. S. Bureau of Reclamation for their surface water deliveries.

The Colorado River Indian Reservation Project located in the northwest corner of the county has a recent history of about 32,000 acres of irrigated cropland annually; however, this project has sufficient arable land and water rights to allow for expansion to about 100,000 acres in this area. This Project receives administrative and supervisory support from the Bureau of Indian Affairs and is authorized to issue development contracts and long-term leases to non-Indian farm operators. Present authorization allows for the issuance of large-scale development leases, for as long as 25 years. Lessees are required to construct ditches and field diversion facilities and make certain other improvements. Annual rentals are graduated and generally do not exceed $25 to $30 per acre once the facilities have been developed. But, at the expiration of the lease period, all improvements inure to the Reservation Irrigation District. Prospective lessees, therefore, must plan to amortize all fixed costs of improving the land over the lease period. If reclamation and development of these additional lands proceed according to present plans, the entire 100,000 acres should be under cultivation by 1975.

Additional irrigation diversions from the Colorado River have been made by farmers who pump directly from the river, or in the absence of a clearly defined water right, from shallow wells adjacent to the river. Lands irrigated in this manner are concentrated in two areas: along the left limit of the Colorado River adjacent to the Yuma Valley Irrigation Project but outside of the district itself; and in the Cibola area located about 20 miles downstream from Blythe, California, on the opposite bank. Both of these areas lie adjacent to the meanders of the Colorado River and as a by-product of attempts to regulate the flow of the river in the past three decades considerable land has been created along the present river channel through the processes of accretion or avulsion. Some of this has been brought into cultivation and has been irrigated directly from the river. Other land more distant from the river bank is irrigated from shallow wells which are recharged from percolations from the river flow.

Ownership to some of this land, resting on color-of-title claims or on claims of accreted land, is presently in doubt and has been the subject of considerable litigation between private claimants and the United States Government through its Department of Interior agencies. Other privately owned land has been irrigated by pumping directly or indirectly from the river without proper authorization--clearly cases of water trespass. Because of the unclear status of ownership of some of these riparian lands and the equally questionable status of water rights, it is difficult to estimate the acreage of irrigable lands of this type.

In the past as much as 15,000 acres has been reported under cultivation on nonproject-riparian land; however, more informed estimates by U. S. Department of Interior employees and County Extension Service personnel suggest that privately held lands subject to irrigation and with a potentially valid water right do not exceed more than about 10,000 acres at the present time.

The remaining cropland in Yuma County is widely scattered in the eastern and northeastern section of the county where water supplies are pumped from groundwater basins. Costs and returns and cropping patterns in this area are more similar to those found in adjacent areas of Maricopa County directly to the east, and for this reason these areas are included in the study which encompasses land in western Maricopa County.[9] Figure 1 shows the geographic distribution of irrigated lands within the county which are included in the study area. The scope of this study includes only those lands in Yuma County which are irrigable with surface waters of the Colorado River.

Water Rights

The nature of water rights and water availability varies among the several irrigation districts within the study area. In the earlier organized districts, the doctrine of beneficial use determines the water right, and water availability may be limited only by the capacity of the diversion facilities and not by any institutional or contractual

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9. This area is the subject of a similar study being carried on by Kenneth Hock, Department of Agricultural Economics, The University of Arizona, Tucson.

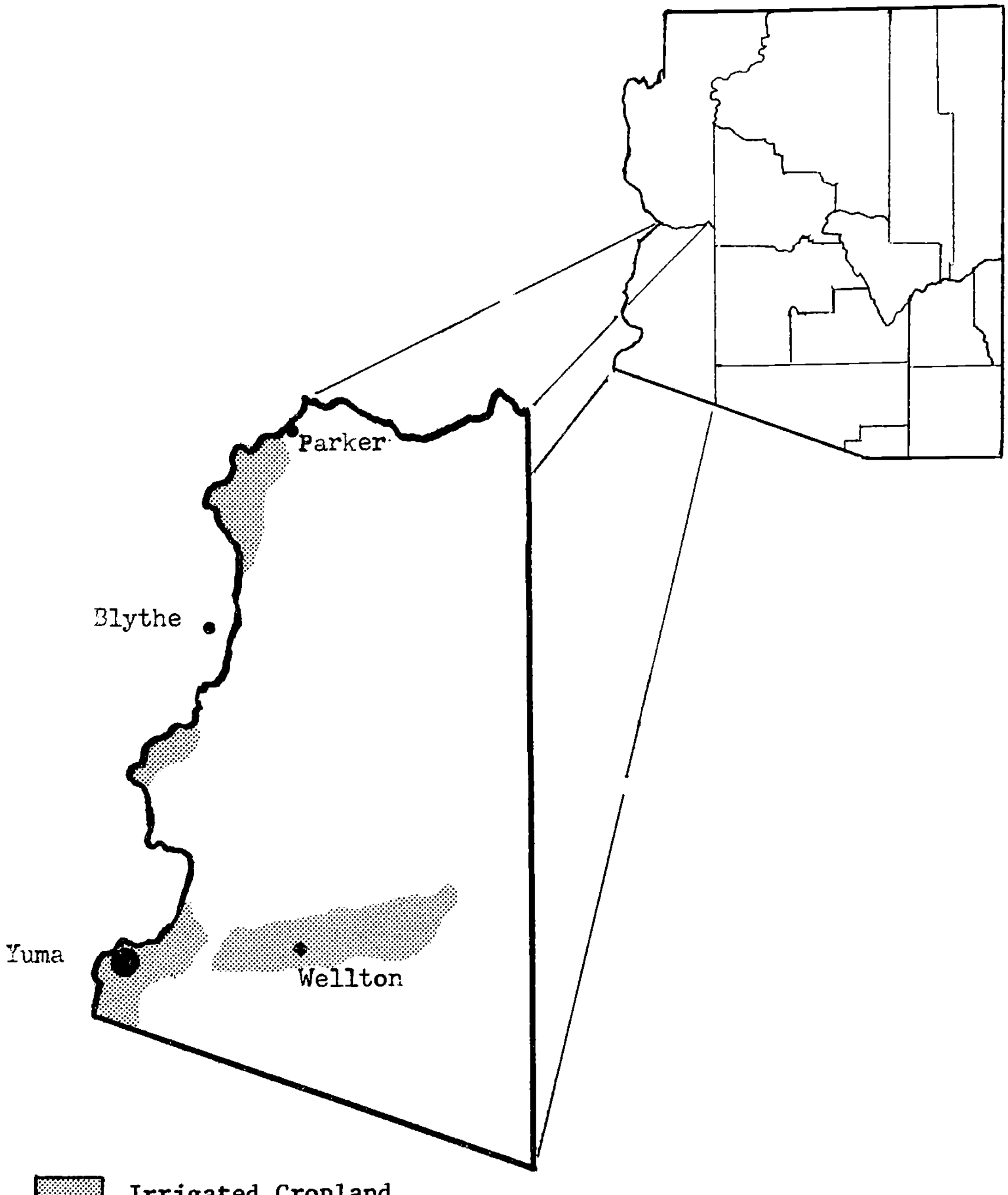

Figure 1. Location of Cropland Included in Study Area, Yuma County, Arizona.

restriction. In other cases the water right is specified in terms of a maximum aggregate flow rate (for example, not to exceed so many second feet) to the district as a whole without regard to its distribution to specific lands. In some instances water rights take the form of contracts between water user groups and the United States, through U. S. Department of Interior agencies. These may call for the delivery of a specified volume of water annually to the irrigation districts.

The districts themselves then, are able to specify how water may be allocated to users through the rate structure of water delivery charges or by specifying other limitations on delivery. As the land use pattern changes from agricultural to nonagricultural uses (which tend to use less water per acre), the amount available for agricultural use may be increased. Water availability for a given acre of land for agricultural use, therefore, may vary from year to year and the combination of land and water does not necessarily occur in a fixed ratio over time.

The legal status of water rights for the nonproject-riparian lands is even more nebulous; for land owners here are not under contract with the U. S. Department of Interior for water deliveries but must depend on the flow of the river for their water supplies. In some cases these rights have not yet been adjudicated.

Past experience, however, has shown that water supplies are generally adequate for the amount of irrigable and developed land in each district even though problems of timely delivery sometimes occur during peak water using periods.

The agricultural potential of the study area, therefore, is limited not by water availability alone but also by the amount of land which has a water right associated with it.

Table 1 summarizes the land-water resource base potential for the study area under presently perfected water rights.

Water requirements for those lands indicated in Column 2 will probably not differ greatly from that of lands presently in production. Therefore, it might be assumed that as these lands are developed an additional 6 to 6.5 acre-feet of water can be put to beneficial use for each irrigable acre of reclaimed land.

As most of this potentially irrigable acreage is within the Colorado River Indian Reservation where the water right is clearly specified[10] and adequate in terms of present use patterns, physical shortages of water alone should not be expected to be the limiting factor on <u>extensive</u> agricultural growth within the study area. The scarce factor is land with a water right. But even with a limited land-water base, adjustments in agricultural resource use and particularly water use may be expected to occur at the intensive margins in response to changes in prices, technology, institutional factors, or the character of the demand function for agricultural products; and economic growth may occur as a result of factor substitutions which will intensify land and water use and change the level and character of agricultural output.

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10. <u>Arizona vs. California</u>, 373 U.S. 546, (1963), Report of the Special Master, (1960).

Table 1. Yuma County Land Irrigated by Surface Water Diversions.

Irrigation District or Other Identifying Name	(1) Land in Irrigation Rotation (1964)[a] (Acres)	(2) Additional Lands with Water Right but not in Irrigation Rotation[b] (Acres)	(3) Irrigated Land Average 1961-1964[a] (Acres)	(4) Average Water Use per Irrigated Acre 1961-1964 (Acres-feet)
Yuma Valley	46,345		45,449	5.41
Yuma Auxiliary (Unit B)	3,211		3,137	12.02
Yuma Mesa Irrigation And Drainage District	17,082		16,496	14.02
North Gila Irrigation District	6,082		5,716	6.74
Yuma Irrigation District Including Warren Act Contractors (South Gila)[c]	12,119		11,590	5.75[d]
Wellton-Mohawk Irrigation District	61,259	10,000[d]	54,780	5.69
Colorado River Indian Reservation Irrigation District	33,810	60,000[d]	30,900	5.82
Nonproject-Riparian Lands	10,000[d]		10,000[d]	5.75[d]
Total	189,908	70,000	178,068	6.72

Source: U. S. Bureau of Reclamation *Status of Water Users Annual Report* 1961-1964 for Yuma and Gila Projects and Bureau of Indian Affairs *Irrigation Crop Report Annual* 1961-1964.

Table 1. (Continued).

[a]Column 1 differs from column 3 because irrigable land may have been idle or fallow during the year for land leveling, ditch repair, disease or insect control or other reasons; for some districts, 1961-64 average shows a gradual increase to level indicated in column 1.

[b]These lands are eligible for water delivery and represent estimates of additional land which may come into irrigation rotation if suitably reclaimed. This does not include land within the service area which will be used for farmsteads, ditches and roads.

[c]Yuma Irrigation District did not receive surface water diversion until 1965. 1961-64 data, therefore, represents acreage irrigated with groundwater from shallow wells. Water use is estimated.

[d]Estimated.

Water Drainage Problems

In past years some areas within the county have been subjected to severe sub-surface drainage problems. Application of large amounts of irrigation water has resulted in raising the level of the ground water table to within a few feet of the surface. Because of the effective leaching properties of the surface water as it is applied for irrigation purposes, ground water has a relatively high salt content. If sub-surface drainage is inadequate, saline ground water moves by capilliary action into the plants' root zone, and reduction of the water content of the upper layers of soil either through plant use or evaporation, results in the build-up of alkaline soil conditions which are unfavorable for production of most crops.

These problems have been rather severe in some areas in the past; however, in most of the problem areas extensive drainage and pumping facilities have been constructed to lower the ground water level and halt any further advance of this salinity condition. As these facilities continue to operate and as the afflicted lands continue to be irrigated with "sweet" surface water, residual salts will be leached out of the upper soil strata and carried downward and into the drainage system. Over a period of several years soil salinity conditions may be expected to improve. Therefore, drainage problems may be considered to be of temporary duration and of minor importance over the long run.

Possibilities for Agricultural Expansion

It is not even necessarily true that the existing land-water resource base is fixed. Additional water flows might be made available which could be allocated to presently undeveloped arable lands.

The court decree in Arizona vs. California[11] awarded an additional 1.4 million acre-feet beyond present use commitments for use in Arizona. While the major political effort is directed toward transporting this water into central Arizona, purportedly to modify the rate at which groundwater overdrafts are occurring in Pinal and Maricopa Counties, the possibility remains that this water could be used to reclaim new lands nearer the river. Alternative water supplies might also be obtained by modifying existing institutional limitations to permit freer water transfer from upper basin states or by undertaking one of the more ambitious interbasin transfer schemes. A further possibility for expansion of the irrigated area is to modify existing institutional arrangements to permit the transfer of a portion of existing water rights to lands which are now not under cultivation. The average per acre "water buy" in one area could be reduced in order to increase the irrigable acreage in another. Water use could be intensified through application of water saving techniques such as dead leveling, lining of ditches, or covering canal systems to reduce water loss by evaporation; this would permit greater extensity in land use, with more intensive use of water.

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11. Arizona vs. California, 373 U. S. 546, (1963), for decree see 84 Sup. Ct. 775 (1964).

Whether or not these alternatives are economically sound will require careful analysis of agricultural production possibilities and the costs involved in developing the water flow. At any rate, the opportunity for reclaiming new lands within or adjacent to the study area remains a distinct possibility.

The possibility also exists that water supplies could be developed from groundwater; in recent years some wells have been drilled and desert land has been successfully reclaimed in this way. These have occurred on a very modest scale, however. Therefore, the expansion of water supplies through development of groundwater is regarded as improbable in the light of present-day expectations and this possibility shall be ignored in this study.

Objectives and Procedures

The overall objective to which this study is addressed is that of projecting the potential level and character of agricultural output which may be achieved in future time periods under certain assumed conditions. A corollary problem is that of determing the resource combinations which will occur to produce that level of output. The problem, then, is one of the allocation of resources.

Three general conditions are dealt with. The first concerns the allocation of the presently assured water supply and its associated resource base under the assumption that the size structure of the agricultural industry remains constant, and the second allows for limited transfer of resources between firms allowing for variations of the size structure. The third deals with the allocation of additions to the water supply which would occur if additional surface diversions from the Colorado River or other water imports were to be made possible. Equilibrium resource allocation solutions under the three conditions indicated above are obtained and analyzed.

The results of this analysis may then be integrated with other studies in process in order that the broader impact of agricultural adjustment to changing water conditions in Arizona may be assessed by means of the interindustry model.

Specific tasks to be accomplished are as follows:

1. Describe the framework within which resource allocation may be expected to occur and specify appropriate criteria by which alternative allocations may be evaluated.
2. Identify the relevant set of resources to be allocated and alternative sets of uses to which these resources may be put.
3. Identify exogeneous forces which will alter the resource base, its distribution and pattern of use over time.
4. Analyze the pattern of resource use and agricultural output which may be expected to occur over time, consistent with the specifications of 1 through 3 above. This includes projection of the elements of an aggregate agricultural production function for the area over time.

Order of Presentation

In Chapter II the theoretical model, its adaptation to the problems at hand, and the methodological implementation are discussed. Chapter III deals with the representative firm concept employed in the model and defines a set of five representative farm firms around which the analysis is based. Chapter IV develops a linear programming model involving the representative firms described in the previous chapter, and indicates possible variations which might be anticipated. The results of the basic linear programming formulation are examined and other modifications are also analyzed in Chapter V. Summarization and integration of the various phases of the study are also accomplished in Chapter V and conclusions based on the preceding analyses are drawn. A final Chapter VI discusses some of the broad issues of public policy for which the analytical phase of the study bodes importance.

