1968

Production response in the Yaqui Valley, Mexico

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1073

PRODUCTION RESPONSE IN THE YAQUI VALLEY, MEXICO

by

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A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE

Major Subject: Agricultural Economics

Signatures have been redacted for privacy

Iowa State University
Of Science and Technology
Ames, Iowa

1968

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CHAPTER I. INTRODUCTION

Until recent years, Mexico's main agricultural goal was to increase total agricultural production.

In order to accomplish this goal, the Mexican government made large investments in research programs to develop new technology; similar investments were made to increase the supply of fertilizers. The government also invested large quantities of money and other resources in irrigation projects, which improved the irrigation practices of areas already established and made possible the opening of new lands for cultivation. Private capital contributed to the production and distribution of new products for the farmers, such as agricultural machinery, pesticides, fertilizers, and improved seeds. The government programs of guaranteed prices, combined with the farm insurance policies, helped to reduce the uncertainty of the farmers' investment in agricultural production, and raised their profits. The large investments in highways and secondary roads helped to connect the production areas with the urban markets. The extension and credit programs accelerated the agricultural growth.

All these programs resulted in agricultural development. Mexico's average rate of growth in agriculture was approximately 6 percent per year. The nation went from importing half of the quantity of wheat required to satisfy internal demand, to exporting this grain and satisfying internal growing demand. The demand for corn was also satisfied and this grain has also been exported. The production of export crops such as cotton also had a significant increase.

Now the situation has changed and the new national needs call for a more planned use of the agricultural resources. The resources as well as the incentives have to be allocated to maximize the value of agricultural output. The relative production of fruit, vegetable, and oilseed crops have to be increased; while the relative production of some crops such as wheat, rice, and beans, which at the present is being encouraged, must be decreased. The resources of each production region must be used more efficiently; this means that the comparative advantages of the different regions for producing certain crops must be considered. Regions with abundant labor should produce crops requiring intensive use of labor, and the same rationale applies to the use of other resources such as capital or land. Resources and incentives should be allocated where they yield the maximum benefit to the nation.

To solve this new problem, it is necessary to guide production in the right direction; and to do this, we have to know how the different agricultural producers in the country respond to the various factors that affect the production of specific crops. This must be known for all the different agricultural regions. The general objective of this thesis is to analyze changes in agricultural production for one region.

The area chosen for this study is the irrigated Yaqui Valley which is situated in Northwestern Mexico. It is a relatively homogeneous area with a highly commercialized and technically based agriculture. The increase in agricultural production in this area is impressive. This increase is a result of the government and private programs aimed at raising the level of the national production. These programs had a great impact in the Yaqui Valley because of the willingness of the farmers to adapt new technology and change traditional patterns of production.

The specific objectives of this thesis may be stated as follows:

1. To describe the area with respect to its historical development and the present organization and technology of production.
2. To determine the growth trend in production, harvested area and yield for each of the three major crops: wheat, cotton, and corn.
3. To analyze the production response function for the three major crops with respect to the variables in the following categories:
    - environmental
    - technological
    - institutional
    - economic
4. To suggest additional research needed for improving the value productivity of the region in accordance with national goals.

CHAPTER II. THE YAQUI VALLEY, HISTORICAL DEVELOPMENT, AND THE PRESENT ORGANIZATION AND TECHNOLOGY OF PRODUCTION

Geographic characteristics

The Northwest of Mexico is constituted by the states of Sonora, Sinaloa, and the Baja California Peninsula. The Yaqui Valley is located in Southwestern Sonora, between the 27° 10' and 27° 40' North latitude; and 109° 50' to 110° 40' longitude, west of the Greenwich Meridian (1, p. 4).

This Valley contains an area of about 450,000 hectares which is bounded to the north by the Bacatete mountain range, to the south and west by the alkali soils that separate it from the Gulf of California, and to the east by the Sierra Madre Occidental and the Mayo River (15, p. 5).

A dry climate predominates through the Valley; with the temperature ranging from 48° C. during the summer to -1° C. during the winter, with a mean of 26.5° C. for the whole year. The vegetation can be classified as a desert; and its annual precipitation is 294 mm., which means that rainfall is not enough to support dry land agriculture (1, p. 4).

The soils of the Valley are quite fertile. The only plant nutrient commonly used is nitrogen, but in recent years some soils have shown a lack of phosphorus.

