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Water Supplies and Cost in Relation to Farm Resource Use Decisions and Profits on Sacramento Valley Farms

by

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WATER SUPPLIES AND COSTS IN RELATION TO FARM RESOURCE USE DECISIONS AND PROFITS ON SACRAMENTO VALLEY FARMS

1. Enterprise Choices, Resource Allocations, and Earnings on 1,280-Acre Rice Farms in the Central Sacramento Valley

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FOREWORD

This report focuses on the rice farming phase of an investigation into how water quantities and costs affect enterprise choices, resource allocations, and profits in the Sacramento Valley. The investigation was authorized under California Agricultural Experiment Station Project Number 1321-07-10. Support for the research leading to this report came from the OFFICE OF WATER RESOURCES RESEARCH, USDI, under the program of Public Law 88-379, as amended, and by the University of California, Water Resources Center. It is a part of the Office of Water Resources Research Project No. B-068 CAL as well as the California Water Resources Center Project UCAL-WRC-W-111.

This over-all investigation, under the title, "On-Farm Irrigation Water Supplies and Costs in Relation to Cropping Systems and Production Adjustments in the Sacramento Valley," also includes a second phase that centers on the southern Sacramento Valley. A report on this additional research, now nearing completion, will bear the title, Water Supplies and Costs in Relation to Farm Resource Use Decisions and Profits on Sacramento Valley Farms; 2. General Crop Farms in the Southern Sacramento Valley.

The author acknowledges his debt to the many individuals and organizations who contributed importantly to the success of the research that led to this report. Ralph Hanan and Raúl Fiorentino, at the time of their contributions Research Assistants in the Department of Agricultural Economics at Davis, bore primary responsibility for the statistical work. Hanan aided in Collecting and processing the field and secondary data, and did the planning and operation of the programming and other analytical procedures. Fiorentino assisted in completing the statistical work on this report, and, particularly, in final refinements of both the data and the exhibits that appear herein. Craig Boyer also shared in the statistical analysis.

Many people provided data, viewpoints and/or advice and judgments that were essential for pursuing and completing the analyses reported here. I also drew heavily on work published by researchers and other personnel in the California Agricultural Experiment Station and Agricultural Extension Service, the Department of Water Resources, the United States Department of Agriculture, the Agricultural Stabilization and Conservation offices in the rice-producing counties, the County Agricultural Commissioners' offices and other state experiment stations, as well as on some unpublished data that became available to me.

I am particularly grateful to W. O. Pruitt for making available experimental results on evapotranspiration rates and water use for crops, to Milton Miller for his valuable counsel and suggestions. Thanks, too, to many other individuals in County Agricultural Extension, Irrigation District, County Assessor's, and individual business firm office for a great deal of information and many suggestions. The farmers who furnished information in formal interviews, and on other occasions, merit special thanks; it is only through their cooperation that it was possible to obtain critical technical farm organization and operating information.

SUMMARY

This study of 1,280-acre rice farms in the Butte-Colusa subarea of the Sacramento Valley focuses on the economic impacts of variations in available water quantities and costs on farm earnings and profits (see pages 10-22). It examines three farm models each representing an important rice-growing soil and reflecting the dominant organization and operating characteristics of 1,280-acre rice farms in the study. Total irrigation water available approximated 5.75 acre-feet per acre for 60,000 acres of basin land, and 6.75 acre-feet per acre for 104,000 acres of alluvial soils. Cost rates per acre varied from about $10.00 to approximately double that level for rice and usually ranged from $4.00 to $5.00 per acre for other crops, except pasture rates for which crops were $1.00 to $1.50 higher. Price levels, acreage allotments, and other politico-economic aspects of the context for the investigation reflect the middle 1960's (1964-1966). The analysis draws on latest research information concerning irrigation practices for rice to evaluate differences in water quantities and costs, yields, and net returns for each of these varying irrigation practices. It undertakes to relate these irrigation practice phenomena to total farm earnings and profits for each of three major categories of soils commonly used to produce rice. Growers in Butte and Colusa counties normally produce 45 to 50 percent of all the rice produced in the Sacramento Valley, and 40 to 45 percent of California's total production. The rice acreage concentrates on the basin and old alluvium soils, but extends onto the more recent alluvium soils to some extent. Differences among these three soils in soil structure, water permeability, and adaptability to crops other than rice made it necessary to include three models in the analyses, one for each of the basin, old alluvium, and new alluvium soils, in order to reflect properly the physical and economic results of these variations.

The study analyzed three rice irrigation practices: (1) deep flooding, not lowered; (2) deep flooding, lowered; (3) shallow flooding. The first practice was standard for rice in California while land remained unlevelled, dikes contoured, and checks irregular in shape. Both deep flooding lowered and shallow floodings, however, expanded during the 1960's as farmers leveled their fields, established uniform slopes and rectangular checks.

Knowledge accumulated through their own experience and experimental research has encouraged rice growers to introduce and expand those practices. Deep flooding remains the most general practice in growing rice, however, at the time of this study. The three practices for irrigated crops other than rice differ according to the percentage of available soil moisture depletion permitted before reirrigating: (1) dry, 100 percent; (2) medium, 80 percent; (3) wet, 60 percent.

Total average investments for 1,280-acre rice farms range from nearly $700,000 for the basin model to over $800,000 units on recent alluvium. Capital represented by land dominates these total investments. These relatively high capital investments also mean large annual fixed costs, whether expressed on the total farm or the per acre basis. Such costs of owning and maintaining the capital range from about $81,000 total farm and $68.00 per acre for the basin, to over $91,000 total farm and $77.00 per acre for the recent alluvium models. The high original and average investments required for power units, and for dikers, harvesters, and other machinery large enough to permit operators to use power and labor efficiently, largely explain why this study focuses on 1,280-acre rice farms; the 400 to 550 acres of rice possible on a unit of this size (depending on acreage allotment regulations), constitute enough acreage to use most of the unit capacity of such efficient machinery.

An analysis of net returns-over-variable expenses for rice, and other adapted crop alternatives showed that, with fixed costs ignored, rice yielded net returns per acre at double or greater the level of crops ranking next highest in earnings on all three of the soils studied. These returns range from $219.00 per acre for the basin soils under a deep-shallow treatment to $184.00 for the deep flooding irrigation practice. The same relationships, with somewhat higher per-acre returns, held for rice on the other two soils. These results, particularly for rice, reflect results of applying latest research knowledge and technology under careful water management and control on levelled land with rectangular checks. The physical inputs, production expenses, and prices for rice are those in effect during the late 1960's. Acreage allotments, however, represent 40 percent of tillable land on these 1,280-acre analysis models. Rice yields reflect superior management, as well as the advantages of latest research technology; they range from 60 hundredweight per acre for the deep flooded irrigation to 68 hundredweights per acre for the other two methods on basin soils to a spread from 65 to 72.5 hundredweights per acre on the two alluvial models. These yields compare with the state average for each of the 1969 and the 1970 seasons at 55 hundredweights, per acre. The differential between this statwide average at 55 hundredweights, and the yields used in the analysis of these three soils, represent the premium on up-to-date technology based on the latest research, optimal water control and management, and sound decisions and management by the operator.

A series of linear programming analyses within the framework of 28 constraints evaluated the potential effect on total farm net returns-over-variable expenses of varying water quantities, water prices, and prices for rice. The constraints relate to seasonal totals and intraseasonal water quantities available, total tillable land, and the maximum acreages of individual crops within this total, and harvester hours per season. This analysis yielded the total farm net returns-over-variable expenses, ignoring fixed costs. A comparison of this total farm net receipt figure, under varying conditions of water quantity and price as well as rice prices, with total farm fixed costs identifies the "breakeven" level at which these farm receipts exactly cover fixed costs. This level includes interest on investment at a market rate but leaving no income or profit to management.

Total farm net returns-over-variable expenses decline sharply as water prices rise from zero to the highest price tested in the analysis. The highest water prices at which total farm net income would cover fixed costs and leave a postive return to management are $15.00 per acre-foot for basin, $14.00 for old alluvium and $21.00 for recent alluvium income in the linear program analyses under these specified optimal management, technology and allotment conditions. These analyses apply the high performance yields and 40 percent acreage allotments used in this study. Rice growers would find production quite profitable, however, at prices in the vicinity of $7.00 per acre-foot, provided their rice yields and acreage allotments remain at these high performance levels. Total farm net returns drop sharply on basin soils for each dollar of rise in the earlier increments of water prices. A drop of nearly $22,000 in net returns accompanies a rise in water costs from zero to about $8.00 per acre-foot, this means about $2,800 decline in net returns per dollar rise in water prices.

Another analysis examined the effects on total farm net returns-over-variable expenses of increasing total seasonal water quantities available from zero to the maximum level associated with increases in net returns. The results clearly show that rice has a high advantage over other irrigated crops on all three of the soils in the Butte-Colusa rice subarea. The results also indicate that the increases in total farm net returns per acre-foot of irrigation water added is extremely high for the initial increments up to about 2,500 acre-feet on the basin, 4,200 acre-feet on the two alluvial soils. The greater adaptability of these latter two soils as compared with the basin, soil with acreage allotments in effect for rice, explain the larger quantities of water that the alluvial soils can use effectively in expanding total farm net returns. It is due to this same crop adaptability advantage, that the two alluvial soils are able to use profitably 4,300 and about 5,000 acre-feet of water, respectively, for the old and recent alluvium, as compared with about 3,000 acre-feet for the basin soil at maximum total farm net returns with irrigation water price at $1.25 per acre-foot.

An analysis of shifts in land use and cropping patterns as quantities of water available rise progressively from the zero level, further confirms the economic advantage of rice over other crops on farms in this subarea. The cropping system on 1,280-acre non-irrigated farms would include barley 354, wheat 354, safflower 236, fallow 118, and idle land 118 acres; this pattern would apply on all three farm models, regardless of soils. Rice would yield the highest returns for all water increments on basin soils until the entire 472 acre allotment is reached. There would be some shifts in rice acreages among irrigation practices as water quantities increase. Grain sorghum would enter the basin cropping system after water quantities exceed rice requirements.

The two alluvial soils reflect their greater range of crop adaptability as additional increments of irrigation water become available, beginning with zero quantities. Beans, a crop with minimal water requirements as compared with rice, appears before rice, and occupies the 177-acre maximum within the acreage constraint applying to this crop at maximum water availability on both of these soils. Sugar beets, again subject to its own constraint, comes into the cropping system at maximum water availability levels on the recent alluvium.

The pattern of change in land use and cropping patterns as water prices drop from levels initially so high as to prohibit use for irrigation is quite similar on all three soils. These relationships resemble those exhibited as water quantities rise at the fixed price of $1.25 per acre-foot. The first shift from the non-irrigated cropping system brings in rice on the basin, and dry beans on the two alluvial soils; the alternate cropping system with water prices at $7.00 per acre-foot or lower is the same for all three soils as at maximum water use with prices at $1.25 per acre-foot.

Budget analysis comparisons demonstrate clearly that operators producing rice on each of the three 1,280-acre models, according to soils, in this study would earn quite satisfactory profits under the cost and price conditions of the late 1960's provided that they have acreage allotments representing 40 percent or more of the tillable land, and that they can maintain yields at the high performance levels used in this study. Thus the basin soil model would return its operator nearly $100,000 in net farm income. This amount would represent nearly $92,000 of profit to this operator after he has allowed himself $7,700 of wages (the same figure that he pays his hired employees). This total profit would represent $44,600 as interest on the capital that the farm employs calculated at the market rate of 6.5 percent, plus $46,900 as a return to the operator for risking this capital and for performing other management functions. This operator, alternatively, can express his $92,000 profit figure as a percentage of his total farm capital; the result is a 13.4 percent rate of return. Similar earnings at satisfactory levels would accrue to operators on the two alluvium soils under the same set of cost, price, and acreage allotment conditions, combined with high performance yields.

Unfortunately these high performance yields, reflecting a combination of technology based on the latest research knowledge, efficient water application and control, and optimum management, are not typical of California rice operations. The 40 percent acreage allotment for rice also is distinctly higher than the level typically available to California growers during recent seasons.1/ The statewide average rice yields of 50 hundredweights per acre, at an acreage allotment representing about 30 percent of the tillable land on the rice producing farms represent a much more typical condition for most basin soil rice farms. The total profit of $38,700 on such an operation would lack $5,900 of covering the entire 6.5 percent interest allowance on farm capital. Thus the operator would lack $5,900 of getting any return at all for assuming capital risks and would receive nothing to pay him for performing management functions!

Similar analyses of farm earnings and profit for the two alluvial soils yield similar results. The rice grower on such soils would receive positive returns to risk capital and management with a lower (30 percent) acreage allotment and rice yields at 55 hundredweights per acre. This total management income would amount to only about $14,000, after setting aside allowances of $48,800 for interest on his capital invested at an assumed market rate of 6.5 percent. Such a level of management income for managing and operating a three-quarters of a million dollar business, and for assuming the uncertainties and risks involved in using capital for this purpose, is a decidedly more favorable return to the manager than the negative income to the operator on the basin farm. This $16,000 management income, however, probably is not comparable with the level of income that managers of three-quarters of a million dollar nonfarm businesses commonly expect to receive. This analysis of earnings indicates clearly, first, that the typical California rice grower with acreage allotments and yields below the 40 percent and 60 to 72 hundredweight levels receives decidedly lower incomes to capital and management than those indicated in these analyses

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1/ An announcement by the Secretary of Agriculture on 6 August 1971 but later rescinded on 20 December 1971, would have reduced 1972 allotments 10 percent under those for 1971. Total U. S. allotments had been set at 1,652,600 acres, and California (estimated) at 299,800 acres by this announced cut. California's Butte and Colusa County growers would have been able to plant in 1972 only about 35 percent of their total rice land, had this 6 August rule stood. The cut would have been even more serious for many individual growers, probably to about 30 percent of their suitable cropland.

for the models with high performance yields and 40 percent acreage allotments. It also is evident, in the second place, that farmers could better afford to pay in the range of $7.00 per acre-foot for their water, if this price is accompanied by a 40 percent acreage allotment, than to operate with a 30 percent allotment and water prices at $1.25 per acre-foot.

A final linear programming analysis established the effects of varying rice prices on, first, the acreage and production of rice on these 1,280-acre models, and, second, total farm net returns-over-variable expenses. It would be profitable for farmers to introduce rice into their cropping systems in the Butte-Colusa subarea at prices of $2.55 to $2.62 per hundredweight under the conditions of this study. This analysis shows, furthermore, that under the conditions of this study only shortages of water would keep rice from preempting practically all of the tillable acres on these farms as rice prices rise further to a range between $3.00 and $4.00 per hundredweight. Physical and biological factors whose effects this study does not identify nor measure probably would intervene to check rice acreage much short of levels considering only price rises for rice. These data do suggest, however, that rice acreage at somewhere in the range of 40 to 50 percent of total tillable land would represent a sound cropping system in this area, provided water supplies are adequate, and, that farmers apply the most efficient technology based upon up-to-date research.

WATER SUPPLIES AND COSTS IN RELATION TO FARM RESOURCE USE
DECISIONS AND PROFITS ON SACRAMENTO VALLEY FARMS

1. Enterprise Choices, Resource Allocations, and Earnings on 1,280-Acre Rice Farms in the Central Sacramento Valley

Trimble R. Hedges*

THIS STUDY ANALYZES HOW VARIATIONS IN IRRIGATION WATER QUANTITIES AND/OR COSTS AFFECT FARM DECISIONS AND RESOURCE USE, HENCE EARNINGS, ON 1,280-ACRE RICE FARMS

The Analysis Involves a Broad Range of Resource Allocation and Technological Decisions

This study has as its primary over-all objective to establish economic guidelines that farmers may use effectively when making decisions on crop choices, land and other resource allocations, and related production technology and methods. The actual procedures and analysis center on three specific objectives underlying the broad over-all objective of the study.

1. To identify the physical attributes of irrigation water supplies in the Sacramento Valley. This information is esential to establish current cost structures, flexibility components, uncertainty elements, and long-term trends in water supplies, and to determine the physical and economic characteristics of supply schedules for irrigation water.

2. To establish: (a) the physical input-output relationships for water and crop yields in producing adapted crops, within relevant output ranges; (b) the impact of prices for products and costs for input factors upon water allocations among such crops; (c) the effects of alternative irrigation practices on yields and production input costs; and (d) combinations in which different crops will fit together to form cropping systems under varying water supply conditions.

3. To establish appropriate criteria and effective analysis to: (a) guide choices for particular cropping systems; (b) evaluate opportunities for adjustments and limitations on such adjustments, including irrigation practices; (c) maximize earnings and profits.

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The analytical approach centers attention on irrigation water quantities and costs as dominant issues in farm operations for an area where precipitation during the summer months is totally inadequate to permit economic production of any nonirrigated crop. Thus the analysis undertakes to establish and measure, on the one hand, how variations in water quantities and irrigation practices affect physical output and net dollar returns under constant price conditions for rice and other alternative crops. It also examines on the other hand the impact on such net returns that varying water prices (costs) exert. The analysis could not ignore other important phenomena and problems in the physical-institutional-economic context within which the rice farmer must operate. The complete analysis considers, therefore, such additional profit-affecting factors as prices for inputs other than water, and also for rice and other farm outputs. It also considers the more important production-and-market-regulating forces such as allotments under the Federal Agricultural Stabilization and Conservation Act, institutional and other informal marketing constraints, and historical evidence as to market capacity for certain products.

Not only farmers planning and managing rice production operations, but also many agencies, firms, and individuals providing farmers with goods, services or other production and/or marketing needs should find these results useful. These findings relate most closely to the prices, production technology, and general condition that prevailed during the mid- to late 1960's, the time period to which most of the data used in the analysis apply. Concerned users should find, however, that with appropriate adjustments the results of this investigation will aid in decisions, and in planning and executing rice farm operations, under conditions that differ from those of the latter 1960's. This same comment is appropriate concerning the farm model to which these findings relate. The analysis focuses on a 1,280-acre farm size with characteristics that reflect those most common or typical in the geographic area studied. But, with certain adjustments, farmers or others concerned with other sizes of operation should find these results useful. The analysis centers on this particular size because the 400 to 550 acres of rice normally associated with such a total farm acreage fit well within the unit capacities of certain equipment, notably the diker and the harvesters (see page 22). Here again, relatively simple adjustments can bring the analytical results into a framework geared to farms of differing sizes. Another feature of this study is the attempt that it makes to evaluate the possible range of gains in profits that farmers may obtain by putting latest research findings and technology into use. Thus the analysis compares the relative returns per acre and in total farm profits under alternative rice irrigation technology and practices.

The two major analytical tools that this investigation employs are 1) linear programming, and 2) budget analysis. It was possible with these tools to accomplish five specific steps essential to the study's ultimate objective:

1. Construct a farm model that will typify modal characteristics for a specific farm organization and size under specified conditions, in order to identify and measure how varying water supply and cost conditions affect total farm performance and profits.

2. Construct complete input-output models for all production materials and services; determine total revenue, aggregate variable expenses, and net returns-over-variable expenses for each alternative crop; relate these basic facts to relevant resource, economic, and institutional conditions for the farm model.

3. Identify economic choice criteria governing crop selection and resource allocations; develop effective measurement techniques for the purpose of maximizing enterprise and, ultimately, total farm net profits.

4. Establish the relationships between irrigation water supply and costs, and seasonal availability characteristics, on the one hand, and the critical resource use and earning features of the total farm business, on the other; consider the influence of varying supply and price conditions for other critical resources and for important farm products.

5. Explore the opportunities for adjusting the farm organization to variations in availability and cost of water, and to changes in other major institutional and economic forces affecting farm organization and earnings.

Earlier Work Provides Essential Background Data for This Investigation

Rice research in California has emphasized variety selection and breeding, fertilization, irrigation, pest control; all are important subject matter areas. The work on irrigation has particular relevance to this study, however; this is because problems of water quantities and prices represent the central issues in this analysis. Some recent research on weed control problems and fertilization under varying irrigation practices also has special significance to this study, due to the impact of such variations in weed control and fertilization practices on irrigation requirements and costs. Other research on biological problems and production technology in rice has also contributed heavily to the data used, the methods of organization, and the analytical approaches in this investigation. But the impact of this biologically-oriented research expresses itself primarily in the choices and quantities of specific inputs, and in the technology that the input-output analysis in this study reflects. We do not undertake to evaluate the economic implications of research findings other than those concerned expressly with irrigation.

Adams [1] reported some of the pioneer work on rice irrigation in California. He concluded from irrigation experiments during the years 1914 through 1919 that about five feet of irrigation water is an adequate seasonal total to produce rice on the principal rice soils in the Sacramento Valley (clays and clay adobes of the Willows, Stockton, Sacramento, Capay, and Yolo series). He also found that, "The previous loam soils require an excessive amount of irrigation water and, from a water standpoint are not suitable for rice growing." More recent experience, and current practice in the Sacramento Valley, substantiate these findings as well as Adams' other observations that about one-third of the water applied to rice evaporates into the atmosphere, and that farm operators vary widely in the quantities of water that they use in growing rice. Adams reports, on this latter issue, that 43 full-season measurements from 1914 to 1918 revealed a range in quantities applied from 3.91 to 18.70 feet per acre. Wide ranges in water use still exist in the Sacramento Valley rice area.

Oelke [23] and [24] cites evidence from experiments in 1963 through 1967 that a combination of shallow irrigation along with herbicide applications to control weeds, particularly water grass, results in higher rice yields than those possible from deep irrigation. He indicates, also, that reduced fertilizer applications tend to increase the yields under the shallow irrigation (one to two inches deep), as compared with the customary deeper flooding practices (six to eight inches average depth). Both Adams' and Oelke's work provided highly important technical information for the analysis in this study; it is basic to the assumptions and the alternative production technologies and resource combinations that our analysis employs. Our analysis of comparative profits according to different levels of rice yields and acreage allotments provides some evidence as to the economic importance of yield-increasing technology for rice.

Much of the research concerned with rice varieties, fertilization, pest control, and other technical aspects of rice production appears in circulars, leaflets, and the monthly periodical, California Agriculture. Thus Davis' [7] circular represents one of the earlier general reports on rice and its production in California. Leaflets by Mikkelsen, Finfrock, and Miller [21]; Finfrock, Raney, Miller, and Booher [10]; Thysell, Miller, and Booher [29]; and by Burton, Grigarik, Hall, Lange, Swift, and Webster [4] include recommendations on rice technology in the areas of fertilization, water management, varieties and seed selection, and pest control, respectively.

Studies concerned with the economic aspects of rice production range from the (processed) "Sample Rice Costs" that Lindt [19] prepared for growers in Placer, Sacramento, Sutter, and Yuba counties in 1966 to Grant's [12] sophisticated analysis on evaluating government program costs for rice, the latter being a cooperative study in 1969 involving the U.S.D.A. and Texas A. & M. University. Sitton's [27] Sacramento Valley study in 1958, a systematic analysis of organization, costs, and returns, provides basic information on resource use, technology, production costs, and returns during the late 1950's for Sacramento Valley rice farms, including a range of from 150 to 600 acres of rice. A more recent series of analytical reports dealing with problems of farm organization, risk, and economics of size in tractor and labor combinations under Arkansas conditions was released in 1969 by Hottel, Grant, and Mullins [16 and 17]. A leaflet by Sitton, with Reed and Davis [26], considers possible adjustments to controls, and one by Mehren [20] examines the broader questions relating to government policy for rice. All of these studies deal with economic questions and issues important to farmers and others involved in the rice industry. None seeks to attain the specific objectives of this investigation, however, although individually and collectively they do contribute to such goals.