CHAPTER II

THEORETICAL CONSIDERATIONS, THE MODEL, AND METHOD OF ANALYSIS

Production response and supply analysis are terms commonly used by economists to describe the forces which determine patterns and levels of output. Many studies of production or supply response are concerned with the relationship between output and price and employ the statistical technique of regression analysis to predict the levels of output, or alternatively to estimate long-run price trends.

While an important objective of this study is to project potential levels and patterns of regional output, the major interest is in how resources might be combined to achieve that output. Therefore, methods other than regression analysis are more appropriate.

It may seem unnecessary to emphasize that in a market economy where the resource base is for the most part privately held, the locus of resource allocation decisions rests with the various producing units. It is the behavior of individual firms that determines the aggregate patterns of resource use; aggregate output may be represented as the sum of the output of all firms.

Accordingly, levels of total agricultural production for the area involved in this study may be estimated by predicting the behavior of the various farm firms which operate within the area and then aggregating the predicted output from all farm firms.

As a practical matter, it is impossible to analyze the behavior of every firm within the area. As an alternative, the approach which is followed here includes the use of the representative firm. A number of "typical" farm firms are synthesized to represent various levels of farming operations which are prevalent within the area. These are analyzed under various sets of conditions which are believed to represent an approximation of the real world situation. Certain conclusions about the hypothetical behavior of the "typical" firms may then be extended to represent the actual behavior of farms in the real world.

Appropriate weights may be applied according to the number of actual firms that each of the model firms purport to represent. The results of the analyses may then be aggregated to project levels of output potential and resource use patterns for the area as a whole.

Applicable Theory and Assumptions

The body of theory which is applicable in analyzing the behavior of the firm is commonly known as production economics. The conventional approach to production economics has been succinctly summarized by Carlson.[14] More recently a mathematical programming approach to production decisions has been put forth. (See, for example, Dorfman, Samuelson, and Solow.[15]) Although these two formulations represent

14. Sune Carlson, A Study on the Pure Theory of Production, King and Son, Ltd., London, 1939.

15. Robert Dorfman, Paul A. Samuelson, and Robert M. Solow, Linear Programming and Economic Analysis, McGraw-Hill, New York, 1958.

statements of the same theory, in application, the latter approach is better able to make direct use of large amounts of technical data, whereas the former typically subsumes such information in parameters of the production and cost functions. The latter approach, that of linear programming, will be relied on for the framework for this analysis.

One of the basic postulates of production economics is that firms will allocate resources in such a manner as to achieve some optimum position over a certain time horizon. Profit maximization is commonly specified as this objective. It is appropriate then to ask if behavior of farm operators within the study area is consistent with this assumption. There is no unambiguous answer. Farmers generally (and there is no reason to suspect that those within the study area are exceptions) do respond to stimuli other than profit maximization in their economic decision making and behavior. These may include a wide array of goals ranging from clearly rationalized socio-economic objectives to personal whims. But if a decision must be made, it can be expected that the firm will choose the alternative which it considers "best" in the light of expectations prevailing at the time of the decision. (This is the rationality assumption which is discussed in the various theoretical treatments of firm behavior.) Day[16] has observed that while profit maximizing is not always exercised as a tool of ideal optimal choice, it seems to be a guide to choosing among limited alternatives in an environment that is beset by many uncertainties. This he

16. Richard Day, "An Approach to Production Response," Agricultural Economics Research, Vol. XIV, No. 4, p. 134, October 1962.

refers to as "constrained profit maximization." Throughout this analysis, it is assumed that profit maximization is the major goal toward which the production decisions of individual firms are directed. Further discussion of a precise definition of the term profit as used in the analysis presented below.

The previous statement of objectives implies a primary interest in production response which is predictive, whereas the methodological approach may be considered normative. Projection of an aggregate supply function for an agricultural region concerns what farm firms will do rather than what they ought to do to achieve some goal. However, if we are able to determine what farmers should do, and if we assume that they behave accordingly (i.e., rationally), then their normative behavior becomes a basis for prediction. Dean, et al.,[17] have observed that while in the short run normative analyses constitute an unsatisfactory predictive device, as the time horizon is lengthened, the normative and predictive solutions tend to converge and in the long run the tools of normative analyses may be used for predictive purposes. This view is also supported by Toussaint[18] who asserts that knowledge of what farmers should do will be quite representative of what they will do under the same condition if the necessary time for adjustment is permitted.

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17. Gerald W. Dean, Stanley S. Johnson, and Harold O. Carter, "Supply Functions for Cotton in Imperial Valley, California," Agricultural Economics Research Vol. XV, No. 1, p. 1, January 1963.

18. W. D. Toussaint, "Programming Optimum Farm Supply Functions," Farm Size and Output Research, Southern Cooperative Series Bulletin 56, p. 57, June 1958.

However, even if we are able to determine what farmers should (or will) do under a given set of conditions, our ability to relate those conditions to the real world situation affects the accuracy and validity of the resulting predicitons.

Method of Analysis

The basic analytical technique which is used to study the behavior of the firm is that of linear programming. While other methods such as partial budgeting, simulation models, and functional analysis can be used (and indeed do underlie many of the assumptions about the empirical data), linear programming is a well adapted technique for the problem at hand.

Linear programming is an empirical tool used widely in solution of mathematical systems. The procedure involves maximizing (or minimizing) an objective function subject to a number of related linear inequalities. A more complete description of the theoretical assumptions and application of linear programming to economic problems may be found in Dorfman, Samuelson, and Solow,[19] Boulding and Spivey[20] or Heady and Candler[21] among others.

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19. Dorfman, *et al.*, *op. cit.*

20. Kenneth Boulding and W. Allen Spivey, *Linear Programming and the Theory of the Firm*, MacMillan and Co., New York, 1960.

21. Earl Heady and Wilfred Chandler, *Linear Programming Methods*, Iowa State University Press, Ames, Iowa, 1958.

The basic assumptions which underlie this technique have been well summarized by Dorfman.[22] These he lists as linearity, divisibility, additivity and finiteness. Further discussion of these assumptions and their relevance in an agricultural firm context is available in a contribution by Swanson.[23] He concludes that these assumptions are not limiting when applied in analysis of specific firms and may be appropriate in a more general application of the technique if adequate empirical data are available.

A critical problem arises in expanding the linear programming solution to estimate aggregate levels of output. This has been referred to as aggregation bias.[24] It is said to exist when the sum of the solution of the farms in the population (i.e., real world results) does not equal the estimate obtained by the empirical model. Conditions for bias-free aggregation have been discussed by Day[25] and Miller.[26] While their discussions are highly rigorous and complex, an interpretation in terms of empirical work would suggest that aggregation bias can

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22. Robert Dorfman, Application of Linear Programming to the Theory of the Firm, University of California Press, Berkeley, 1951.

23. Earl R. Swanson, "Programming Optimal Farm Plans," Farm Size and Output Research, Southern Cooperative Series Bulletin 56, p. 47, June 1958.

24. Lee M. Day, "Use of Representative Firms in Studies of Interregional Competition and Production Response," Journal of Farm Economics, Vol. 45, No. 5, p. 1431, December 1963.

25. Richard H. Day, "On Aggregating Linear Programming Models of Production," Journal of Farm Economics, Vol. 45, No. 4, p. 797, November 1963.

26. Thomas Miller, "Sufficient Conditions for Exact Aggregation in Linear Programming Method," Agricultural Economics Research, Vol. XVIII, No. 2, p. 52, April 1966.

be reduced by increasing the number of representative farms such that a high degree of homogeneity occurs in the subpopulations which the typical or model farms purport to represent. Carried to its extreme this method would result in analysis of each firm in the population being studied; but for practical reasons the number of representative farms must be kept small perhaps at the expense of some aggregation bias.

Edwards[27] has also presented some of the shortcomings of linear programming and classified them according to their origin in faulty mathematics, statistics, economics, or programming. In spite of these difficulties the continuing wide use of this method of analysis strongly supports its usefulness for certain problems. Abstractions, accompanied by a certain amount of unrealism are the price which must be paid to make the analysis of specific situations useful for more general purposes. Linear programming shares these shortcomings with other related methods of analysis.

The Conceptual Model

The linear programming methods noted in the previous section are used to determine optimum combinations of resource use and output for five typical farm firms designed to represent various sizes of farming operations within the study area.

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27. Clark Edwards, "Shortcomings in Programmed Solutions to Practical Farm Problems," Journal of Farm Economics, Vol. 43, No. 2, p. 393, May 1961.

The programming model uses profit defined as gross income minus variable and cash overhead costs as the objective to be maximized. The coefficients of the objective function represent the net returns (profit) from each activity in the set of alternatives open to the various representative firms.

Three general types of restrictions are specified: those indicating limits of resource availability; those which constrain activity output levels due to insitutional inflexibilities, or traditional patterns relating to risk preference; and artificial restrictions which function to maintain internal consistency in the aggregate solution of the model.

Technical coefficients provide the link between the various activities and constraint equations. Conceptually, these are represented as factor input requirements for each activity.

Common linear programming practice is to formulate the model in terms of a matrix where the rows represent the constraint inequalities and the columns describe the various activities within the field of choice.[28] As the optimum solution for each of the representative firms becomes known, the results may be added to give levels of aggregate output and resource use. When the element of time enters the analysis, it is realized that certain parameters change and that resources may move from one representative farm to another. This is handled through the introduction of resource transfer activities and by resource acquisition activities.

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28. For a good example of form and format, see Heady and Candler, _op. cit._ Chapters 3, 6.

Several assumptions are made in order to simplify the model. The first is that the factor supply functions for both labor and capital are perfectly elastic. Obviously, this is not precisely true for any specific farm--representative or real. Farmers do face problems of labor and/or capital scarcity. Nevertheless, these resources are highly mobile in Arizona and are supplied at no increase in price over the range of the firm's demand.

Another assumption which is made is that price ratios--involving both factor and product prices--remain constant throughout the analysis. Here again, and particularly in the short run, this assumption is not necessarily realistic. However, as the time horizon lengthens, fluctuation becomes less significant when viewed in the context of a long-run equilibrium. What is important is not the shift along a supply function in response to price change but shifts of that supply function through time.

It is also assumed that production technologies are constant throughout the period of analysis. This assumption is intimately related to the previously mentioned assumption of constant price ratios. We expect technology to increase firm output and to reduce unit costs. This will result in a downward shift in the supply function and thus lower real prices of the products being produced. In the absense of any dependable ability to predict technological change or price ratios over long periods of time, this simplification, namely that the changes in technology and price ratios will be offsetting such that the relationship between net revenues of alternative activities remains constant over time, seems reasonable.

While these assumptions may limit the analysis in terms of the absolute values reported in the aggregate solution, it perhaps is not too serious for in the long run the mantle of technological advance and price change may be expected to touch all activities (though not always with the same impact). However the relative ordering of the alternatives of choice are thus assumed to be stable over the period of analysis and the problem solution may better be interpreted in terms of physical input and output levels rather than monetary measures of the same.

It is also assumed that the major institutional parameters which affect the agricultural sectors will remain constant over the period of analysis. These include government programs designed to support prices and income or to control agricultural output, and unless specifically indicated, the nature of property and water rights. Undoubtedly, changes in government programs will occur, however in the absence of any specific proposals the assumptions that the present programs will not be continued is highly speculative.

Data Requirements

While the nature of the problem being studied normally determines the kind of data needed to support the analysis and the simplifying assumptions which can be made, the technique or method of analysis often influences the form and extent of data requirements.

For this study information about farm organization, production techniques, and resource availability was needed. Specific input requirements for the programming problem are as follows.

1. Information was needed about the number and type of alternative activities to be included in the range of choice open to each representative farm firm.
2. Since profit maximizing is assumed it was necessary to know how each activity would contribute to the profit function.
3. Information was needed about production practices and physical input requirements for each activity.
4. Data were required on the types of resources available to each representative firm and levels of those believed to be most important in the allocation process. Where restrictions were specified limiting aggregate levels of output for an activity at a point in time, these had to be developed.
5. Data on rates of resource mobility also had to be obtained.

Data Sources

At the outset of this investigation very little was known about the nature of the population which was to be included in the study. Data for 1959 from the U. S. Census of Agriculture were used as a starting point in determining acreages, numbers, and types of farm firms; however, the census did not present sufficient detail to be useful for more careful analysis.

One of the major problems which became apparent very early was how to handle the citrus farms. These were clearly agricultural firms but of a very special character. Early investigation of these revealed a great deal of absentee ownership, and that citrus farming operations were very often contracted out to farm management firms specializing in developing and husbanding citrus groves. With a few exceptions, there was no horizonal integration of citrus operations with general crop farming. And inasmuch as citrus enterprises require that land resources be committed for long periods, it became apparent that the citrus industry could be treated as a separate population and need not be integrated into the Leontief interindustry model until final aggregation phases were undertaken. A previous investigation by Spears[29] reports on the structure and organization of the Yuma County citrus industry so no further analysis of the citrus industry is reported here.

Data for the population of general crop farms are based largely on information gathered in a survey of Yuma County farmers in the summer of 1964. This survey was designed and executed specifically for this project. A schedule was developed to gather information about farm organization, resources, production practices, costs and returns and other relevant data. Since corollary studies were being undertaken in other areas of the state, the schedule was designed to be used generally for all areas. After a pretest, certain revisions were made and a final version agreed upon. A copy of this schedule is available among the author's working papers through the University of Arizona Department of Agricultural Economics.

Other sources of data utilized include a number of technical publications and miscellaneous letters, and other correspondence and

29. Robert L. Spears, "Federal Income Taxes and the Structure of the Arizona Citrus Industry," unpublished file report, Department of Agricultural Economics, The University of Arizona, 1966.

interviews with agricultural service industry representatives in the area.

The Farm Survey

Data were obtained by personal interview with approximately one hundred farm operators in the county using the schedule mentioned above. A minimum interview time of about 45 minutes was required to complete each schedule with the mean being closer to one hour and fifteen minutes. Because of the difficulty in contacting farmers and arranging for a convenient meeting time and place, one interviewer would normally complete no more than two schedules per day.

The frame used to represent the population was from the list of farms maintained by the county Agricultural Stabilization and Conservation Committee office. This list purported to include all cropland within the county. It was indexed in such a manner as to be able to identify those farms which were located within the county yet outside of the study area (i.e., those farms located in areas where groundwater is used for irrigation). These were deleted from the list.

Farms were identified by the name and address of the operator. Examination of the list revealed that the same name often appeared more than once and that similar names and identical addresses were prevalent. This led to the conclusion that some operators were farming several tracts of land as a single farm operation, but on those tracts where they operate as lessees or through joint arrangements with others, they found it necessary to maintain a separate file with the Agricultural Stabilization Committee office. By combining these names which appeared to represent unified operations, a single list of farms for the study area was compiled. This list included about 400 farm operations and provided the frame from which a sample was to be chosen.

Sampling Procedure

Several requirements were deemed necessary in selecting the sample. All of the geographical areas within the study area should be represented. A cross section of sizes should be obtained. Because larger farms represent a greater proportion of total cropland and hence weigh more heavily in the aggregate, these should represent a larger proportion of the sample. Randomness in drawing was also considered desirable in that it would tend to eliminate selection bias.

The sample was drawn as follows: First, the list of farms was arrayed according to the number of cropland acres reported in the records of the Agricultural Stabilization Committee office. Those farms having less than 30 acres of cropland were excluded on the grounds that they did not represent bona-fide full time farming operations nor were they of sufficient importance in the aggregate to warrant spending extensive resources to gather data which would yield only minor refinements.