The Yaqui Valley can be divided into three zones: Valle Nuevo[1], or the land that has been recently opened for cultivation (1952); Valle Viejo[2],

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[1]New Valley.

[2]Old Valley.

the land that has been worked for more than 40 years; and the zone of the Rio Muerto[1] (1, p. 4).

Tenure system

The number of landholders in the Valley was around 9,000 in 1963 and their area in crops was around 229,000 hectares. This area is held by farmers in the three tenure systems that are common in Mexico.

Table 1. Yaqui Valley, Mexico. Number of landholders and hectares in crops by tenure of holder in 1963[a]

TENURE OF HOLDER	LANDHOLDERS		AREA IN CROPS		HECTARES PER HOLDER
	NUMBER	PERCENT	HECTARES	PERCENT	
Small owners	2,262	25.5	122,023	55.1	53.9
Colonos	1,200	13.6	24,072	10.9	20.1
Total	3,462	39.1	146,095	66.0	42.2
Ejidatarios	5,399	60.9	75,136	34.0	13.9
GRAND TOTAL	8,861	100.0	221,231	100.0	25.0

[a]Source: (7, p. 74).

There were 5,400 ejidatarios[2] with an area harvested of 75,136 hectares; 1,200 colonos[3] with 24,072 hectares; and 2,262 private owners with

[1]Dead River.

[2]An ejido is an extension of land given to a group of farmers with all the rights to work it, but not sell it or mortgage it. This land can only be inherited to a member of the family. These farmers are known as ejidatarios. The ejido can be worked individually or collectively.

[3]Colonos is a modification of the ejido. The land is sold to the colono at a low price. Payments are spread over a long time.

122,023 hectares under cultivation (7, pp. 73-74). Most of these farmers are engaged exclusively in a commercialized crop production.

Important crops

Different crops have predominated in the Valley during the past 50 years; this fact can be seen in Table 2. Corn had been increasing until the last two years when production of this crop decreased. Wheat has always been a very important crop in the Valley and since 1950 it had been first in land use. Cotton was first grown in 1950 and since 1952 it has been the second leading crop with regard to land use. Rice used to be a very popular crop, but in 1962 it was discontinued mainly because of its high requirements of water. Chickpeas was also harvested in the Valley but was discontinued.

In recent years new crops like soybeans, safflower, barley, and sorghum grain have been introduced. Crops such as sesame, alfalfa, and flaxseed have had a fluctuating importance in the Valley and at the present time they are not very important.

The most important crops during the last 15 years have been wheat, cotton, and corn. Total product, area harvested, and yield of these crops have had an increasing but fluctuating trend. These data will be analyzed in the third chapter of this thesis.

Agricultural production

Production in the Valley has been increasing since cultivation began. In value terms, the maximum was reached in 1964; in this year the total value of the agricultural production (expressed in 1961 prices) was $961,698,104 pesos. For the years 1952 to 1966 the total value of produc-

Table 2. Yaqui Valley, Mexico. Five-year average of area harvested of major crops, 1911-1940 and annual area harvested 1941-1966. Expressed in thousand hectares[a]