PHYSICAL RESOURCES, PARTICULARLY SOIL AND WATER, STRONGLY INFLUENCE CROP PROFITS

Land and Soil Characteristics are Critical

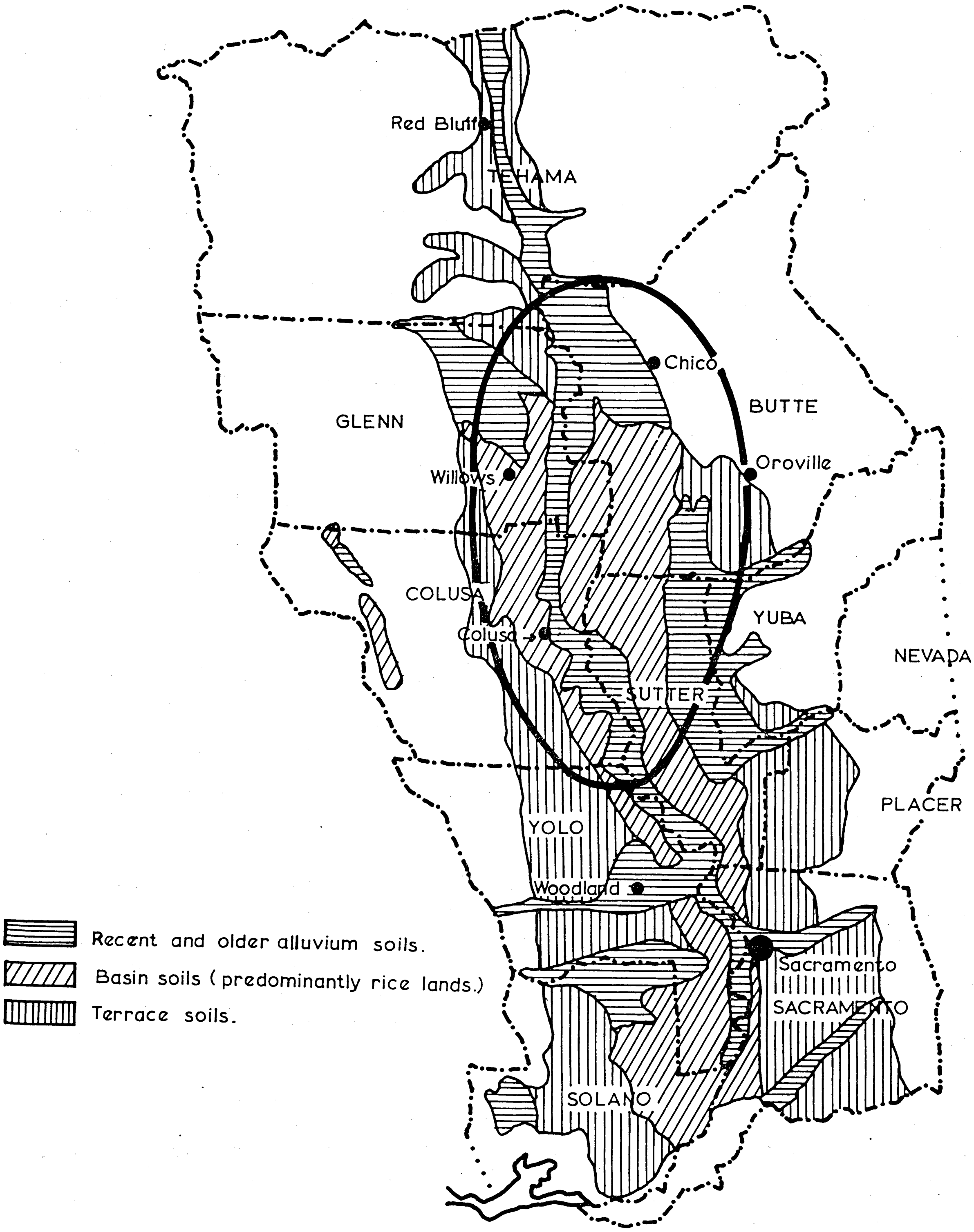
That section of the Mid-Sacramento Valley that the Chico, Colusa County [18], and Oroville [34] soil surveys include in their reports provides the physical setting for this investigation of Sacramento Valley rice farming. This study does not undertake, however, to examine the economic aspects of profitable farm operation for all soil types in this over-all area. It focuses, instead, on the heavier and more poorly drained soils on which rice enjoys unique advantages over other alternative crops, and on only two of the several counties in the Sacramento Valley that are important rice producers. These three surveys provide soil inventory and classification data for western Butte County (Chico and Oroville surveys), and Colusa County (Colusa County survey) (see Figure 1). Sources in Butte and Colusa counties provided most of the data for the analysis in this study, but some information on irrigation water supplies did come from Glenn County.

The three reports, in combination, furnish information on about 1,33,000 acres of which slightly more than half is in Colusa County. The remaining acreage divides almost equally between the Chico and Oroville survey reports. Alluvial soils account for about 55 percent of the total land in the general area that these surveys cover. The proportion of such land in the total for Butte County, nearly 60 percent, slightly exceeds that for the Colusa survey; the latter reports shows approximately one-half of all land that is alluvial.

This study centers primarily on the soils that farmers commonly use to produce rice; this means it largely excludes the Grades I and II soils according to the Storie Index. It includes, instead, Grades III, IV, and V soils in the basin, older alluvial, and, to a limited extent, more recent alluvial soils in the aforementioned western portion of Butte County and eastern portion of Colusa County.

FIGURE 1

SACRAMENTO VALLEY STUDY AREA
AND GENERALIZED SOIL MAP



Butte County has slightly fewer than 160,000 acres of such soils, predominantly in the Storie Index Grade IV classification, and of Stockton or Landlow clay or clay adobe series (see references 16 and 18 above). These grades III, IV, and V soils represent about 25 percent of the total acreage covered by the two Butte County surveys combined. During recent years, subject to government acreage limitations that vary somewhat from one year to another, rice usually has occupied from 33.33 to 40 percent of this acreage, with other grains and safflower accounting for most of the other land in crops. Actually, the total acreage in other crops tends to be somewhat less than that in rice, while approximately an equal acreage usually is in fallow or lying idle.[2/]

The alluvial soils on which farmers usually grow rice in Colusa County show a wider range of Storie Index Grades (III, IV, V) than those in Butte County. They also represent a larger proportion of the total alluvial soil resources in the Colusa County survey, about one-third of all land as compared with about 25 percent in Butte County.[3/] In Colusa, as in Butte County, other grains and fallow occupy most of the land not in rice during any particular season. Here again, during recent years, rice has accounted for about one-third of the crop acreage for this rice-growing area west of the Sacramento River.

In summary, this investigation centers on the rice-growing, predominantly basin and older alluvial soils in Central California and draws most of the data used in the analysis from Butte and Colusa counties. These soils, lying on either side of the Sacramento River, are quite similar in

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2/ Grades I and II soils, approximating a total of 200,000 acres, accounted or about one-third of all land in the two Butte County surveys combined. Such lands lie largely to the north, but include some acreage to the east, of the Grade IV (basin) soils that farmers commonly use to produce rice. These latter rice soils occupy about 156,000 acres in the county, or approximately 25 percent of the land in the Chico and Oroville soil surveys combined.

3/ Grades I and II soils in Colusa County include about 133,000 acres of land or approximately 20 percent of all soils included in the report; they lie largely to the west of the rice growing area. The basin and old alluvium soils are mostly in Storie Grade IV through V (about 225,500 acres) but include about 23,200 acres of Grade VI basin soil in their total area of 248,700 acres.

physical characteristics (Figure 1 and references 6, 18, 34). They range in texture from clayloam through clays to clay adobe. Along with heavy textures, these soils manifest the characteristics of limited water percolation, poor drainage, and problems in management [33]. These characteristics tend to limit the number of profitable crops adapted to the area, hence the range of choices that farmers have in crop selection.

It was noted above that other grains, plus safflower, occupy most of the land in crops other than rice in the area studied; also that an acreage about equal to either that in rice or in the other crops combined, usually lies fallow during any given season. This holds for these soils in both Butte and Colusa counties. Limited crop adaptability on the so-called rice soils, plus the restrictions on rice acreage imposed under government income support programs, and a number of other less specific problems, all combine to present a relatively unique set of farm problems to growers operating on these soils. Nor is this problem limited to rice growers on such soils in the two counties cited here. On the contrary, these two counties combined in 1968 included 48 percent of the rice acreage in Sacramento Valley and 43 percent of the total in California. They accounted for 185,100 acres of rice harvested (with a total production of 9,841,200 cwt.) out of a total Sacramento Valley acreage of 383,600 acres (20,848,200 cwt.) and a State total of 432,000 acres (23,328,000 cwt. [5]).[4/] These same two counties, in 1972, included 138,300 acres or 42 percent of California's total rice acreage. Most of the total California production is in the Sacramento Valley; other important counties in this valley, with major areas of similar soils and sizable rice acreages during 1968, included Sutter 80,200 acres; Glenn, 57,800; Yolo, 30,900; Yuba, 16,800; and Sacramento County 12,800 acres. Comparable acreages for 1972 were 55,700, 45,000, 21,600, 15,400, and 9,900, respectively.

In Colusa County, and also to a considerable degree among various of the other counties cited in the preceeding paragraph, farmers produce rice

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4/ The California Crop and Livestock Reporting Service reported in California Field Crop Statistics, 1959-68, issued June 1969, that Butte County had 66,000 acres in rice during 1967 and 77,100 acres during 1968. The comparable data for Colusa County were 89,900 in 1967 and 180,000 during 1968.

on several different types and Storie Index grades of soil. Thus, Colusa County during most seasons includes a sizable acreage of rice grown on older alluvial and, to a limited extent, newer alluvial soils, as well as that on basin soils. Soils of these different types and Storie Index grades differ, sometimes importantly, in physical characteristics and adaptability for profitable crop production. It is necessary, in this study therefore, to analyze separately the basin, older alluvial, and recent alluvial soils when studying the impact of variations in irrigation water prices and quantities available on optimum decisions and resource allocations.

Climatic Factors Exert Important Influence

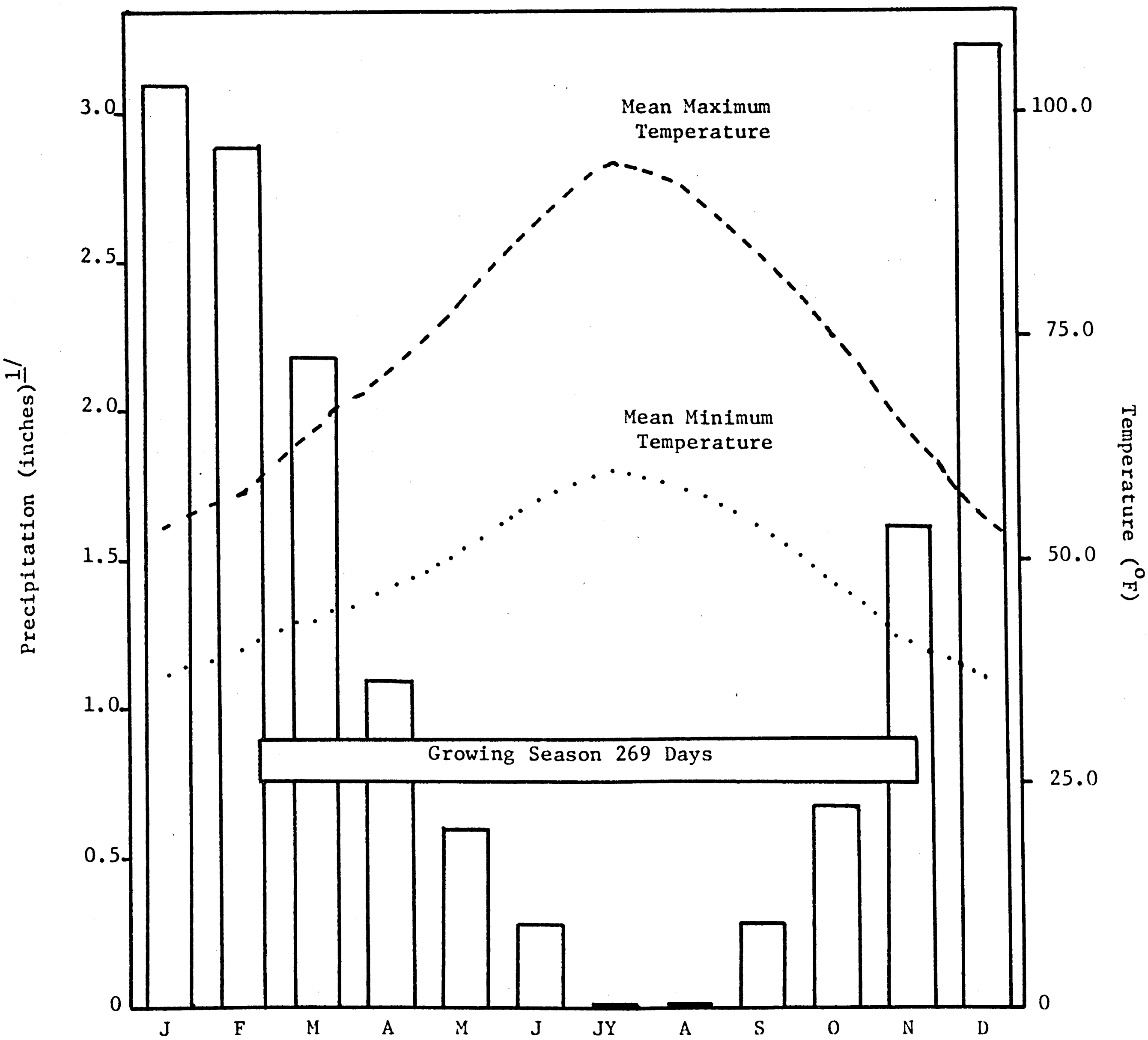
Sitton has pointed out that, in general, climatic characteristics favor rice production in the Sacramento Valley [7]. Butte and Colusa and the other rice-growing counties of the valley (as well as those in the San Joaquin Valley to the south) all have long growing seasons with equable temperature levels. This subarea of the valley has only two climatic limitations; first, normal precipitation during the growing months is entirely inadequate to produce rice (or other summer growing crops) without irrigation, using ground or surface water; second, inclement weather during the period from late September through November may lower quality, reduce yields and/or increase harvesting costs (see Figure 2). The 242-day normal growing season, beginning in April and ending in early September, is long enough for rice to develop and mature. Farmers drain and dry their fields during September in normal years and complete harvest by the end of October. Unseasonable or heavier-than-usual storms during October may delay harvest sufficiently that storms normal for November and later months cause losses or increased cost.

Low-Cost Water Favors Rice Production

Surface water from the Sacramento and Feather rivers represents by far the major source of irrigation water for rice farmers in the study area. Irrigation districts, organized for this purpose, furnish the greater part of this water. Some farmers also obtain additional irrigation

FIGURE 2

PRECIPITATION, TEMPERATURES, AND GROWING SEASON
COLUSA, CALIFORNIA



1/ Annual 15.16 inches

Sources: Climatalogical Data, U.S. Weather Bureau; Period Averages water from incorporated or unincorporated mutual water companies and from private firms. The State Department of Water Resources reports the following California water districts together with the acres of irrigated cropland served according to counties [8]: Butte County: Biggs-West Gridley Water District, 29,000 acres: Butte Water District, 14,000 acres; Richvale Irrigation District, 25,000 acres. Colusa County: Colusa County Water District, 30,000 acres; Glenn-Colusa Irrigation District, 150,000 acres (Colusa and Glenn counties); Princeton-Codora-Glenn Irrigation District, 11,700 acres. Water quantities available to some of these districts are relatively large in relation to acreage served. This is particularly true for irrigated land on the western side of the Sacramento River. Thus water diversions for irrigation purposes by the Glenn-Colusa Irrigation District averaged about 960,000 acre-feet during the four years, 1963 through 1966.5/ Of this total, about 180,000 to 185,000 acre-feet represented recaptured drain water while the remainder came directly from the Sacramento River. On the east side of the Sacramento River the Richvale Irrigation District reported about 127,000 acre-feet of water diverted in 1964. This district delivered 114,000 acre-feet of this water to farmers for irrigation purposes [9]. The Butte Water District reported total diversions of about 118,000 acre-feet of which 116,000 was for irrigation purposes during 1966.6/ Both these latter districts purchased small amounts of these reported totals.

Information available for the Glenn-Colusa (Colusa and Glenn counties) and Richvale (Butte County) districts during 1964 provide a clear indication of both the crops using this water, and the approximate amount of water that growers applied per acre on these crops. Thus in Colusa County 106,200 acres of crops received irrigation water and rice acreage represented almost 65,000 acres (about two-thirds) of this total. In addition, 32,350 acres of normally irrigated land remained idle or fallow as did nearly 4,000 acres of land normally dry-farmed.7/ The Glenn-Colusa Irrigation District reports

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5/ Information available through courtesy Glenn-Colusa Irrigation District, Willows, California.

6/ Information by courtesy Butte Water District, Gridley, California.

7/ Information by courtesy Glenn-Colusa Irrigation District, op. cit.

955,400 acre-feet of water diverted during this season for irrigation purposes, or an average of almost 9 feet for each of the 160,200 acres irrigated. Farmers did not apply this water at uniform rates to all of the crops. An estimate of how they did allocate their total water supply, assuming usual irrigation practices for crops other than rice, indicates that these farmers applied 11 or more feet of water per acre to their rice and approximately 4-1/2 feet to the other irrigated crops. During this season, farmers in Richvale District (Butte County) diverted nearly all of about 114,000 acre-feet of water to 12,810 acres of rice; other irrigated crops accounted for only 25 irrigated acres [9]. Thus, rice growers in this district applied about 9 acre-feet of water for each acre of rice during 1964.

The same fortuitous circumstances making relatively ample water quantities available to farmers in these Central Sacramento Valley rice growing counties also explain low water costs. Mountain-origin streams with generous flow throughout the season, plus early-established water rights for the districts involved, enable these suppliers to make water available to farmer patrons at quite nominal prices. The water service agencies establish their rates on a per-acre basis with some variation among crops and with or without a minimal assessment (also on an acre basis). The rates for irrigation water to produce rice in the 1964-1966 period varied among the several districts from about $10.00 per acre to approximately double that level.8/ Rates for other crops usually range from about $4.00 to $5.00 per acre for crops other than pastures; rates for the latter use typically are $1.00 or $1.50 higher.9/

Data also are available from one major irrigation district to indicate how total annual water diversion for irrigation purposes varies among the

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8/ Irrigation water variable expenses (costs) in this study include only tolls paid for surface water plus a minimal acre assessment. In actual practice, water tolls in the study area are levied on a per acre basis and vary according to the crop. It was necessary for purposes of this analysis, to express these water costs on a per-acre-foot basis; hence, the range of charges indicated here.

9/ Information by courtesy of various water service agencies and farmers.

irrigation season months from April through October. In percentages, the proportions by months are as follows:

April	May	June	July	August	September	October
11.1	20.3	18.2	20.1	18.5	7.9, and	3.9 percent

These diversion percentages are useful in estimating monthly quantities of water applied on the several soil categories used to grow rice. We applied these percentages by months to total annual diversions corresponding to the approximate acreages involved for land according to major categories (basin, older alluvium, and recent alluvium). The results represent estimates of the total and montly amounts of water available for irrigation on these major soil types. Considering basin soils in the Glenn-Colusa and Richvale districts, combined, it appears that about 350,000 acre-feet of water were available during the 1964-1966 period for approximately 60,000 acres of basin land and that total water available per acre-foot represented about 5.75 acre-feet per acre. The comparable data for the alluvial soils show about 700,000 acre-feet of water for approximately 104,000 acres of land, or approximately 6.75 acre-feet of water per acre.

THE 1,280-ACRE FARM SIZE PERMITS EFFICIENT RESOURCE COMBINATION

Farmers, Federal and State Agencies, Farm Suppliers and Individuals Provided Information

Growers of rice, the dominant crop in this Butte-Colusa County study area, received acreage allotments allocated by the U. S. Department of Agriculture under the Agricultural Stabilization and Conservation Act. Local farm program administrative officers provided factual information regarding total farm acreages, rice allotments, and other farm operating information for individual growers under this program. The same agency also furnished information on support prices, production goals, and other administrative features of the rice program. The California Department of Water Resources and various irrigation districts and water districts in the Butte-Colusa area supplied specific information on water quantities, and acres irrigated, plus conditions and costs for water delivered. Such information came through both official releases and interviews or correspondence. The California Crop and Livestock Reporting Service also provided much data for this study. Their official releases containing historical data on crop acreages, yields, and sales prices for farm products proved essential.

The three soil survey reports cited in the previous section provided detailed information on soil resources, their classification and characteristics that influence crop adaptation and yields. We used official climatological data, as published in various reports of the U. S. Weather Bureau, to identify weather characteristics and patterns for the study area and to evaluate how such phenomena affect seedbed preparation, the growing season, and the critical harvesting period.

Evapo-transpiration and the influence of soil characteristics on water-holding capacity and percolation were particularly important to this investigation. Researchers in the area of soil-water-plant relationships were most helpful concerning these questions. They furnished all available information and gave generously of their time and counsel. Fundamental research in this field has progressed well and experimental work has yielded some important quantitative results. Unfortunately, these results do not provide all detailed and complete quantiative data needed for the crops, soils, and climatic conditions included in this analysis. We used estimates to compensate for such deficiencies. These reflect the available experimental data plus the suggestions and judgments of researchers in soil-water-plant relationships. The author assumes full responsibility, however, for any deficiencies in these estimates. Interviews with farmers, machinery dealers, other supply agencies, agricultural researchers, and extension specialists and farm advisors provided basic information on farm organization, resource availability and use patterns, and production technology, practices, and input patterns.

The 1,280-Acre Farm Studied Is a Common Size for Rice Farms[10/]

This operation, including two sections of land, is large enough to use economically tractors and field machinery with characteristics required to

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10/ Major terms relating to farm models appearing in this report, and their definitions, are as follows:

(Continued on next page.)

meet the physical conditions in the area. The distribution of total soil resources in the study area among three general soil groups (basin, older alluvium, and recent alluvium) made it necessary to analyze each of these three soil situations. Thus the study includes three models for the 1,280-acre unit, one for each of three soil groups.

(Footnote 10 continued from page 15.)

Subarea - a segment of a major geographic area, such as the Sacramento Valley, selected for study.

Irrigation Practice - technique or method used in irrigation, identified in this study by the depth of applications for rice and by the depletion level for available soil moisture prior to irrigation for other crops.

Variable Expenses (Costs) - sum of annual cash operating expenses, plus unpaid family (operator's) labor (see Appendix Tables A-8, A-18). This item may appear as Variable Expenses (Costs) per Acre for a single crop, or as Farm Variable Expenses (Costs) representing the total for an entire farm.

Fixed Costs - sum of annual cash and noncash for using capital items and for general costs not readily allocated to specific enterprises (see Appendix Table A-3).

Gross Receipts - sum of annual receipts from sales of farm crops.

Net Returns-Over-Variable Expenses (Costs) - Gross Receipts minus Variable Expenses. (Costs) (See Appendix Tables A-8 and A-10). This item may appear as Net Returns-Over-Variable Expenses (Costs) representing the total for an entire farm.

NET FARM INCOME - Net Cash income plus (or minus) inventory changes on noncapital items and minus noncash fixed costs (not including interest on investment). Any unpaid labor contributed by the farm operator is not included in the farm expenses.

PROFIT (Capital and Management Income) - Net Farm Income minus the value of any unpaid labor (including operator's).

MANGEMENT INCOME - PROFIT less 6.5 percent on the total farm capital. The residual (and it may well be negative) is payment for the operator's managerial ability and services.

RATE EARNED - PROFIT (Capital and Management Income) expresses as percentage of the farm capital.

Water quantities available for irrigation differ as between the model for the basin soils and those for the other two categories. These water quantities, distributed according to half-month irrigation periods during the growing season, reflect the variation in total water available in ratio to total irrigated land according to the soil differences in the area.

Soils and land use on the three models reflect the patterns established by the producer survey, and confirmed by the ASC data for Butte and Colusa counties. They are the same for each farm as far as over-all use is concerned. About eight percent of the 1,280-acre total in each model is in farmsteads and headquarters sites, easements for public roads, and drainage ditches, farm roads, and wasteland. Of the remaining 92 percent--1,180 acres--rice normally occupied slightly over one-third during the latter 1960's with the remainder divided between, (a) other crops, and (b) fallow or idle land. The specific crops other than rice differ and vary in acreage among the three different soil groups as will be evident in later sections. The basin group shows the narrowest range of adaptation for crops other than rice. The submodel for this soil group essentially represents Storie Grade IV soil in Butte County and a combination of Grades IV and V in Colusa County. The Stockton clay adobe series dominates in the former, while Colusa County basin soils includes Grimes, Marvin, Marmon, Sacramento, and Willows series, [6, 18, 34]. The recent alluvium and older alluvium soils, largely in Colusa County, include mostly Storie Index, Grade III soils but also some of higher grades, largely intermixed. With Grade III the chief soil series involved are Genevra, Harrington, and Myers. These alluvial soils, particularly the recent alluvium group, have a wider range of crop adaptation than the basin soils. The analysis recognizes this difference in the choice of crops for testing on these two soils, as compared with those in the basin group.