Ten farms at the upper end of the array were noted to have more than 2,000 acres of cropland. It was decided that an attempt should be made to enumerate each of these. The remainder of the array (393 farms) was divided into quartiles. Each quartile was separated into four geographic areas. Within each area group in the first quartile every fifth farm was selected for sampling; within the second and third quartiles every fourth farm was chosen and within the fourth quartile every third farm was selected for sampling.

It was decided that in event of a "no response" or "no contact", that the farm immediately preceding the nonrespondent in the array would be substituted and an attempt would be made to enumerate that farm; if no response could be elicited from him, than the second alternative would be the farm immediately following the original sample element in the array within the area group.

Evaluation of the Sampling Method

In general, the sampling method worked out satisfactorily. Only three farmers contacted were unwilling to respond, however, the proportion of "no contacts" was somewhat higher (about 18 substitutions had to be made for this reason). A genuine effort was made to contact the farm operators drawn in the original sample; however, in some cases farmers were away on vacations or business trips and substitutions had to be made. In only three cases was it necessary to select the second alternative. While no statistical measures of bias were attempted, it is felt that the sampling method gave a satisfactory cross section of farms from which to develop empirical data for the model.

As soon as possible after completion of the interview the schedule was edited and checked for accuracy and completeness. In no case was it necessary to go back for an additional interview, although in a few instances verification or additional information was obtained by telephone.

Data Processing

After the schedules were completed, the data were tabulated and coded for automatic data processing operations. Production patterns, enterprise combinations, and selected resource inventory information were used to specify the final stratification boundaries which define the representative farm firms discussed in the following chapter and as a basis for specifying their resource inventories. This information, together with data from other sources, provides the empirical data for the input into the linear programming problems discussed in Chapter IV.

Mathematical solution of the various subsets of the problem was carried out on the IBM 1401 computer at the University of Arizona Numerical Analysis Laboratory. Further discussion of the programming system and its application description will be found in Chapter IV.

CHAPTER III

DEFINING REPRESENTATIVE FARM SITUATIONS

This chapter discusses the basis for using representative farm firms for the analysis, identifies the criteria and method used to delineate the various typical farm models developed for this study, and discusses more specifically the characteristics of the representative farm firms and their resource inventories and production activity budgets.

Methodological Basis for the Representative Firm

The use of the representative firm concept for economic analysis has an historical basis which can be traced to Alfred Marshall.[30] Several subsequent writers have been more explicit in their definition of the representative or typical firm. Taussig,[31] for example, has conceived of the representative firm as being "one not far in the lead, not equipped with the latest and best plant and machinery, but well equipped, well led and able to maintain itself permanently with substantial profits." Elliott,[32] one of the first to apply the representative firm concept in farm management research, defined a typical farm

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30. Alfred H. Marshall, Principles of Economics, 8th Edition, MacMillan and Co., Ltd., London, 1948.

31. Frank W. Taussig, Principles of Economics, Volume 2, 4th Edition, MacMillan and Co., New York, 1939.

32. Foster F. Elliott, "The 'Representative Firm' Idea Applied to Research and Extension in Agricultural Economics," Journal of Farm Economics, Vol. 10, No. 3, p. 483, October 1928.

as being a modal farm in a frequency distribution of farms from the same universe. More recently, further application of the representative firm technique to agricultural economics research has been widely discussed.[33] In spite of its shortcomings, the representative firm method is widely accepted, both in farm management research, as well as in aggregative studies.

Criteria for Defining Representative Farm Firms

When defining or specifying representative farm situations, it is essential that farms be stratified according to the most crucial factors which affect the decision-making process. Once this is done, a typical farm may be selected or synthesized to represent the group. Several criteria may be mentioned as being an appropriate basis upon which to stratify: size, management ability, geographic location, soil productivity, water availability, age or education of the farm operator, net worth or capital position, all might be listed as crucial variables.

Because it was believed that economies of size were most important in differentiating methods of production and in adjustment decisions; and because land area is the least flexible resource reflecting size of operation, the typical farm models developed in this study purport to represent groups of farms having similar size characteristics as differentiated by land area. This stratification criterion was

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33. Several pertinent papers on the subject were presented and discussed at a section of the annual meeting of the American Farm Economics Association in 1963. These proceedings are published in the Journal of Farm Economics, Vol. 45, December 1963, pp. 1438-1468. See also Gerald W. Dean, Stanley S. Johnson, and Harold O. Carter, "Supply Functions for Cotton in Imperial Valley, California," Agricultural Economics Research, Vol. XV, No. 1, January 1963, p. 1.

convenient and consistent with the method used for sampling. Five different typical farm models are specified and identified according to acres of irrigated cropland.

The procedure for differentiating the strata to be represented by each model was established after the survey was completed and after careful study of the arrayed data. Ideally, stratification should precede sampling; if enough is known about the population and if the strata may be specified prior to gathering the data, then it is often possible to reduce the size of the sample or redistribute it so as to gain greater statistical efficiency. In this study however, the critical variables were identified and stratification accomplished after the sample data had been gathered and examined. This method, while perhaps not ideal, falls within the range of acceptable statistical procedures.[34]

The procedure for stratification is described as follows: All farms in the sample were arrayed according to cropland acres. By inspection, five different sets of breaking points were identified as being possibly appropriate boundaries for stratifying various representative farms according to size. Two sets of breaking points specified five individual farm models and the other three specified four.

Five variables were considered as being important in differentiating levels of operation by size: These were cropland acres, number of wheel tractors, number of crawler tractors, number of full-time

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34. William G. Cochran, Sampling Techniques, Second Edition, John Wiley & Sons, New York 1963, see especially pp. 135 ff.

nonsupervisory employees, and number of hired supervisors. While the strata were to be identified and divided on the basis of cropland acres, the other variables were considered important in determining where divisions between strata should be made.

Using analysis of variance statistical procedures, (ANOVA) the within-group variance for each of the five sets of breaking points was determined for each of the five variables. The possibility sets were ranked from 1 to 5 for each variable based on the sum of within-group variances for each set. The set having the lowest sum of within-group variances was deemed to be the best. The logic behind this method is that by minimizing the sum of within-group variances, each stratum becomes more homogeneous and, thus, an appropriately delineated representative farm based on that variable will be more "typical" than any alternative stratification. This method also may be considered appropriate in mitigating the problems of aggregation bias discussed above.[35]

The rankings for each of the five variables were reviewed and the set showing the greatest number of "best" rankings was selected as the basis for the stratification used to develop the typical farm firms.

Table 2 identifies the stratification limits used to define the representative farms used for the study and gives other related data.

Consideration was given to developing models for certain substrata based on geographic area, soil productivity levels, and other criteria. However, in view of the relatively small sample supporting

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35. p. 22, <u>supra</u>.

Table 2. Basis for Stratification of Representative Farms and Other Selected Data.

(1) Farm Size Identification Category[a]	(2) Strata Limits	(3) Number in Sample	(4) Mean Cropland Acres Per Farm
	(Acres)		(Acres)
80-acre farms	120 or less	23	77
200-acre farms	121-320	31	207
480-acre farms	321-640	24	481
1000-acre farms	641-1500	15	980
Large corporate farms	Greater than 1500	9	3,912

a. Terms used are for easier identification and do not represent mean acreages.

each of the above representative firms, any attempt toward further stratification would appear to result in the loss of statistical validity by further reducing sample size. Accordingly, the farm models selected for this study here purport to represent typical or modal data for the entire area and variation from the specified criteria may be quite wide for any given farm situation.

Characteristics of Typical Farm Models

A complete delineation of all the relevant characteristics of each of the representative farm firms developed for this analysis involves a large volume of detailed information. Normally, this information would be appended to the dissertation. However, because the large amount of detail involved may be of interest to users other than those having ready access to this dissertation, a supplemental report has been developed containing the supporting data which describes the important characteristics of each of the representative firms, including data on costs and returns.

This report has been reproduced as one of the Department of Agricultural Economics File Report Series[36] and copies are available to interested specialists upon request. The report, while not formally a part of this dissertation, is referenced widely in the following section and should be considered a supplement to this dissertation; appropriate portions are extracted for further discussion here.

Production Resources

The major production resources have been discussed in detail in the above mentioned file report, however, a brief review of some of the basic assumptions concerning these factors is in order here.

Land

It is assumed that all land is homogeneous in its productivity level. While soil types, fertility, and slope do differ widely throughout the area, there are insufficient data to provide a basis for differentiating productivity levels, either geographically or between farm sizes.

Interviews with informed Agricultural Extension Service personnel support the view that except for the "mesa soils" which are

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36. Douglas M. Jones, "Selected Data Relating to Resources, Costs and Returns on Irrigated Crop Farms in Yuma County, Arizona," File Report 67-4, Department of Agricultural Economics, The University of Arizona, August 1967.

susceptible to citrus crop husbandry, no major geographic patterns of differential soil productivity levels exist and the data from the farm survey give no evidence indicating different productivity levels between farm size groups based on soil conditions. Accordingly, the assumption of a homogeneous soil productivity level seems to be reasonable and useful for the analysis here.

Irrigation Facilities

It is assumed that each of the model farms has comparable irrigation facilities for all lands. Analysis of the survey responses indicates an average per acre investment in irrigation ditches and appurtenant fixtures of $91.50.[37]

Buildings

Investment in buildings varies with farm size. While many farms presently have a greater inventory in buildings than is presently being used, there is no evidence to indicate that the major proportion of these would be replaced after their useful life is over. Table 10 in the supplemental report[38] and its accompanying explanatory data indicate the building inventory and investment level for the various farm sizes. This will be discussed further in a subsequent section.

Water Availability

As noted in the introductory chapter, water availability varies according to the irrigation district in which a farm is located, as well

37. *Ibid*.

38. *Ibid*.

as from year to year. Since the model farms do not represent a particular irrigation district, it is necessary then to assume that water availability is homogeneous for all farms and the amount of water available represents a weighted average for all the districts.

Based on data from Table 1, average water use per irrigable acre (not including lands located in the major citrus producing areas) is 5.7 acre-feet. Accordingly, it is assumed that water and land occur in a constant proportion of 5.7 acre-feet of water to one acre of land on each of the farm size groups. It is further assumed that water is of a homogeneous quality and that no adverse quality problems exist or that such quality problems as do exist are uniform across all farms.

Machinery Inventories

The supplementary report[39] presents a detailed inventory of farm machinery and equipment for each of the typical farm models based on data collected on the farm survey. This machinery inventory provides the basis for the budgeting data developed in the following subsection on costs and returns. The assumption that this machinery inventory remains constant over time for each of the farm size groups (along with the assumptions about constant levels of technology and prices) is a sufficient condition for concluding that costs are also constant over time. Data on the total value of the machinery investment and its relation to fixed costs and residual returns will be discussed below.

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39. *Ibid.*, Part II.

Labor

The supply function for the various classes of labor discussed in the supplementary report is assumed to be perfectly elastic with regard to price.

Capital

The capital supply function is also assumed to be infinitely elastic. The rationale for these assumptions has been discussed above.[40]

Management Ability

While the human element is, perhaps, one of the most variable factors in the production process, this analysis assumes that management for each of the farm models is capable of achieving specified levels of technology and that output levels are the same for all farm size groups.

Alternative Enterprise Activities

Based on data obtained from the farm survey, the following crops were found to be grown widely within sample areas: Short staple cotton (planted on both solid and skip-row patterns), barley, wheat, grain sorghum, alfalfa (used for hay, seed production, and for grazing, in various combinations), Bermuda grass for seed production, lettuce, cantalopes, and sudan grass. Other crops, such as safflower, flax, long staple cotton, and various specialities, particularly seed crops, were also reported in the survey. However, in recent years these have not appeared in sufficient acreage (less than 2 percent) to warrant being considered as likely alternatives in the cropping pattern.

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40. p. 25, supra.

The number of crop enterprises showed considerable variation between farm size groups. As would be expected, the smaller farms were less diversified than the larger. This condition also reflects itself in the machinery inventory and other resources related to farm size, which have been discussed in various sections of the supplementary report.

While in principle, all of the typical farm models might select from any of the alternatives listed above, the pattern found in the study area indicates that the more "specialized" crops are found predominately on the larger farms and that smaller farm operators typically grow cotton, grain, and alfalfa in rotation. Table 3 is based on the results of the farm survey and shows the alternative enterprises from which the various representative model farms may typically choose.

Costs and Returns

This section presents a discussion of cost and returns data applicable to the farm models developed in the previous sections of this chapter. Two relevant sets of data are discussed. The first deals with net returns over operating costs and the second comes under the heading of fixed costs and residual returns.

Net Returns over Operating Costs

Per acre unit budgets were prepared for each of the crop enterprise activities specified in Table 4 for the various farm models. The method and procedure used to develop these is described in detail in

Table 3. Alternative Crop Enterprise for Typical Farm Models.

Crop Enterprise	Farm Size: 80-Acre Farms	200-Acre Farms	480-Acre Farms	1000-Acre Farms	Large Corporate Farms
Short staple cotton (solid-planted)	x	x	x	x	x
Short staple cotton (skip-row planted)	x	x	x	x	x
Alfalfa (for hay only)	x	x	x	x	x
Alfalfa (for hay and seed)		x	x	x	
Alfalfa (for hay and grazing)			x	x	x
Alfalfa (for green-chopped ensilage)					x
Barley	x	x	x	x	x
Wheat		x	x	x	x
Grain sorghum	x	x	x	x	x
Bermuda grass for seed		x	x	x	
Lettuce			x	x	x
Cantalope			x	x	x
Sudan grass					x

"x" indicates eligible alternative for cropping pattern for size group.

the supplementary file report,[41] however, the major steps will be reiterated here.

Since production practices for each of the various crops typically follow in some sequence, calendars of operations and schedules of inputs were developed for each crop enterprise. Direct capital and labor requirements for each operation were specified and costs were assigned to each. In addition to these costs which vary directly with the number of acres produced, certain overhead costs are also incurred. These include, but are not limited to, supervisory labor, transportation expenses, and costs of other services needed by the farm business. While these costs are not directly allocable to any given unit or crop, they must be covered if the farm is to remain in business. These differ from fixed costs in that fixed costs are incurred even at levels of zero output.

These additional costs which may be called cash overhead costs, were broken down using various criteria and were added to the direct costs for each unit budget to obtain per acre operating costs.

Per acre gross returns were computed using average product yields determined from the farm survey data and other sources. Earlier statistical analysis had indicated no significant difference in yields according to farm size, so the same yield estimates were used for all farm size groups. Product prices were taken from estimates of prices received as presented in Young, et al.[42] In the case of cotton, the

41. Jones, op. cit.

42. Robert A. Young, William E. Martin, and Dale L. Shaw, Data for Arizona Crop Farm Planning, College of Agriculture, The University of Arizona, Tucson, June 1968.

government "subsidy" payment was also included as a portion of the gross return to the crop.

Operating costs were subtracted from gross returns to obtain net returns or "profit", which make up the coefficients of the objective function of the linear programming model discussed in the following chapter.

Table 4, abstracted from Section IV of the supplementary report,[43] presents in summary form the gross returns, operating costs, and net returns or "profit" from each of the unit budgets developed for the various crop enterprises for the typical farm models.

Fixed Costs and Residual Returns

Short run "operational" decisions are based largely on net returns over variable or operating costs. These are usually made in periods of time too brief to permit the wearing out of capital resources or to allow for shifts in investment. However, as the time horizon lengthens and decisions must be made regarding replacement or acquisition of new capital items, fixed costs become more relevant. Ultimately, the farm operator may be faced with the decision as to whether to remain in business or transfer his resources to other operators. Here especially fixed costs are of primary importance.

Traditional economics defines fixed costs as those costs which are incurred regardless of the level of output--even if output is zero.