PERIOD	WHEAT	COTTON	CORN	RICE	CHICKPEA	BEANS	FLAX	BARLEY	SESAME	SOYBEANS	ALFALFA	SAFFLOWER	OTHERS	TOTAL
1912-15	1.3		1.7	0.5	0.4								6.1	10.0
1916-20	1.3		2.4	1.5	2.4								2.2	9.6
1921-25	6.7		1.6	4.8	1.5								2.8	17.4
1926-30	17.0		2.2	13.0	0.8								10.4	43.4
1931-35	21.3		4.0	12.4	0.1		0.6		0.1				6.8	45.3
1936-40	34.7		2.5	16.0	0.0		0.0		0.6				2.3	56.1
1941	31.3		1.9	24.3	0.2		0.0		1.2				2.0	60.9
1942	30.2		1.7	25.9	0.6		1.5		0.6				5.5	66.0
1943	12.6		1.3	30.3			21.5		1.9				4.2	71.8
1944	21.0		4.9	31.0			13.3		1.9				5.4	77.5
1945	14.4		6.0	33.6			12.2		1.7				3.8	71.8
1946	36.7		9.0	28.6			5.3		2.7		1.1		3.2	86.6
1947	33.6		4.1	37.7			11.3		11.4		1.0		3.4	102.6
1948	24.4		3.7	43.4			15.5		6.0		0.4		2.8	96.6
1949	32.3		5.3	42.3			25.0		20.3		0.5		0.7	126.4
1950	48.0	3.7	2.7	57.3			7.4		10.3		0.4		0.3	130.1
1951	46.8	21.9	6.1	30.9		0.7	13.6		3.3		0.4		0.2	123.9
1952	50.8	24.7	6.2	13.4		0.6	2.6		6.6		0.9		0.3	106.1
1953	56.7	42.7	3.0	14.4		0.9	6.1		1.2		0.9		0.1	126.0
1954	94.3	45.4	4.8	3.0	SOR-	1.1	0.0		2.4		1.2		2.2	154.4
1955	113.3	86.9	2.6	4.1	GHUM	0.1	0.2		0.4		1.3		0.6	209.5
1956	154.0	31.9	9.6	8.2	GRAIN	0.2	0.1		7.3		1.3		1.1	231.7
1957	143.1	49.7	15.4	1.6		0.1	0.3		2.3		1.2		8.1	221.8
1958	105.2	74.0	18.4	1.9	7.0	0.0	0.8		0.3		1.2		3.8	212.6
1959	130.5	47.7	26.6	4.3	2.0	0.0	0.5	3.7	3.7		1.1		6.4	226.5
1960	90.8	79.0	15.3	9.2	1.6	1.0	6.3	1.4	9.3	3.0	1.1	0.4	2.9	221.3
1961	110.7	56.0	23.0	14.5	3.7	0.8	2.3	12.5	22.0	8.6	2.1	0.9	1.8	258.9
1962	114.5	64.3	20.3	0.0	1.8	0.3	0.4	1.0	18.9	28.6	2.6	1.2	1.7	255.6
1963	143.5	47.2	36.1	0.0	1.7	0.0	0.2	0.0	2.1	0.6	2.3	0.1	1.0	234.8
1964	134.0	61.0	54.0	0.0	0.9	0.1	0.3	0.2	0.2	1.2	2.6	0.2	1.4	256.1
1965	138.4	53.3	44.2	0.0	2.3	0.0	0.1	0.2	4.9	17.3	2.2	0.1	0.8	263.9
1966	85.7	64.8	11.0	0.0	8.9	0.1	1.5	5.5	2.6	28.5	2.2	12.9	2.3	226.1

[a]Source: (2).

tion of the Valley in constant prices can be seen in Table 3. The increase in production is due to increase in area and higher yields.

Table 3. Yaqui Valley, Mexico. Value of agricultural production for the years 1952 to 1966, expressed in constant prices (year 1961) of the following crops: Alfalfa, barley, beans, corn, cotton, flax, rice, safflower, sesame, sorghum grain, soybean, and wheat[a]

YEAR	VALUE IN PESOS
1952	$ 193,793,007
1953	270,791,517
1954	372,513,174
1955	462,993,848
1956	440,387,088
1957	536,834,650
1958	501,490,596
1959	454,796,145
1960	533,080,756
1961	688,123,895
1962	787,689,842
1963	731,142,271
1964	961,698,104
1965	818,101,273
1966	743,420,443

[a]Source: (2).

The value of production per se is important, but it would be more significant if it could be compared against the cost of production. Unfortunately, data of production cost of the different farmers in the Valley is not available; but by direct observation, it can be said that for the individual producers the gross value of production has exceeded the costs. On the other hand, if we consider the investments that were made on irrigation projects, research, subsidy prices, etc. no definite statement can be made without a closer and more accurate analysis. It is important to note that the government subsidies to the Valley have been gradually declining; guaranteed prices have been lowered or discontinued, price of irrigation water has been raised, the share of the farmers in the cost of research is greater, etc.

Production growth rate The trend and growth rate in value of agricultural production were calculated from the data shown in Table 3. The growth per year was found to be 9 percent (Regression estimate of "b" in the equation log Y = a + b · time), or $44,735,216 pesos (regression estimate of "b" in the equation Y = a + b · time). Both of these values were found positive and highly significant. This growth in production is represented by the growth in the yields and area harvested of wheat, cotton and corn; these growths as well as the factors affecting them are discussed in the third chapter of this thesis.