Land dominates inventory and investment values for all three models in this study (see Tables 1 and 2). Thus land values, including the cost of leveling for the 1,180 acres of cropland, account for 77 percent of the original investments and 85 percent of the average investments (814,470) for the recent alluvium model, all prices reflecting 1964-1966 price levels. Similar relationships for the other two were 75 and 85 percent, respectively, for the older alluvium ($750,470 average investment) and 73 and

TABLE 1

Real Farm Estate and Operating Equipment Inventories and Investments;
1,280-Acre Rice Farm, 1964-1966 Average Prices

Item	Size or capacity	Number	Useful life on farm	Initial cost	Salvage value	Average value	Total depreciation
	1	2	3	4	5	6	7
			years	dollars			
LAND							
Raw land							
Recent alluvium	$450/acre	1,280	--	576,000	N.A.[a]	576,000	0
Old alluvium	$400/acre	1,280	--	512,000	N.A."	512,000	0
Basin	$350/acre	1,280	--	448,000	N.A."	448,000	0
Leveling	$100/acre	1,180	--	118,000	N.A."	118,000	0
TOTAL (R.A.)	$542/acre	1,280	--	694,000	N.A."	694,000	0
TOTAL (O.A.)	$492/acre	1,280	--	630,000	N.A."	630,000	0
TOTAL (Basin)	$442/acre	1,280	--	566,000	N.A."	566,000	0
IMPROVEMENTS							
Shop-storage	4,000 $ft.^2$	1	30	10,400	1,000	5,700	9,400
Machinery shed	2,400 $ft.^2$	1	20	3,200	500	1,850	2,700
Shop equipment	N.A.[a]	N.A.[a]	10	2,500	0	1,250	2,500
Fuel storage (gas)	2,000 gal.	1	10	500	60	280	440
Fuel storage (diesel)	2,000 gal.	1	10	375	50	213	325
TOTAL				16,975	1,610	9,293	15,365
EQUIPMENT							
Irrigation							
Siphons	3"	200	4	900	0	450	900
Power							
(track-layer tractor)							
D-7		1	10	33,640	5,050	19,345	28,590
D-6		1	10	26,074	3,911	14,993	22,163
D-4		1	10	16,149	2,422	9,286	13,727
(row-crop tractor)							
W-3		1	6	7,900	1,580	4,740	6,320
TOTAL				83,763	12,963	48,364	70,800
Transport							
Truck	2-ton	2	6	8,320	1,660	4,990	6,660
Pickup	1/2-ton	2	4	6,450	2,580	4,515	3,870
Pickup	1/2-ton	1	6	3,225	645	1,935	2,580
TOTAL				17,995	4,885	11,440	13,110
				Rice			
Machinery							
Landplane	12' x 60'	1	10	3,720	372	2,046	3,348
Plows	6 x 16"	1	10	5,720	572	3,146	5,148
Plows	5 x 14"	1	10	2,525	0	1,263	2,525
Field cultivator	12'	1	10	936	0	468	926
Disk	21'	1	10	3,744	0	1,872	3,744
Disk	15'	1	10	2,445	0	1,223	2,445
Harrow	24'	1	15	624	0	312	624
Float	12'	2	15	300	0	150	300
Drill (grain)	14'	1	10	1,200	0	600	1,200
Fertilizer disk	12'	1	10	470	0	235	470
Bulldozer blade	10'	1	10	1,460	0	730	1,460
Harvester (S.P.)	16'	2	5	45,000	13,500	29,250	31,500
Bankout wagon (S.P.)	140 cwt.	1	8	5,720	572	3,146	5,148
Bankout wagon	140 cwt.	1	10	2,500	0	1,250	2,500
Grease wagon	250 gal.	1	10	1,000	0	500	1,000
Grease wagon	350 gal.	1	10	1,500	0	750	1,500
Lowbed trailer	350 gal.	1	10	1,600	0	800	1,600
Equipment carrier	25'	1	10	1,040	0	520	1,040
Weedsprayer	200 gal.	1	10	832	0	416	832
Rice boxes		200	4	1,000	0	500	1,000
TOTAL				83,336	15,016	49,177	68,320
				Other crops			
Machinery							
Planter	6 bed	1	10	1,196	0	598	1,196
Cultivator	6-R	1	10	1,404	0	702	1,404
Ditcher	4'	1	10	364	0	182	364
Mower	7'	1	10	520	0	260	520
TOTAL				3,484	0	1,742	3,484
EQUIPMENT TOTAL				189,478	32,864	111,173	156,614
ALL PROPERTY TOTAL							
Recent alluvium				900,453	37,474	814,466	171,979
Old alluvium				836,453	34,474	750,466	171,979
Basin				772,453	34,474	686,466	171,979

a/ N.A. = Not applicable

TABLE 2

Summary of Fixed Costs, 1,280-Acre Rice Farm, 1964-1966 Average Prices

Basis	Noncash fixed costs			Cash fixed costs				Total all fixed costs
	Interest on average investment	Annual depreciation		Taxes	Insurance a/	Other		
	6.5 percent	Years life	Total	Assessment @ 25 percent of value x levy rate	Varies	N.A.	Total	
	1	2	3	4	5	6	7	8
	dollars							
PROPERTY								
Land - 1,280 acres								
Recent alluvium	45,110		45,110	11,278			11,278	56,388
Old alluvium	40,950		40,950	10,238			10,238	51,188
Basin	36,790		36,790	9,198			9,198	45,988
Improvements	604	775	1,379	151	74		225	1,604
Equipment								
Irrigation	29	225	254	7			7	261
Power	3,144	7,501	10,645	786			786	11,431
Transport	744	2,508	3,252	415 b/			415	3,667
Machinery								
Rice	3,192	10,230	13,422	799	1,462 c/		2,261	15,683
Other crops	113	348	461	28			28	489
Total property								
Recent alluvium	52,936	21,587	74,523	13,464	1,536		15,000	89,523
Old alluvium	48,776	21,587	70,363	12,424	1,536		13,960	84,323
Basin	44,616	21,587	66,203	11,384	1,536		12,920	79,123
GENERAL OVERHEAD								
Electric & other services						445		445
Accounting						600		600
Dues, fees						300		300
Office						300		300
ALL FIXED								
Recent alluvium								91,168
Old alluvium								85,968
Basin								80,768

a/ Insurance calculated @ 1 percent on 80 percent of average value for improvements; 5 percent on average value of equipment.
b/ Also includes 2 percent of market value for motor vehicle tax.
c/ Harvesters only.

82 percent, respectively, for the basin ($686,470 total average investment soils. The amounts that inventory and investments for improvements represent are only nominal; repair and storage space for machinery plus storage for fuel accounted for all of these investments. Field power and rice machinery, roughly equivalent in investment values, accounted for most of the equipment inventory and investments on all three submodels. Transportation equipment also requires a sizable investment for trucks and pickups (bankout wagons appear under rice machinery), but machinery for other crops is minimal. It facilitated the analysis in this study to include only planting and cultural machinery for these other crops, and to include practically all harvesting machinery costs under contracted services. This procedure permits a stable level of total farm fixed costs, regardless of changes in the cropping system to maximize returns.

Total fixed costs include noncash and cash overhead on farm property, plus general farm overhead (see Table 2). The land valuations do not reflect precise market or sales values; they do reflect the influence of a combination of price-indicating phenomena, including tax assessments, basic physical productivity, and farm products prices computed on a period-normal basis. Such estimates are useful to suggest the relationship between total farm earnings and capital investments, and to make comparisons among farm units differing in basic characteristics, such as our three farm units in this study. The various elements that affect farm costs, such as useful life for structures and equipment, salvage values if any, prices and cost rates, and tax assessments and levies all reflect existing or normal levels at the time of the study. Data to identify such levels came from official reports and interviews. Aggregate farm costs for the three 1,280-acre submodels varied from $91,200 on the recent alluvium to $80,800 for the basin units; thus, they ranged from a high of $77.00 per tillable acre on the former to $68.00 per tillable acre on the latter submodel (see Table 2).

Quantities of irrigation water differed between the basin soil model and the other two farms. The 6,784 acre-foot total for the former represents about 5-3/4 acre-feet per acre for the season, or about one acre-foot per acre less than the 7,964 acre-feet available for each of the two other models. The seasonal distribution of these aggregate quantities in acre inches among half-month irrigation periods from April through September appear in the accompanying text table.

	Basin	Old Alluvium	Recent Alluvium		Basin	Old Alluvium	Recent Alluvium
April 1-15	4.512	5.304	5.304	August 1-15	7.524	8.844	8.844
16-30	4.524	5.304	5.304	16-31	7.524	8.844	8.844
May 1-15	8.256	9.696	9.696	Sept. 1-15	3.216	3.768	3.768
16-31	8.268	9.708	9.708	16-30	3.216	3.780	3.780
June 1-15	7.404	8.688	8.688	Oct. 1-15	3.168	3.720	3.720
16-30	7.404	8.700	8.700				
July 1-15	8.184	9.600	9.600				
16-31	8.184	9.612	9.612				

Farm labor requirements for these three analytical models of 1,280-acre rice farms represent full-time work for two workers assumed to be hired plus one-half time of the operator (management functions occupy the rest of the operator's time). Such a labor force, supplemented as necessary by contract operations and temporary workers to meet seasonal peak requirements, can prepare the seedbed, plant, and irrigate, and perform the cultural operations, and also provide a part of the harvest labor for a cropping system including approximately 472 acres of rice, 177 acres of dry edible beans, 295 acres of wheat, and 118 acres of fallowed land or reasonable modifications of it. Variations in the cropping system, such as substituting barley, safflower, or milo in varying proportions for the beans and wheat also would be manageable with this labor force. The farm supply of regular labor will have to expand, however, if shifts in the cropping system are toward substituting such crops as corn, alfalfa, sugar beets (where the two latter crops are adapted), or other crops with high cultural labor requirements for the crops supplementary to rice.

High-Capacity Machines and Heavy Investments Lower Costs Per Product Unit and Lessen Time-Related Uncertainty

Farmers who produce rice have discovered that heavy-duty equipment, and corresponding high-powered tractors, are essential to obtain optimum rice yields. These requirements reflect the unique characteristics of the heavy soils in the Central Sacramento Valley, and the irrigation requirements for rice. The limited-duration harvesting period also places a premium on timeliness in this operation.

All three of these 1,280-acre models include in their power complement one D-7 and one D-6 tracklayer tractors, plus two 16-foot self-propelled rice harvesters on tracks. These four equipment items, alone, represent an initial cost of more than $120,000. Their average value exceeds $70,000. Such heavy investment outlays are acceptable for this kind of equipment only if rice farm operations require such equipment for effective performance, and if total annual use is heavy enough to permit reasonable total costs per unit of product. These conditions hold for these power units on the 1,280-acre rice farms. They have the capacity to operate large-scale seedbed machinery on the heavy soils and under the sometimes difficult moisture conditions on these ricelands. The two tractors, in combination, also are capable of operating one-time-over diking machines for building rice levees. It is because farmers can build levees in this manner that it is feasible to plan operations to remove the levees following each rice crop, and rebuild them for those that follow. The necessity to establish a balance between operating capacity for such large power units and their total cost for ownership and operation is one of the basic reasons for choosing the 1,280-acre models for this analysis. Farmers on smaller operations find it difficult to justify such equipment in terms of per-unit of product cost.

Uncertainty is a major element determining the choice of two 16-foot self-propelled rice harvesters for these analytical models. The two in combination include enough daily harvesting capacity to permit harvesting the potential maximum rice acreage on units of this size within the time normally available for such harvests. Weather conditions, primarily rainy spells with heavy amounts of precipitation in early November, plus the time required to produce rice and drain and dry the fields, establish an effective limit of some four to six weeks for completing rice harvest. Increased costs are almost certain, and some reduction in either quantity or quality or both are probable, for rice remaining unharvested after about 10 November.

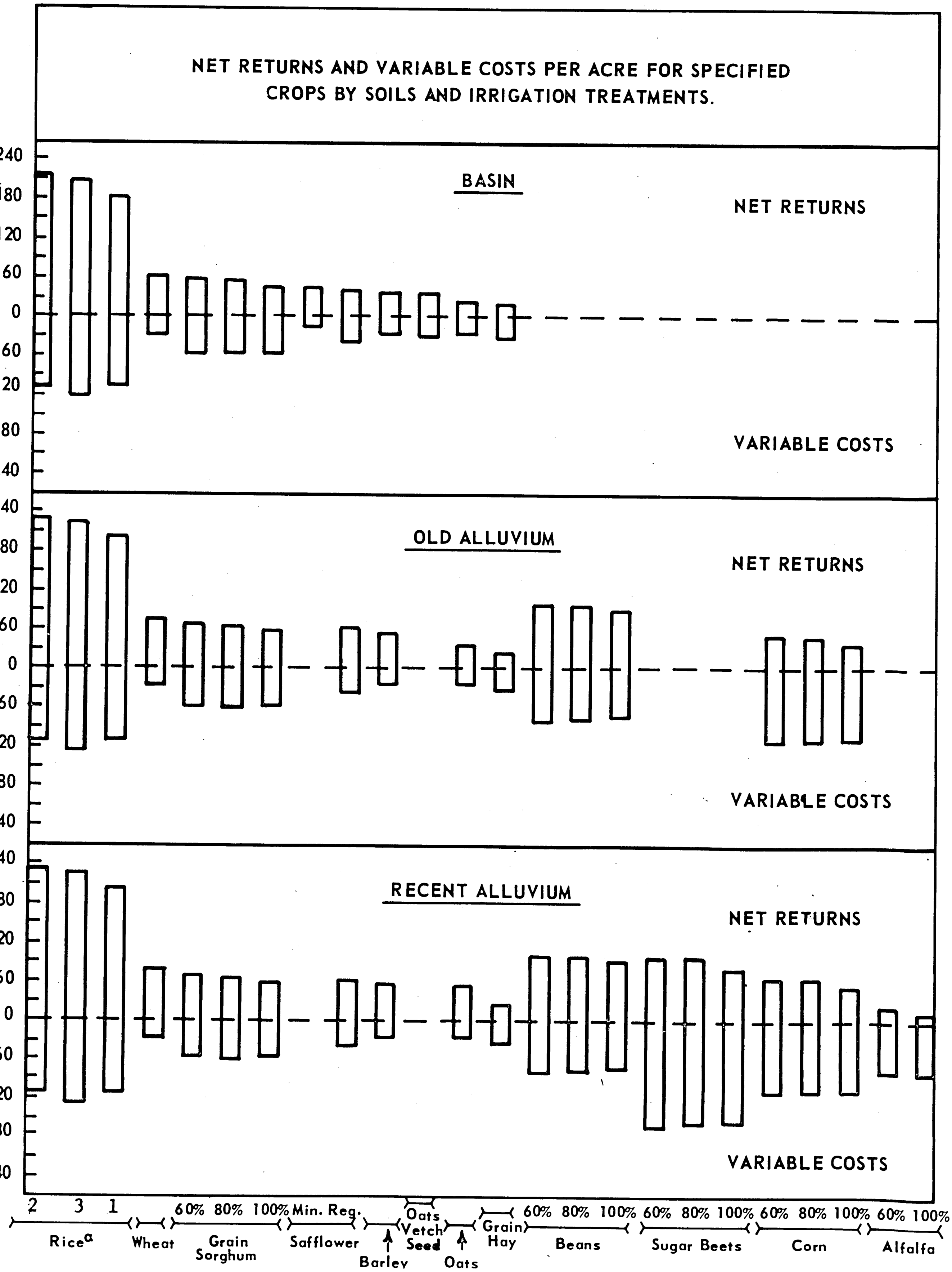
Alternative Crops Vary Widely in Output, Revenue, Costs, and Net Returns Per Acre

A preliminary step in the analysis for this study was to rank the various possible alternative crops according to net returns-over-variable expense per acre, using 1964-1966 average prices for both inputs and outputs. We included, in calculating these net returns, certain items that in other circumstances might appear under fixed costs or "overhead". Thus irrigation district assessment fees and fringe costs for labor were deducted from gross receipts per acre as variable expenses to determine net returns-over-variable expenses.

The results of these calucations and crop rankings show a sharp variation among crops in relative earning capacity under the conditions of this study.

The basin soils show the narrowest range of crop adaptation of any of the three soil categories. Rice provides the highest net returns; only small grains, grain sorghum, and safflower also appear in the later analysis. Soils in the old alluvium group show a wider range of adapation with beans and corn added to the list of crops considered, while the recent alluvium soils also include sugar beets and alfalfa (see Figure 3). Rice, with three alternative irrigation treatments considered in this study, is decidedly the most profitable crop that farmers in the study area can produce under the conditions for this analysis. Net returns-over-variable expenses ranged from \$185.00, to \$219.00 per acre on the basin soils, and from \$205.00, to \$232.00 on the old alluvium and recent alluvium soils (see Appendix Table A-10). These net returns to rice ranged from about 2.3 to 2.8 times the level of those for the next ranking alternative crop, depending on the soil and the irrigation treatment. The relative rankings of the alternative crops differed somewhat among the three soils studied. There was little difference in net returns per acre among unirrigated wheat (\$65.00 per acre) and grain sorghum irrigated under either the 60- or 80-percent soil moisture depletion ratio on the basin soils (\$61.00 per acre and \$58.00 per acre respectively). Grain sorghum at the 100-percent ratio followed next in the order of net returns with safflower, barley, oats and vetch seed, oats, and grain hay following in that order. Data already presented indicate that fixed costs

FIGURE 3



a: 1 = RICE, DEEP; 2 = RICE, DEEP/SHALLOW; 3 = RICE, SHALLOW for the basin soil model amount to over $85,000, or $68.00 per acre; thus rice is the only one of the alternative crops with net returns-over-variable expenses sufficient to cover all fixed costs (see Table 2). Wheat and grain sorghum come closest to this net returns level, while the remaining crops tested fall distinctly short of it.

Dry edible beans irrigated at the 60- and 80-percent soil moisture depletion levels ($101.00 per acre and $99.00 per acre, respectively) ranked next to rice in net earnings-over-variable expenses on old alluvium soils (see Figure 3). Both of these net returns, however, were less than half those for the least profitable rice irrigation practice. The advantage to the operator on the old alluvium lies in the fact that these returns levels, plus those for wheat, are higher than fixed costs per acre ($73.00 per acre). Thus they will cover such costs and leave some margin to help pay for management. The remaining crops ranked in about the same order as for the basin soils, but showed somewhat higher levels of returns. In addition, corn, not included in the basin group, showed net returns-over-variable expenses somewhat above safflower but below those for grain sorghum.

Dry edible beans and sugar beets showed similar levels of net returns-over-variable expenses on recent alluvium soils in this analysis. Again, both crops showed lower earning capacities than rice grown under any one of the three irrigation practices, but did show net returns-over-variable expenses that exceed fixed costs. Wheat showed net returns equal to fixed costs with grain sorghum and corn following closely on these soils. Alfalfa ranked lowest of any of the alternatives tested (see Figure 3 and Appendix Table A-10).

It is evident from these data that rice holds a distinct economic advantage for production in the area studied, and under the conditions of the analysis. It also is clear that both differences in soil quality and in irrigation practices affect net returns-over-variable expenses. Relatively high variable expenses, as compared with gross receipts, placed the row crops and alfalfa at a disadvantage as compared with rice whose input cost-versus-receipts ratio is highly favorable.

THE METHODOLOGY FOCUSES ON AN ECONOMIC ANALYSES OF PHYSICAL, BIOLOGICAL, AND ECONOMIC RELATIONSHIPS

Crop Yield Estimates Vary According to Irrigation Treatments on Each Soil

An important step in this analysis was to estimate crop yields for each soil considered, according to specified irrigation treatments for each crop. The procedure used to compare these estimates for crops other than rice was the same as that developed and used for earlier similar investigations in the San Joaquin Valley by Hedges and Moore [15].11/ This Central Sacramento Valley study is, however, the first such investigation that includes rice as one (here, the principal) alternative crop. We define and explain in a subsequent section the procedure used to relate rice yeilds to irrigation practices. First, however, we will review the procedure for row crops and close-grown crops not requiring submergence irrigation.

The purpose of the procedure for preparing yield estimates is to evaluate how irrigation practices interact with soil-water-plant relationships to regulate yields. Two definitions are important in analyzing relationships, field capacity (FC) and permanent wilting percentage (PWP). The first, FC, represents all the water that a particular soil will hold following a thorough wetting, but after allowing enough time for free water to drain out by gravity. PWP refers to the soil moisture content below which the plants cannot obtain water readily. Plants wilt at this moisture level and do not recover unless water is added immediately to the soil, Viehmeyer and Hendrickson [30], Viehmeyer and Hendrickson [31], and Beringer [2]. Questions regarding profitable irrigation practices therefore concern the amounts of water to be added, and their proper timing, in order to maintain soil moisture within the range between FC and PWP that will enable the operator to maximize net dollar returns.

We base our analysis in this study on the concept that in general the relative rate of plant growth depends upon the mean soil moisture stress

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11/ See Appendix Table A-1 for procedure in relating moisture availability to growth rates.

in the active root zone; that is, that the tension with which moisture adheres to the soil particles near the active roots regulates the amount of moisture available to the plant, and, hence, its growth rate Hagan [13], Wadleigh [32].

Not all scientists fully accept this view of soil-water-plant relationships. Some researchers of long standing in the field hold that variations in soil moisture content between FC and PWP have little bearing on plant development and yield. Some among those who support the mean moisture-stress concept, moreover, concede that brief periods of high stress can have an exaggerated impact upon plant growth. They hold, nonetheless, that the moisture-stress theory represents the best approximation for a wide range of crops under varying soil and climatic conditions.

Yield Estimates Reflect Mean Soil Moisture Availability Ratios for Crops Other Than Rice

We use the mean soil moisture availability-stress theory as the basis to analyze how irrigation affects growth and yields for row and close-grown crops except rice. Irrigation practices represent an important influence regulating profits on the individual farm because they affect soil moisture stress, Moore [22]. We assume, in applying this concept that growth is a completely reliable indicator of yield; that a yield reduction in the same proportion accompanies any given departure of growth rate from the maximum potential. The starting point for estimating yields associated with each irrigation practice is an estimate of potential yields under optimum soil moisture conditions; these estimates reflect the research findings, experience, and judgments of researchers and specialists working on irrigation problems. The subsequent procedure involved six steps for the crops studied on each soil type categories according to a given set of climatic conditions.

1. Determining amounts of water, days between each successive pair of irrigations (length of cycle, and timing for applications, under each of three specified irrigation treatments. These represent for crops other than rice different percentage depletions of available soil moisture (100, 80, and 60 percent, respectively) permitted before applying water.

2. Measuring changes in soil moisture depletion levels throughout each irrigation cycle during the season. We obtained soil moisture releases curves representative of each of the soils studies. With these data, we constructed relative growth rate curves.

3. Estimating plant growth (hence under the assumed relationships, yields) according to levels of available soil moisture for each irrigation cycle. Relative growth curves provide the basis for these estimates.

4. Establishing the mean growth rates for each crop during each cycle according to soils and irrigation treatments and expressing each as an index of the potential yield possible under physically optimum moisture conditions.

5. Cumulating the growth rates (and yields) for the several cycles into a seasonal yield index for each crop, according to soils and irrigation treatments.

6. Applying the seasonal yield indices from (5) to the potential yields estimated to obtain yields associated with each of the various irrigation treatments for crops involved on each soil series type.

This approach uses the (1) dry, 100-percent, (2) medium, 80-percent, and (3) wet, 60-percent available soil moisture depletion levels, respectively, to define the three major irrigation practices for analyzing irrigation practices in relation to yields for crops other than rice.

Rice Irrigation Practice Definitions are Distinct From Row Crop Practices

The fact that California rice growers use the submergence method in irrigating rice makes necessary a different approach for this crop than other crops in measuring the relationship between irrigation practices and yields. Both research investigations and observations indicate that growers' irrigation practices vary widely and, consequently, that the total quantities of water that they apply to produce rice also differ. Adams' 1914-1919 study reported variations from slightly less than 4 feet to almost 19 feet in the total depth of water applied in the Sacramento Valley [1]. Total water applications for rice must be adequate to meet three requirements: (a) fill the root zone to holding capacity, (b) supply the water transpired during the growing season, and (c) provide quantities

TABLE 3

Irrigation Water Budget; Rice on Basin Clay Adobe Soil, Continual Deep-Flooding (45 Days), Followed by Shallow-Flooding, Calculated From Physical Data

Month	Available water (inches)			Water added	Total water[b/]	Consumptive use		Out-flow[d/]	Total water with-drawn[e/]	Water at end of period
	Per-foot	Root zone[a/]	Surface			Per-day	For period[c/]			
	1	2	3	4	5	6	7	8	9	10
April 1-15	1.50	4.50	0	17.3	21.80	.14	2.10	0	2.10	19.70
April 16-30	3.00	9.00	10.7	8.4	28.10	.18	2.70	6.40	9.10	19.00
May 1-15	3.00	9.00	10.0	5.6	24.60	.21	3.15	2.45	5.60	19.00
May 16-31	3.00	9.00	10.0	5.6	24.60	.24	3.84	1.76	5.60	19.00
June 1-15	3.00	9.00	10.0	5.6	24.60	.28	4.20	3.40	7.60	17.00
June 16-30	3.00	9.00	8.0	5.6	22.60	.32	5.15	2.45	7.60	15.00
July 1-15	3.00	9.00	6.0	5.6	20.60	.33	4.95	1.65	6.60	14.00
July 16-31	3.00	9.00	5.0	5.6	19.60	.31	4.96	1.64	6.60	13.00
Aug. 1-15	3.00	9.00	4.0	5.6	18.60	.27	4.05	2.55	6.60	12.00
Aug. 16-31	3.00	9.00	3.0	5.6	17.60	.22	3.52	5.08	8.60	9.00
Sept. 1-15	3.00	9.00	0	0	9.60	.17	2.55	0	2.55	6.45
Sept. 16-30	2.15	6.45	0	0	6.45	.14	2.10	0	2.10	4.35
TOTAL	f/	f/	f/	70.5	f/	f/	43.10	27.38	70.65	f/

a/ Moisture available in root zone when soil is at field capacity (col. 1 3-foot depth of root zone).
b/ (Cols. 2, 3 and 4).
c/ Evapo transpiration rate per day times number of days in time period.
d/ Water flowing through and out of the checks.
e/ Col. 7 + Col. 8.
f/ Not applicable.

Note: Data in columns 2, 3, 6 and 8 must be obtained from outside sources such as agronomists, irrigation personnel, and irrigation district personnel.

necessary to "flow through" the rice checks during the season. These are minimum requirements. If soil structure and conditions are such that losses occur from water percolating through the root zone, then total applications also must be adequate to replace these losses, and still meet the minimum requirements. Likewise, additional quantities will be necessary to produce rice if flow-through and tail water drainage, or transpiration, are at usually high levels.

Estimates of total water used in rice production in this study included allocations to meet the three normal requirements, to bring soil in the root zone to holding capacity, cover transpiration requirements, and maintain a continual flow of water through the checks and out as tail water. Quantities of water required to meet these total requirements varied among the three different soil categories studied, and according to three different irrigation practices for rice.

An irrigation budget, based on simple accounting principles, served to calculate total irrigation water requirements. Such a budget indicates seasonal water requirements for rice grown on basin (clay adobe) soils under irrigation treatment No. (1), continual deep flooding (approximately 10 inches) to be 68.9 inches (5.74 feet). The requirements for treatment No. (2), initial deep flooding for 45 days, followed by later shallow flooding (4 inches) for the remainder of the season were comparable to 70.5 inches (5.9 feet) (see Table 3).

Treatment No. (3), continual flooding, requires 62.3 inches (5.2 feet) of water to produce rice on this same soil. The treatment No. (2) total water requirement for the basin soils includes 43.1 inches of water to meet transpiration requirements, and 27.4 inches for out-flow during the season. These totals include no allowances for saturating the root zone soil because water initially added for this purpose was withdrawn prior to harvest. The clayloam soils, both recent and older alluvium, required considerably more water for irrigation under each of these three irrigation practices. These requirements, indentical for both soils, were (1) deep-flooded, constant level, 106.6 inches (8.9 feet), (2) initial deep flooding, subsequent shallow flooding, 100.6 inches (8.2 feet), and (3) constant shallow flooding, 99.0 inches (8.2 feet).

Pruitt's [25] work as well as Adams' [1] earlier work provides the basis for our estimates on transpiration; we considered Adams' work heavily in estimating the quantities of water necessary to maintain a continual flow through the checks, but also drew on sample data from irrigation districts and growers in the Sacramento Valley. Booher's and Houston's [3] data on water holding capacity of soils in California and Weir's and Storie's [33] soil analysis and classification studies, as well as indivual soil survey reports [6, 18, and 34] provided the essential information for estimating water-holding capacity, and other soil characteristics that affect irrigation.