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43. Jones, op. cit.

Table 4. Summary of Income, Operating Costs, and Returns Over Operating Costs per Acre for Selected Crop Enterprises, Yuma County, Arizona, 1966.

Activity	Gross Returns	Total Operating Costs: 80-Acre Farms	200-Acre Farms	480-Acre Farms	1000-Acre Farms	Large Corporate Farms	Net Returns Over Operating Costs[a]: 80-Acre Farms	200-Acre Farms	480-Acre Farms	1000-Acre Farms	Large Corporate Farms
	(Dollars)										
Cotton, solid[b]	572.34	289.45	281.92	215.43			283	290	357		
	581.10				213.45	197.74				368	383
Cotton, skip	334.00	206.97	200.55	160.52			127	133	173		
	339.52				153.35	140.90				186	199
Barley	91.00	55.80	54.33	48.85	46.80	40.79	35	37	42	44	50
Sorghum	88.00	64.97	63.81	58.65	52.40	47.08	23	24	29	36	41
Wheat	96.00		58.24	52.60	50.51	46.01		38	43	45	50
Alfalfa, establish stand[c]		53.37	52.18	44.76	43.51	43.29					
Alfalfa, hay only[d]	175.00	133.75	127.70	89.71	86.55	77.98	41	47	85	89	97
Alfalfa, hay and seed[d]	198.00		163.34	127.23	118.78			33	69	77	
Alfalfa, hay and grazing[d]	164.50			78.78	76.57	69.40			86	88	95
Alfalfa, green chop	195.00					98.84					96
Bermuda, establish[e]			70.42	56.82	55.65						
Bermuda, seed production[f]	289.00		168.72	143.72	132.56			120	145	156	
Cantaloupes[g]	812.00			159.79	145.76	133.49			145	152	316
				362.50	362.50	362.50					
Lettuce[g]	967.20			227.09	211.28	202.32			175	183	375
				390.00	390.00	390.00					
Sudan grass	102.50					68.70					34

a Rounded to nearest dollar.

b Upper figure includes 50 percent of return from scrap lint. Lower figure includes 100 percent return from scrap lint. Gross return includes government payment of $203.80 per acre of cotton allotment.

c No returns are listed for establishing the alfalfa stand. Life of stand is assumed to be three years. Average annual costs can be determined by dividing by three.

d Total operating costs include one-third of establishment cost.

e No returns are listed for establishing the Bermuda stand. Life of stand is assumed to be eight years. Average annual costs can be determined by dividing by eight.

f Total operating costs include one-eighth of establishment cost.

g Upper figure is production costs. Lower figure is marketing cost. Usual practice is that smaller growers obtain financing and technical aid from packer-shipper and returns after marketing costs are split fifty-fifty between farmer and packer-shipper. Net returns for 480- and 1,000-acre farms represent the farmer's share, or 50 percent of net return. Large corporate farms perform all the functions of grower, packer, and shipper and, thus, net returns are not shared.

Table 5 presents a summary of fixed costs which apply to the five typical farm models defined above.

After all fixed and variable costs have been paid, there remains a residual return. This may be allocated to either the land input or to management. If the opportunity cost of either of these is known the residual may then be allocated to the remaining factor--as rent in the case of land or economic profit as the return to management. Further discussion of residual returns appears in Chapter V.

Table 5. Annual Fixed Costs for Typical Farm Models, Yuma County, Arizona.

	80 Acre Farms	200 Acre Farms	480 Acre Farms	1,000 Acre Farms	Large Corporate Farms
1. Total Irrigable Acres per Farm	77	207	481	980	3912
Farm Buildings					
2. Total Investment per Farm[a]	1,380.00	2,760.00	6,900.00	10,800.00	38,600.00
3. Annual Amortized Cost[b]	107.91	215.83	593.58	884.56	3,018.52
4. Annual Insurance Cost[c]	6.90	13.80	34.50	54.00	193.00
5. Annual Repair Cost[d]	27.60	55.20	138.00	216.00	772.00
6. Total Annual Cost per Farm[e]	142.41	284.83	766.08	1,154.56	3,983.52
Irrigation Facilities					
7. Total Investment per Acre[f]	91.50	91.50	91.50	91.50	91.50
8. Annual Amortized Cost per Acre[g]	6.72	6.72	6.72	6.72	6.72
9. Annual Cost per Farm[h]	517.44	1,391.04	3,232.32	6,585.60	26,288.64
Machinery Inventory					
10. Total Investment per Farm[i]	14,190.00	28,490.00	93,975.00	163,805.00	423,275.00
11. Annual Amortized Cost[j]	1,928.42	3,871.79	12,771.20	22,261.10	57,523.07
12. Annual Insurance Cost[k]	14.19	28.49	93.98	163.80	423.28
13. Total Annual Cost per Farm[l]	1,942.61	3,900.28	12,865.18	22,424.90	57,946.35
Taxes					
14. Real Property Tax on Land per Acre[m]	4.00	4.00	4.00	4.00	4.00
15. Real Property Tax on Land per Farm[n]	308.00	828.00	1,924.00	3,920.00	15,648.00
16. Real Property Tax on Farm Buildings[o]	12.42	24.83	62.10	97.20	347.40
17. Personal Property Taxes[p]	38.31	76.92	253.73	442.27	1,142.84
18. Total Taxes per Farm[q]	358.73	929.76	2,239.83	4,459.47	17,138.24
Miscellaneous					
19. Personal Liability Insurance[r]	---	100.00	280.00	500.00	1,200.00
20. Total Annual Fixed Cost per Farm[s]	2,961.19	6,605.91	20,383.41	35,124.53	106,556.75
21. Average Annual Fixed Cost per Acre[t]	38.46	31.91	42.38	35.84	27.24

Table 5, Continued.

a. From Table 2, supplementary report, Jones, *op. cit.*, p. 6. Value given is new cost. Does not include owner's home or any buildings which have little value and will not be replaced.

b. Amortization cost includes depreciation and interest on investment at six percent for 25 years.

c. Annual insurance cost is based on $1 per $100 valuation. Average valuation is one-half of total investment given in Line 2.

d. Annual repair cost is assumed to be two percent of total investment.

e. Sum of Lines 3, 4, and 5.

f. From supplementary report, Jones, *op. cit.*, p. 5.

g. Amortization cost includes depreciation and interest on investment at six percent for 30 years.

h. Line 8 x Line 1.

i. From Tables 3, 4, 5, 6, and 7, supplementary report, Jones, *op. cit.*, p. 8-13.

j. Amortization cost includes depreciation and interest on investment at six percent over 10 years. While many machines have a useful life greater than this, the major power driven machines are perhaps less. All machines are assumed to be depreciated to zero value at the end of ten years.

k. Annual insurance cost is based on $.20 per $100 valuation. Average valuation is one-half of Line 10.

l. Sum of Lines 11 and 12.

m. Estimate of per acre taxes is based on selected data from farm survey.

Table 5, _Continued_.

n. Line 14 x Line 1.

o. Assumes tax rate of $9 per $100 of assessed valuation. Assessment valuation is assumed to be ten percent of Line 2.

p. Assumes tax rate of $9 per $100 of assessed valuation. Assessed valuation is assumed to be three percent of Line 10.

q. Sum of Lines 15, 16, and 17.

r. Estimated, based on amount and type of machinery and number of employees.

s. Sum of Lines 6, 9, 13, 18, and 19.

t. Line 20 ÷ Line 1.

CHAPTER IV

THE LINEAR PROGRAMMING MODEL

This chapter presents the details of the empirical linear programming model. Data for the programming matrices are based largely on the typical farm models developed in the previous chapter and on other data taken from the farm survey.

The analysis proceeds in four phases. Initially, in Phase I, equilibrium solutions are obtained assuming that the irrigable land acreage and the farm size group distribution remain constant at present levels. In this initial stage, certain analyses of the sensitivity of the solution to additional water supplies are also performed. Phase II permits land transfer activities, allowing for limited shifts of resources from one size group to another. Land transfer price ranges are also analyzed. Phase III introduces activities which allow for the reclamation of additional lands, assuming that necessary additional water supplies can also be obtained, either from present basin sources or through inter-basin water transfers. Finally, in Phase IV the independently formulated models are integrated into a single general model and an aggregate solution allowing transfer of resources between farm size groups is obtained.

Computer Programming System

Solution of the linear programming problem was carried out at the University of Arizona Numerical Analysis Laboratory, using the IBM 1401 computer system. The program used for the computer solution is identified as IBM 1400-1311 Linear Programming System (1401-CO-13X).[44] This is a modified simplex algorithm using Autocoder as a source language.

The usual linear programming matrix format is followed with alternative activities being represented by column vectors and constraint equations indicated by row vectors. In linear programming parlance, the constraint levels are referred to as the "right-hand side" and normally appear as a column vector at the far right of the tableau.

This particular computer program has a capability of handling up to 47 row vectors, including the objective function, and as many as 900 column vectors including alternative right-hand sides. Constraints may take the form of equalities, "less than" or "greater than" inequalities, or may appear as range constraints. Similarly, the program system provides for designating an upper or lower bound (or range) on the level of any activity; designation of these does not "use up" a constraint row.

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44. For further system documentation, see the following manuals: Application Description (H20-0164), User's Manual (H20-0174), Operator's Manual (H20-0175). These are available through International Business Machine Corporation's Data Processing Division.

Components of the Model

The various components of the programming model may be identified as follows: the objective function; alternative activities, including relevant technical coefficients; and resource restrictions and other constraining factors.

The Objective Function

Under the assumptions and conditions given in Chapter II, profit, defined as net return over operating cost, is the objective to be maximized for each typical farm model. The elements of the objective function are taken from the relevant net revenue coefficients developed in unit budgets in the supplementary report[45] and presented in summary form in Table 4. These represent the net revenue over operating costs which is generated by producing one acre of the particular crop activity. As the analysis proceeds in Phase II, III and IV, certain activities are introduced which have costs rather than net revenues associated with them. These appear in the objective function with a negative sign rather than positive as for the profit coefficients.

Alternative Activities

Three major types of activities enter into the programming models. These are referred to as (1) crop production alternatives, (2) resource transfer activities, and (3) land reclamation possibilities. Slack or disposal activities are automatically generated in

45. Jones, op. cit.

the computer program output and do not enter directly into the formulation of the problem.

Restrictions

Three types of restrictions are specified in the model. The first type represents limitations on resource availability, such as land and water. The second type restricts output levels to predetermined limits due to institutional inflexibilities such as cotton and wheat allotments or because of constraints which limit the amount of a crop that can be successfully marketed from the area as a whole at the assumed prices. Third, artificial restrictions are also used to maintain internal consistency within the model or are imposed to facilitate summarizing. These are discussed in greater detail below.

The Problem Matrices

Tables 6 through 10 present the basic matrices used to formulate the programming problems for each of the five representative farm models. For Phase I of the analysis only the crop production activities are relevant. In Phase II and IV resource transfer activities are added. Phase III modifies the Phase I formulation to include land reclamation activities.

Weighting of the various farm size groups is accomplished by specifying restrictions in terms of aggregates for each of the different size models. This is done by allocating land acreage, water availability and other factors among the farm size groups according to averages indicated by the farm survey and adjusted in accordance with other relevant known totals for the study area. As individual solutions are obtained for each farm size model the results may then be added to get aggregated production potential and resource use solutions for the study area as a whole.

Phase I - The Basic Formulation

This first step of the analysis assumes that the present land resource base remains constant for each of the five model farms and that no shift of resources between size groups will occur.

The crop production alternatives open to each farm size group have been specified in the previous chapter.[46] Constant technical coefficients based on data developed in the unit budgets presented in the supplementary report[47] are used.

A more detailed explanation of the technical coefficients and restrictions as they apply to this and subsequent phases of the study follows.

Double Cropping Patterns and Land Availability Restrictions

Because climatic conditions within the study area often permit the production of two or more different crops from the same land in one year, a land availability constraint has been specified for four time periods for each of the representative farms. These conform to the calendar quarters of the year. Barley, for example, may be planted in

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46. See Table 4, p. 49, *supra*.

47. Jones, *op. cit*.

Table 6. Linear Programming Problem Matrix, 80-Acre Farm, Yuma County, Arizona.

Row Number	Description	Unit	Crop Production Activities (Acres) (1) Solid-Planted Cotton	(2) Skip-Row Cotton	(3) Alfalfa for Hay	(4) Barley	(5) Grain Sorghum	Land Transfer Activities (Acres) (6) Land Disposal $1200 Equivalent	(7) Land Disposal $1500 Equivalent	(8) Land Disposal $1800 Equivalent	Constraint Limitation
	PROFIT	Dollars	283.00	127.00	91.00	35.00	23.00	56.00	85.00	102.00	
(1)	1st Quarter Land	Acres	1.10	1.10	1.00	1.00		1.00	1.00	1.00	≤ 8,624
(2)	2nd Quarter Land	"	1.10	1.10	1.00		1.00	1.00	1.00	1.00	≤ 8,624
(3)	3rd Quarter Land	"	1.10	1.10	1.00		1.00	1.00	1.00	1.00	≤ 8,624
(4)	4th Quarter Land	"	1.10	1.10	1.00	1.00		1.00	1.00	1.00	≤ 8,624
(5)	Available Cotton Allotment	"	1.00	.50				.14	.14	.14	≤ 1,231
(6)	Diversion Use Balance	"	.10	.60	1.00			.08	.08	.08	≥ 664
(7)	Water Availability	Acre-feet	5.00	3.67	7.10	2.50	3.50	5.70	5.70	5.70	≤48,941
(8)	Gross Income	Dollars	572.00	334.00	175.00	91.00	88.00				> 0

Table 7. Linear Programming Problem Matrix, 200-Acre Farms, Yuma County, Arizona.

Row Number	Description	Unit	Crop Production Activities (Acres): (1) Solid-Planted Cotton	(2) Skip-Row Cotton	(3) Alfalfa for Hay	(4) Alfalfa for Hay and Seed	(5) Barley	(6) Grain Sorghum	(7) Wheat	(8) Bermuda Grass	Land Transfer Activities (Acres): (9) Land Disposal $1200 Equivalent	(10) Land Disposal $1500 Equivalent	(11) Land Disposal $1800 Equivalent	Constraint Limitation
	PROFIT	Dollars	290.00	133.00	47.00	33.00	37.00	24.00	38.00	120.00	56.00	85.00	102.00	
(1)	1st Quarter Land	Acres	1.10	1.10	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	≤ 21,714
(2)	2nd Quarter Land	"	1.10	1.10	1.00	1.00		1.00		1.00	1.00	1.00	1.00	≤ 21.714
(3)	3rd Quarter Land	"	1.10	1.10	1.00	1.00		1.00		1.00	1.00	1.00	1.00	≤ 21.714
(4)	4th Quarter Land	"	1.10	1.10	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	≤ 21,714
(5)	Available Cotton Allotment	"	1.00	.50							.14	.14	.14	≤ 3,061
(6)	Diversion Use Balance	"	.10	.60	1.00	1.00					.05	.05	.05	≥ 1,649
(7)	Wheat Allotment	"							1.00		.08	.08	.08	≤ 1,085
(8)	Water Availability	Acre-feet	5.00	3.67	7.12	6.40	2.50	3.50	2.80	4.75	5.7	5.7	5.7	≤ 123,226
(9)	Gross Income	Dollars	572.00	334.00	175.00	196.00	91.00	88.00	96.00	289.00				> 0
	Upper Limit on Activity	Acres								1,900.00				

Table 8. Linear Programming Problem Matrix, 480-Acre Farm, Yuma County, Arizona.