Irrigated area

Irrigation is necessary to grow any crop in this Valley, and the first step to irrigate it was taken by Carlos Conant in 1890, who asked for and got a concession to use the waters of the Yaqui River. He, then, constituted the Sonora and Sinaloa Irrigation Co. in order to realize his project. This company started to build the Canal Principal[1] in 1891 but in 1908 became bankrupt and the concession was shifted to the Constructora Richardson, S.A. that continued the construction of the canal and started to clear the land for cultivation (3, pp. 267-315).

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[1]Main Canal.

In 1928 the government took control of the company and gave the administration of the irrigation system to the Banco Nacional de Credito Agricola y Ganadero[1] (3, p. 327).

In 1938 the area under cultivation was 52,511 hectares and the irrigation system was not sufficient anymore to handle this area. The Federal Government started then the construction of the "Angostura Dam," a project that was finished in 1941. This dam has a total capacity of 840,000,000 Mts^3. With the water provided by this dam, the area under cultivation increased to 123,000 hectares in 1951 (3, pp. 330-334). It was in this year that the administration of the irrigation system was given to the Secretaria de Recursos Hidraulicos[2]. In 1952 the "Alvaro Obregon Dam," with a capacity of 3,000'000,000 Mts^3. was opened; and with this dam a new great canal was also opened, Canal Alto[3]. These two projects made possible to irrigate more land; specifically, the Valle Nuevo area, and in 1965 there were 263,913 hectares harvested[4] (2). In 1963 the "Plutarco Elias Calles Dam" was opened, but this dam was not planned to help to irrigate more land, but to increase electric power.

The Valley is irrigated in the present time, mainly, but the water available in the three dams already mentioned. The control, distribution, and selling of the water among the farmers is in the hands of the Comite

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[1]National Bank of Agricultural Credit.

[2]Department of Water Resources.

[3]High Canal.

[4]This figure includes double cropping.

Directivo Agricola del Distrito de Riego del Rio Yaqui, Sonora[1]. This committee is constituted by the chief of the irrigation district No. 41[2] of the Secretaria de Recursos Hidraulicos, who serves as chairman, the local representative of the Secretaria de Agricultura y Ganaderia[3], who serves as secretary, and representatives of the Banco Nacional de Credito Ejidal[4], Banco Nacional de Credito Agricola y Ganadero, ejidatarios, and private proprietors.

The committee prepares a plan for each agricultural year, taking into consideration the desires of the farmers, the water available in the dams, and also the needs of the area and the nation for certain crops. This plan is not definitive; it is flexible. It is constantly modified as the cropping year advances depending on the water in the dams and also in the actual plantings which are not exactly equal to the planned.

The committee is always careful that enough water is available to irrigate the crops that are already planted. Therefore, there is no abandonment of planted hectares because of lack of water; and in general, there is a high assurance of harvest from planted crops.

Depending on the water available, double cropping is permitted by the committee. Usually a small percentage of the total area can be planted twice a year.

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[1]Agricultural Directive Committee of the Irrigation District of the Yaqui River, Sonora.

[2]Irrigation District No. 41, corresponds to the Yaqui Valley irrigation district.

[3]Department of Agriculture.

[4]National Bank of Ejido Credit.

The committee also fixes the price of water, which is sold by cubic meters at the same price for all crops.

The distribution of the water is accomplished by the following system: From the Main Canal water is transported via primary and secondary canals to irrigate certain sections. The farmers request from the person in charge of the section the amount of water that they need; and this person asks for the water from the district office.

Prices

Prices received by farmers throughout the Valley are homogeneous with regard to the type of buyer or seller. This is specially true for the crops that have a guaranteed price. A guaranteed price exists for wheat, which was recently lowered. A guaranteed price for corn has existed in some years. This same price policy is currently being followed for oilseed crops.

Cotton has a free and fluctuating price determined by market forces. This price has not had a significant increasing trend.

Research and extension

The institution responsible for the increase in level of technology in the Valley is CIANO[1]. This institution is partially sponsored by the farmers and does research in all important crops in the area. It is also responsible for the introduction of new crops. CIANO recommends farming practices for each crop (quantity and kind of seed, irrigation, fertilization, pest control, cultural practices, etc.) and the farmers follow its

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[1]Centro de Investigaciones Agricolas del Noroeste - Center of Agricultural Research for the Northwest.

recommendations very closely each year.