Estimated Plant Growth and Yields Reflect Irrigation Practices and Moisture Availability During the Growing Season

The basic physical-biological problem in this study was to establish and measure as accurately as possible the precise relationship between irrigation practices, and water available to the crop, on the one hand, and plant growth rates during each irrigation cycle, and the impact of variations in irrigation practices and moisture availability on crop yields, on the other. Irrigation practices for crops other than rice reflect the impact of soil characteristics, the stage in plant growth, and other factors on available soil moisture. We use an irrigation budget, based on the same principles as the one for rice presented above to identify irrigation cycles, and amounts of water to apply to meet the conditions specified for (1) dry, or 100 percent depletion, (2) medium, or 80 percent depletion, and (3) wet, or 60 percent depletion of soil moisture prior to irrigation at the end of each cycle (Table 3). The alternative treatments for rice irrigation, as indicated above, included (1) continual deep flooding, (2) initial deep flooding (10 inches) for 45 days, followed by shallow flooding (4 inches), and (3), continual shallow flooding. We found experimental data on growth rates and yields for various crops in relation to variations in soils and irrigation practices inadequate to meet the requirements of this study. It was possible, however, through personal consultation and interviews, to obtain from agronomists, farm operators, and farm advisors judgments and estimates to fill in these gaps. We used a definite procedure that identifies plant growth rates inversely with percentages of available soil moisture depletion to adjust estimated "ideal" yields, obtained from these qualified agricultural authorities. The result was to relate variations in growth rates and yields to available soil moisture under varying irrigation treatments according to soils.[12/]

Net Returns Per Acre Determine Profit Bankings for Individual Crops

Most farmers in the Central Sacramento Valley have two or more alternative choices in deciding what crop to produce on a particular piece of land, although these alternatives may vary sharply in net returns. This choice situation presents operators with decision problems. These farmers almost always must consider how variations in physical, economic, and institutional conditions affect such choices and their financial outcomes. Governmental statutes and regulations (e.g., acreage allotments) may seriously limit freedom of decision. Rice is the principal profit-returning crop in the Central Sacramento Valley. All three of the soils examined in this study also can grow winter grains, grain sorghum, safflower, and dry edible beans. Field corn also is a possible alternative on the old and recent alluvium soils.

This analysis includes detailed summaries of production requirements and costs, outputs, and revenue, and net returns-over-variable expenses for each of these crops, usually under two or more sets of conditions. Interviews with farmers, commerical agencies serving farmers, and public officials, as well as published reports from available secondary sources yielded data for these summaries. Procedures for preparing summaries involved five steps for each crop under each unique set of conditions:

1. Determining the cultural and harvest operations involved, the timing for each one according to caldendar dates, and the equipment, power, labor, and materials involved.

2. Calculating physical quantities for all inputs, including services such as labor, power and machinery hours, plus seed, fertilizer, irrigation water, and other materials.

12/ See Appendix Tables A-4 and A-5 for crop irrigation water requirements according to soils.

3. Estimating yields according to the relevant determinants. Thus for each irrigation treatment considered (deep, deep-shallow, and shallow for rice; 100, 80, and 60 percent available soil moisture depletion, respectively, between irrigations for other crops) it was necessary to estimate the appropriate yield, as well as all associated inputs that vary with irrigation practice or yield.

4. Applying relevant cost rates and prices to express all inputs and yields in dollar values. These calculations included only variable expense items; depreciation, taxes on equipment, and other fixed costs were omitted in this initial accounting.

5. Summing total variable costs and revenues, according to appropriate classifications, in order to obtain gross receipts, total variable expenses, and net returns above variable expenses for each crop.

This procedure excludes fixed costs for this step because the specific purpose at this step is to afford a basis to compare crops, and to use the resulting data in developing criteria to choose crops and allocate resources. Comparisons within a constant fixed cost structure for the entire farm are entirely feasible for many crucial decisions, and require only minor modifications for others. Thus it simplifies calculations and saves time to omit the fixed costs and to concentrate on variable inputs and costs for this step in the analysis.

Linear Programming Analyzes Alternative Resource Use Opportunities and Identifies Optimum Choices Under Specified Assumptions and Constraints

Limited water quantities and relatively wide price variations generate irrigation water use problems on many California farms. Such constraints require farm operators to choose among several competing uses for available water. The result is that these operators must make decisions involving complicated interrelationships among these several enterprises, as well as with other necessary resources, within a framework of shifting and uncertain prices. Linear programming offers important advantages as a technique for analyzing such problems. In the words of Heady and Candler [14], "A linear programming problem has three quantitative components: an objective, alternative methods or processes for attaining the objective, and resource or other restrictions.[13/] Garvin [11], in a more technical definition states

13/ See page 2, Heady and Candler.

that, ". . . linear programming deals with the minimization of a linear function, subject to the subsidiary conditions that the variables are non-negative and must satisfy a set of linear equations.[14]

We use linear programming techniques in this analysis to obtain answers under specified sets of conditions to three types of questions: (a) what enterprises should the operator include in the total farm business (what to produce?); (b) how should he allocate available water and other resources among enterprises (how much to produce?); and (c) in what proportion should he combine irrigation water with other materials and services used for each product or enterprise (what irrigation treatments [practices] should he use)?

A simple problem including two alternative crops, rice and safflower, and two resource restrictions (constraints), 400 acres of land and 1,000 hours of tractor power illustrates the linear programming method (see Figure 4).

The 400 acres of land, at alternative yields of 30 hundredweights of safflower sorghum or 60 hundredweights of rice per acre, can produce 12,000 hundredweights of safflower or 24,000 hundredweights of rice. Available tractor hours will operate 600 acres of safflower producing 18,000 hundredweights, or 200 acres of rice producing 12,000 hundredweights. The farmer is limited, therefore, to producing 12,000 hundredweights of safflower (point A) due to the land limitation, or 12,000 hundredweights of rice (point C) due to the tractor hour limitation, or to some combination of the two crops that is consistent with both constraints, as defined by the line ABC (see Figure 4). His problem is to decide which crop or crops, and how many acres of each, to produce in order to maximize income.

Sales prices are \$4.00 per hundredweight for safflower and \$5.00 per hundredweight for rice. When we draw a constant revenue (isorevenue) line that just touches (is tangent to) the heavy crooked line ABC and has a slope to the ratio of the two product prices $\frac{\$5.00 \text{ rice}}{\$4.00 \text{ safflower}} = 1.25$), we find the combination of production that maximizes income. This combination,

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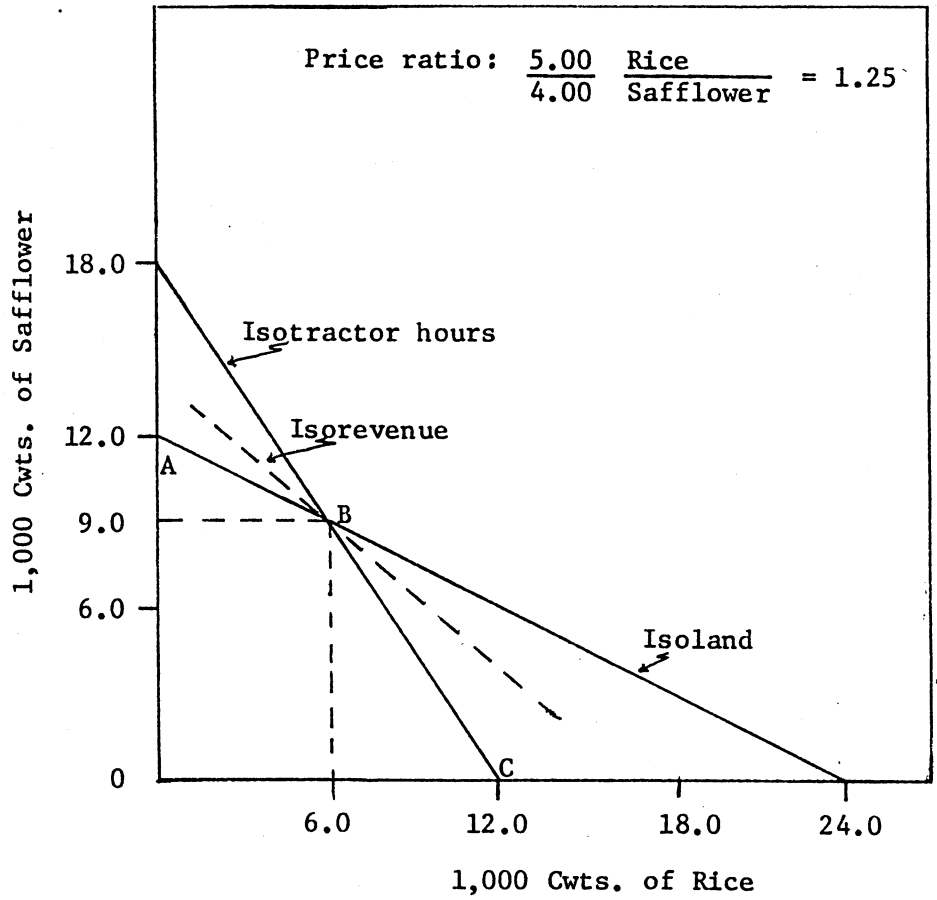
14/ See page 3, Garvin.

FIGURE 4

PRODUCTION POSSIBILITY CHART, SAFFLOWER AND RICE



for our example, includes 9,000 hundredweights of safflower and 6,000 hundredweights of rice (point B) with total revenue of $66,000.15/

This problem is quite simple with two enterprises (crops) and two restrictions. But our problem with 12 enterprises under three differing irrigation practices, and 28 restrictions, does not lend itself to solution by this method of simple charts and budget calculations. Maximum restrictions (on recent alluvium) include formal or informal acreage constraints [14], limits on water quantities available in different time periods [13], and rice harvester hour limits (see Figure 2). These plus the 12 enterprises and three irrigation practices, present a problem that is too unwieldy for the graphic method. Linear programming allows simultaneous consideration of all these factors, however, and yields optimum solutions that maximize net farm income under a varying range of conditions. Machine computation makes it more manageable, and speeds the analysis.

Constraints Reflect Limits Set By Resource Availability, Technology, Market Conditions, and Institutional Factors

Growers seeking to obtain maximum profits from their operations usually try to put as many acres as possible into the crop offering the highest net returns-over-variable expenses. If no constraints exist to interfere, therefore, we would expect an operator on our 1,280-acre farm model to plant all his irrigable acres in rice. He would divide these acres between rice and his next most profitable crop if, for some reason, it is not possible to plant all land to rice. He would extend this principle to bring in other crops in order of profitability as further constraints might require. Constraints do exist in this problem; they include physical resource limitations, economic conditions, and institutional forces. We have attempted to recognize such limitations on freedom of management decision through defining a set of 28 constraints that reflect conditions on the farm and in the study area:

15/ Rice produced to the limit of tractor hours available would return $60,000; safflower expanded to the limit of land resources would produce $48,000 in revenue.

A. Land Resource Constraints

	Acres	Percent	
Total farm	1,280		
Maximum tillable land	1,180 =	100	
Maximum tillable land in crops	940 =	80	
Maximum tillable land in irrigated crops	826 =	70	
Maximum tillable land in rice (40 percent allotment)	472 =	40	
Maximum tillable land in other crops	354 =	30	
Maximum tillable land in beans (dry edible)	177 =	15	(recent and old alluvium)
Maximum tillable land in grain hay	118 =	10	
Maximum tillable land in safflower	236 =	20	
Maximum tillable land in sugar beets	236 =	20	(recent alluvium only)
Maximum tillable in wheat	354 =	30	
Minimum tillable land idle	118 =	10	
Minimum tillable land in fallow (25 percent of rice)	R/4 =	R/4	
Miximum tillable land in oats and vetch seed	118 =	10	(old and recent alluvium)

B. Water Resource Constraints (13)

	Acres Inches	Basin Soils
Seasonal totals	95,568	$1,384
April 1-15	5,304	4,512
16-30	5,304	4,524
May 1-15	9,696	8,256
16-31	9,708	8,268
June 1-15	8,688	7,404
16-30	8,700	7,404
July 1-15	9,600	8,184
16-30	9,612	8,184
August 1-15	8,844	7,524
16-31	8,844	7,524
September 1-15	3,768	3,216
16-30	3,780	3,216
October 1-15	3,720	3,168

C. Rice Harvestor Hour Constraint (1)

	Hours
September (5 days @ 9 hours x 2)	90
October 1-15 (15 days @ 8 hours x 2)	240
October 16-31 (15 days @ 7.5 hours x 2)	225
November 1-15 (13.5 days @ 5.75 hours x 2)	155
Total Hours (Seasonal)	710

Our analysis includes 12 crops; rice, sugar beets, dry edible beans, safflower (two cultural methods), alfalfa hay, grain sorghum (milo), field corn, barley, wheat, oats, oats and vetch seed, plus grain hay, each adapted to one or more of the three soil categories. The 12 crops expand in number to 27 income activities, or "processes" in linear programming terminology (a maximum of 23 on any one soil) since a single irrigated crop is listed once for each irrigation treatment, or other input combination. These 28 constraints and 27 income activities establish the framework for the analysis in the following sections. They define the range within which the forces regulating optimum crop choices and resource allocations for maximizing profits under specified conditions must operate.

Important variations exist among farms in the study area, according to the soil characteristics. Our analysis recognizes these variations. Thus we examine each of three different soils with its own properties and range of adapted alternatives. We identify these three soil-crop pattern models by capital letters in the tables and figures accompanying the main body of this report:

A--The analysis for basin soils and adapted crops.

B--The analysis for old alluvium soils and adapted crops.

C--The analysis for recent alluvium soils and adapted crops.

Budgeted Total Farm Earnings Statements Determine Profits and Returns to Various Resource Categories

Linear programming analysis in this study identified the optimum resource pattern and indicated the total farm net returns-over-variable expenses under each set of assumptions and conditions examined. This approach, however, did not determine total Net Farm Income, nor measure Profit and the respective earnings shares to capital, management, or operator labor.[16/] Further analysis is necessary in order to calculate these measures of farm business success under varying water quantity and cost condition. We used budget analysis for this purpose: this method combines the Cross Receipts, Variable Expenses, and Net Returns-Over-Variable Expenses yielded by the linear

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16/ See pages 15 and 16, above.

programming analysis with data reflecting capital investments, and related Fixed Costs. It is possible through this approach, therefore, to calculate the necessary earnings measures and, evaluate (a), the effect of a given set of conditions on farm resource use, total farm profits, and the returns to various farm resources, and/or (b), how various plans associated with the respective sets of conditions compare in financial returns and resource earnings.

SHIFTS IN NET RETURNS AND OPTIMUM RESOURCE USE ACCOMPANY VARIATIONS IN WATER PRICES AND QUANTITIES

A linear programming analysis effectively identified and measured the relationship between, first, varying water prices and, second, varying water quantities on the one hand, and total farm net returns-over-variable expenses on the other. It was necessary to make a separate analysis for each of these relationships and for each of the three soils situations in the study (basin, old alluvium, and recent alluvium).

Net Returns-Over-Variable Expenses Drop Sharply As Water Costs Rise

Water costs were allowed to vary from zero to $34.00 per acre-foot in the analysis for the basin soil and from zero to $26.00 per acre-foot for the other two soil situations (see Table 4). Maximum quantities of water used and maximum net returns-over-variable costs for all three soil situations are with water price at the zero level. This total use was 3,000 acre-feet for the basin soils, compared with 4,300 on old alluvium and 5,200 on recent alluvium soils (see Table 4). The greater amounts of water used on the latter two soil categories reflect the wider range of irrigated crops adapted to these two soils.

Both net returns-over-variable expenses and the amount of water applied declined sharply on all three soils as water costs rose. Total net returns-over-variable expenses at zero water prices ranged from $136,600 for the basin soils to $160,300 for the recent alluvium with the old alluvium soil at $154,400; falling only slightly behind the recent alluvium. As water costs rose to about the $15.00 level, the net returns figure dropped to

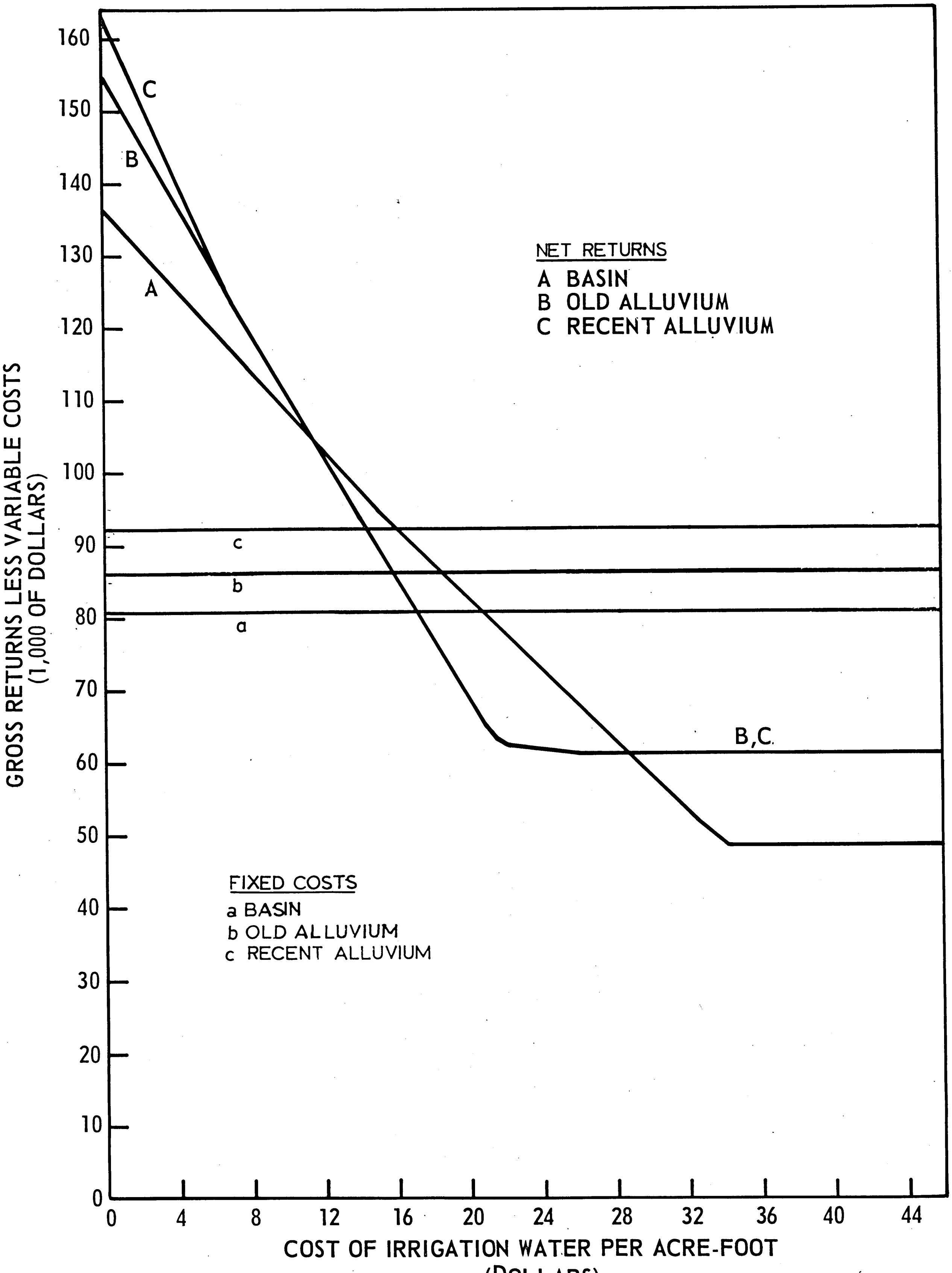
TABLE 4

Variations in Farm Net Returns and Irrigation Water Variable Costs for Three Soils, 1964-1966 Average Prices

Basin			Old alluvium			Recent alluvium		
Net returns	Cost per acre-foot	Quantity	Net returns	Cost per acre-foot	Quantity	Net returns	Cost per acre-foot	Quantity
1	2	3	4	5	6	7	8	9
dollars		acre-feet	dollars		acre-feet	dollars		acre-feet
136,605	0	3,017	154,423	0	4,313	160,336	0	5,193
114,660	7.90	3,017	123,563	7.20	4,313	126,144	6.60	5,193
95,214	14.90	2,773	93,480	14.20	4,256	123,563	7.20	4,313
51,664	32.60	2,451	64,845	21.10	4,156	93,480	14.20	4,256
48,789	34.20	1,838	63,348	21.50	3,761	64,845	21.10	4,156
48,789	100.00	0	62,278	22.10	1,783	63,334	21.50	3,761
			61,096	26.10	299	62,271	22.10	1,783
			61,096	100.00	0	61,089	26.10	299
						61,089	100.00	0

FIGURE 5

FARM NET RETURNS AT VARYING IRRIGATION WATER COSTS FOR THREE SOILS



$95,200 on the basin soils and, at this level, afforded only about $14,400 above the amount of net returns required to cover fixed costs ($80,800) on this basin soil model (see Figure 5).

Further rises finally to $30.00 per acre-foot, reduced net returns to levels markedly below total farm fixed costs for this basin soil. Reductions in water quantities that maximized net returns-over-variable expenses also dropped simultaneously. The total amount stood at 2,800 acre-feet with water prices at about $15.00 per acre-foot, but dropped to 1,800 acre-feet at a $34.00 price (see Table 4).

Total farm fixed costs, as calculated in this study, include two major categories of overhead costs. First, and by far the largest, of these categories is that group of costs incurred by owning property. This category, in turn, includes two major types of costs: (a) noncash fixed costs, including interest on investments and annual depreciation costs and, (b), cash fixed costs, including taxes and insurance. Total fixed costs for this first major category (costs incurred by owning property) ranged from $79,000 on basin soils to $89,500 on the recent alluvium (see Table 2). Land costs, including only interest on investments and taxes (no depreciation), represented by far the largest item here. Equipment accounted for most of the rest of these property-oriented fixed costs, with improvements accounting for only $1,600.

Cost items in the second major category, general overhead, were of minor importance in this study; they accounted for about $1,600.

Total farm fixed costs are highly important to an individual farm operator; they represent an overhead charge that his net returns-over-variable expenses must cover before any net profit remains to pay for his own management and risk assumption. Thus the point at which net returns-over-variable expenses exactly equals these total farm fixed costs represents a "breakeven" financial result for the operator's total farm business, including wages at going rates for his own labor. At this point, net returns from his income enterprises exactly cover the total farm fixed costs or overhead--the "burden" that the farm must carry in order to operate at all. To the extent that his net returns-over-variable expenses exceed this breakeven point, the farm operator receives a surplus or profit to pay him for his management and for the risk that he runs in carrying on his farming operations. The land value and interest-on-investments data in this report represent estimates based on "going rates," as determined from public records and interviews. Depreciation costs, likewise, represent approximations rather than precise determinations. This is because the latter values, representing annual costs for "using up" property, depend heavily upon accurate judgments as to length of useful life. These life-expectancy figures, in turn, can only be estimates or human judgments; at best they will correspond closely with reality, due to the background of experience of the person(s) making this judgment.

In summary, the amounts that this report presents as total farm fixed costs may or may not agree closely with reality. Their greatest usefulness lies in providing a basis to compare results from each of the several different farm models included in the study with <u>each other</u>, and to provide perspective on the net earnings significance of the total farm figure net returns-over-variable expenses. Even if land values estimated for this study are precisely accurate, the interest component of noncash fixed costs will vary with any changes in the assumed going rate (6.5 percent per annum in this study).

It is evident from this analysis of net returns-over-variable expenses, and the quantities of water used that farmers cannot profitably pay prices greater than $15.00 per acre-foot under the yield, price, costs and other conditions specified in this analysis. It is reasonably certain, furthermore, that the conditions used in this analysis are much more favorable than those that most Butte-Colusa area rice growers have faced during recent seasons. The assumed price ($4.90 per hundredweight) is in line with those of the 1967-1969 seasons, but both yields (60-72 hundredweights per acre, depending upon soils group and cultural practices), and acre allotments for rice exceed the usual levels for rice growers in the Butte-Colusa area during these seasons.

A water price of about $11.00 per acre-foot would associate with the break-even point for the basin soil model in this study at a rice yield of 50 hundredweights per acre--a typical yield level for many rice farmers in the Butte-Colusa subarea, and the three-year (1967-69) average yield for

Butte County. Rice allotments at 30 percent of tillable land also would result in drastically lowering prices for water that farmers could pay and still break-even on their total farm variable and fixed costs. The impact would be about the same as for the 10-hundredweight yield reduction. A combination of reduced allotments plus the yield reduction would mean that farmers could not pay more than about $5.00 per acre-foot for irrigation water and still hope to cover total farm variable and fixed costs, with no allowance for management or risk. Similar analyses indicates that reducing the yields or the allotments to typical levels would sharply lower the water prices that rice growers on old or recent alluvium soils could afford to pay and still recover all costs except returns to management.

Our analytical approach uses better-than-typical yields and allotments, however, because we believe that so doing will make the results more meaningful for future reference. The technology and "know-how" already exist to accomplish such yields on a broad basis in this subarea, as is evidenced by the performance that some growers now are achieving. As for allotments, we believe the 40 percent used is more realistic than a lower figure would be in terms of population growth, both at home and abroad, and the pressure of world food needs. Certainly, sound resource use in terms of alternative choices for rice growers on all three of the soil categories in this study strongly support acreage allotments for rice not lower than the 40 percent level. The wide economic advantage of rice over alternative crops indicates that higher-than-40 percent allotment levels for rice would permit even more effective use of resources in the Butte-Colusa rice-producing area.