			Crop Production Activities															Land Transfer Activities			
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	
Row Number	Description	Unit	Solid-Planted Cotton	Skip-Row Cotton	Alfalfa for Hay	Alfalfa for Hay and Seed	Alfalfa for Hay and Grazing	Early Planted Barley	Late Planted Barley	Early Planted Grain Sorghum	Late Planted Grain Sorghum	Early Planted Wheat	Late Planted Wheat (Acres)	Bermuda Grass	Cantaloupe	Early Planted Lettuce	Late Planted Lettuce	Land Acquisition $1500 Equivalent	Land Acquisition $1800 Equivalent	Land Acquisition $2100 Equivalent	Constraint Limitation
	PROFIT	Dollars	357.00	173.00	85.00	69.00	86.00	42.00	42.00	29.00	29.00	43.00	43.00	145.00	145.00	175.00	175.00	90.00	108.00	126.00	
(1)	1st Quarter Land	Acres	1.10	1.10	1.00	1.00	1.00	1.00	1.00			1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	≤ 40,194
(2)	2nd Quarter Land	"	1.10	1.10	1.00	1.00	1.00		1.00	1.00			1.00	1.00	1.00			1.00	1.00	1.00	≤ 40,194
(3)	3rd Quarter Land	"	1.10	1.10	1.00	1.00	1.00			1.00	1.00			1.00		1.00		1.00	1.00	1.00	≤ 40,194
(4)	4th Quarter Land	"	1.10	1.10	1.00	1.00	1.00	1.00			1.00	1.00		1.00		1.00	1.00	1.00	1.00	1.00	≤ 40,194
(5)	Available Cotton Allotment	"	1.00	.50														.14	.14	.14	≤ 4,687
(6)	Diversion Use Balance	"	.10	.60	1.00	1.00	1.00											.08	.08	.08	≥ 2,532
(7)	Wheat Allotment	"																.05	.05	.05	≤ 2,010
(8)	Water Availability	Acre-feet	5.50	4.00	7.12	6.40	6.70	2.50	2.50	3.50	3.50	2.80	2.80	4.75	3.50	3.30	3.30	5.7	5.7	5.7	≤ 250,910
(9)	Gross Income	Dollars	572.00	334.00	175.00	196.00	165.00	91.00	91.00	88.00	88.00	96.00	96.00	289.00	812.00	9.67	9.67				> 0
	Upper Limit on Activity Level	Acres												3,800	4,800	1,600	3,200	5,000	5,000	5,000	

Table 9. Linear Programming Problem Matrix, 1,000-Acre Farms, Yuma County, Arizona.

Row Number	Description	Unit	Crop Production Activities (1) Solid-Planted Cotton	(2) Skip-Row Cotton	(3) Alfalfa for Hay	(4) Alfalfa for Hay and Seed	(5) Alfalfa for Hay and Grazing	(6) Early Planted Barley	(7) Late Planted Barley	(8) Early Planted Grain Sorghum	(9) Late Planted Grain Sorghum	(10) Early Planted Wheat	(11) Late Planted Wheat	(12) Bermuda Grass	(13) Cantaloupe	(14) Early Planted Lettuce	(15) Late Planted Lettuce	Land Transfer Activities (16) Land Acquisition-$1500 Equivalent	(17) Land Acquisition-$1800 Equivalent	(18) Land Acquisition-$2100 Equivalent	Land Reclamation Activities (19) Land Reclamation Low Cost	(20) Land Reclamation High Cost	Constraint Limitation
			(Acres)																				
	PROFIT	Dollars	368.00	186.00	89.00	77.00	88.00	44.00	44.00	36.00	36.00	45.00	45.00	156.00	152.00	183.00	183.00	90.00	108.00	126.00	42.00	55.00	
(1)	1st Quarter Land	Acres	1.10	1.10	1.00	1.00	1.00	1.00	1.00			1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	≤ 38,038
(2)	2nd Quarter Land	"	1.10	1.10	1.00	1.00	1.00		1.00	1.00			1.00	1.00	1.00			1.00	1.00	1.00	1.00	1.00	≤ 38,038
(3)	3rd Quarter Land	"	1.10	1.10	1.00	1.00	1.00			1.00	1.00			1.00		1.00		1.00	1.00	1.00	1.00	1.00	≤ 38,038
(4)	4th Quarter Land	"	1.10	1.10	1.00	1.00	1.00	1.00			1.00	1.00		1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	≤ 38,038
(5)	Available Cotton Allotment	"	1.00	.50														.14	.14	.14			≤ 6,432
(6)	Diversion Use Balance	"	.10	.60	1.00	1.00	1.00											.08	.08	.08			≥ 3,463
(7)	Wheat Allotment	"										1.00	1.00					.05	.05	.05			≤ 1,902
(8)	Water Availability	Acre-feet	5.50	4.00	7.12	6.40	6.70	2.50	2.50	3.50	3.50	2.80	2.80	4.75	3.50	3.30	3.30	5.70	5.70	5.70	6.21	6.21	≤ 215,866
(9)	Gross Income	Dollars	581.00		175.00	196.00	165.00	91.00	91.00	88.00	88.00	96.00	96.00	289.00	812.00	967.00	967.00						> 0
	Upper Limit on Activity Level	Acres												3,800	3,200	800	2,400	5,000	5,000	5,000	15,000	15,000	

Table 10. Linear Programming Problem Matrix, Large Corporate Farms, Yuma County, Arizona.

Row Number	Description	Unit	Crop Production Activities (1) Solid-Planted Cotton	(2) Skip-Row Cotton	(3) Alfalfa for Hay	(4) Alfalfa for Hay and Grazing	(5) Alfalfa for Green Chop Ensilage	(6) Early Planted Barley	(7) Late Planted Barley	(8) Early Planted Grain Sorghum	(9) Late Planted Grain Sorghum	(10) Early Planted Wheat	(11) Late Planted Wheat	(12) Sudan Grass	(13) Cantaloupe	(14) Early Planted Lettuce	(15) Late Planted Lettuce	Land Transfer Activities (16) Land Acquisition $1500 Equivalent	(17) Land Acquisition $1800 Equivalent	(18) Land Acquisition $2100 Equivalent	Land Reclamation Activities (19) Land Reclamation Low Cost	(20) Land Reclamation High Cost	Constraint Limitation
			(Acres)																				
	PROFIT	Dollars	383.00	199.00	97.00	95.00	96.00	50.00	50.00	41.00	41.00	50.00	50.00	33.00	316.00	375.00	375.00	90.00	108.00	126.00	42.00	55.00	
(1)	1st Quarter Land	Acres	1.10	1.10	1.00	1.00	1.00	1.00	1.00			1.00	1.00		1.00		1.00	1.00	1.00	1.00	1.00	1.00	≤ 45,430
(2)	2nd Quarter Land	"	1.10	1.10	1.00	1.00	1.00		1.00	1.00			1.00		1.00			1.00	1.00	1.00	1.00	1.00	≤ 45,430
(3)	3rd Quarter Land	"	1.10	1.10	1.00	1.00	1.00			1.00	1.00			1.00		1.00		1.00	1.00	1.00	1.00	1.00	≤ 45,430
(4)	4th Quarter Land	"	1.10	1.10	1.00	1.00	1.00	1.00			1.00	1.00				1.00	1.00	1.00	1.00	1.00	1.00	1.00	≤ 45,430
(5)	Available Cotton Allotment	"	1.00	.50														.14	.14	.14			≤ 3,991
(6)	Diversion Use Balance	"	.10	.60	1.00	1.00	1.00											.08	.08	.08			≥ 2,194
(7)	Wheat Allotment	"																.05	.05	.05			≤ 2,272
(8)	Water Availability	Acre-ft.	5.50	4.00	7.12	6.70	7.50	2.50	2.50	3.50	3.50	2.80	2.80	4.83	3.50	3.30	3.30	5.70	5.70	5.70	6.21	6.21	≤ 257,815
(9)	Gross Income	Dollars	581.00	339.00	175.00	165.00	195.00	91.00	91.00	88.00	88.00	96.00	96.00	102.00	812.00	967.00	967.00						> 0
	Upper Limit on Activity Level	Acres													8,000	3,000	8,000	5,000	5,000	5,000	20,000	20,000	

October and may be harvested in late March, thus requiring land in the 4th and 1st quarter. After this, a grain sorghum crop can be planted to mature in the fall, using land in the 2nd and 3rd quarters. Or, as another possibility, lettuce may be planted in August and harvested in November or December, followed by cantaloupes or late planted barley. Other complementary combinations could also be suggested. Since these combinations do not always occur in a prescribed or set rotation, the division of land according to time periods is an appropriate method of handling this situation.

The use of calendar quarters as an appropriate dividing point for land availability is somewhat arbitrary. For some crops it may have been more appropriate to divide the year into three periods or to specify the beginning and end of the periods at a different time. In other cases, it might be more appropriate to designate time periods of different lengths rather than have the year equally divided. However, examination of the calendars of operation for the several affected crops indicates that division according to calendar quarters does not present any major difficulties that do not adjust themselves when viewed in the aggregate.

Since there is considerable latitude in planting and harvesting dates for some of these crops, alternative activities may be specified for the same crop. Lettuce, for example, may be planted as early as mid-August or as late as November. The early planted crop will be harvested in the 4th quarter, while the late planted crop will tie up land into the 1st calendar quarter. The two alternatives require different sets of land resources and, accordingly, must be considered different activities.

The calendars of operation from which the unit budgets were developed provides the basis for specifying these alternatives. While, no doubt, yields may differ between early and late planted crops resulting in different revenues (and, in some cases, different costs), no distinction is made in the net revenue coefficients used here. It is assumed that the net revenues will be the same whether the crop is planted early or late.

The land acreage constraints and other resource restrictions are specified as aggregates for each of the farm size groups. These aggregates were developed by appropriately weighting the data from the sample survey and then adjusting the final totals proportionately to square with known totals for the study area. In this way, problems of weighting and summarizing results for the aggregative solution are much simplified.

The Cotton Enterprises and Allotment Restrictions

Over the past several years cotton has been the major income-producing crop within the study area. One of the major factors affecting production decisions is the government program for cotton. Throughout the analysis it is assumed that the 1966 government cotton program shall continue in its present form. Government payments constitute approximately 35 percent of the gross income from the cotton enterprise.[48] These are divided into two parts: a price support payment and diversion payment.[49]

Analysis completed in early 1966 by Pawson and Nelson[50] has indicated that it would pay the profit maximizing farmer to divert up to 35 percent of their effective cotton allotment in order to obtain the maximum diversion payment from the government. Farmer behavior in 1966 for Yuma County supported this view as approximately 28 percent of the total cotton allotment acreage was diverted. (Had the details of the program been announced earlier, it is likely that this proportion would have been even greater. It is believed that many farmers had already made their decisions before they had time to consider the effects of the program). Estimates for the 1967 season indicate that 34.9 percent[51] of the cotton allotment acreages has been diverted. Accordingly then, a condition is imposed on the model to provide that farmers divert 35 percent of their cotton allotment. This is referred to as the Diversion Use Balance constraint. It may be satisfied by

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48. See Jones, op. cit., Parts C of the relevant unit budgets for cotton.

49. For a concise explanation of the 1966 cotton program, see The 1966 Upland Cotton Program, Publication No. PA-685, United States Department of Agriculture, Agriculture Stabilization and Conservation Service, November 1965.

50. Walter W. Pawson and Aaron G. Nelson, Economics of Skip-Row Cotton Production, Report 231, Agricultural Experiment Station, The University of Arizona, Tucson, February 1966.

51. The source of this estimate is from informal conversations with ASCS office personnel in Yuma County.

either leaving land idle or by planting with soil conserving crops which, for practical purposes, means alfalfa.

The new revenue coefficients for the cotton enterprises were prepared, based on the assumption that the land requirement and cropped acres were equal (or, in the case of skip-row cotton, crop acres would be exactly half of the land requirement). However, in actual practice the two figures do not jibe. If, for example, a farm has an aliquot forty-acre parcel, about 10 percent (or four acres) will be taken up with ditches, roads, etc., leaving approximately 36 acres of irrigable cropland. If the field is planted to cotton, the usual practice is to leave sufficient room at the ends of the field to allow cultivating and harvesting machinery to maneuver without destroying any of the crop. In this manner, the farmer is able to obtain the maximum production from his cotton acreage allotment for no plants are destroyed in the interim between planting and harvesting time. These "turn rows" will usually amount to about 10 percent of the planted acreage. Accordingly, the matrix elements reflect this additional land requirement for an acre of cotton. But, since nothing is planted on the field ends, the "idle" land may be considered as filling a part of the diverted acreage requirement. Technical coefficients for the various cotton enterprises are formulated so as to reflect this situation. For most other crops, a greater proportion of the field will be used. Acreages and yields per acre are probably less carefully measured than for cotton and are based on irrigable acres.

Allotment restriction and diversion use constraints for each farm size group were derived from the sample survey data and adjusted to be consistent with the total cotton allotment levels as reported by the county ASCS office.

A similar method was used to specify wheat allotment levels.

Activity Restrictions

For some activities it is necessary to place restrictive constraints on the levels at which the activity may enter the problem solution lest certain high valued crops dominate the solution.

Net returns for all crop activities are based on the assumption that the demand is perfectly elastic with respect to price. This, however, is not true for lettuce, cantaloupe and bermuda grass seed. The product prices which underlie the profit coefficients given in the objective function are relevant under the assumption that total production will fall within a certain range, therefore it is necessary to indicate the bounds within which the profit coefficients for these crops may be relevant. Because the net returns per acre generated by each of these crops is considerably higher than for most of the other crop activities, it may be expected that these activities will enter the solution at their maximum level; therefore upper limits must be imposed in order to maintain the problem solution within the bounds of realism.

No clear-cut guideline exists as to how to set these constraint limits for the various farm size groups. If it can be assumed that past history for the area is indicative of "what the market will bear" at the assumed product prices, then maximum acreage levels for the area can be estimated. This, however, does not indicate how the acreage may be distributed among the various size groups.

In the initial stages of the analysis where each farm model solution is computed independently, the upper bound for the respective activities is indicated in the bottom line in Tables 6-10. These limits were estimated based on data obtained in the 1964 farm survey and adjusted to gain consistency with an estimated maximum for the area as a whole. However, in Phase IV when the five separate models were integrated into a single problem, a different method was used.

Based on the sample survey data, mean averages for the three crops were calculated for each of the relevant farm size groups. Standard deviations were computed for each. It was assumed that one standard deviation each side of the mean would set the maximum and minimum acreage levels which could be expected, given that risk preferences remained consistent with the levels indicated by the 1964 farm survey data. These estimates were expanded and adjusted to agree with the constraint limits estimated for the area as a whole.

Water Availability Restrictions

The water availability constraint limits are based on data discussed in Chapter III above.[52] For each acre of irrigable land, it is

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52. See p. 42, *supra*.

assumed that there are 5.7 acre-feet of water available. While water requirements per acre may differ, based on the particular crop selection pattern, water deliveries are made to the farm irrespective of any particular crop mix. The per acre "water buy" is assumed to be the same for each acre in the entire study area.

In the exploratory stages of the analysis an attempt was made to determine if seasonal water availability was an effective restriction on the cropping pattern. Seasonal water requirements for the peak demand period were determined for the various crops and average water delivery capabilities for the same periods were estimated, based on capacity of the delivery system as indicated by previous maximum flow rates. A pilot model of the same form as those presented in Tables 6 through 10 was formulated, incorporating seasonal water constraints and a solution was obtained.

The results of this analysis indicated that the system as a whole contained adequate capabilities to meet any peak water demand conditions which might be anticipated, given the effectiveness of other constraints on the model. While isolated peak delivery problems undoubtedly do exist, this conclusion is generally supported by responses of farm operators to the farm survey questionnaire. Accordingly, it is assumed that seasonal water requirements are not a restrictive factor on production or resource use patterns within the area.