Among the main achievements of CIANO are: The development of improved varieties of wheat which are not susceptible to rust and give higher yields; continuous work on new varieties is in progress so that the old ones can be replaced as soon as they become susceptible to the disease. Another wheat improvement has been the development of dwarf, stiff-straw varieties that respond well to large applications of nitrogen fertilizer and high seeding rates.

The research done by CIANO in soils yielded information on the need for phosphorus in some areas in the Valley, and by applying this nutrient, higher yields are expected to be obtained.

The most important of its extension activities is the "Day of the Farmer," which is held once a year. On this day, hundreads of farmers visit the experimental station and get information about its research. Because of the large number of farmers attending, CIANO has instead recently began the "Week of the Farmer."

Marketing and credit

CoNaSuPo[1] has established an unlimited demand for wheat at a guaranteed price; and therefore, controls all of the purchases of this product. In some years, CoNaSuPo also bought corn but purchase of this product has been discontinued in the Valley. Most of the warehousing of these grains is done by another governmental agency, ANDSA[2].

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[1]Compañia Nacional de Subsistencias Populares - A federal institution created to control price fluctuations in the basic food crops such as wheat, corn, rice, beans, and sugar for the protection of farmers as well as consumers.

[2]Almacenes Nacionales de Deposito, S.A. - This public corporation provides warehousing and marketing facilities for the agricultural products bought by CoNaSuPo.

There are no farm storage facilities; therefore, the product is transferred from farms to central warehouses at harvest time. The secondary roads in the Valley are in good condition, so transportation is easy. Nevertheless, there is the problem of jammed traffic at the warehouses.

Cotton is sold to independent ginners or to cotton merchandising companies that have gins. The cotton gins are not evenly distributed in the Valley and experience the same traffic problem as corn and wheat at harvest time.

Obtaining credit is no serious problem in the Yaqui Valley because ejidatarios, colonos, and small farm proprietors can obtain credit from government agencies. Large farm owners have good sources of credit in private banks and their own credit unions. The cotton industry plays an important role in the granting of credit to farmers for the growing of this crop.

Agricultural cropping year and common rotations

An agricultural cycle in the Valley goes from the first of October to the 30 of September of the following year.

The seeding and harvesting time for the most common crops are listed in Table 4 as well as the standing period of each crop. From this table we can see that cotton and wheat cannot be harvested in the same year; also that if we plant corn one year, wheat cannot be planted the following cropping year.

Wheat has lower requirements for water than cotton; so from this point of view the growing of wheat is usually more encouraged by the Secretaria de Recursos Hidraulicos than the growing of cotton. For this reason the area desired to be planted with cotton has been restricted to a percentage, more often than the one of wheat. The production plan is prepared at the

Table 4. Yaqui Valley, Mexico. Seeding and harvesting time, and standing period for the most common crops[a]

CROPS	MONTHS[b] O	N	D	J	F	M	A	M	J	J	A	S
wheat		X	X	X	X	X	X	X				
Cotton						X	X	X	X	X	X	X
Corn	X	X	X	X							X	X
Soybean	X						X	X	X	X	X	X
Safflower		X	X	X	X	X	X	X	X	X		
Flax		X	X	X	X	X	X	X	X	X		
Barley		X	X	X	X	X	X	X	X			
Sesame									X	X	X	X
Sorghum grain						X	X	X	X	X	X	
Rice	X	X								X	X	X

	SEEDING TIME	HARVESTING TIME
wheat	November 15 - December 31	April 15 - May 31
Cotton	March 15 - April 15	August 1 - September 20
Corn	August 15 - August 31	January 1 - January 31
Soybean[c]	April 15 - May 15	October 1 - November 10
Safflower	November 15 - December 15	June 15 - July 15
Flax	November 15 - December 15	May 15 - June 30
Barley	November 15 - December 15	April 15 - May 31
Sesame[c]	March 15 - May 15	July - September
Sorghum grain	March 10 - April 10	July 15 - August 15

[a]Source: (14).

[b]Months go from October to September of the following year.

[c]When used for double cropping, usually sown early in June.

beginning of the cropping year, therefore the area of wheat and the area of cotton planted is decided simultaneously.

Soybean and corn are not as profitable per acre as wheat and cotton, and are usually used for double cropping; therefore, their area is highly restricted because of lack of water for double cropping in the Valley.