Growers on old and recent alluvium soils show little difference in the water price and the associated net returns-over-variable expenses associated most closely with the break-even point. Both these units, however, would use about 1,500 acre-feet more water at this break-even point than the basin soil model (see Table 4). These two alluvium soil units show more capacity to maintain both irrigation water use and the level of net returns-over-variable expenses as water prices increase further, at least up to levels in the $20.00 range. The reasons for these differences are evident in the data showing the net returns-over-variable expenses for the various adapted crops presented in an earlier section (see Table 4). We do not anticipate that rice growers with rights in surface water obtained from irrigation districts in the Butte-Colusa subarea will have to face water prices running up to the levels tested here. We believe, nonetheless, that the results obtained in this test constitute conclusive evidence that rice production has a preferred position as compared with alternative choices under any reasonable set of conditions to be anticipated in this subarea.

This analysis demonstrates, further, as is evident in the accompanying text table based on 1964-1966 prices, that relatively sharp drops in net returns-over-variable expenses accompany water price rises for all three soil situations tested.

Net Returns		Water Price		Net Returns Per
Amount	Change	Amount	Change	Dollar Price Change
		BASIN SOILS		
136,605		0.00		
114,660	-$21,945	$ 7.90	+ $ 7.90	-$2,778
95,214	- 19,446	14.90	+ 7.00	- 2,735
51,664	- 43,550	32.60	+ 17.70	- 2,460
		OLD ALLUVIUM SOILS		
154,423		0.00		
123,563	-$30,860	$ 7.20	+ 7.20	-$4,286
123,563	- 30,083	14.20	+ 7.00	- 4,293
64,485	- 28,995	21.10	+ 6.90	- 4,202
		RECENT ALLUVIUM SOILS		
160,336		0.00		
126,144	-$34,193	$ 6.60	+ $6.60	5,176
93,480	- 30,083	14.20	.60	4,302

Thus, a drop of nearly $22,000 in net returns accompanied a rise in water cost from zero to $7.90 per acre-foot on basin soils; this drop represents $2,780 decline per $1.00 rise in price per acre-foot of irrigation water. Further declines of similar magnitude accompanied water price rises from $7.90 to $14.90 and on to $32.60 per acre-foot. The comparable changes on old alluvium and recent alluvium soils were still greater, those on the recent alluvium soils being almost twice as large per dollar of water price rise as were the drops in net returns-over-variable expenses for the basin soils. On the old alluvium soils, the drop in net returns was nearly $31,000 for the initial rise in water prices to $7.20 per acre-foot or $4,300 per acre-foot. The change on recent alluvium soils was a $34,200 drop for a water price rise from zero to $6.60--a reduction of nearly $5,200 for each rise of $1.00 in water price.

Initial Water Increments Above Zero Bring High Added Net Returns Per Acre-Foot: Basin Soils Use the Least, Recent Alluvium, the Most Irrigation Water

A linear programming analysis indicates, for each of the three soils studied, the effects on net returns-over-variable expenses as irrigation water quantities vary from zero to the amount that maximizes net returns. Small grains, grain hay, and safflower represent the principal economically adapted crops from among which farmers must choose in this subarea if they do not have water for irrigation. The minimum net returns-over-variable expenses associated with zero water quantities in this linear programming analysis, therefore, reflect one or a combination of these adapted crops for each soil category (see Figure 6). The level of these net returns at zero water applications ranged from 58 percent of total farm fixed costs (net returns $47,000 versus fixed costs of $80,800) for basin soils to 70 percent ($61,000 versus $86,000) for old alluvium soils. Sharp gains in net returns accompanied the initial water additions for all three soils. This water enabled farmers to divert land from the nonirrigated crops to rice production. Thus the first 1,800 feet of irrigation water available to operators on basin soils returned $33.00 per acre-foot applied, with a resulting gain of about $60,000 in net returns-over-variable expenses (see Table 5). The analyses for the two alluvium soils show net returns of $25.00 and $24.00 respectively, per acre-foot for the old and the new alluvium soils.

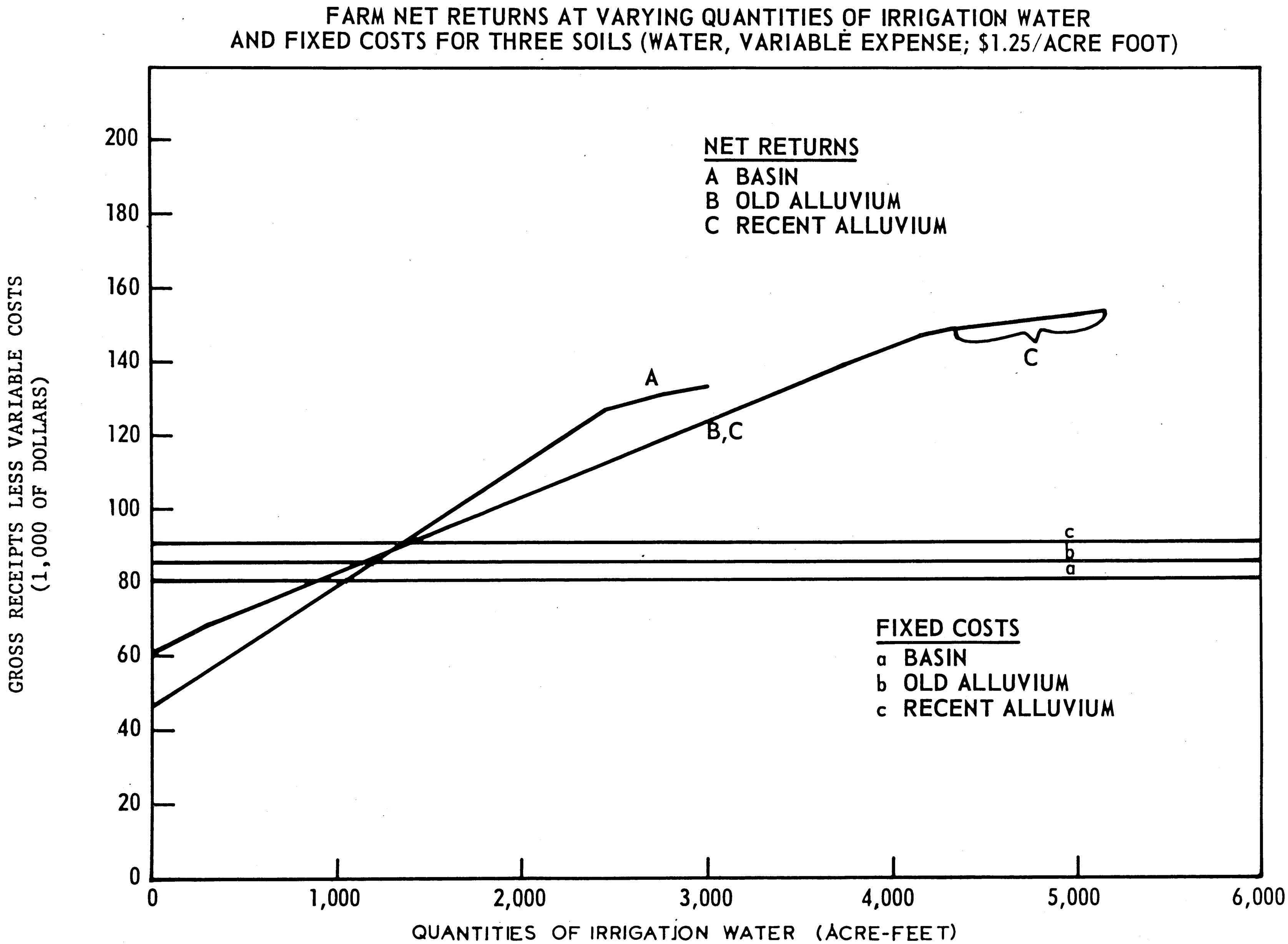
Increases in total farm net returns continue to accompany additional increments of irrigation water. The addition net returns per acre-foot

TABLE 5

Farm Net Returns Per Acre-Foot of Water Varying Quantities of Irrigation Water on Three Soils, 1964-1966 Average Prices

Net Returns		Irrigation water		Net returns
Total	Change	Total	Change	Per acre-foot
1	2	3	4	5
dollars		acre-feet		dollars
		Basin		
47,012	0	0	0	0
107,592	60,570	1,838	1,838	32.96
126,828	19,236	2,451	613	31.38
131,217	4,389	2,773	322	13.63
132,830	1,613	3,017	244	6.61
		Old alluvium		
61,096	0	0	0	0
68,519	7,423	299	299	24.82
99,475	30,956	1,783	1,484	20.85
139,562	40,087	3,761	1,978	20.26
147,406	7,844	4,156	395	19.85
148,699	1,293	4,256	100	12.93
149,034	335	4,313	57	5.87
		Recent alluvium		
61,096	0	0	0	0
67,237	6,141	250	250	24.56
98,193	30,956	1,733	1,483	20.87
138,280	40,087	3,712	1,979	20.25
146,551	8,271	4,123	411	20.12
147,629	1,078	4,194	71	15.18
149,034	1,405	4,313	119	11.80
152,643	3,609	4,973	660	5.46
153,706	1,063	5,172	199	5.34

FIGURE 6


FARM NET RETURNS AT VARYING QUANTITIES OF IRRIGATION WATER
AND FIXED COSTS FOR THREE SOILS (WATER, VARIABLE EXPENSE; $1.25/ACRE FOOT)
NET RETURNS
A BASIN
B OLD ALLUVIUM
C RECENT ALLUVIUM
FIXED COSTS
a BASIN
b OLD ALLUVIUM
c RECENT ALLUVIUM
A
B,C
C
c
b
a
GROSS RECEIPTS LESS VARIABLE COSTS (1,000 OF DOLLARS)
0
20
40
60
80
100
120
140
160
180
200
0
1,000
2,000
3,000
4,000
5,000
6,000
QUANTITIES OF IRRIGATION WATER (ACRE-FEET)

(marginal returns) for each added water increment, however, decline steadily after the initial applications (see Table 5). Thus basin soils returned about $6.60 per acre-foot for the last increment (244 acre-feet) of the 3,000 acre-feet total associated with the maximum net returns-over-variable expenses ($132,800). Similar declines in marginal net returns per acre-foot accompanied added increments of water up to 4,300 acre-feet on the old alluvium soils. These reductions were from the $25.00 level to slightly less than $6.00 (see Table 6). Total net returns at this maximum water application level were $149,000 on the old alluvium soils.

The analysis for recent alluvium soils revealed a drop in marginal returns from over $25.00 per acre-foot for the initial increments to slightly over $5.00 for the final ones as total water applications reached 5,200 acre-feet, and total net returns $154,000 for these soils.

The increases in total water quantities from 3,000 acre-feet for the basin to 4,300 for old alluvium, and to 5,200 for recent alluvium soils reflects the adaptability of irrigated crops other than rice to these latter two soils. The correspondingly greater aggregate totals for net returns-over-variable expenses indicates the greater profit potential for soils with a greater range of adaptability for irrigated crops.

This analysis also reveals considerable variation among the three soil categories in the level of marginal net returns before and after total water applications reach the level accompanying the break-even point for total farm net returns versus fixed costs. Net returns from the basin soils reach this break-even point at water applications of about 1,050 acre-feet. The comparable quantities were 1,200 acre-feet for the old alluvium and 1,400 acre-feet for the basin soils (see Figure 6). Average marginal net returns per acre-foot of irrigation water applied were $32.00 per acre-foot for the basin soils up to the break-even point, and about $27.00 for the remaining applications up to the 3,000 acre-foot total. Comparable figures for the other two soils were $21.00 per acre-foot, and $20.00 per acre-foot for the old alluvium and $21.00 and slightly over $16.00 per acre-foot of water before and after the break-even point on the recent alluvium soils.

WATER QUANTITIES AND PRICES GOVERN OPTIMUM MANAGEMENT DECISIONS, RESOURCE ALLOCATIONS, AND CROPPING SYSTEMS

Water Quantities Sharply Limit Crop Choices, Resource Allocation, and Net Returns on Irrigated Farms

Water is a limited, if not actually a scarce, resource on many rice farms. This is particularly true for much of the basin soil area east of the Sacramento River in Butte County (see Figure 1). We used a linear programming analysis to determine what specific land allocations would optimize total farm net returns-over-variable expenses for the three farm models in this study. We pointed out earlier that without irrigation water, farmers have no economic alternative other than to plant their crop land to winter and spring crops adapted for dry farming. The constraints, farm input and product prices, and other conditions established for this study indicate that without irrigation water, farmers on all three soil categories studied would maximize their total returns with the following cropping system: barley, 354; wheat, 354; safflower, 236; fallow, 118; and idle land 118 acres (see Tables 4 and 5, and Figure 7).

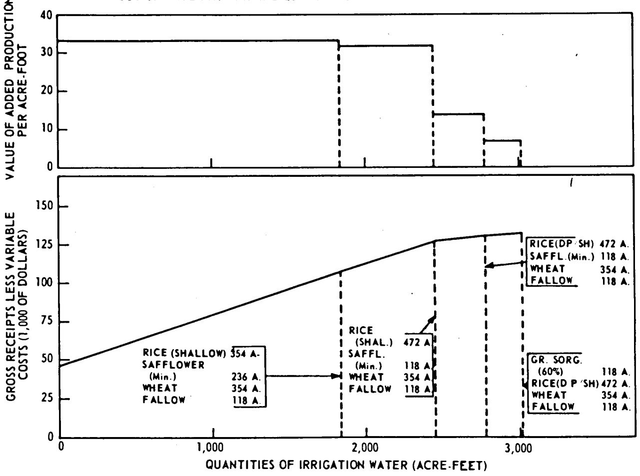
Rice, the crop with the highest net returns-over-variable expenses per acre, would claim all water increments on the basin soil until the entire 472 acres permitted under assumed government allotments is in operation (see Figure 7). The shallow irrigation treatment would be the optimum practice until after water increments reach 2,450 acre-feet; the deep-shallow practice would optimize net returns for the total farm cropping system at water quantities exceeding this quantity.

Our earlier analysis identified grain sorghum as the only irrigated crop other than rice that appears to be an economic alternative on the basin soils (see Figure 3). This analysis confirms the earlier indication; actually grain sorghum appears in the farm cropping system only at water quantities exceeding about 2,800 acre-feet.

The order in which irrigated crops other than rice enter the cropping system that yields maximum net returns-over-variable expenses is quite different for the two alluvial soils than for the basin soils (see Figure 7). Dry beans appear in the cropping system for the old alluvium category

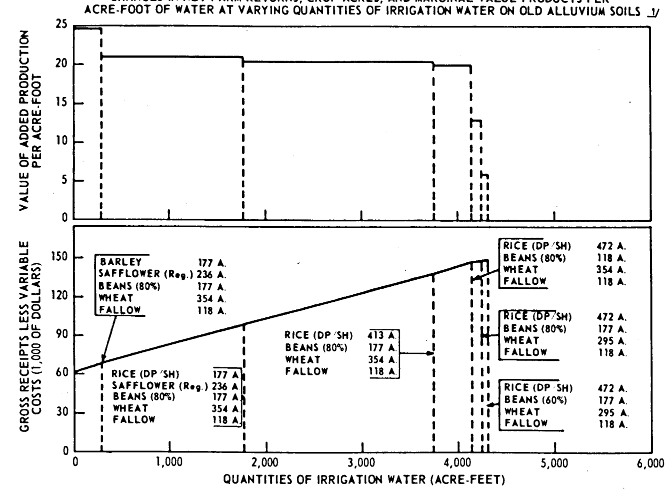
FIGURE 7

CHANGES IN NET FARM RETURNS, CROP ACRES, AND MARGINAL VALUE PRODUCTS PER ACRE-FOOT OF WATER AT VARYING QUANTITIES OF IRRIGATION WATER ON BASIN SOILS. 1/



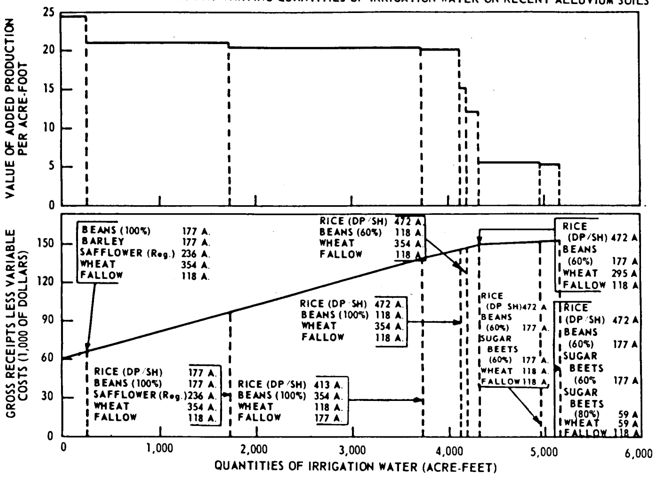
1/ AT O WATER QUANTITY: BARLEY 354, SAFFLOWER 236, WHEAT 354, FALLOW 118 ACRES

CHANGES IN NET FARM RETURNS, CROP ACRES, AND MARGINAL VALUE PRODUCTS PER ACRE-FOOT OF WATER AT VARYING QUANTITIES OF IRRIGATION WATER ON OLD ALLUVIUM SOILS 1/



1/ AT O WATER QUANTITY: BARLEY 354, SAFFLOWER 236, WHEAT 354, FALLOW 118 ACRES

CHANGES IN NET FARM RETURNS, CROP ACRES, AND MARGINAL VALUE PRODUCTS PER ACRE-FOOT OF WATER AT VARYING QUANTITIES OF IRRIGATION WATER ON RECENT ALLUVIUM SOILS



1/ AT O WATER QUANTITY: BARLEY 354, SAFFLOWER 236, WHEAT 354, FALLOW 118 ACRES with the initial water increment. Irrigation requirements for this crop are sufficiently low as compared with rice, that a water addition insufficient to bring in rice acreage does make it possible to include 177 acres of dry beans. Rice (177 acres irrigated under the deep-shallow practice) appears with the second water increment, expands to 413 acres with the third, and reaches its maximum 472 acres permitted under the allotment program with the fourth water increment (see Figure 7).

The cropping pattern on recent alluvium as successive increments of irrigation water bring quantities to the 5,200 foot maximum, is similar for beans to the pattern on the old alluvium soils. This low-water-requirement row crop (177 acres) appears in the optimum cropping system before rice and continues to retain a place in the maximum net returns cropping system for all successive water increments. In contrast with its unchanging position in the acreage for each cropping system on the old alluvium soils, however, the dry bean acreage on recent alluvium varies among the optimum net returns cropping systems. Beans appear in the initial irrigated system at 177 acres, continue at this acreage under the second water addition, expand to 354 with the third increase in water quantity increments by which water quantity finally reaches its maximum 5,200 acre-foot total for recent alluvium soils (see Figure 7). Rice, appears in the cropping system at the second water increment with 177 acres under deep-shallow irrigation. This crop requires two more increments to reach its maximum 472-acre allotment level. The deep-shallow irrigation practice is the most profitable for this maximum return crop for all water quantities in which the highest net total farm return cropping system includes rice. The range of crop adaptation for the recent alluvium soils makes it profitable for sugar beets to appear in the optimum cropping system at the final two water additions. This crop, irrigated at the 60 percent soil depletion level, occupies 177 acres at the next-to-last water increment, and a total of 236 acres (177 at 60 percent and 59 at 80 percent available soil moisture depletion levels) under the final water increment. This was at maximum water availability of 5,200 acre-feet for the entire farm.

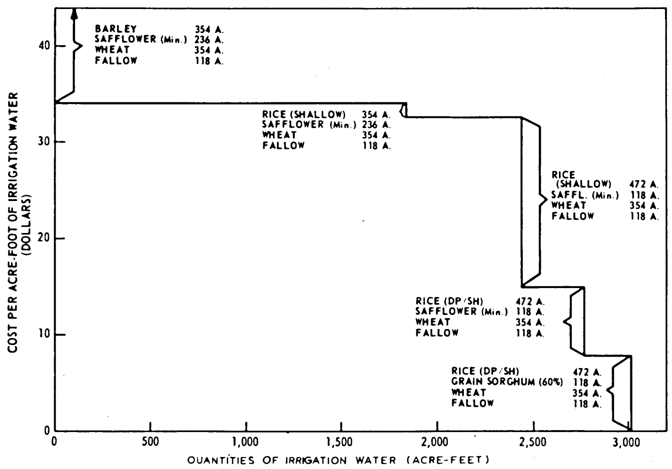
WATER PRICE VARIATIONS REGULATE QUANTITIES USED, CROP CHOICES, AND RESOURCE ALLOCATIONS

A farmer seeking to maximize his profits, will use smaller quantities of irrigation water at relatively high prices per acre-foot. It is self-evident, also, that he will make every effort to apply the quantities that he does use to the crops or other enterprises that will yield the highest net returns to the water applied. We wanted to go beyond these general guidelines in this analysis; we undertook, also, to identify as precisely as possible the effects of water price variations on quantities used and the choice of crops to which water is applied. We set up to accomplish such identification a linear programming analysis in which water prices begin at levels uneconomic for irrigation use, and then lower, progressively, until further reductions bring no expansion in quantities that optimize total farm net returns-over-variable expenses. The result was a series of water prices and the cropping systems (crops and acreages of each) associated with each price (see Figure 8).

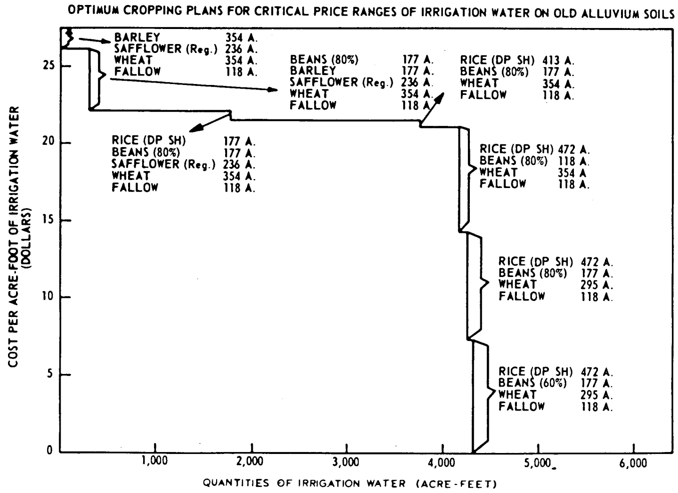
The cropping system on basin soils with water prices at levels that prohibit irrigation, again, include the winter grains, safflower, and fallow (cultivated but unplanted) land. Acreages in each of these used were barley, 354; wheat, 354; safflower, 236; and fallow land, 118 acres; these land allocations among crops and fallow land apply not only to basin, but also to the two alluvium soils under the prices, constraints, and conditions of this study. The highest water price at which the linear programming analysis shows an irrigated crop coming into the farming system was at $34.20 per acre-foot. Rice, under the shallow irrigation treatment, replaced the 354 acres of barley, and used the entire first increment of irrigation water (about 1,840 acre-feet--see Figure 8). Rice acreage continued to expand, and the quantities of water applied to increase, as water prices decline, successively, to about $33.00, and then to about $15.00 per acre-foot. Rice reached its maximum acreage permitted under the allotment program at the $33.00 price. The third water increment, at a price of about $15.00 per acre-foot, brought, therefore, not added rice acreage but a shift from the shallow to the deep-shallow irrigation practice. The

FIGURE 8

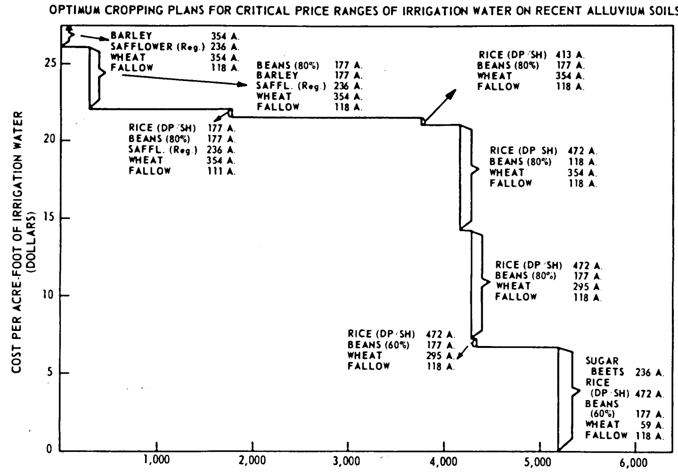
OPTIMUM CROPPING PLANS FOR CRITICAL PRICE RANGES OF IRRIGATION WATER ON BASIN SOILS



OPTIMUM CROPPING PLANS FOR CRITICAL PRICE RANGES OF IRRIGATION WATER ON OLD ALLUVIUM SOILS



OPTIMUM CROPPING PLANS FOR CRITICAL PRICE RANGES OF IRRIGATION WATER ON RECENT ALLUVIUM SOILS



result of this shift was to utilize an additional 325 acre-feet of water on the rice enterprise. The final adjustment on the basin soils as water prices lowered came with the drop from $15.00 to $8.00 per acre-foot; 118 acres of grain sorghum irrigated under the 60 percent available soil moisture depletion practice replaced the safflower. This shift accounted for the 255 acre-foot expansion in water use (see Figure 8). Only at the latter two irrigation water price levels of $15.00 and $18.00 per acre-foot, respectively, did total farm net returns-over-variable-expenses exceed the break-even point under this analysis, by about $14,000 and about $34,000, respectively.

The two alluvium soils show a wider range of adjustments to declining water prices than the basin soil. This difference reflects the greater range of crop adaptability characterizing these two soils. Thus the old alluvium requires lesser price declines to stimulate shifts in the cropping pattern and, naturally, displays a greater number of such cropping pattern changes (see Figure 8). The initial water use (about 300 acre-feet) came at the $26.00 per acre-foot price and brought into the cropping system 177 acres of beans under the medium irrigation practice. Rice (177 acres under the deep-shallow irrigation practice) came in with the second water increment of about 1,500 acre-feet, and at the $22.00 water price. Rice acreage continued to expand to its 472-acre allotment level, while dry beans dropped to 118 acres, as water prices declined in two steps to $21.00 per acre-foot (see Figure 8). Further drops in water prices, finally to about $7.00 per acre-foot, resulted in acreage shifting from wheat to beans, thus increasing the latter back to the 177-acre level, and water use to a total of about 4,200 acre-feet.