Gross Income Constraint

The Gross Income Constraint is an artificial function which is put into the programming model only for the purpose of easier summarization results. The inequality constraint is written such that gross income must be greater than zero. (Obviously this will be the case if any activity level is positive.) Matrix coefficients represent gross revenues generated by an acre of each of the alternative activities. This constraint does not affect the solution of the problem, but the computer program output will indicate the total gross revenue generated by the problem solution; thus alleviating the necessity for many additional calculations.

Other Considerations

While the above described model is necessarily simplified, mention should be made of some of the other factors which were considered in developing the final form of the Phase I model but which have not been included.

Labor, capital, and credit restrictions, for example, do enter into the farm decision-making process; however, since the problem is framed in a long run equilibrium setting where factors can be assumed to be mobile and in elastic supply these were not believed to be restrictive. Moreover, the production functions for each activity are developed under the assumption that each factor input has a marginal value product at least equal to its cost. These factors, therefore, were not considered as being restrictive on the model.

Consideration was also given to rotation restrictions, or diversity requirements for the cropping programs. Farmers have many reasons for following crop rotation programs: improving soil conditions, disease and insect control, risk aversion, and in the short run, to make better use of resources. There is no consensus, however, among plant and soil scientists that rotational requirements are necessary to maintain crop yields at the indicated levels. Therefore, it was assumed that rotational requirements are not restrictive and that price-quantity relationships will determine the optimal solution.

While many farmers have a high aversion for risk and may wish to diversify their cropping program, the alternative activities available (some of which are otherwise restricted in the programming model) provide ample basis for a diversified solution to the model.

Additional crop production activities might also have been included to present a greater choice of alternatives from which farm operators typically may choose. However, those included in the model represent a sufficiently varied array of the choice possibilities open to the various farm size groups and, although other alternatives remain open, the ones presented are sufficiently similar to act as a stand-in for other possible alternative activities.

Phase II--Modifications to Allow for Land Transfer Activities

For this phase of the analysis, the individual farm models presented in Phase I were modified to include land transfer activities. Like the crop production activities, these activities appear in the matrices as column vectors.

Land transfer activities were of two types--either acquisition or disposal. For the two smallest farm size models, it was assumed that only the land disposal activity would be relevant. For the three larger size groups, only acquisition activities were provided for.

In order to test the sensitivity to various land prices, transfer activities were permitted at three alternative sets of land prices. These were identified by different coefficients in the objective function. For the two small farm size models, these coefficients appeared with a positive sign indicating that the activity would return a positive profit. For the acquisition activities in the larger farm size groups, the profit coefficients were negative indicating a cost.

The values for these coefficients were determined by specifying alternative land sale prices based on the range of prices at which known land sales had been consummated. For disposal activities an amount equal to a 6 percent real estate commission was deducted from the posited sale price. It was assumed that the remaining amount could be invested to yield a 6 percent annuity each year. Acquisition activity cost coefficients were based on the assumption that the annual cost of land was 6 percent of the sale price--this representing the opportunity cost of the investment expenditure on land.

No account was taken for the salvage value of machinery and other capital items, nor for the opportunity cost of the operators' labor. While in the short run this omission might be a source of bias, over the long period this is not too serious, especially in view of the previously noted assumptions with regard to the supply function for labor and capital.

Technical coefficients within the body of the matrix were specified such that if the activity were to enter the solution, the appropriate constraint limits for land, cotton and wheat allotments and water would adjust accordingly.

For solution of the problem in Phase II, it was necessary to specify an upper bound on the land acquisition activities. Otherwise, the activity might enter the solution at an unlimited level and no determinate solution could be obtained. It was not necessary to restrict the land disposal activity, since sufficient constraints were already specified by the land availability equations in rows 1-4.

In Phase IV, however, when the five separate models were combined into a single problem, an additional constraint called Land Transfer Balance was imposed. This constraint merely specified that for each unit of land disposed of by the smaller farm sizes there must be a unit acquired by a larger farm. Thus the internal consistency of the generalized model could be maintained.

Phase III--Modification to Allow for Additional Land Reclamation

This phase of the analysis is designed to simulate the reclamation of approximately 70,000 acres of presently undeveloped land which includes as a major portion those lands in the Colorado River Indian Reservation.

In order to determine the possible effects and potential uses of additional land brought into cultivation, land reclamation activities were added to the basic formulation developed for the Phase I analysis. It was assumed that additional water would be made available in a ratio of 6.21 acre feet of water per acre of land. Inasmuch as a large block of potentially irrigable lands exist in the Colorado Indian Reservation where present water use commitments average 6.21 acre feet per acre, this figure seems to be reasonably representative of water availability for additionally reclaimable lands (see Table 1). The coefficient given in the objective function includes both an annual land rental cost per acre and the yearly amortized cost of the initial investment necessary to bring land into production. The latter includes cost of brush clearing, land leveling and installation of concrete irrigation facilities amortized at 6 percent over a 25 year period.

According to data provided by Soil Conservation Service personnel, approximately half of the potentially irrigable acreage is covered with heavy brush which would require a greater expense in clearing, leveling and breaking. Therefore alternative activities representing two different development cost estimates are provided for. It was also assumed that new lands would be reclaimed in large blocks of several hundred acres and therefore that these activities would be relevant only for the 1,000-acre and large corporate farm size groups.

Phase IV--Integration of the Individual Models

In the final phase of the analysis, the five individual farm models as formulated in Phase II were integrated into a single problem. Solution of the system in this manner allows for the automatic transfer of resources between farm size groups. While in reality the decision to transfer or acquire resources is made at the individual farm level with individual farm goals in mind, the solution arrived at by arranging each of the five individual models into an integrated model represents a socially optimum solution which may not necessarily be optimum for any or all of the individual farms. This, of course, does not mean that given present institutional arrangements that such a solution represents an equilibrium which will shape future resource allocation decisions, but rather such a solution might serve as a guide for public policy actions which would, in addition to market forces, encourage reallocation of available resources to meet a socially optimum economic efficiency criterion.

No changes were made in the various matrix coefficients; however, it was necessary to sum certain of the row vectors in order to determine appropriate restrictions for the aggregate solution.

Similarly it was necessary to add an additional row constraint vector in order to obtain internal consistency within the aggregate model.[53]

The resulting matrix included 46 row vectors and 77 column vectors. Because of its large size, the aggregate matrix is not reproduced here.

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53. See p. 74, supra.

CHAPTER V

RESULTS AND CONCLUSIONS

This chapter presents the results of the linear programming solution and analyzes various aspects and implications of the equilibrium levels of output and resource use.

Phase I--An Initial Solution

Table 11 presents a summary of optimum cropping patterns based on the independent solution of the matrices presented in Tables 6-10 but without allowing for land transfer or land reclamation activities. As would be expected, high-return crops enter the solution at their maximum allowable levels. Sufficient land and water resources are available to permit cotton, lettuce, cantaloupe and Bermuda grass to be grown in acreages up to the constraint level. Other crops, however, are limited at the margin by land and/or water constraints.

It may be noted from Table 11 that the total acreage of all crops exceeds the land acreage limitations indicated by the right-hand-sides as shown in Tables 6-10. This is due to the considerable amount of double cropping which can be carried out by full utilization of the land resources.

Table 11. Optimum Solution to Linear Programming Problem--Summary of Crop Production Activities and Returns, Phase I.

Farm Size	(1) Solid Cotton	(2) Alfalfa (all Forms)	(3) Barley	(4) Grain Sorghum	(5) Bermuda Grass for Seed	(6) Lettuce	(7) Cantaloupe	(8) All Crops	(9) Net Revenue	(10) Gross Revenue
	(Acres)								(Dollars)	
80-Acre Farms	1,231	541	6,729	6,317				14,818	751,374	1,728,249
200-Acre Farms	3,061	1,342	15,104	14,735	1,900			36,142	2,091,308	4,612,360
480-Acre Farms	4,687	22,270	968		3,800	4,800	4,800	41,325	5,716,165	15,171,782
1,000-Acre Farms	6,432	20,660	902		3,800	3,200	3,200	38,194	6,005,365	12,713,369
Large Corporate Farms	3,991	1,795	25,245	29,436		9,000	8,000	77,467	10,071,196	21,889,629
Total	19,402	46,608	48,948	50,488	9,500	17,000	16,000	207,946	24,635,408	56,115,389

Marginal Crops and Limiting Resources

The marginal crops are the forage and feed grain crops: alfalfa, barley, and grain sorghum; the latter two are typically found in some form of double-crop combination. The solution for the different programming problems indicates that the various farm size groups do not respond similarly with respect to these latter indicated crops. The models for 480- and 1,000-acre farms indicate alfalfa as the crop entering the solution at the extensive margin, while the 80-acre, 200-acre, and large corporate farm models indicate only enough alfalfa to meet the minimum diversion use balance constraint, and any additional resources are put into a double-cropped barley-sorghum combination. While this difference may appear significant on its face, further analysis indicates that a small change in relevant net revenue coefficients, or an increase in the water availability constraint, would result in quite different solutions with relatively little change in the value of the objective function.

Table 12 compares net revenues per acre, water use, and average revenue per acre-foot of water used for the marginal crops entering the programming solutions.

Assuming that alfalfa and double cropped barley-grain sorghum compete for the same resources, it can be seen that a slight change in the unit price of alfalfa (of \$1 or \$2 per ton) could change the ordering of the net revenues between the two crop alternatives. (Compare Column 3 and Column 12, Table 12.) It can thus be concluded

Table 12. Comparative Analysis of Marginal Crop Enterprises, Phase I.

Farm Size	Alfalfa			Barley			Grain Sorghum			Barley-Sorghum Combined as a Single Enterprise		
	(1) Net Revenue	(2) Water Use	(3) Average Net Return Per Acre-foot	(4) Net Revenue	(5) Water Use	(6) Average Net Return Per Acre-foot	(7) Net Revenue	(8) Water Use	(9) Average Net Return Per Acre-foot	(10) Net Revenue	(11) Water Use	(12) Average Net Revenue Per Acre-foot
	(Dol.)	(Acre-ft.)	(Dol.)	(Dol.)	(Acre-ft.)	(Dol.)	(Dol.)	(Acre-ft.)	(Dol.)	(Dol.)	(Acre-ft.)	(Dol.)
80-Acre Farms	41.00[a]	7.10	5.77	35.00	2.50	14.00	23.00	3.50	6.57	58.00	6.00	9.66
200-Acre Farms	47.00[a]	7.12	6.60	37.00	2.50	14.80	24.00	3.50	6.86	61.00	6.00	10.16
480-Acre Farms	86.00[b]	6.70	12.83	42.00	2.50	16.80	29.00	3.50	8.29	71.00	6.00	11.82
1,000-Acre Farms	88.00[b]	6.70	13.13	44.00	2.50	17.60	36.00	3.50	10.28	80.00	6.00	13.33
Large Corporate Farms	95.00[b]	6.70	14.18	50.00	2.50	20.00	41.00	3.50	11.71	91.00	6.00	15.16

a. Alfalfa for hay only.

b. Alfalfa for hay and grazing.

that there is really very little difference between the two choices in terms of the effect on the total net revenue indicated by the objective function.

For each of the model farms, these crops are limited by the 1st quarter land availability constraint and also by the water limitation. As an example, the indicated solution for the 80-acre farm finds that after the cotton allotment restraint is reached and the diversion use balance satisfied, the next crop to enter the solution is barley. This crop is the "next best" alternative in terms of both net return to land and returns to water. As the first quarter land restriction is reached, no more barley can be grown; however, sufficient water resources are available to be combined with second and third quarter land and grain sorghum enters the program solution up to the limit of water availability.

For the 480-acre and 1,000-acre farms alfalfa is the dominant crop. However, barley also enters the program to complement other high-value crops which utilize land for only part of the year. In the final iterations, the program choice is between alfalfa and barley-grain sorghum double-cropped until either the land or water constraint is reached.

Table 13 shows the shadow prices for first quarter land, water availability, and cotton allotments as generated in the program output for each of the five farm models. These shadow prices are an approximation of the marginal value product of the resource, since they represent the amount by which the value of the objective function would be increased, given a corollary increase of one unit of the resource.

Table 13. Marginal Value Product of Selected Resources.

Farm Size	1st Quarter Land Availability (1 Acre)	Water Availability (1 Acre-Foot)	Cotton Allotment (1 Acre)
80-Acre Farms	18.57	6.57	232.15
200-Acre Farms	19.86	6.58	236.04
480-Acre Farms	15.80	10.48	281.99
1,000-Acre Farms	17.81	10.48	308.79
Large Corporate Farms	20.17	11.71	296.21

Demand Function for Additional Water

In order to test the sensitivity of the model to the possibility of additional water supplies, the water availability constraints were increased in increments of 3, 5, 10, and 12 percent. The technical coefficients within each matrix were held at their original levels, indicating that no change along the production functions for the various activities was contemplated. The only change was to increase the right-hand side water availability level in successive increments to determine how the enterprise combination for the various farm models would change in response to additional water supplies.

Table 14 shows the shadow prices (marginal value product) for additional water and the proportional increases in net revenue under the several incremental increases assumed. Under presently assumed water availability conditions, the two small farm sizes are very close to the limiting point in terms of their ability to make use of

Table 14. Marginal Value Product of Additional Water and Proportional Revenue Increases for Selected Levels of Water Availability.

Farm Size	Marginal Value Product of Additional Water (5.7 Acre-Feet per Acre)	3% Increase in Water Availability (5.85 Acre-Feet per Acre)		5% Increase in Water Availability (5.96 Acre-Feet per Acre)		10% Increase in Water Availability (6.24 Acre-Feet per Acre)		12% Increase in Water Availability (6.36 Acre-Feet per Acre)	
		Marginal Value Product of One Additional Acre-Foot	Percent Increase in Net Revenue	Marginal Value Product of One Additional Acre-Foot	Percent Increase in Net Revenue	Marginal Value Product of One Additional Acre-Foot	Percent Increase in Net Revenue	Marginal Value Product of One Additional Acre-Foot	Percent Increase in Net Revenue
		(Dollars)	(Percent)	(Dollars)	(Percent)	(Dollars)	(Percent)	(Dollars)	(Percent)
80-Acre Farms	6.57	0	1.13	-	-	-	-	-	-
200-Acre Farms	6.58	0	.47	-	-	-	-	-	-
480-Acre Farms	10.48	8.29	1.15	8.29	1.81	8.29	3.46	0	3.99
1,000-Acre Farms	10.48	10.29	1.12	10.29	1.86	2.38	3.58	2.38	3.75
Large Corporate Farms	11.71	11.71	.90	11.71	1.50	5.71	2.88	5.71	3.17

additional water. For both of these models the marginal value product of water reaches zero at some point less than a 3 percent increase in the water availability constraint. For the 480-acre farm, the marginal value product for water remains constant at $8.28 until the zero marginal value product level is reached with the addition of between 10 and 12 percent additional water. For the two largest farm sizes the marginal value of additional water declines, but water still has a positive marginal value product even at the point where the water constraint is increased by 12 percent. No sensitivity analysis was carried out beyond this level, however, the different marginal value product levels provide the basis for developing a demand schedule for additional water up to this point.

Table 15, derived from data given in the programming output, indicates the quantities of water which could be profitably utilized at various prices by the relevant size units, assuming that the marginal value product represents the short run demand price per acre foot of additional water. By arraying the data according to the marginal value product levels, the information may then be transformed into the demand function shown in Figure 2. It must be realized, however, that this represents a short run demand function which would have to be adjusted downward in the long run when net returns must be allocated to cover fixed costs. More will be said on this point below.

The lower right hand portion of the demand function shown in Figure 2 contains two discrete sections which are indeterminate as

Table 15. Demand Schedule for Additional Water.