The most important decision of the farmers is the choice between wheat or cotton, and after this decision, the pattern of the rotation or the selection of the crop for double cropping is almost fixed. This comes from the fact that after cotton, you cannot plant any other crop in that year; and after wheat, you can plant either corn or soybeans, but in making the decision for planting corn you have to choose between wheat or cotton in the following cropping year due to the fact that after corn, wheat cannot be planted.

The most common rotations that can be observed in the area are:

Wheat - Corn - Cotton . . . in two years

Wheat - Soybeans . . . in one year

Wheat . . . in one year

Cotton . . . in one year

Farmers usually plant part of their area with wheat and leave part to plant to cotton since this spreads their incomes, costs, and risks throughout the entire year. Few farmers specialize in wheat or cotton alone.

The first two rotations are generally more profitable because the fixed factors are better utilized. Land, machinery, and fixed labor are used more intensively over the year.

CHAPTER III. PRODUCTION OF WHEAT, COTTON, AND CORN

Wheat, cotton, and corn are the most important crops in the Valley. This chapter analyzes the growth in production of these three crops, the variables affecting this growth, and some relevant economic factors which affect their production.

Growth in production

The magnitude of the growth in production of these crops during the years 1952 to 1966 can be seen in Table 5.

The sources of these growths are increase in area harvested and increase in yields.

Table 5. Yaqui Valley, Mexico. Total production and production growth, in metric tons, of wheat, cotton, and corn for the years 1952 to 1966[a]

YEAR	WHEAT	COTTON	CORN
1952	70,373	38,022	8,027
1953	88,132	69,174	2,013
1954	169,656	84,807	1,998
1955	195,669	114,851	2,586
1956	325,946	47,648	12,000
1957	300,481	95,580	34,115
1958	230,837	116,589	6,249
1959	222,610	75,984	57,211
1960	204,226	114,465	22,049
1961	275,570	117,228	52,704
1962	336,410	135,263	59,108
1963	396,424	114,981	102,642
1964	449,972	155,935	190,793
1965	352,106	130,089	162,015
1966	240,422	155,407	36,530
Percent growth per year[b]	8.9	7.2	29.0
Growth per year in metric tons[c]	17,620	6,598	9,636

[a]Source: (2).

[b]Regression estimate of "b" in the equation $\log Y = a + b \cdot time$.

[c]Regression estimate of "b" in the equation $Y = a + b \cdot time$.

Area effects

The increase in production due to growth on area harvested is shown in Table 6.

Table 6. Yaqui Valley, Mexico. Area harvested in hectares, and area growth of wheat, cotton, and corn for the years 1952 to 1966[a]

YEAR	WHEAT	COTTON	CORN
1952	50,783	24,654	6,235
1953	56,755	42,658	3,056
1954	94,283	45,576	4,804
1955	113,267	86,874	2,597
1956	154,039	31,935	9,605
1957	143,110	49,695	15,418
1958	105,126	74,014	18,382
1959	130,500	47,672	26,600
1960	90,799	78,975	15,270
1961	110,685	56,041	23,016
1962	114,546	64,336	20,276
1963	143,504	47,226	36,174
1964	134,016	61,017	53,961
1965	138,392	53,265	44,186
1966	85,716	64,815	10,976
Percent growth per year[b]	3.6	3.4	16.2
Growth per year in hectares[c]	3,058	1,354	2,514

[a]Source: (2).

[b]Regression estimate of "b" in the equation log Y = a + b · time.

[c]Regression estimate of "b" in the equation Y = a + b · time.

The increase in area accounts approximately for one half of the total growth in production of these crops. The most important source of this increase is the development of irrigation projects which permitted more land to be cleared for cultivation and also the double cropping of certain portion of the area. Due to the opening of new land, the area harvested of cotton and wheat increased very much from 1952 to 1956. The area of corn increased more gradually as more area was double cropped in the Valley. The use of specialized machinery has played an important role in the double cropping of land in the Valley by shortening the harvest time and also by speeding up the seeding of the crops.

Even if new land is not opened for cultivation, the area harvested could be increased by double cropping larger portions of the area; but this is limited by the water available and projects to increase irrigation water are not in sight for the near future. Therefore, further increase in the area harvested of these crops as a whole can only come from more economic use of the water available. Significant increase of the area of any particular crop can be obtained by shifting the area of one crop to another.