The general relationship among water prices, quantities used, and cropping patterns for the recent alluvium soil was similar to that on the old alluvium. Beans appear in the cropping system at a water price of about $26.00 per acre-foot, and continue to occupy crop acres for all of the remaining systems associated with successively lower water prices. This crop, however, does, first lose acreage to rice, and, later, regain it at the expense of wheat, as water prices drop from $22.00 to $21.00 per acre-foot (see Figure 8). Rice (177 acres deep-shallow irrigated) appears in the cropping system with the second water increment, and continues to increase until it reaches the 472 acre maximum with the fourth water addition. Sugar beets also find a place in the cropping system on the recent alluvium soils, but only at the lowest water price appearing in this analysis, about $7.00 per acre-foot, at which price they occupy 236 acres.

The old alluvium soil model reaches its maximum total water use at about 5,100 acre-feet at this $7.00 water price with three irrigated crops, rice, sugar beets, and beans accounting for 885 acres with the rest of the tillable area in wheat (59 acres) and fallow land (118 acres). It is true for the recent alluvium model, as for the other two, that total farm net returns-over-variable expenses equal or exceed total farm fixed costs only at relatively low water prices. These net returns, at $93,500, approximately equal fixed costs at the $14.00 water price; they increase to show net profits at prices below this level.

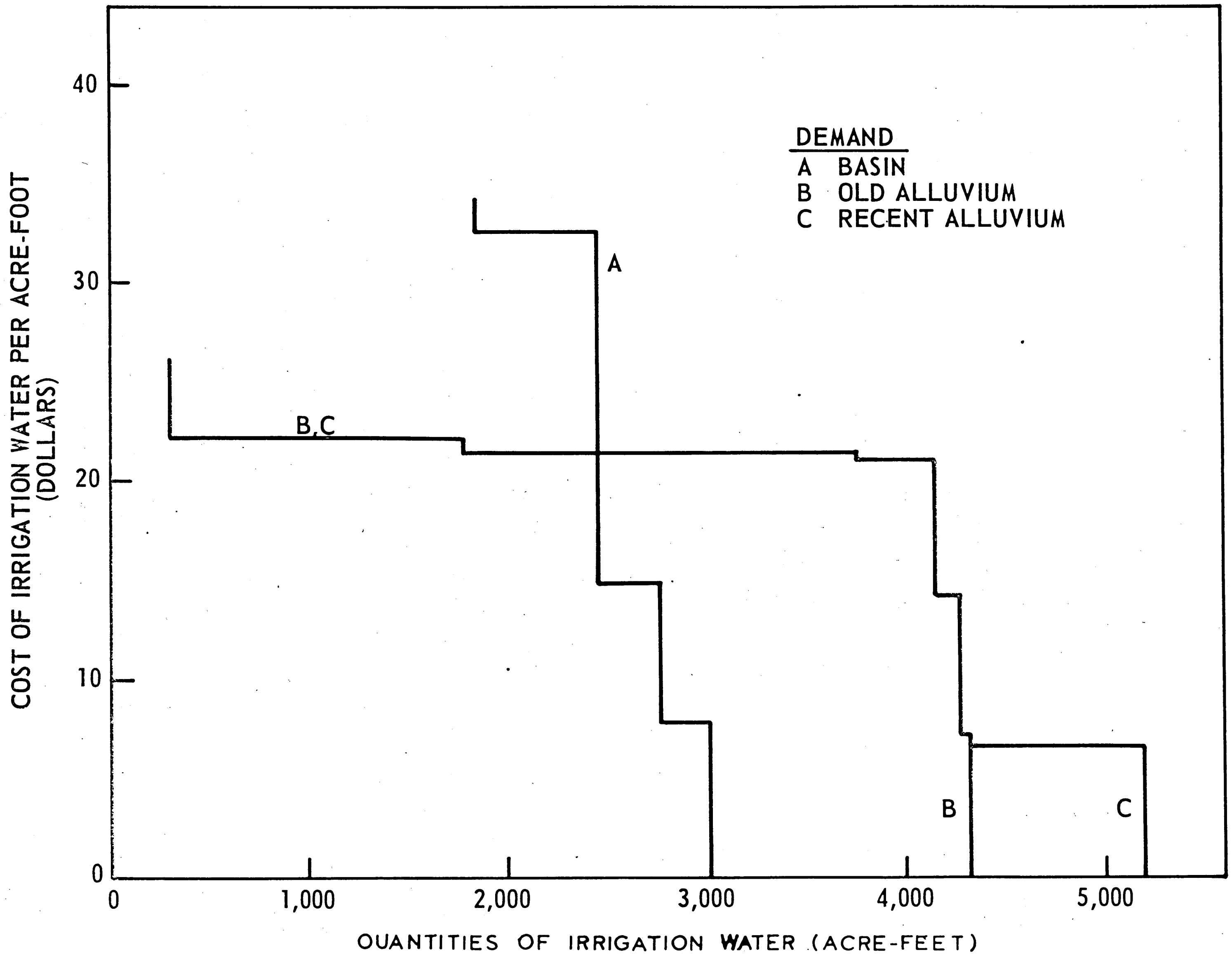
WATER PRICES AND SOIL ADAPTABILITY GOVERN FARM WATER DEMAND

It was evident in the preceding section, as well as in earlier ones, that the total amount of water used at maximum total farm net returns-over-variable expenses varies widely among the three farm models. The actual range of this variation is from slightly over 3,000 to 5,200 acre-feet (see Figure 9). This initial water increment of about 1,800 acre-feet on the basin soil meets requirements of 354 acres of rice, and displaces a like acreage of barley at an initial price of $34.00 per acre-foot, as shown in the preceding section (see Figures 8 and 9). No gain in net returns accompanies this shift from a non-irrigated to an irrigated crop, however, due to the extremely high price of water. Gains in net returns do accompany the next three water increments, however; net returns exceed the break-even point with the third, and reach a maximum (at about $115,00) with the fourth and final increment (3,000 acre-feet).

The analysis in the preceding section traces the shift from low to higher water use, and accompanying expanded acreage for rice plus the appearance of grain sorghum in the cropping system, as these water prices

FIGURE 9

FARM DEMAND FOR IRRIGATION WATER ON THREE SOILS



decline. The relatively narrow range of choice among profitable uses for irrigated land on the basin soils explains why only rice and grain sorghum appear in the cropping systems on this type of soil. This same fact, also, explains the relatively small water quantity (3,000 acre-feet) associated with maximum net returns on this soil. The elasticity of demand for irrigation water on rice farms of this size on basin soils, in other words, was quite low; relatively sharp drops in water prices generated only small increases in total water use. In contrast, the other two soils with a wider range of adaptability to crops show much higher demand elasticity for irrigation water. The recent alluvium model with the widest range of crop adaptability, furthermore, shows the highest demand elasticity level of any of the three soil category models (see Figure 9). This is evident in the relatively small drop in prices required to stimulate expanded water use, and in the wide range in quantities between the low initial increment of about 300 acre-feet and the 5,200 acre-foot maximum usage.

EXPENSIVE OR LIMITED QUANTITIES OF WATER SHARPLY REDUCE FARM PROFITS

Sacramento Valley rice growers apply relatively large quantities of irrigation water to rice; this holds even for producers with leveled fields of basin or other soils the structure of which largely prevents downward percolation, and who control their water applications effectively. The requirement standards on the basin model in this study range from 5.2 to 5.9 acre-feet per acre of rice, depending upon the irrigation technology. The standard for growers producing rice on alluvial soils with higher percolation rates ranges from 8.2 to 8.9 acre-feet. We chose to use these standards deliberately, although available information from previous studies, records, and interviews indicate that many farmers use quantities considerably greater than these to produce rice in the Sacramento Valley. We chose these water use rates on the basis of research information and actual performance by some growers in order that our results may reflect the production and returns possible for growers applying the most up-to-date research knowledge who also use superior water management practices. Water prices and quantities exert important influence on rice farmers' profits.

The quantities of water required to produce rice under conditions specified for the three models in this study, though less than many farmers apply, still are large enough to leave no doubt on this conclusion. One of the marked advantages accruing to rice growers planting and producing the bulk of the rice grown in the Sacramento Valley is the relatively large supplies of water available, and the nominal price of this water. Both of these favorable conditions would tend to disappear with any major increase in the total Sacramento Valley rice acreage. Such acreage expansion would soon exhaust water supplies, while additional quantities of water, if available at all, could be had only at sharply increased prices.

Water quantities and prices represent only two of the major forces that jointly regulate the profits that Sacramento Valley farmers obtain from growing rice. These farmers must control and use large amounts of capital; a combination of inflationary price rises plus new technology and increased mechanization during the 1960's and early 1970's stimulated an upward trend in these capital requirements. Thus the average investments for the three models in this study ranged from slightly less than $700,000 for the basin to over $800,000 for the recent alluvium unit (see Table 1). Investments at such levels as these entail heavy fixed costs obligations. Interest on investment, alone, at an assumed rate of 6.5 percent per annum amounts of nearly $45,000 for the basin, nearly $49,000 for the old alluvium, and nearly $53,000 for the recent alluvium model in this study. Total fixed cost, including depreciation, taxes, insurance, and other items for these three models were $81,000, $86,000, and $91,000 per year, respectively, for these three units.

We have related these fixed costs to total farm <u>net returns-over-variable expenses</u> in our several analyses prior to this section in this report. We pointed out that the break-even point, at which the total farm net return exactly covers the fixed cost, represents a critical economic balance in the farm operations. It is at this balance that the operator is able to recover all of his costs, both variable and fixed and including pay for his own in field work at the same pay rate that he pays his hired employees. This break-even point, however, leaves nothing above this equated balance either to pay him as manager for performing the functions of planning, organizing, directing, and otherwise managing the business, or to reward him for risking the capital, either owned or borrowed, in this operation. A farmer, like any other businessman, does not willingly operate at this level; he expects his farm operations to pay him something more for his capital and management than these two resources can earn in the market if he hires them out.

We include in this report an analysis to show on a comparative basis the level of arm earnings under the conditions specified in this study, and under some other sets of conditions. The basin model offers a useful starting point for these comparisons. This model (Case 1), with no restrictions on the typical 3,017 acre-feet of water available under conditions of this study, a water price of $1.25 per acre-foot, and at rice yields of 68 hundredweights per acre under the deep flooding-lowered irrigation practice, would result in gross receipts over variable expenses of $132,834 for the total farm operation (see Table 6). The cropping system at this level of net returns would include 472 acres of rice, 118 acres of grain sorghum (irrigated at the 60-percent level of soil moisture depletion), 354 acres of wheat, and 118 acres in each fallow and idle land.

This total net returns figure lends itself to analysis according to standard farm earnings measures. We subtract fixed costs ($80,800) from the net returns, to obtain $52,034 as <u>Net Returns over fixed costs</u>. We then add to this latter item the <u>Value of Operator's work in</u> field operations at $2,575 (estimated at one-third the total annual cost for a full-time employee), plus $44,616, representing <u>Interest</u> on <u>capital</u>, to determine that <u>NET FARM INCOME</u> is $99,225 (see Table 6, column 1). This is the figure from which the farmer must allocate the proper shares in earnings to all resources that he uses. We estimate his own <u>Operator's Wages</u> (full-year basis) at the same rate that he pays his hired employees, $7,725, and subtract this amount from <u>NET FARM INCOME</u>. The result, $91,500 is <u>PROFIT</u>; this is what the farm pays the operator under the operating conditions of this study as a reward for using capital and his management, including risk assumption.

TABLE 6

Farm Earnings and Profits (Capital and Management Income) at Varying Water Quantities and Costs, Rice Yields, and Allotments, 1964-1966 Average Prices, Except as Indicated

	Basin soils				Old alluvium soils	
	Case 1 a/	Case 2	Case 3	Case 4	Case 6 b/	Case 7
Water: quantity	3,017 A-feet	1,838 A-feet	1,838 A-feet	3,017 A-feet	4,300 A-feet	3,603 A-feet
price	$1.25/A-foot	$1.25/A-foot	$1.25/A-foot	$7.90/A-foot	$1.25/A-foot	$1.25/A-foot
Rice: allotment	40 percent	30 percent	40 percent	40 percent	40 percent	30 percent
yield	68 cwt/A	50 cwt/A	68 cwt/A	68 cwt/A	71 cwt/A	55 cwt/A
	dollars					
	1	2	3	4	5	6
Total farm capital c/	$686,470	$686,470	$686,470	$686,470	$750,466	$750,466
Gross receipts less variable expenses	132,834	80,036	109,351	112,771	149,032	106,811
Total fixed costs	80,800	80,800	80,800	80,800	85,968	85,968
Net returns over fixed costs	$ 52,034	$(-) 764	$ 28,551	$ 31,971	$ 63,064	$ 20,843
Add						
Value operator's work d/	2,575	2,575	2,575	2,575	2,575	2,575
Interest on capital	44,616	44,616	44,616	44,616	48,776	48,776
NET FARM INCOME	$ 99,225	$ 46,427	$ 75,742	$ 79,162	$114,415	$ 72,194
Subtract						
Operators wage e/	7,725	7,725	7,725	7,725	7,725	7,725
PROFIT (return to capital and management)	$ 91,500	$ 38,702	$ 68,017	$ 71,437	$106,690	$ 64,469
Interest on farm capital @ 6.5 percent	44,616	44,616	44,616	44,616	48,776	48,776
MANAGEMENT INCOME f/	$ 46,884	$(-) 5,914	$ 23,401	$ 26,821	$ 57,914	$ 15,693
RATE EARNED	13.3	5.6	9.4	10.4	14.2	8.6

a/ Rice yield @ 68 cwt., unlimited water and 30 percent allotment would result in PROFIT $73,342, MANAGEMENT INCOME $28,726, and RATE EARNED 10.7 percent.

b/ Yield reductions, alone (Case 9), would result in PROFIT of $72,040, MANAGEMENT INCOME of $23,467, and a RATE EARNED of 9.6 percent, a 30 percent allotment, alone (Case 9), in PROFIT of $90,304, MANAGEMENT INCOME of $41,518 a RATE EARNED of 12.0 percent.

c/ Average investment in farm property.

d/ Calculated @ $2.60 per hour for 16.5 60-hour weeks.

e/ Full year wages for operators time at hired workers rates.

f/ Reward for risk assumption, decision making, and other management functions.

This profit figure has its usual meaning as a measure of earnings; it constitutes an undivided return that belongs jointly to capital and management. But the farmer can identify a market, or "competitive," rate of return for the capital that his business employs. That figure, representing the rate the money could earn in alternative investments and calculated at 6.5 percent in this study, amounts to $44,616. This amount, subtracted from the PROFIT ($91,500) yields $46,884 as MANAGEMENT INCOME, the operator's return for managing, and for assuming the risks involved in the farm business.

Another way to evaluate these farm returns is to express the $91,500 PROFIT as a percentage of the $686,470 Total Farm Capital investment; the result of this calculation is 13.3 percent representing the RATE EARNED by this farm model (Case 1) on the capital investment under the conditions of this study (see Table 6, column 1). This RATE EARNED figure represents a joint return to capital plus management.

Most rice farmers in the Sacramento Valley would consider the earnings at the levels determined by the analysis in the preceding paragraph as highly favorable. By far, the great majority of such farmers who operate basin farms under water quantity and price, and other conditions specified in this study--except for government allotments and rice yields per acre--would add that their own operations do not yield returns at these levels, that they receive lower earnings! One reason is because their yields do not come up to the 68 hundredweights per acre specified for Case 1, the 1,280-acre basin model analyzed in the preceding paragraph (Table 6, column 1). Thus the statewide average yield for rice during the five seasons, 1966 through 1970, according to the California Crop and Livestock Reporting Service, ranged from 49 to 55 hundredweights per acre. The latter yield figure applies to the 1969 and 1970 crops. The 40 percent level assumed for the rice acreage allotment, as a percentage of total tillable land, also exceeds the acreage that farmers were permitted to plant if they elected to comply with the Federal Acreage Allotment Program during the early years of the 1970's.

Our analysis includes the better-than-typical conditions and earnings example represented by the Case 1, basin soil, unit because this example reflects a level of performance possible to many growers applying presently known technology effectively, and planting the proportion of their available total crop land in rice that reflects good land use practice for these basin soils in this subarea. It also is useful, however, to examine the effects on farm production and earnings that result when farmers are unable to apply, or for other reasons fail to apply these relatively optimum production conditions. Case 2 among our comparisons will serve our needs for this purpose. These earnings data reflect rice yields of 50 hundredweights per acre, a 30 percent allotment, and water supplies at $1.25 per acre-foot in sufficient quantities to irrigate the 354 acres of rice representing the 30 percent allotment (see Table 6, column 2). Our Case 2 basin farm operated under these conditions, falls short by nearly $800 of yielding enough net returns-over-variable expenses to cover all fixed costs. The other earnings measures also show to a sharp disadvantage, as compared with those highly favorable ones applying to Case 1, in which both yields and acreage allotments exceed the typical in the area (see Table 6, column 1). Thus NET FARM INCOME, which earnings measure includes no allowance for the Operator's own unpaid labor nor for the interest on the capital he uses, barely exceeds the return that this capital could earn if invested in an alternative use at a rate of 6.5 percent. The total PROFIT at $38,702 lacks $5,900 of equalling this interest return at the competitive rate of 6.5 percent. RATE EARNED, is 5.6 percent, and thus falls nearly one percent short of equalling the "market" rate. Farmers who operate under conditions such as these definitely are at an earnings disadvantage!

The Case 3 comparison for the basin soil model also features the 30 percent allotment but its rice yields are at 68 hundredweights per acre (see Table 6, column 3). Those growers who have been successful in attaining comparable yields during recent seasons should find this a useful basis of comparison with their own operations in the earnings data for this particular variation of the basin soil model. The extra 18 sacks add over $80.00 per acre to gross returns ($88.00 less minimal added expense, primarily for drying and hulling extra rice). The result is to establish total farm Net Returns over Fixed Costs at $28,550; this gain is enough to put all the remaining earnings measures in a favorable position. NET FARM INCOME is almost $76,000, PROFIT slightly over $68,000, and MANAGEMENT INCOME $23,400 (see Table 6, column 3). PROFIT, expressed as a percentage of total farm capital, comes out at 9.4 as the RATE EARNED on investment, or nearly three percent above the assumed market rate. We hold that most managers would not view these earnings as unreasonably high for a business with $700,000 capital investment. The $44,600 interest on capital at a 6.5 percent rate of return represents a relatively low percentage, as compared with such virtually risk-free alternatives as insured savings and loan accounts, mortgages, and high grade bonds. We believe, furthermore, that most business owners would consider the $23,400 MANAGEMENT INCOME as a bargain price at which to hire a competent manager for a business requiring a $700,000 investment!

We show a fourth variation of the basin soil model in this study; this is Case 4, in which all the standard conditions and restraints of the study apply except that water prices are at $7.90, instead of at the standard $1.25 per acre-foot water cost (see Table 6, column 4). This modification of the basin soil model, as might be expected, shows sharply lower earnings than Case 1 in which water prices are at the standard $1.25 per acre-foot. The earnings on this Case 4 basin model, however, are more favorable, than for the Case 3 example, with the same (68 hundredweights per acre) yield, but a 30-percent acreage allotment (354 acres of rice). Thus MANAGEMENT INCOME, at ($26,820 exceeds that for Case 3 ($23,400) by $3,400), while RATE EARNED (10.4 percent), is one percentage point higher than the 9.4 percent earnings for the example with a 68 hundredweights yield, but a 30-percent allotment (see Table 6, columns 1 and 4). Rice growers, in other words, could better afford to pay nearly $8.00 an acre-foot for water than take a cut in allotments from 40 to 30 percent of tillable basin land, provided they are able to obtain rice yields of 68 hundredweights per acre.

A final example for the basin soil model, Case 5 (not shown), differs from the Case 3 only in that the limitation on rice acreage reflects a reduction from 40 down to 30 percent in acreage allotment for this crop, as compared with the Case 3 example in which the limitation on rice reflected a shortage of water. The earnings measures for this Case 5 variation of the basin model (NET FARM INCOME $81,070, PROFIT $73,340 and RATE EARNED 10.7 percent) come out somewhat higher from those for Case 3. This differential reflects the advantage of irrigated grain sorghum over dry-farmed safflower on the basin soil.

The remaining earnings comparisons in this analysis indicate the results from varying water quantity, water price, and acreage allotments on the old alluvium model. The first example, Case 6, representing efficient use of research technology combined with a 40 percent allotment, shows highly satisfactory earnings. The PROFIT at a dollar magnitude of nearly $107,000 affords nearly $58,000 MANAGEMENT INCOME after covering the cost of interest on capital investment at the 6.5 percent assumed rate (Table 6, column 5). Or this same PROFIT expressed as a percentage of total farm capital investment ($750,470) represents a RATE EARNED of 14.2 percent. Here, again, as for the basin soil model, these optimum management and earning performance levels do not reflect the typical performance that farmers obtain on this type of soil in the Sacramento Valley rice producting area. In contrast, the example (Case 7) using a 55 hundredweights rice yield, combined with a 30 percent acreage allotment, shows PROFIT at slightly under $64,500, MANAGEMENT INCOME at about $16,000, and 8.6 percent as the RATE EARNED on capital investment (see Table 6, column 6). The same comments with reference to the adequacy of returns for the basin soil Case 2 apply here in an even greater degree. It is equally true for this Case 7, old alluvium, example that the level of earnings much more nearly reflects actual performance than do those earnings indicated for the Case 6 example under optimum use of research technology, and a 40 percent acreage allotment.

Our analysis included two other comparisons for the old alluvium model, Cases 8 and 9 (not shown). Each of these represents a modification of Case 6; Case 8 includes a 30 percent acreage allotment but a 71 hundredweights per acre rice yield; Case 9 includes a 40 percent acreage allotment and the 55 hundredweights per acre rice yield. The yield reduction, from 71 to 55 hundredweights per acre for rice, would have the most unfavorable effect upon earnings. The result (Case 9) would be to cut PROFIT to about

FARM PRODUCT PRICES STRONGLY INFLUENCE WATER USE, CROP CHOICES AND ACRES, AND PROFITS

Rice Prices Dominate Decisions on Sacramento Valley Rice Farms

Most farmers in the Butte-Colusa subarea of the Sacramento Valley traditionally have looked to rice as their principal source of farm earnings. The analytical results presented in the earlier portions of this study fully substantiate the soundness of this viewpoint; these results identify rice as the most profitable crop for this subarea. But all of our results from analysis of water quantity and water price-versus farm earnings relationships reflect the $4.90 per hundredweight rice price, and the 40 percent of cropland specified as the government acreage allotment in the conditions of this study. The earlier linear programming results leave unanswered, therefore, questions concerning optimum rice production policies on these farm models in the absence of government acreage allotments, and at prices differing from the $4.90 per hundredweight (but the preceding section on profits does examine these questions). A linear programming analysis in which prices varied from zero to $4.90 per hundredweight of rough rice, and with no government acreage allotments specified, throws some added light on these questions.

The effect of thus modifying the conditions assumed for this study varied importantly among the three soil categories considered. There was little variation among the three soils, however, in the rice price necessary to cause farmers to allocate a substantial part of their land to this crop; operators on the basin soil would find it advantageous to substitute rice for nonirrigated crops at a price of $2.55 per hundredweight while a slightly higher price, $2.62 per hundredweight, would have the same effect for operators on the two alluvium soils (see Table 7). At this $2.55 price, and with no acreage allotments in force, farmers on the basin soils would maximize net returns-over-variable expenses by planting 546 acres of rice (see Figure 10). They would substitute rice for a like acreage of grain sorghum, thus leaving only 44 acres in the latter crop along with 354 acres of dry-farmed wheat, 100 acres in fallow, and 118 acres idle. A further price rise to $2.98 per hundredweight would displace the remainder

TABLE 7

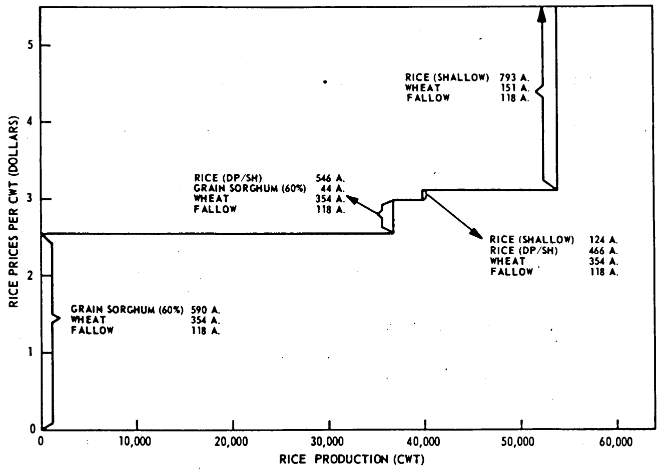
Rice Production and Net Returns at Varying Rice Prices Without Allotments, 1964-1966 Average Prices Except for Rice

Basin			Old alluvium			Recent alluvium		
Net returns	Price per cwt.	Quantities	Net returns	Price per cwt.	Quantities	Net returns	Price per cwt.	Quantities
1	2	3	4	5	6	7	8	9
dollars		cwt.	dollars		cwt.	dollars		cwt.
57,952	0	0	73,155	0	0	79,553	0	0
57,952	2.55	36,855	73,155	2.62	29,323	79,553	2.62	12,567
73,680	2.98	39,887	75,155	2.72	35,500	80,743	2.72	29,323
78,936	3.11	53,924	102,222	3.46	42,050	89,164	3.01	35,500
111,290	3.71a/	53,924	112,734	3.71a/	42,050	114,101	3.71	42,050
121,535	3.90	53,924	120,724	3.90	42,050	114,101	3.90a/	42,050
148,497	4.40	53,924	141,749	4.90	42,050	122,020	4.40	42,050
175,459	4.90	53,924	162,774	4.90	42,050	164,140	4.90	42,050

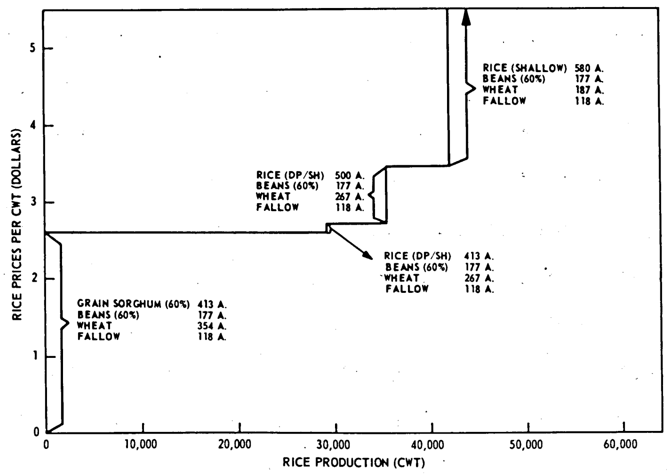
a/ No change in cropping system at this or higher prices.