Farm Size	Price per acre-foot	Quantity which could be utilized at indicated price	Use to which additional water would be put
	(dollars)	(acre-feet)	
480-Acre Farms	8.29	22,810	Grain Sorghum.
1,000-Acre Farms	10.29	10,793	Grain Sorghum.
	2.38	15,111[a]	Shifts production of alfalfa from hay and grazing to hay only.
Large Corporate Farms	11.71	12,893	Grain Sorghum.
	5.71	18,050[a]	Shifts production of alfalfa from hay and grazing to hay only.

a. Additional water in excess of this level, undoubtedly, could be profitably utilized at the indicated price. However, the effect of additional increments of water beyond the 12 percent level was not analyzed.

to the amount of water demanded at that price. Additional water in excess of the amounts given undoubtedly could be utilized at the indicated prices. However since no analysis of additional water increments beyond 12 percent was carried out, the amount which could profitably be used is not known. Since the additional water at the margin is used to produce alfalfa for hay only rather than for hay and grazing--the impact of this shift on other resource uses may be considered to be of minor importance.

Value of Cotton Allotments

Returning now to Table 13, the marginal value product given for cotton allotments may be considered to be representative of the maximum

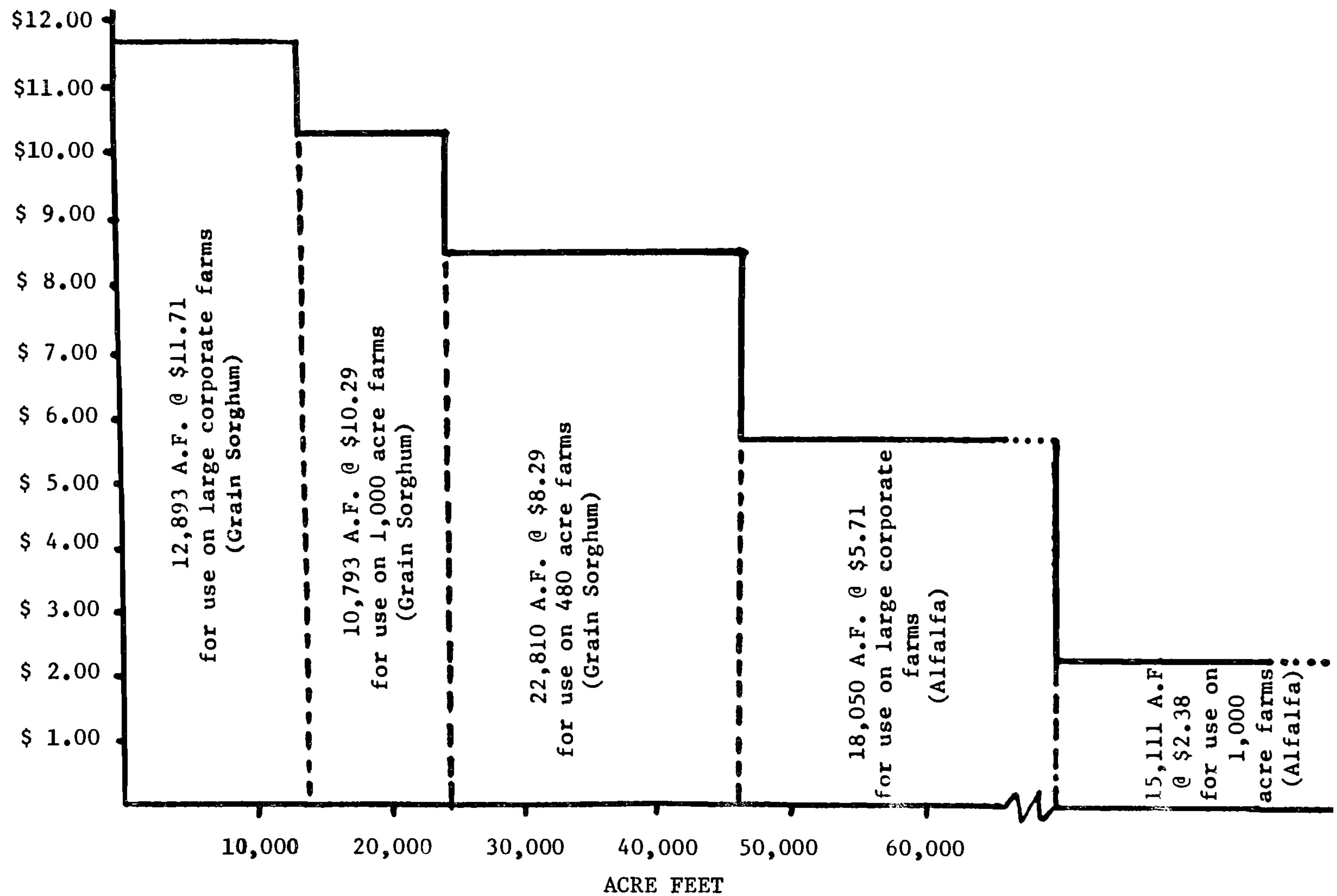

Figure 2. Short Run Demand Function for Additional Irrigation Water, Yuma County, Arizona (Assumes No Additional Cropland in Production)

rental demand price for an additional acre of cotton allotment. These range from $232 for the 80-acre farms to $309 on 1,000-acre farms. Under the present government program, cotton allotments are transferable within counties and under certain conditions they can be transferred from one county to another. Allotments can be leased or transferred permanently. In order to establish price expectation levels for either outright sale of an allotment or in a leasing market, it would be necessary to analyze the reservation supply prices for the various alternative allotment supply sources. While this may be of some importance in farm management decisions, the scope of such a study is beyond what can be accomplished here. The marginal value products of cotton allotments indicated above are mentioned only to indicate possible ranges within which the magnitude of market prices might be expected to occur.

Fixed Costs and Residual Returns

The solutions presented in Table 11 represent optimum use of resources and maximum output for each size group under the condition that net returns over variable costs are maximized. In the short run this is the relevant decision criterion. However, as the time horizon lengthens, it is necessary that these returns be sufficient to cover fixed costs, otherwise the farmer would no longer find it profitable to make new investments in capital resources as present capital items wear out and must be replaced. As fixed costs are met the residual returns may be allocated to land and management. Table 16

Table 16. Allocation of Returns to Fixed Costs and Residual Factors.

(1) Farm Sizes	(2) Net Returns Over Variable Cost (per farm)	(3) Annual Fixed Costs (per farm)[a]	(4) Net Returns To Land And Management[b]	(5) Allocation For Management Services[c]	(6) Net Returns To Land (per farm)[d]	(7) Net Returns To Land[e]	(8) Gross Returns Per Acre
	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)
80-Acre Farms	6,708	2,961	3,747	1,543	2,204	28.62	200
200-Acre Farms	19,936	6,606	13,330	4,397	8,933	43.15	212
480-Acre Farms	68,457	20,383	48,074	18,170	29,905	62.17	377
1,000-Acre Farms	154,777	35,124	119,653	32,766	86,887	88.66	334
Large Corporate Farms	868,206	106,556	761,649	188,704	572,945	146.46	482

a. From Line 20, Table 5, page 51.

b. Column 2 - Column 3.

c. Represents 10% of gross return per farm.

d. Column 4 - Column 5.

e. Column 6 ÷ Column 4, Table 2.

presents data on fixed costs and residual returns for the various farm size models. These data are based on the values given in each of the aggregated size group solutions but adjusted to be consistent with the average cropland acreage per farm given in Table 2.

Allocation for management services is estimated at 10 percent of gross income per farm. This figure is somewhat arbitrary and produces what may at first seem an exorbitant return to management especially on the larger farms. However, the 10 percent figure is not out of line with known charges levied by professional farm management firms and bank trust departments for similar services. Moreover it must be realized that for the larger size farms, this return must cover both the guarantee or risk bearing function as well as the operational control function of management. These may not necessarily lie with the same individual. Often times too, the control function may be vested in a consortium of subsidiary management level personnel and may require additional management expenses such as special training sessions, consulting services, computer studies, or other remedial analyses which have not been included elsewhere in either fixed or variable costs. Given these considerations the charges for management services do not seem unreasonably large.

Column 7, Table 16 represents the net rent to the residual factor land. More properly it might be said that the residual factor is land and its associated water right. The figures given here are estimates of the annual net rent accruing to land which represent the annual annuity which may be capitalized into per acre land values for each of the farm size groups. Using the formula $V = \frac{A}{i}$

where V = the value of land

A = annuity or annual rent flow

i = capitalization rate

land values may be estimated based on a given capitalization rate. Or alternatively if land values can be estimated from independent sources (such as market sales data) then rates of return on the land investment may be calculated.

Table 17 gives indicated land value estimates based on alternative capitalization rates of 6, 7, and 8 percent.

Table 17. Estimates of Land Value.

Farm Size	(1) Average Net Rent Per Acre $	(2) Land Value at Alternative Capitalization Rates 6%	(3) 7%	(4) 8%
80-Acre Farms	28.62	477	408	358
200-Acre Farms	43.15	719	616	539
480-Acre Farms	62.17	1,036	888	777
1,000-Acre Farms	88.66	1,477	1,267	1,108
Large Corporate Farms	146.46	2,441	2,092	1,803

Opinions about land values in the study area solicited from real estate sales personnel in Yuma and Wellton during the summer of 1964 indicated that sale prices for land ranged from about $900 per acre for less well-situated parcels to as much as $2,000 for agricultural land with more desirable features. One speculative buyer in

Yuma had a standing offer of $1,500 per acre for any land having been in cultivation for over 10 years and without subsurface drainage problems. These estimates may be considered to be representative of the range of prices actually being paid for comparable agricultural land within the study area. While no careful study of land sale prices was undertaken, these opinions are consistent with land value estimates for the larger size farms arrived at by the income capitalization method of appraisal shown in Table 17.

Table 18 indicates rates of return on land investments of $1,200, $1,500, and $1,800 per acre. Designation of these land value estimates is somewhat arbitrary, however, as noted above, they do lie within the relevent range of prices as indicated by actual land sales. As can readily be seen from the data in the table, the smaller size farms have a lower rate of return to land investment than can usually be obtained from other high quality-low risk investments. Inasmuch as the investment in land is not being returned its opportunity cost, it would be expected that in the long run smaller farmers would find it more profitable to dispose of their land resources or to combine into larger scale operations which yield a higher rate of return to the land investment operations. Assuming that this trend may be expected to occur the second phase of the analysis is designed to consider the possibilities of land transfers to larger farm operations.

Table 18. Rates of Return on Land Investment.

Farm Size	(1) Average Net Rent Per Acre	(2) Per Acre Rate of Return For Alternative Land Investment Levels $1200	(3) $1500	(4) $1800
	---$----	-----------Percent---------		
80-Acre Farms	28.62	2.4	1.9	1.6
200-Acre Farms	43.15	3.6	2.9	2.4
480-Acre Farms	62.17	5.2	4.1	3.5
1,000-Acre Farms	88.66	7.4	5.9	4.9
Large Corporate Farms	146.46	12.2	9.8	8.1

Phase II--Effects of Land Transfers

In order to determine the effect of the transfer of land from one size group to another, the solutions to each of the five matrices were again computed, but this time including the land transfer activities. As noted in Chapter IV, land disposal activities were provided for the two smaller farm size models and land acquisition activities were shown as relevent activities for the larger farms. Three alternative land transfer prices were specified for each farm size model.

Land disposal prices for the two smaller farm models were specified as being $1,200, $1,500 and $1,800. Arbitrary constraints were imposed to insure that the solution did not degenerate to a single activity (i.e., dispose of all land at the maximum land transfer price). Each farm size model was limited to the transfer of an aggregate of 1,000 acres at each price.

As noted above, the land disposal "profit coefficients" were computed as the amount of a 6 percent perpetuity based on investment of the net returns from the sale of land after a 6 percent real estate commission had been paid. For both the 80 and 200-acre farm models, the solution indicated that land sales would occur at the $1,800 price level but not at the $1,500 price. Further analysis of the computer output indicated that the minimum sale price that would result in a higher net income per farm in the short run was $1,535 for the 80-acre farms and $1,632 for the 200-acre farms. Given these prices, disposal of the entire aggregate farm acreage would give a greater net return to the land operator in the short run than could be obtained from remaining in business. If the salvage value of undepreciated capital and the opportunity costs of underemployed labor and management were also considered the reservation supply prices given above would be even lower.

Three land acquisition activities were also included as relevant alternatives in the matrices which represent each of the three larger farm models. As before, each activity was differentiated on a basis of land value. Acquisition prices of $1,500, $1,800 and $2,100 were specified with the negative profit coefficient given in the objective function representing a cost equal to an annual 6 percent interest charge on investments of those magnitudes. Each farm size was limited in the amount of land which could be acquired at each price; elsewise if the activity entered the basis no bounded solution could be obtained. Aggregate land acquisition levels were arbitrarily set at 5,000 acres for each activity.

The problem solutions indicated the 480-acre farms could increase annual net revenues by purchasing land for any price less than $1,943 per acre, while $2,012 and $2,159 per acre would set the upper limit of land purchase prices for the 1,000-acre and large corporate farms respectively.

The foregoing analysis indicates that the reservation supply price for potential land sellers is below that which could be profitably paid by buyers who wish to expand their farming operation. This suggests that an active real estate market for agricultural land exists, and that present farm land prices (in the $1,500-$2,000 per acre range) do not appear to be out of line with the productivity potential of the land.

It can therefore be concluded that trends toward further farm size expansion may be expected to continue as in the past, and that these adjustments will result in an increase in net returns to the agricultural sector.

In this phase of the analysis it was not possible to assess the precise changes in the output pattern which might be achieved through interfarm land transfers. However, since it was assumed that disposal or acquisition of land would also involve transfer of cotton allotments, diversion use requirements and water availability, the right hand side constraints would effectively be reduced or augmented if land transfer activities entered the solution for any given model farm. Thus, for the two smaller farm models, when the land disposal activity enters the solution the amount of cotton allotment restriction is also reduced and the new solution shows a decrease in the cotton activity. Conversely, those farm size models acquiring land will show a corrollary increase in the cotton activity. Reduction in the acreage of low value marginal crops on farms disposing of land would not necessarily be offset by increasing in acreages of the same crops on farms acquiring land, because the matrix solutions were computed independently and no effort was made to insure that land disposals must exactly offset land acquisitions. Therefore, it is impossible to show shifts in the total output pattern that might be expected. This however will be analyzed more carefully in the discussion of the final phase of the study.

Phase III--Land Reclamation Activities

The third phase of the analysis purports to determine what use will be made of the potentially irrigable lands within the study area. As discussed in Chapter 4 this phase simulates the reclamation of approximately 70,000 acres of arable land which lie largely in the Colorado River Indian Reservation. As noted earlier, only the 1,000-acre and large corporate farms are involved in this phase of the study.

Analysis of the computer output indicates that both the high cost and low cost reclamation activities enter the solution for both of the two large farm size groups.

The large corporate farms could pay the equivalent of an annual cost of $92 per acre in order to bring additional lands into production and the 1,000-acre farms could pay $83 annually for each reclaimed acre. These estimates do not include fixed costs associated with development--such as the annual amortized costs of additional machinery and building investments. However, if the relevant estimates of fixed costs given in Table 5 may be considered applicable for these new lands (a close estimate may be made by subtracting lines 12 and 8 from line 21), then long run profits appear sufficient to encourage large farmers to undertake these land reclamation projects.

The matrix solutions indicate that these additionally reclaimed lands would be used to raise barley and sorghum in a double-cropped rotation. However, as noted earlier since the per acre returns to alfalfa are almost as great, it is likely that a large part of this new land would be used for alfalfa, particularly in the first several years after the land is brought into production and when the "land conditioning" benefits of planting alfalfa may be important.