Yield effects

The rate of increase in yields of the three crops is shown in Table 7. Approximately 60 percent of the increase in production of wheat, 50 percent in cotton, and 45 percent in corn was due to increase in yield. Unfortunately, it has not been possible to measure the exact influence of each factor on this growth. Nevertheless, the principal contributing factors will be briefly mentioned.

Seeds The development of new and improved seeds was the main factor making possible the increase in yields for wheat and corn. This factor has been of less importance for cotton. Locally-adapted varieties were developed for wheat which not only were resistent to rust, but also responded well to large applications of fertilizer. The development of hybrid corn varieties suited for the region brought as consequence the increase of yields in this crop. The research done in this field has been great but it must be continued because hybrid varieties as well as varieties resistent to rust loose their effectiveness with time.

Fertilization   The use of inorganic forms of fertilizers is almost always present when there is an increase in agricultural production due to yields. The double cropping of an area requires large additions of fertilizer. The use of new varieties for increased yields also requires fertilizer to take advantage of the inherent yield potential of the improved seed. In the Valley, fertilization of all three crops has been increasing as farmers actually see the response of the plants to it. The use of fertilizer at the moment is widespread in the Valley, this is in part due to the fact that the farmers like inputs which give quick returns.

Table 7. Yaqui Valley, Mexico. Yields in kilograms per hectare, and yield growth of wheat, cotton, and corn for the years 1952 to 1966[a]

YEAR	WHEAT	COTTON	CORN
1952	1,386	1,542	1,287
1953	1,553	1,622	659
1954	1,799	1,869	416
1955	1,728	1,322	996
1956	2,116	1,492	1,249
1957	2,100	1,923	2,213
1958	2,196	1,575	340
1959	1,706	1,544	2,151
1960	2,249	1,449	1,444
1961	2,490	2,092	2,290
1962	2,937	2,102	2,915
1963	2,762	2,435	2,841
1964	3,358	2,556	3,536
1965	2,544	2,442	3,667
1966	2,805	2,398	3,328
Percent growth per year[b]	5.1	3.8	12.8
Growth per year[c] in Kgs./Hectare	111	74	280

[a]Source: (2).

[b]Regression estimate of "b" in the equation log Y = a + b · time.

[c]Regression estimate of "b" in the equation Y = a + b · time.

Plant protection The increase in the use of pesticides, herbicides, and other forms of plant protection has been significant in the Valley. Pest control has been a very important factor in obtaining higher yields of cotton; and every farmer protects his cotton by large applications of insecticide. The use of herbicides,to control weeds is also very popular in the Valley.

Irrigation The availability of more water for irrigation not only increased the area harvested, but gave the opportunity to use better irrigation practices which are also significant in the increase in yields, specially for cotton.

Cultural practices The extensive use in the Valley of mechanical implements has made possible large improvements in the quality of the agricultural operations performed and most important it has made possible the performance of production operations that could not be made with traditional implements; thus, contributing to larger yields per hectare. Among these operations are the use of special machinery to level the soil for cultivation, this has resulted not only in higher yields, but in a better use of irrigation water. The use of agricultural machinery also made possible double cropping of the area by the fast performance of the required operation to grow two crops in one agricultural year.

These are the factors that were most important in the increase of yields in the area; but anyone of them alone could not have accomplished anything, the higher yields are a combination of all, although it is not possible to quantitatively allocate the yield increases among the factors causing them.

Incentives for growth

The physical aspects of the increase in production of the three main crops in the Yaqui Valley were mentioned above, but perhaps the actions that created the economic climate that induced the use of improved physical inputs were of greater importance.

There has been a government action by agricultural policy which was aimed at improving the income incentives of the farmers; this was the guaranteed price program. But the actions also include those designed to bring about a managerial class by social reforms, the improvement of the quality of labor by improving their health conditions through medical services, sanitation, nutritional level, and living and working conditions through the Instituto del Seguro Social[1]; and also by education programs, provisions of large scale public investment and credit, and improving the marketing facilities of the area.

These government actions designed to increase directly or indirectly agricultural production were strong factors creating the right environment for agricultural growth in the Yaqui Valley.