FIGURE 10

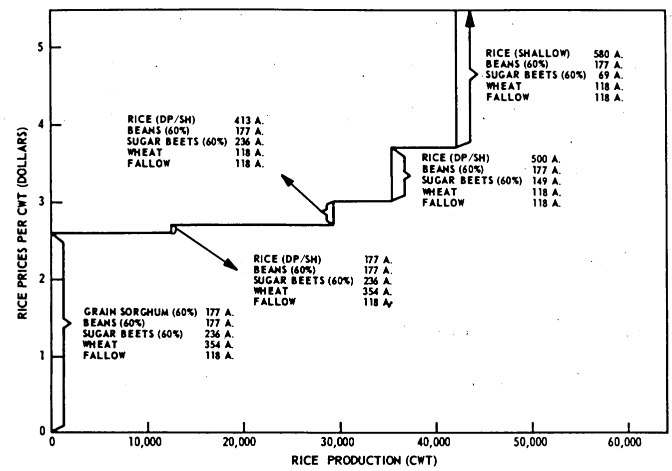
OPTIMUM CROPPING PLANS AND RICE PRODUCTION
ON BASIN SOILS AT VARYING CRITICAL RICE PRICES



OPTIMUM CROPPING PLANS AND RICE PRODUCTION
ON OLD ALLUVIUM SOILS AT VARYING CRITICAL RICE PRICES



OPTIMUM CROPPING PLANS AND RICE PRODUCTION ON RECENT
ALLUVIUM SOILS AT VARYING CRITICAL RICE PRICES



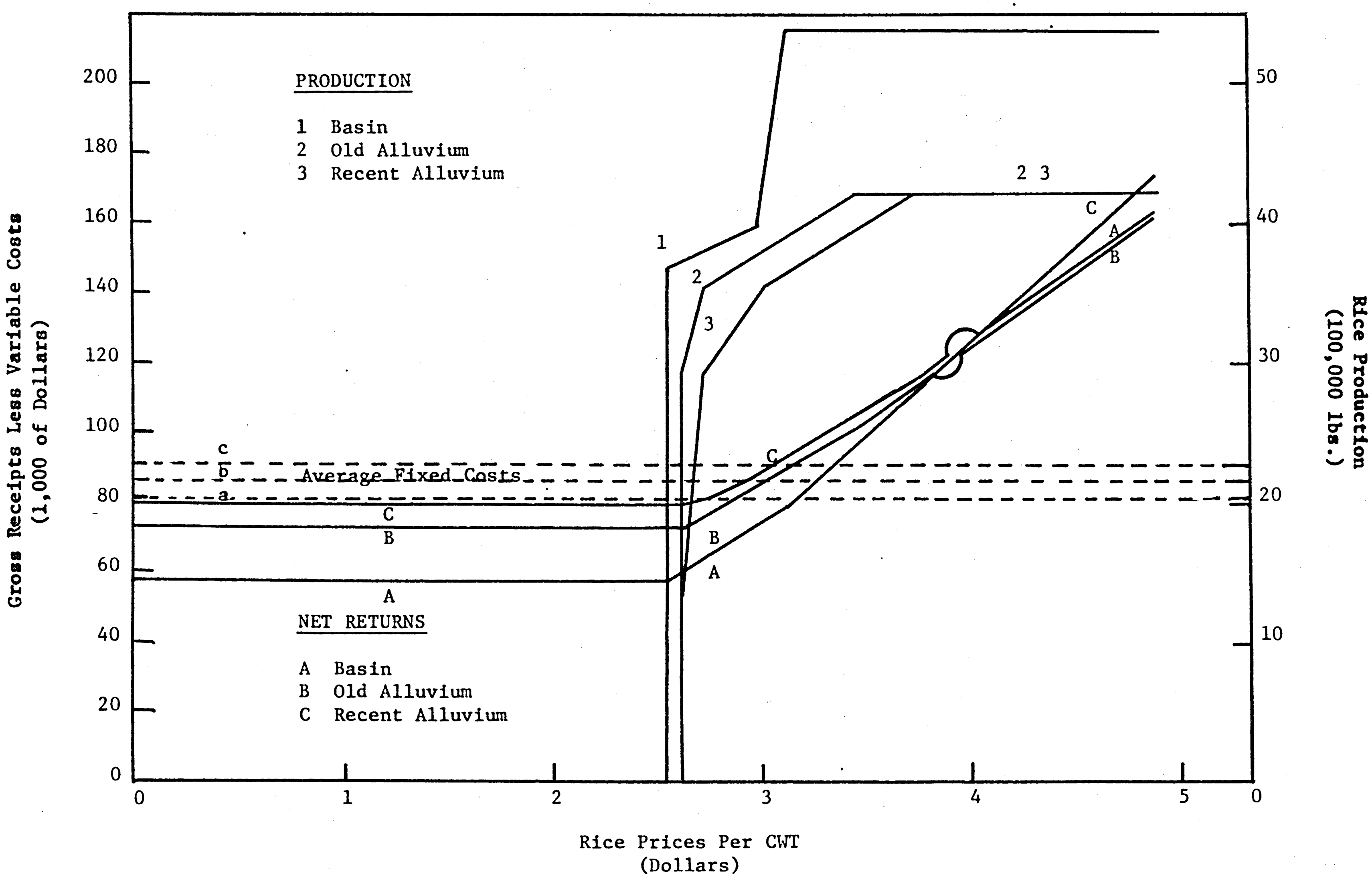
of the grain sorghum as well as over half of the wheat (see Figure 10). Rice acreage would climb to 570 acres, with 446 under the deep-shallow, and the rest under the shallow irrigation. A slight increase in rice prices (to $3.11 per hundredweight) would bring rice plantings to 793 acres, the maximum potential for the basin model, considering water supplies, harvesting equipment, and the rest of the power and machinery complement of this 1,280-acre unit (see Table 7). This analysis does not consider yield reductions resulting from rice following rice in the cropping system, nor their rotational or biological factors that might check rice acreage or reduce yields.

Total farm net returns at this maixmum rice acreage in the absence of acreage allotments and at a $3.11 per hundredweight price would fall slightly short of total farm fixed costs ($80,800). Further gains in rice prices would have no effect toward increasing rice acreage and production, but would greatly improve total farm net returns-over-variable expenses. The $32,000 gain in net returns that would accompany a 20 cent gain in rice prices (to the $3.71 level) would bring total farm net returns to $30,500 above the level of total farm fixed costs (see Table 7). This surplus over the break-even level for total farm fixed costs versus net returns would represent the return to the operator for assuming capital risk, making decisions and directing the farm operations, and other management functions. Further gains in total farm profit would accompany additional price rises. A price equal to the $4.90 per hundredweight of rough rice assumed in this study, coupled with unrestricted freedom for farmers to plant rice without acreage allotments, would result in total farm net returns of $17,550, if rice yields and all costs per unit remained unchanged, or almost double the level of total farm fixed costs (see Table 7 and Figure 11). This figure, however, again reflects rice planting at nearly 800 acres and no yield reductions; neither of these conditions appears realistic (see Figures 10 and 11). It is highly likely, also, that rice yields would fall below the 68 hundredweights per acre level if rice occupied 800 acres (68 percent) of 1,180 tillable acres, of which only 944 are in crops.

The effect of increasing rice prices, in the absence of government acreage allotments, would be similar for the two alluvium soils to that

FIGURE 11

RICE PRODUCTION AND FARM NET RETURNS FOR VARYING RICE PRICES WITHOUT ALLOTMENTS



for the basin soils (see Figure 10). The 580-acre maximum rice acreage under these conditions on each of these two farms, however, is sharply below the maximum for the basin model. The old alluvium model would include the 177 acres of dry beans, a low water requirement crop, at the maximum rice acreage (see Figure 10). The recent alluvium soil also would include a like acreage of dry beans and, in addition, 69 acres of sugar beets. Thus sugar beets substitute for wheat on the recent alluvium model with maximum rice acreage, but not on the old alluvium soil (see Figure 10).

Rice acreage, reaches its 580-acre maximum at a price of $3.71 per hundredweight on the old alluvium, and at a price of $3.90 per hundredweight on the recent alluvium soil (see Figure 10). Added gains in price would increase the total net returns for the entire farm because they would expand the net returns-over-variable expenses to the rice enterprise. Such price gains would exert no influence, however, toward stimulating growers on these alluvium models to expand rice acreage beyond the 580-acre maximum. Water supplies available during the pre-seeding flooding stage would not permit any such expansion due to the relatively high percolation losses on these soils. This situation constrasts to that for the basin soil model, with minimal losses from percolation. Available water quantities would permit rice acreage to expand to nearly 800 acres on this latter soil type.

Actually there is room for serious doubt as to whether it would be advantageous for rice growers on the alluvium soils to expand acreage beyond the 580-acre level at which it represents about 50 percent of all tillable land. Here, again, as with respect to the hypothetical 800-acre seeding on the basin model, it is entirely likely that biological and economic factors not evaluated in this study would make it unprofitable to expand rice acreage to such levels. Growers on the alluvium soils have certain positive forces operating to limit the profitability of excessively high rice acreage. The greater range of crop adaptation on these better-drained soils also makes some of the alternative crops more profitable relative to rice as rice expands on the alluvium soils, as compared with the basin soils. These forces would operate on the alluvium soils in addition to reduced rice yields and other negative forces that would tend to reduce rice profits as acreage expands.

The data showing comparable rice production in total hundredweights and net returns at varying rice prices in the absence of government acreage allotments require some evaluation (see Table 7 and Figure 11). The comparisons among the three models reflecting the three soil situations appear valid within the analytical framework up to the point that rice acreage ceases expanding as prices increase (see Table 7, columns 2, 3, 5, 6, 8 and 9). Total farm net returns-over-variable expenses at this point of maximum rice acreage and production on the three farms would be highest for the recent alluvium model ($114,101) and lowest for the basin model ($111,209). This relationship shifts, however, as prices rise to the $4.90 maximum for this analysis, which price also is the standard one for the analyses previously presented in this study. Total farm net returns at this $4.90 price would be greatest for the basin model ($175,459) and lowest for the old alluvium ($162,774). This shift in net returns levels among the three soils reflects the greater acreage and production of rice at the maximum level for the basin soil. The result is that the basin soil model would have more total rice on which to gain the advantage of price increases (the 93,924 hundredweights for the basin soil model represents 28 percent more rice than the 42,050 hundredweights totals for the other two models). We do not consider these total farm net returns comparisons valid for prices higher than those associated with 580 acres of rice for these three models, based on a total of 1,180 acres of tillable land. This is for reasons already stated in terms of rice yields, feasible acreages, and available water supplies.

Changing Economic Conditions Bring New Price Production and Price Relationships for California Growers

The $4.90 per hundredweight maximum rice price in the preceding analysis is consistent with the economic context prevailing during the 1960's and early 1970's. California rice production and prices during this period ranged from 19.1 million hundredweights (produced on 360 thousand acres) and $4.30 per hundredweight in 1966, to 17.2 million hundredweights (from 331 thousand acres) and $5.24 in 1971. The average production during the three year period 1966-1968 was 19.9 million hundredweights (from 384 thousand acres) and the weighted average price was $4.78 per hundredweight.

The average, combined Butte and Colusa County rice acreage for these three years was 165 thousand acres or about 40 percent of the land available for rice growing in these counties. Acreage limitations and price supports applied during these years.

Changes in the overall economic situation, both in the U. S. and abroad, and in the foreign demand for rice after 1971, brought an economic context markedly different after that year from the one during the period ending with 1971. General price rises, unusual foreign demand that drained away accumulated grain stocks of all types, and sharp increases in off-shore demand for rice all combined to create new relations between prices and production of California rice.[17/] Farmers dare not assume that the unusual price-supporting influences, and this uniquely high price for rice in 1973, represent a permanent shift, so that similarly high prices will continue during the remainder of the 1970's. They may expect, however, that new market and price conditions will prevail, and that rice prices will be higher than during the 1960's unless production and supply completely outrun demand. The 1973 demand and price situation should favor some increases in California rice acreages and production during the latter half of the 1970's if the U. S. Government relaxes or suspends acreage limitations.[18/] The problem that rice growers would face under such circumstances is to decide how much they safely can expand acreage and production and

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17/ The California Crop and Livestock Reporting Service reported that U. S. rice prices averaged $13.70 on October 15, 1973 as compared with $6.78 per hundredweight one year earlier. U.S.D.A. purchase and loan prices per hundredweight for rice were $5.27 in 1972, $6.07 in 1973 (U.S.D.A. 2374-73) and are announced at $6.23 in 1974 (U.S.D.A. 3275-73).

18/ The Secretary of Agriculture announced in November 1973 (California Rice-77) that 1974 rice allotments will be 1,652,296 and 299,766 acres respectively for the U. S. and California. The latter acreage compares with an 332,990-acre allotment for California in 1973, thus represents a reduction. A later announcement (Rice 222-74), however increased these allotments to 2,100,000 and 380,921 acres respectively, for the U. S. and California. This later figure for California represents an increase of 81,000 acres over 1973 allotments.

still be able to sell at prices that will permit profitable operation. There are no precise advance answers to this question. Information is available, however, to relate Butte and Colusa County rice acreage both to the land available to produce rice in these counties and to total California acreage. Data presented earlier in this study indicate that land available, and adapted for rice growing in Butte and Colusa counties combined, totals about 405 thousand acres. This figure provides a basis to examine how changes in total California acreages might affect Butte and Colusa counties assuming that these two counties continue to account for the same proportion (about 43 percent) of this state total as during the three years 1966-1968.

California acreage	Butte-Colusa Counties combined (43 percent of California total) (Acres)	Percent adapted land in rice
400,000	172,000	42.0
450,000	193,500	47.8
500,000	215,000	53.1
550,000	236,500	58.4
600,000	258,000	63.7

California's 400,000 acres in rice for harvest in 1973 represents only a slight increase above the three-year average for 1966-1968 (384 thousand acres). The accompanying increase in Butte and Colusa counties, combined, to maintain the acreage in those two counties at the 43 percent level of the state total, however would mean an 16.5 thousand acre, or 10 percent acreage gain. We already have pointed out that the 1973 October price level is double that of one year earlier in spite of the fact that rice acreage in California is the highest since 1968. Further expansion in California's total rice acreage to 450 thousand acres, with Butte and Colusa counties continuing to maintain their same percentage of the total, would mean 193.5 thousand acres for Butte and Colusa counties, or almost 48 percent of the rice land adapted primarily to this crop. An increase to the 500 thousand acre level for California under the same assumptions would increase the combined Butte and Colusa Counties' acreage to 215 thousand acres, or about 25 percent above its 1973 level (see text table).

Similar percentage acreage increases for our analytical models with 1,180 acres of tillable land would indicate rice acreage increases from the 472 acres representing the 40 percent allotment to 525, and 590 acres, respectively. We have already indicated that biological and management problems may well make it difficult to maintain the 68 and 71 hundredweights per acre yield levels used in this analysis if acreage expands to the latter level. The other question, that farmers know from past experience to be critical, is whether aggregate California rice production at the level accompanying such acres expansion would lead to disastrous price declines.

Up-to-Date Technology and Efficient Resource Use Are Essential to Profitable Rice Farming

This analysis of rice acreage, production and prices in the absence of allotments, as is true of that in earlier sections, assumes much above state average yields (68 to 71 cut as compared with 50 to 60). Farmers obtaining average yields, and particularly those with less than 55 hundredweights rice yields, would face quite different earnings situations. The earlier section on "FARM PROFITS" compares PROFIT, MANAGEMENT INCOME, and RATE EARNED under varying levels for yield, allotments, water supplies and costs (see Table 6, pages 15 and 16). This comparison shows farmers with the 50 or 55 hundredweights yields at a sharp earnings disadvantages.

Higher Acreages Could Bring Greater Profits at Recent Rice Prices

Our main conclusions from the price-acreage analysis centers on the earlier adjustments of rice acreage to the price increases at lower initial prices for this crop.

1. Rice would come into the cropping system on the central California rice farms at relatively low prices; actually these prices barely exceed 50 percent of the $4.90 standard price used in this study.

2. The acreage response to rising rice prices in this analysis clearly confirms the marked economic advantage rice has over other alternative crops in this rice growing subarea.

3. Rice acreage would reach its maximum, at relatively low prices on farms in the central Sacramento Valley, within the framework of resources available and economic conditions of the 1960's.

4. Yield reductions for technical reasons, plus limited water supplies, would operate to set limits on rice far short of the total amount of cropland on these farms. We believe that the 580-acre maximum indicated for the two alluvium soils by a water quantity restraint certainly represents an upper limit for rice acreages on all soils in this subarea. Such rice acreages on these models with 1,180 acres of tillable land represent 49 percent of all tillable land and 61 percent of the total land seeded to all crops. The practicable maximum rice acreages for all three of these soils actually may be lower than 580-acres on the 1,280-acre rice farms.

5. Water shortages would limit rice acreage to lower levels than these as a percent of available land for the Butte-Colusa subarea as a whole. Unless farmers improve water management and irrigation practices, the standards used in this study are lower than the amounts farmers in the subarea consistently use to produce rice.

6. Rice holds a strong production and earnings advantage in the central Sacramento Valley. Artificial constraints to restrict this crop to acreages lower than the levels indicated by technical and resource factors are definitely against the economic interest of farmers in this part of the Sacramento Valley.

CONCLUSIONS

The results of this study point to conclusions that farmers and those who serve farmers in the central Sacramento Valley, and particularly in the Butte-Colusa County subarea, should find useful.

These conclusions focus on the major issues that farmers must face in allocating and using land, water and other resources: 1) the place that rice holds in the cropping patterns and farming systems in this subarea; 2) the relative rank of alternative crops as profit makers--or as fixed cost payers; 3) the physical and economic relationships involved in using water to irrigate rice and other crops; 4) the impact of variations in water quantities and costs on optimum farm organization and resource allocation; 5) the influence of Agricultural Stabilization and Conservation Act acreage allotments and price supports on rice and other crops with respect to sound use of land and other resources and, importantly, farm earning levels; finally, 6) some of the more important technological and managerial choices that offer possibilities to farmers seeking to increase resource productivity and farm earnings. The more important of these conclusions relate specifically to rice, the primary source of gross and net farm income for farmers in the two counties:

1. Rice shows relatively high net returns-over-variable expenses per acre for rice on the basin, old alluvium, and recent alluvium soils in the Butte-Colusa subarea studied. These net returns for rice range from slightly below, to more than $200 per acre for each of the three soil situations (ignoring fixed costs), depending upon the irrigation practice used. These high returns give rice a distinct economic advantage over alternative economically adapted crops. They represent double or more the net returns possible from the strongest competitor among alternative crops with the margin of advantage for rice somewhat greater on the basin than on the old or recent alluvium soils.

2. Farmers who successfully apply the latest research knowledge and technology may obtain rice yields that range from nearly, to slightly over 70 hundredweights per acre during normal seasons. These excellent yields enable such growers to gain the maximum financial advantage from rice's strong competitive position, as compared with other crops in this subarea. The 12 to 15 hundredweights per acre (or greater) yield advantage of such farmers, as compared with state average yields of 55 hundredweights per acre during the latter 1960's and the 1970 season, clearly establishes the importance of this advantage.

3. Relatively generous water supplies, available for rice irrigation in the past at the nominal total flat rate cost of $10.00 to $12.50 (or, at the most $15.00) per acre, including assessments, have constituted one of the important advantages of many rice growers in this subarea. Government acreage limitations and allotments during recent years have restricted rice acreage to such extent that most growers, particularly on the west side of the Sacramento River, have experienced no shortage of water to irrigate their total rice seedings.

4. Many rice growers commonly use more water than necessary to obtain optimum rice yields, according to research findings, particularly at the Biggs Experiment Station, and empirical evidence, both for individual farm operations and on aggregate use in the subarea. Both controlled experiments and the experience of some growers indicate that better field layout and leveling, improved land preparation, more effective water control, and irrigation practices featuring lower water applications can increase rice yields as compared with the water management policies and practices many growers commonly follow.

5. Aggregate water quantity data for the subarea, coupled with research findings on rice irrigation requirements, suggest that if all farmers were to adopt improved rice irrigation practices,

farmers could expand rice acreage in the subarea to a level representing between 40 and 50 percent of the tillable land primarily adapted for rice production. This would mean that growers would need to limit total seasonal water applications to between 5 and 6 acre-feet for the basin adobe soils, and to not over 8 acre-feet for the alluvium soils producing rice.

6. A farmer on a typical 1,280-acre rice operation with 1,180 acres of tillable land and about 950 acres in crops essentially can grow only barley, wheat, or safflower, if he has no irrigation water available. Rice will yield him the highest net returns for initial water increments if, as, and when supplies become available for irrigation. His marginal increases in total farm net returns-over-variable expenses would be about $33.00 per acre-foot of water for the first 1,800 acre-feet on basin soil, $21.50 per acre-foot for the first 2,200 acre-feet on the old alluvium, and about $21.40 for the first 1,700 acre-feet on the recent alluvium soil. The rates of return for subsequent increments of water would decline sharply as rice acreage reaches its maximum allotment level and it becomes necessary to introduce other irrigated crops.

7. Farmers with a 40-percent rice allotment, and using latest research knowledge and technology to obtain yields in the 70 hundredweights per-acre range, could pay up to about $15.00 per acre-foot for irrigation water on the basin, and up to about $14.00 on either of the two alluvium soils, on a non-profit (but break-even) basis for the balance between total farm net returns and fixed costs. But a farmer who operates at this break-even point under conditions of this study will earn no return whatever for his managerial efforts, nor will he receive any earnings above the "going market rate" on his capital as a reward for risking it in the farm operation. A water price of between $7.00 and $8.00, however, would permit the farmer who succeeds in producing under these optimum conditions to receive substantial total farm net returns-over-variable costs in excess of those required to cover his fixed costs; he thus would receive a profit on his management and capital.

8. Optimum production conditions for the 1,280-acre farm models in this study include a 40 percent acreage allotment, combined with a 68 hundredweights yield per acre for rice, and an economic combination of supplementary crops to use planted land not in rice. A farmer on basin soils operating under such conditions could earn about $92,000 total profit, which amount would pay him $44,600 as interest on his capital investments and the remaining $47,200 for his own management and for risking his capital. But, unfortunately, most farmers do not produce under these optimum conditions. A farmer on basin soil with a 50 hundredweights per acre rice yield and a 30 percent acreage allotment can obtain only $38,700 as profit. This amount lacks $5,900 of equalling what his capital investment would earn him if he put it into a savings account, or other use, at 6.5 percent interest. Such an earnings

level means that the operator gets nothing whatever to pay for his own managerial efforts, nor for running the risk of imparing or losing his capital. A grower with this earnings level, furthermore, lacks $5,900 of receiving the market rate on his investment, while all he can point to for his year's work as an individual is $7,700. This latter amount equals what he pays one of his employees, and the operator presumably could have earned it by working in the fields for someone else.

9. The earning opportunities for the operator on old alluvium soil with rice yields at 55 hundredweights per acre and, again, a 30 percent allotment are somewhat more favorable. Such an operator would have nearly $16,000 left over as reward for his own management and risk assumption, after allocating $48,800 to pay interest on his capital at the competitive rate assumed to be 6.5 percent per annum. The slightly higher yields for rice, plus the greater range of crop adaptability and somewhat higher yields for supplementary crops, explains why the operator on an old alluvium would fare better than one on basin soil. The 6.5 percent rate of return on capital, plus $16,000 management income for organizing, managing, and assuming risks on a business representing a three-quarter of a million dollars investment likely would not attract very many managers from nonfarm business of similar dollar magnitude.

10. A final, and conclusive, fact to confirm the economic advantage rice in this subarea is the low rice prices at which farmers would find it profitable to substitute rice for other crops in their cropping systems; a price of $2.55 per hundredweight on basin and $2.62 per hundredweight on the two alluvium soils would have this effect under the yield and cost conditions of this study. Presently available water quantities would limit rice acreage to not more than one-half the total tillable acres on the alluvium soils. Quite possibly such an upper limit also would apply to the basin soils as well, if not because of water shortages, then due to soil and biological factors.