Phase IV--Solution of the Integrated Problem

For the final phase of the analysis the five individual models were integrated into a single problem as described in Chapter 4. The purpose of this phase was to determine what land transfers might take place, given that the goal was to allocate resources so as to maximize net revenues for the study area as a whole. The imposition of the land transfer balance constraint discussed above insures that total land disposals will equal total land acquisitions and that a determinate solution is obtainable.

Initially a solution was obtained under the assumption that there would be no exogenous restriction on the amount of land that the larger farm sizes could acquire nor on how much the smaller farm sizes could dispose of. However the solution obtained under these assumptions revealed that the large corporate farms would acquire all of the land resources of the two smaller farm sizes. Since this solution, though economically efficient, did not seem too realistic except in an extremely long-run time horizon, an additional solution was obtained; but this time upper bounds on the amount of land which could be acquired or disposed of by any single farm size group were specified. These additional constraints specified that not more than one-half of the 80-acre farm aggregate acreage could be disposed of, nor more than one-third of the total acreage for 200-acre farms. Limits were also set on the amount that any farm size group could acquire. These were specified as 40 percent of the total acreage eligible for disposal.

As before, the solution indicated that land transfers could take place up to the limits set by the land disposal bounds and that the two large farm size groups each would acquire the maximum allowable acreage with the remainder being acquired by the 480-acre size group.

By allowing the transfer of 11,550 acres from the smaller farms to the larger, net returns would increase from $24,635,000 to $24,873,000, or by about 1 percent. This amounts to a $20.60 increase in net revenue for every acre transferred from a smaller farm to a larger.

In terms of the crop output pattern, the aggregate solution shows only slight changes in the acreages of alfalfa, barley and grain sorghum from the optimum solution obtained assuming no land transfers. Table 19 compares the total cropping pattern indicated under the present size distribution with that obtained from the problem solution obtained under the assumptions outlined for this final phase. Inasmuch as barley and sorghum commonly appearing in double cropped combinations are not very different in terms of net revenue returned or water use than alfalfa these shifts can be considered to be of minor importance.

Table 19. Comparative Summary of Crop Acreages and Returns.

	(1) Crop Acreages And Returns Assuming No Land Transfers	(2) Crop Acreages And Returns Assuming Limited Land Transfers
Cotton (acres)	19,402	19,399
Alfalfa (acres)	46,608	46,011
Barley (acres)	48,948	49,488
Grain Sorghum (acres)	50,488	59,955
Bermuda Grass Seed (acres)	9,500	9,500
Lettuce (acres)	17,000	17,000
Cantaloups (acres)	16,000	16,000
Total Acreage All Crops (acres)	207,946	207,353
Net Revenue (dollars)	24,635,408	24,873,400

It can be concluded therefore that the increase in net revenue results primarily from lower production costs enjoyed by the larger farms rather than from shifts in the cropping pattern.

Summary and Conclusions

Phase one of the foregoing analysis has indicated equilibrium levels of output for various crops which are grown within the study area. As might be expected the high value-high return crops account for a substantial proportion of the total agricultural output of the region. Even those crops having lower per acre returns such as sorghum, barley and alfalfa, yield sufficient profits to insure their continued importance in the overall cropping pattern of the region.

Further analysis in the initial phase indicated that under present price ratios and production techniques that additional water could be used productively, particularly on larger size farms. Here fuller use of land resources through increased double-cropping programs would return from $8.29 to $11.71 per acre foot if about 46,000 additional acre feet of water were available. Beyond this amount additional water could also be used to increase alfalfa yields but at a lower price.

The relatively small amount of water which could be profitably used at these prices indicates that additional capital investment in major diversion facilities would probably not be feasible. However this should suggest to larger operators that by more careful use of present water resources they might be able to increase net revenues by small increments.

Analysis of land resource productivity indicates that prevailing prices of agricultural real estate in the area appear to be well in line with the earning capacity of the land resource. Larger farm operators can afford to pay from \$1,500 to \$2,000 per acre for land. This is well above the capitalized income value which smaller farmers might expect based on their present costs and returns. Because the indicated demand prices which expanding operators may be justified in offering is well above the reservation supply price of smaller operators, an active and viable market for agricultural land should prevail and the trend toward increased farm size through consolidation of existing operations or additions to present farmland holdings may be expected to continue.

While transfer of land resources from small farmers to larger operators, either on a permanent or temporary basis would increase net farm revenues for the region as a whole there would be no important changes in the cropping pattern and no significant change in the gross value of farm output were such shifts in land ownership to take place. The major impact would be to reduce the number of farms in the region and to increase the average farm size.

Reclamation of additional lands with presently assured water rights appears feasible and should result in an increase in production of crops such as alfalfa, barley and grain sorghum. However as noted above reclamation of new lands requiring construction of major diversion facilities is not indicated, unless of course, it could be expected that such newly productive land might be used to produce high valued crops such as cotton and vegetables.

Given the present price ratios and level of technology and assuming that the increase in acreage of such crops as cotton, lettuce, cantaloupes and bermuda grass is limited, irrigated agriculture in western Yuma County may be expected to continue to yield attractive profits. However with the reclamation of approximately 70,000 acres of arable lands now having a confirmed water right, expansion of agriculture at the extensive margin will be limited, unless water supplies can be increased.

While under present restrictions reallocation of existing water resources at the intensive margin may shift the cropping pattern from alfalfa to barley-sorghum (or conversely) little change can be expected in the gross value of agricultural output. Unless those crops now limited by institutional factors or market constraints can be increased, or unless new high income enterprises enter the cropping program, the growth of irrigated agriculture in western Yuma County will be limited.

CHAPTER VI

IMPLICATIONS FOR POLICY DECISIONS AND ADDITIONAL RESEARCH

The purpose of this final chapter is twofold: first, to present some brief observations about the foregoing analyses as they relate to broad public water policy questions; and second, to point out areas where additional research efforts might provide fruitful extensions of the results of this study to this and other related problem areas.

Public Water Policy Questions

The management of water resources in the arid west includes a range of problems far too broad to be treated comprehensively in the few short paragraphs to be presented here. Accordingly, the policy questions discussed below should be considered as representative of the types of problems for which studies such as this may be useful in guiding policy makers to appropriate courses of action.

Alternatives to the Central Arizona Project

Perhaps one of the most pressing issues involving a major water policy decision in Arizona is that of determining what use should properly be made of that portion of the State's legal share of the waters of the Colorado River which are presently uncommitted. As noted in the introductory chapter, an active effort is being made to authorize construction of the Central Arizona Project which would divert about

1.2 million acre-feet of water from the Colorado River at Parker and transport it through a 340 mile aqueduct system into Pinal and Maricopa Counties where it would be used to stem the continuing over draft on existing groundwater supplies which are now being mined mainly to support irrigated agriculture in Arizona's central plain.

Construction of these facilities would involve the commitment of large amounts of capital. Some estimates indicate that about $900 million would be required to construct the diversion facilities and canal system.

If the decision as to how this water supply should be utilized is to be based on economic efficiency criteria, then the expenditure of such a large sum should not be made without considering alternative uses for these water resources.

Could a portion of this uncommitted water supply be used more profitably in presently developed areas in western Yuma County? As noted in the discussion of the demand for additional water which appears in the preceding chapter, only about 80,000 acre feet could be used profitably on lands presently under cultivation. And under presently perfected rights, sufficient water is available to meet projected needs on the additional 70,000 acres of reclaimable lands analyzed in Phase III. Industrial and municipal uses no doubt may be expected to expand over the years as urbanization increases. However, it may be assumed that any increase in urban land and water uses will involve a compensating shift of resources out of agriculture and total water use will remain largely unchanged.

Beyond this, however, there must be considered the possibility of bringing additional lands into agricultural use through the development of new reclamation projects. The question then arises as to whether there are sufficient areas of arable land which could be reclaimed for agricultural use at a cost low enough to justify their development.

No comprehensive soil surveys are available which suggest that any such reclaimable areas are of sufficient size to warrant consideration as a major reclamation project. While some areas adjacent to existing irrigation districts are known to contain small blocks of arable lands, these are widely scattered; and because of adverse topographic features it is unlikely that these could be developed to any extent such that additional water diversions would be of major significance.

Some areas in the Butler and McMullin Valleys located in the northeastern corner of the county also contain areas of potentially irrigable land. These valleys lie at elevations of from 1,600 to 2,000 feet--some 1,100-1,500 feet higher than the level of the river at Parker, 80-100 miles away. A project to bring Colorado River water to these lands would involve extensive pumping facilities to lift water from the river level to these upland valley floors. Because the acreages of arable lands in these areas are relatively small, and at present water use rates would utilize only a portion of the water supply available. It is, therefore, unlikely that a delivery system could be constructed at a scale sufficient to reduce unit cost enough to render such a project feasible. Moreover, geologic reports indicate that limited water supplies are available from deep groundwater aquifers which underlie the area. It appears likely that this resource could be exploited at a cost lower than that at which Colorado River water could be delivered.

Other areas in the Cactus and Palomas Plains might also be considered as having potential for reclamation, but again the size of the areas susceptible to development limit the scale of irrigation works and the cost of delivering water for irrigation would likely be greater than that which farmers would be justified in paying.

However, if subsequent investigation by soils experts and other physical scientists indicate that other such areas of sufficient size do exist, then the analysis presented in Phase III could be extended to provide a basis for an initial approximation of estimates necessary to determine the economic feasibility of potential reclamation projects. If the assumptions as to productivity levels, factor inputs, prices and returns to fixed factors were applicable to the analysis of new potentially reclaimable areas then such a reclamation project would be feasible if project diversion and delivery facilities could be constructed at a cost not exceeding about $25 or $30 per acre per year over the life of the project. Further refinement of this estimate would of course be necessary if such proposals were actually to be considered.

Another alternative to the Central Arizona Project might be to sell or lease water or water rights to regions in other basin states which are experiencing severe water shortages. The proceeds from such an arrangement could be used for some public purpose within the state. In other words the State of Arizona could act as a rentier and collect a royalty for use of the state's legal share of Colorado River water regardless of where it is used.

In event that the Central Arizona Project is authorized, this proposal might also be explored as an interim measure to insure both maximum return to the State of Arizona and optimum use of the river flow until such time as actual diversion to Central Arizona begins. Many legal questions would remain to be decided and this proposal would necessitate sweeping changes both in water legislation and public attitudes with regard to water rights.

Such a proposal would not of course be directly applicable to the study area. However, conditions within western Yuma County are similar to those found in the Imperial Valley of California, where present water availability may be curtailed if Arizona were to find some other use for the entire flow to which it has legal right.

If lease or sale of Arizona water were legally possible then the estimates of the marginal value product for water in the study area could be used as an approximation of the price which could be paid for water in the Imperial Valley and other similar areas in California which might face water shortages. This would provide a crude basis for estimating a demand price for water if such a leasing or sale arrangement were possible and would set an upper limit on the amount which could be charged for water.

While ultimately the decision as to what use should be made of Arizona's share of the waters of the Colorado River may be based on criteria other than that of economic efficiency, the opportunity cost of this resource as measured by its potential value in alternative uses must enter any rational decision regarding the appropriate allocation of presently uncommitted water resources.

Farm Size Limitations

Another question for which the results of the study may have important implication regards the limitation on farm size in irrigation districts established under the Reclamation Act of 1902. (32 Stat. 389, 43 USC 416.) According to the provisions of the statute, farm units are to be no larger than 160 acres. In actual practice, however, many farm operations are much larger than this.

Farm operators are able to meet the letter of the law by recording ownership of various parcels of land under several interlocking family combinations of partnerships, proprietorships and corporations. In actuality, however, properties held in this manner are operated as a single farming unit. Aside from the legal issues involved in this type of arrangement, there remains the question as to whether or not the 160 acre limitation is reasonable from society's point of view when measured against the criterion of economic efficiency. Inasmuch as the Public Land Law Review Commission is presently considering needed revisions to the public land laws generally and the agricultural land use laws in particular, this question may be of especial interest.

The analysis completed in Phase IV suggests that even though farms were to be consolidated into larger units, that gross regional output would remain largely unchanged. But because of economies of size accruing to larger farms, the net return per acre would be substantially greater if farm consolidation were allowed or encouraged.

Average unit costs of production would be reduced and farm operators would receive greater per unit profits. Moreover, farm numbers would decline and aggregate farm income for the region would be divided among fewer farmers with the result that average income per farm for the region would increase. This should suggest to policy makers that the 160 acre limitation on farm size detracts from the production efficiency of farm operations in irrigation districts where this limitation applies. Net returns per acre could be increased if farmers were encouraged to expand land holdings and benefit from economies of larger size operations. Since the legal constraints are largely ineffective under present property tenure alternatives, it seems questionable whether the 160 acre limitation continues to serve any useful purpose.

Aside from the question of economic efficiency, however, the farm size question has several other socio-economic implications. Increasing farm size will have an impact on certain elements of the farm supply sector. This will be particularly true for those businesses supplying resources which can be used more intensively by larger farms such as farm machinery and short-term credit. Greater opportunities for vertical integration between agricultural production and marketing firms may result in other changes in allied agricultural services.

The social structure of agriculture may also feel the impact of increasing farm size. As net income per farm increases, farmers may change their residence and spending patterns. Possibly these effects will widen the disparity in incomes and changes will occur in the types and quality of public services which are now provided. These latter considerations are mentioned to emphasize that policy makers may wish to evaluate the results of their actions in terms of criterion other than economic efficiency.

Administration of Water Distribution

The results of the study might also be useful to irrigation district administrators in determining district policies with respect to such things as water charges, allocation of surplus water, or shortages during peak water use periods. Possibly systems for water transfer from one farm to another within a given district could be developed or perhaps interdistrict water transfer agreements could be reached. The study provides a basis for determining transfer prices if such a water market were to become a reality.

Opportunities for Additional Research

The preceding section has discussed several areas where this study may be useful in formulating public policy decisions. It is readily apparent that many additional complex water policy problems remain to be faced. It is appropriate, then, to point out some of the more obvious shortcomings of this research effort which the author, in retrospect, has become aware; and to suggest possible areas where additional research efforts may prove fruitful.

The large amount of primary data which was collected to provide a basis for this dissertation have proved useful in developing the input-output relationships for the various farm models designed for this study. However, in some cases more careful estimates of resource needs--particularly with respect to water--would have been desirable. Of particular importance is the accuracy of field estimates of the volume of water needed by the various crop enterprises as opposed to the amount which is applied. A more careful estimate of the production function relationship between water and product output is necessary to refine the problem inputs. Particular attention should be given to problems associated with timing of water application.

Better estimates of water availability for individual farms, as well as for the area as a whole, would result in better resolution of the programming solution.

Additional definitive data about the extent and location of other potentially irrigable lands is necessary in order to estimate total demands for limited water supplies.

Better estimates of prices and price elasticities for the high revenue activities would enable more careful estimates of the acreage of market restricted crops to be made.

Several assumptions which were made to simplify the analytical model used for this study might be examined in more detail. Consideration might be given to alternative government programs for cotton and how these might affect resource use and output. Alternative designs of the model might be considered to include any of the following variables: soil productivity differences, crop rotations, integration of livestock enterprises, alternative levels of management, administrative differences between irrigation districts, different price levels for both factor inputs and product outputs.

More careful consideration might be given to the indirect or secondary effects of economic changes which may be expected to occur, such as the impact on agricultural support sectors, changes in the social structure of both the agricultural and non-agricultural segments of the population, and changes in income distribution.

Finally, it might also be useful to examine the present institutional framework relating to water and administration of water resources. The impact of economic change on these institutions may suggest possible alternative methods of dealing with water resource problems in the arid west.

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