11. The final, and obvious, conclusion from these analyses is that government acreage allotments or other restrictions, tend to prevent growers from using their land and other resources most effectively in order to maximize farm profits, since such restrictions limit acreage at levels below those that farmers normally would find it profitable to plant. Such restrictions also result in less than optimum resource allocation and use from the standpoint of society as a whole. This study did not undertake to determine precisely the optimum proportion of tillable land that farmers should plant in rice. The analyses suggest, nevertheless, that this level may be somewhere between 40 and 50 percent, of these tillable acres, considering quantities of water available to the farmers in the subarea and the relative per acre earnings of other adapted crops. A more precise determination of optimum rice acreage, as a percent of all tillable land, will require biological, soils, and economic information not available for this study.

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APPENDIX TABLE A-1

Growth Rates for Crops Other Than Rice on Various Soils by Five Percent Intervals for Available Soil Moisture Depletion and Combined Averages; Three Irrigation Practices a/

Percentage intervals available soil moisture depletion	Growth rates by soil types		
	Clay	Clay loam	Silt loam
	1	2	3
	percentages of potential		
0-15 b/	300.0 b/	300.0 b/	300.0 b/
15.1-20	100.0	99.0	100.0
20.1-25	99.0	98.5	100.0
25.1-30	98.5	98.5	100.0
30.1-35	98.0	98.0	99.0
35.1-40	97.5	98.0	98.0
40.1-45	96.5	98.0	98.0
45.1-50	96.0	97.5	98.0
50.1-55	95.5	97.0	98.0
55.1-60	94.0	96.0	97.0
60.1-65	92.0	94.0	96.0
65.1-70	89.0	92.0	95.0
70.1-75	86.0	88.0	93.0
75.1-80	82.0	84.0	90.0
80.1-85	76.0	78.0	83.0
85.1-90	70.0	72.0	75.0
90.1-95	62.0	64.0	65.0
95.1-100	50.0	50.0	50.0
Sum at 100 percent level	1,782.00	1,798.50	1,835.00
Sum x $\frac{.05}{100}$ (percent)	89.10	89.92	91.75
Sum at 80 percent level	1,524.00	1,538.00	1,562.00
Sum x $\frac{.05}{80}$ (percent)	95.25	96.12	97.62
Sum at 60 percent level	1,175.00	1,180.00	1,188.00
Sum x $\frac{.05}{60}$ (percent)	97.91	98.33	99.00

a/ Irrigation practices include (1) 100 percent, (2) 80 percent, and (3) 60 percent depletion.

b/ The first three five-percent intervals have been consolidated for brevity.

APPENDIX TABLE A-2

Condensed Basic Computational Form for Linear Programming Calculations; 1,280-Acre Farm; Basin Soil; Variable Water Prices a/

Resource of activity at non-zero level	Supply of activity level	Crop activities, C_{23} through C_{36} b/													
		Rice 1 c/ C_{23}	Rice 2 c/ C_{24}	Rice 3 c/ C_{25}	Grain sorghum 1 d/ C_{26}	Grain sorghum 2 d/ C_{27}	Grain sorghum 3 d/ C_{28}	Saf-flower D c/ C_{29}	Saf-flower E d/ C_{30}	Barley C_{31}	Wheat C_{32}	Oats C_{33}	Oats/vetch seed C_{34}	Grain hay C_{35}	Fallows C_{36}
	C f/	184.83	219.43	210.13	60.79	57.88	49.79	44.63	47.12	39.00	64.90	22.26	37.18	19.26	-7.53
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C_1 Land crops	1062	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C_2 Irrigation crops	826	1	1	1	1	1	1								
C_3 Rice	472	1	1	1											
C_4 Grain hay	118													1	
C_5 Oats/vetch	118												1		
C_6 Safflower	236							1	1						
C_7 Wheat	354										1				1
C_8 Fallow	118														1
C_9 Water 4/1-5/15	17,292A"	28.5	31.3	21.8	4.63	4.63	4.63								
C_{10} Water 5/16-31	8,268A"	5.6	5.6	6.0	3.0	3.69	0								
C_{11} Water 6/1-15	7,404A"	7.6	5.6	6.0	4.15	5.54	7.5								
C_{12} Water 6/16-30	7,404A"	7.6	5.6	7.0	5.54	0	0								
C_{13} Water 7/1-15	8,184A"	6.6	5.6	7.0	7.5	10.71	13.89								
C_{14} Water 7/16-31	8,184A"	6.6	5.6	7.0	0	0	0								
C_{15} Water 8/1-15	7,524A"	6.4	5.6	6.0	0	0	0								
C_{16} Water 8/16-31	7,524A"	0	5.6	1.5	0	0	0								
C_{17} Water 9/1-15	3,216A"		0	0	0	0	0								
C_{18} Water 9/16-30	3,216A"														
C_{19} Water 10/1-5	3,168A"														
C_{20} Harv. hrs.	710	.5	.5	.5	g/	g/	g/								
C_{21} TOTAL H_2O	0	68.9	70.5	62.3	24.82	24.57	26.02								

a/ See also Heady, Earl O., and Wilfred Candler, op. cit., p. 273.
b/ Disposal activities (C_1 through C_{22}) omitted. These serve in calculations to account for resources not used in optimum crop combinations at various prices.
c/ Rice irrigation practices include (1) deep, (2) deep, lowered, and (3) shallow.
d/ Grain sorghum irrigation practices include (1) 60 percent, (2) 80 percent, and (3) 100 percent levels of available soil moisture depletion prior to irrigation.
e/ Safflower production practices include (D) regular, and (E) minimal.
f/ C line includes net returns-over-variable expenses per acre for each of the 14 income (or negative income) activities (farm enterprises).
g/ Not applicable.

APPENDIX TABLE A-3

Calculation Methods for Determining Annual Fixed Costs on Farm Property or Capital Goods

85 drawbar horsepower tracklayer tractor[a]	
NON-CASH COSTS	
Interest (6.5 percent of average investment)	
$\left[\frac{\text{Original cost + salvage value}}{2}\right]$ 6.5/100 = $\left[\frac{\$33,640 + 5,050}{2}\right]$ 6.5/100 =	$1,257
Depreciation	
$\left[\frac{\text{Original cost - salvage value}}{\text{years on farm}} = \frac{\$33,640 - \$2,402}{10}\right]$	3,124
TOTAL	$4,381
CASH COSTS	
Taxes	
[Assessment @ 35 percent of average investment] = [$6,771 x 6.5]	$ 440
Insurance	
[Estimated @ 0.75 percent of average investment] = [$19,345 x 0.75%]	$ 146
TOTAL	$ 586
ALL FIXED COSTS	$4,967

a/ Fixed costs in this report include "overhead" costs that the farm operator incurs largely regardless of variations in the scope of his annual operations. A heavy proportion of these costs relate directly to land, machinery and other capital goods; some refer to such overhead as "cost of owning" such property, or, simply, as "capital costs." Another important category of fixed costs are those administrative expenses that are unavoidable in the function of managing, but that are difficult if not impossible to allocate to specific income-producing activities, or enterprises. Among this latter group are office expenses, and organization dues.

APPENDIX TABLE A-4

Estimated Field Irrigation Efficiency Under Furrow Irrigation for Different Application Depths by Soil Type

Desired application depth in inches a/	Soil type		
	Recent alluvium	Old alluvium	Basin
	percent		
< 2	0.50	0.50	0.60
2	55.00	55.00	63.00
2 1/2	60.00	58.00	65.00
3	62.00	60.00	68.00
3 1/2	64.00	63.00	65.00
4	65.00	65.00	62.00
4 1/2	66.00	65.00	60.00
5	67.00	66.00	60.00
5 1/2	68.00	67.00	58.00
6	69.00	66.00	56.00
7	70.00	63.00	54.00
8	70.00	60.00	52.00

a/ Assumes tail water system.

Source: Estimated by research and Agricultural Extension workers in irrigation problems and methods.

APPENDIX TABLE A-5

Irrigation Water Added to Soil, Irrigation Efficiency, and Total Seasonal Applications by Soils, Irrigation Practices, and Crops, 1,280-Acre Farm

Crop	Depletion levels for available soil moisture								
	100 percent			80 percent			60 percent		
	Water added	Efficiency a/	Total water	Water added	Efficiency a/	Total water	Water added	Efficiency a/	Total water
	1	2	3	4	5	6	7	8	9
	inches	percent	inches	inches	percent	inches	inches	percent	inches
Basin									
Grain sorghum	15.2	58.5	26.0	15.2	61.8	24.6	15.8	63.7	24.8
Old alluvium									
Grain sorghum	17.5	62.3	28.1	19.3	61.9	31.3	16.3	57.0	28.7
Corn	27.8	62.5	44.5	26.0	63.9	40.7	26.8	61.9	43.3
Beans	10.5	62.1	16.9	12.5	61.6	20.3	13.9	57.7	24.1
Recent alluvium									
Grain sorghum	17.5	62.3	28.1	19.3	61.9	31.3	16.3	57.0	28.7
Corn	27.8	62.5	44.5	26.0	63.9	40.7	26.8	61.9	43.3
Beans	10.5	62.1	16.9	12.5	61.9	20.3	13.9	57.7	24.1
Sugar beets	25.3	61.4	41.2	25.5	63.1	40.4	29.1	65.0	44.8
Alfalfa b/	49.0	70.0	70.0	c/	c/	c/	46.2	65.0	71.1

a/ Irrigation efficiencies are seasonal weighted averages of individual water applications.

b/ An established stand.

c/ Not applicable.

APPENDIX TABLE A-6

Quantities and Costs of Irrigation Water
for Rice by Soils and Irrigation Practices

Irrigation practices	Basin clay adobe	Recent and old alluvium clay loam
1 Deep, not lowered		
Quantity of water	68.90" (5.74')	106.6" (8.88')
Cost of water @$1.25/A'	$ 7.18	$ 11.10
Labor	$ 5.20	$ 5.20
TOTAL irrigation cost	$12.38	$ 16.30
2 Deep, lowered		
Quantity of water	70.5" (5.88')	100.6" (8.17')
Cost of water @$1.25/A'	$ 7.35	$ 10.48
Labor	$ 5.20	$ 5.20
TOTAL irrigation cost	$12.55	$ 15.68
3 Shallow		
Quantity of water	62.30" (5.19')	99.0" (8.25')
Cost of water @$1.25	$ 6.49	$ 10.31
Labor	$ 5.20	$ 5.20
TOTAL irrigation cost	$11.69	$ 15.51

APPENDIX TABLE A-7

Calendar of Operations and Physical Inputs Per Acre 1,280-Acre Farm;
Rice on Basin Soil Irrigated Under Deep Flooding--Lowered Practice

Dates and operations	Men	Power	Crew and equipment: Equipment	Acres per 9-hour day	Hours per acre: Man	Hours per acre: Tractor	Materials
	1	2	3	4	5	6	7
PREPLANT							
March							
Plow	1	D-7	6 x 16" bottoms	17	.52	.52	
Disc (2X)	1	D-6	21' disc harrow (offset)	60	.15	.15	
Landplane (2X)	1	D-6	12' x 60' landplane	37	.24	.24	
April							
Survey							
Plow contours	1	D-4	4 x 14" bottoms	250	.04	.04	
Plow checks	1	D-7	6 x 16" bottoms	130	.07	.07	
Check	1	D-7	14' checker	104	.10	.10	
Plowing borrow	1	D-7	6 x 16" bottoms	190	.05	.05	
Discing pits, harrowing	1	D-6	21' disc and 21' harrow	150	.06	.06	
Placing boxes	2	D-4	Dozer	280	.06	.03	Box - 4 acres/box
Closing checks	1	D-4	Dozer	82	.11	.11	
Fertilizing			2 applications (50# and 40#) air @ $3.10/acre				90# N (Urea & Amm. sulphate)
May							
Flood	2				.5		
CULTURAL							
May							
Plant			Air @ $2.00/acre				160# @ $7.30/100#
May-September							
Irrigate	1				2.0		
May-June							
Weed control			Air-propanil @ $2.00/acre, -M.C.P.A. @ $1.50/acre				M.C.P.A. - 10 gallons/ acre = $1.52; Propanil - 12 gallons/ acre = $16.59
Insect control			Air-parathion @ $1.25/acre				Parathion 1/5 pints/ acre = $.32
September							
Draining	1						
Opening checks	1	D-4	Dozer	180	.05	.05	
October							
Remove boxes	2	D-4	Dozer	280	.06	.03	
Knock checks	1	D-7	6 x 16" bottoms	130	.03	.03	
Knock checks	1	D-4	Dozer	190	.05	.05	
Knock checks	1	D-6	14' float	246	.04	.04	
HARVEST							
October							
Harvesting	2		2 J.D. "105's" (16' cut)	16[a/]	1.0		
Banking out	2	D-4	2 Bankout wagons	16	1.0	.5	
Haul to drier	2		2 - 2 ton trucks	16	1.0		
TOTAL					7.13	1.57	

a/ Harvesting: 16 acres/8-hour day from 1-15 October; 12 acres/6-hour day from 16-31 October; 8 acres/4-hour day for remainder of harvest.

APPENDIX TABLE A-8

Variable Input Expenses Per Acre 1,280-Acre Farm; Rice According to Soils and Irrigation Practices, 1964-1966 Average Prices

Input items	Basin			Old alluvium			Recent alluvium		
	1 a/	2	3	1	2	3	1		
	1	2	3	4	5	6	7	8	9
	dollars			dollars			dollars		
PREHARVEST									
Power									
D-7 Tracklayer	3.49	3.49	2.69	3.49	3.49	2.69	3.49	3.49	2.69
D-6 Tracklayer	2.28	2.28	2.43	2.28	2.28	2.43	2.28	2.28	2.43
D-4 Tracklayer	.47	.47	.45	.47	.47	.45	.47	.47	.45
TOTAL	6.24	6.24	5.57	6.24	6.24	5.57	6.24	6.24	5.57
Transport									
Pickup expenses (1/2 T)	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
Machinery									
Plow (6 x 16")	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Plow checks (6 x 16" plow)	.14	.14	.10	.14	.14	.10	.14	.14	.10
Plow borrow (4 x 14")	.10	.10	.03	.10	.10	.03	.10	.10	.03
Disc (21') and harrow (24')	.16	.16	.09	.16	.16	.09	.16	.16	.09
Knock checks (plow)	.06	.06	.06	.06	.06	.06	.06	.06	.06
Disc (21') - 2x	.80	.80	.80	.80	.80	.80	.80	.80	.80
Landplane	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Knock checks (float)	.004	.004	.004	.004	.004	.004	.004	.004	.004
Plow contours (4 x 14")	.03	.03	.03	.03	.03	.03	.03	.03	.03
Place boxes (dozer, 2nd man)	.55	.55	.55	.55	.55	.55	.55	.55	.55
Close checks (dozer)	.002	.002	.002	.002	.002	.002	.002	.002	.002
Open checks (dozer)	.001	.001	.001	.001	.001	.001	.001	.001	.001
Remove boxes (dozer, 2nd man)	.006	.006	.006	.006	.006	.006	.006	.006	.006
Knock checks (dozer)	.001	.001	b/	.001	.001	b/	.001	.001	b/
Grease wagon and low bed trailer	.10	.10	.10	.10	.10	.10	.10	.10	.10
TOTAL	4.32	4.32	4.14	4.32	4.32	4.14	4.32	4.32	4.14
Labor									
General (excluding irrigation)	5.62	5.62	5.25	5.62	5.62	5.25	5.62	5.62	5.25
Irrigation	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20
TOTAL	10.82	10.82	10.45	10.82	10.82	10.45	10.82	10.82	10.45
Contracted									
Fertilizer - materials	10.32	10.32	10.32	10.32	10.32	10.32	10.32	10.32	10.32
- application	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
Weed control - materials	5.67	5.67	18.11	5.67	5.67	18.11	5.67	5.67	18.11
- application	2.00	2.00	3.50	2.00	2.00	3.50	2.00	2.00	3.50
Pest control - materials	.32	.32	.32	.32	.32	.32	.32	.32	.32
- application	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Seed - application	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Checker	1.30	1.30	.52	1.30	1.30	.52	1.30	1.30	.52
TOTAL	25.96	25.96	39.12	25.96	25.96	39.12	25.96	25.96	39.12
Materials									
Seed	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
Irrigation water	7.18	7.35	6.49	11.10	10.48	10.31	11.10	10.48	10.31
TOTAL	19.44	19.61	18.75	23.36	22.74	22.57	23.36	22.74	22.57
Interest									
Operating capital (excluding water)	1.70	1.70	1.94	1.70	1.70	1.94	1.70	1.70	1.94
Water and irrigation labor	.31	.31	.30	.40	.40	.39	.40	.40	.39
TOTAL	2.01	2.01	2.24	2.10	2.10	2.33	2.10	2.10	2.33
TOTAL PREHARVEST COSTS	72.92	73.09	84.40	76.93	76.31	88.31	76.93	76.31	88.31
HARVEST									
Machinery									
Combine (2 x 16')	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31	4.31
S.P. bankout wagon	.73	.73	.73	.73	.73	.73	.73	.73	.73
Bankout wagon	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hauling to drier	.98	1.18	1.18	1.08	1.27	1.27	1.08	1.27	1.27
TOTAL	7.02	7.22	7.22	7.12	7.31	7.31	7.12	7.31	7.31
Contracted									
Drying	17.78	19.56	20.00	19.26	21.04	21.48	17.78	21.04	21.48
Hire truck (2T)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
TOTAL	20.78	22.56	23.00	22.26	24.04	24.48	22.26	24.04	24.48
Labor	8.45	8.45	8.45	8.45	8.45	8.45	8.45	8.45	8.45
TOTAL HARVEST COSTS	36.25	38.23	38.67	37.83	39.80	40.24	37.83	39.80	40.24
TOTAL VARIABLE COSTS	109.17	111.32	123.07	114.76	116.11	128.55	114.76	116.11	128.55

a/ 1 = deep, not lowered; 2 = deep, lowered; 3 = shallow.
b/ Not applicable.

APPENDIX TABLE A-9

Variable Input Expenses and Net Returns Per Acre of Rice According to
Soils and Irrigation Practices, 1964-1966 Average Prices

Inputs by major group	Basin			Old alluvium			Recent alluvium		
	1[a/]	2	3	1	2	3	1	2	3
	1	2	3	4	5	6	7	8	9
		dollars			dollars			dollars	
PREHARVEST									
Power	6.24	6.24	5.57	6.24	6.24	5.57	6.24	6.24	5.57
Transport	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
Machinery	4.32	4.32	4.14	4.32	4.32	4.14	4.32	4.32	4.14
Labor	10.82	10.82	10.45	10.82	10.82	10.45	10.82	10.82	10.45
Contracted	25.96	25.96	39.12	25.96	25.96	39.12	25.96	25.96	39.12
Materials	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
Interest (excluding irrigation)	1.70	1.70	1.94	1.70	1.70	1.94	1.70	1.70	1.94
Water	7.18	7.35	6.49	11.10	10.48	10.31	11.10	10.48	10.31
Interest (water and irrigation labor)	.31	.31	.30	.40	.40	.39	.40	.40	.39
TOTAL Preharvest Costs	72.92	73.09	84.40	76.93	76.31	88.31	76.93	76.31	88.31
HARVEST									
Machinery	7.02	7.22	7.22	7.12	7.31	7.31	7.12	7.31	7.31
Labor	8.45	8.45	8.45	8.45	8.45	8.45	8.45	8.45	8.45
Contracted	20.78	22.56	23.00	22.26	24.04	24.48	22.26	24.04	24.48
TOTAL Harvest Costs	36.25	38.23	38.67	37.83	39.80	40.24	37.83	39.80	40.24
TOTAL VARIABLE COSTS	109.17	111.32	123.07	114.76	116.11	128.55	114.76	116.11	128.55
Yields, cwt. per acre	60.00	67.50	68.00	65.00	71.00	72.50	65.00	71.00	72.50
Price per cwt.	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90
TOTAL GROSS RECEIPTS	294.00	330.75	333.20	318.50	347.90	355.25	318.50	347.90	355.25
NET RETURNS	184.83	219.43	210.13	203.74	231.79	226.70	203.74	231.79	226.70

a/ 1 = deep, not lowered; 2 = deep, lowered; 3 = shallow.

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APPENDIX TABLE A-10

Summary of Variable Input Costs and Net Returns Per Acre for All Crops
According to Soil and Irrigation Practices, 1964-1966 Average Prices

Crops	Irrigation Practice[a]	Preharvest costs	Harvest costs	Total variable costs	Yields	Price per unit	Gross receipts	Net returns	Net returns plus water cost[a]
	1	2	3	4	5	6	7	8	9
	code	dollars			quantity	dollars			
	Basin								
Rice[b]	2	73.09	38.23	111.32	67.50 Cwt.		330.75	219.43	226.78
	3	84.40	38.67	123.07	68.00 Cwt.	4.90	333.20	210.13	216.62
	1	72.92	36.25	109.17	60.00 Cwt.		294.00	184.83	192.01
Grain Sorghum[c]	60	48.59	57.57	57.57	53.80 Cwt.	2.20	118.36	60.79	63.38
	80	48.45	57.40	57.40	52.40 Cwt.	2.20	115.28	57.88	60.44
	100	49.18	58.04	58.04	49.00 Cwt.	2.20	107.80	49.76	52.47
Safflower[d]	D	34.06	6.57	40.63	19.60 Cwt.	4.35	85.26	44.63	44.63
	E	11.46	6.67	18.13	15.00 Cwt.	4.35	65.25	47.12	47.12
Barley		20.15	6.85	27.00	27.50 Cwt.	2.40	66.00	39.00	39.00
Wheat		20.24	8.95	29.19	39.20 Cwt.	2.40	94.08	64.90	64.90
Grain Hay		20.48	13.16	33.64	2.30 Cwt.	23.00	52.90	19.26	19.26
Oats		21.21	6.53	27.71	20.00 Cwt.	2.50	50.00	22.26	22.26
Oats, vetch seed		24.73	18.86	30.95	3.50 Cwt.	23.00	80.50	37.18	37.18
	Old Alluvium								
Rice	2	76.31	39.80	116.11	71.00 Cwt.		347.90	231.79	242.27
	3	88.31	40.24	128.55	72.50 Cwt.	4.90	355.25	226.70	237.01
	1	76.93	37.83	114.76	65.00 Cwt.		318.50	203.74	214.84
Grain Sorghum	60	50.46	9.15	59.61	59.00 Cwt.		129.80	70.19	73.18
	80	51.77	9.15	60.92	57.70 Cwt.	2.20	126.94	66.02	69.28
	100	50.17	8.98	59.15	54.00 Cwt.		118.80	59.65	62.58
Corn	60	75.81	37.77	113.58	63.90 Cwt.		166.14	52.56	57.20
	80	74.52	37.11	111.63	62.50 Cwt.	2.60	162.50	50.87	55.11
	100	76.38	34.91	111.29	58.00 Cwt.		150.80	39.51	44.02
Beans	60	40.56	40.98	81.50	19.70 Cwt.		182.23	100.73	103.24
	80	38.68	40.03	78.76	19.20 Cwt.	9.25	177.60	98.84	100.95
	100	36.98	37.92	74.90	18.00 Cwt.		166.50	91.60	93.36
Safflower	D	34.06	6.67	40.73	23.60 Cwt.	4.35	102.66	61.93	61.93
Barley		20.15	6.95	27.10	35.00 Cwt.	2.40	84.00	56.90	56.90
Wheat		20.24	9.05	29.29	44.25 Cwt.	2.40	106.20	76.91	76.91
Oats		21.21	6.62	27.80	26.60 Cwt.	2.50	66.50	38.67	38.67
Grain Hay		20.48	15.06	35.54	2.70 tons	23.00	62.10	26.56	26.56
	Recent Alluvium								
Rice	2	76.31	39.80	116.11	71.00 Cwt.		347.90	231.79	242.27
	3	88.31	40.24	128.55	72.50 Cwt.	4.90	355.25	226.70	237.01
	1	76.93	37.83	114.76	65.00 Cwt.		318.50	203.74	214.84
Grain Sorghum	60	50.46	9.15	59.61	59.00 Cwt.		129.80	70.19	73.18
	80	51.77	9.15	60.92	57.70 Cwt.	2.20	126.94	66.02	69.28
	100	50.17	8.98	59.15	54.00 Cwt.		118.80	59.65	62.58
Corn	60	75.81	37.77	113.58	68.80 Cwt.		178.88	65.30	69.81
	80	74.52	37.11	111.63	67.30 Cwt.	2.60	174.98	63.35	67.59
	100	76.38	34.91	111.29	62.90 Cwt.		163.54	52.25	56.89
Beans	60	40.56	40.98	81.50	19.70 Cwt.		182.23	100.73	103.24
	80	38.68	40.08	78.76	19.20 Cwt.	9.25	177.60	98.84	100.95
	100	36.98	37.92	74.90	18.00 Cwt.		166.50	91.60	93.36
Sugar Beets	60	114.94	49.56	164.50	18.70 Cwt.		261.80	97.30	101.96
	80	112.78	48.50	161.28	18.30 Cwt.	14.00	256.20	94.92	99.10
	100	112.26	45.05	157.31	17.00 Cwt.		238.00	80.69	84.98
Alfalfa	60	50.15	33.87	84.02	4.29 tons	24.50	105.11	21.09	28.05
	100	49.23	33.87	83.10	3.94 tons	24.50	96.53	13.43	20.21
Safflower	D	34.06	6.67	40.73	23.60 Cwt.	4.35	102.66	61.93	61.93
Barley		20.15	6.95	27.10	35.00 Cwt.	2.40	84.00	56.90	56.90
Wheat		20.24	9.05	29.29	44.25 Cwt.	2.40	106.20	76.91	76.91
Oats		21.21	6.62	27.80	33.40 Cwt.	2.50	83.50	55.70	55.70
Grain Hay		20.48	15.06	35.54	2.70 tons	23.00	62.10	26.56	26.56

a/ Net returns assuming zero water cost.
b/ 2 = deep-lowered; 3 = shallow; 1 = deep, not lowered.
c/ 60, 80, 100 = percent soil moisture depletion before irrigation.
d/ D = regular practice; E = minimal practice.