Prices of the three crops

For wheat, a guaranteed price exists at which the government has been buying most of the production since 1955. This guaranteed price was lowered in 1965. Corn also has a guaranteed price but only in certain years has the government bought the production of this crop in this area. The price of cotton is determined by supply and demand. Table 8 gives the average prices

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[1]Social Security Institute.

received by farmers for these three crops for the years 1951 to 1966 as reported by the Secretaria de Recursos Hidraulicos.

Table 8. Yaqui Valley, Mexico. Prices of wheat, cotton, and corn for the years 1951 to 1966, expressed in pesos per metric ton.[a]

YEAR	WHEAT	COTTON	CORN
1951	762	2,399	713
1952	762	1,996	518
1953	760	1,771	544
1954	814	2,821	550
1955	959	1,965	673
1956	917	2,196	669
1957	906	2,397	800
1958	912	1,764	702
1959	911	1,911	785
1960	912	2,038	800
1961	917	2,305	800
1962	913	2,167	800
1963	913	2,176	940
1964	913	2,167	864
1965	840	2,335	800
1966	800	2,223	800

[a]Source: (2).

Gross returns

The gross returns per hectare of the three crops were calculated by multiplying the yield and price of each crop in a given year. The growth trend of these returns was also calculated, as was the variation of the different values around the estimated trend lines. These values are shown in Table 9.

The gross returns obtained from cotton are significantly higher than those obtained from wheat or corn. The returns of wheat and corn during the last five years are very similar. However, it may be more important to

Table 9. Yaqui Valley, Mexico. Gross value of production per hectare; mean, and variability around the mean; trend line and variability around the trend lines of wheat, cotton, and corn, for the years 1953 to 1966[a]

YEAR	WHEAT	COTTON	CORN
1953	1180.28	2872.56	358.50
1954	1464.39	5272.45	228.80
1955	1657.15	2597.73	670.31
1956	1940.37	3276.43	835.58
1957	1902.60	4609.43	1770.40
1958	2002.75	2778.30	238.68
1959	1554.17	3046.13	1688.54
1960	2051.09	2953.06	1155.20
1961	2283.33	4822.06	1832.00
1962	2681.48	4555.03	2332.00
1963	2521.71	5298.56	2670.54
1964	3065.85	5538.85	3055.10
1965	2136.96	5702.70	2933.60
1966	2244.00	5330.75	2662.40
Mean	2049.01	4189.62	1411.50
Variance	234965	1317961	1554761
Standard deviation	485	1148	1246
Coefficient of variation[b]	23.6%	27.4%	88.3%
Average growth per year[c]	105.6	182.6	222.1
Sum of squares of residuals[d]	2118343	10870163	2493679
Deviation from trend line[e]	420	952	456

[a]Source: (2).

[b]Coefficient of variation = $\frac{\text{Standard deviation}}{\text{mean}} \times 100$.

[c]"b" estimate of the regression equation $Y = a + b \cdot \text{time}$.

[d]Sum of squares of the differences between the observed values and the estimated trend line.

[e]"s" estimate from the equation $(n - 2)s^2$ = sum of squares of residuals.

look at the variability of these returns.

The variability of the returns is calculated under two different assumptions: that the farmers assume an average constant return, and second, that the farmers assume an average increase in the returns each year. The second assumption is preferred because it seems more realistic for the Valley. Under both assumptions the gross returns obtained from wheat are more stable than those obtained from cotton and corn. Under the second assumption the returns from corn are not significantly greater than those from wheat. The returns from cotton are in fact significantly more variable than those obtained from wheat; therefore, we will look at some of the factors causing this greater uncertainty in the returns of cotton.

The greater variability of gross returns from cotton compared to wheat comes from two sources: price variability and yield variability. Wheat has had a guaranteed price for some years. In contrast, the price of cotton depends mainly on the world price which fluctuates when there is a change in the supply of or demand for this product. Therefore, the price of wheat has been more stable in the last fourteen years. The yields of both wheat and cotton depend largely on the weather, but the yields of cotton are less stable from year to year than those of wheat. In the first place, greater pest problems exist for cotton and they vary significantly from year to year. Also, the harvesting of cotton presents some problems which affects its yield. The time of harvest coincides with the rain season in the Valley (July and August). Rainfall affects the quality as well as the quantity of fiber harvested and this rainfall fluctuates from year to year, creating a high variability of yield. A major factor in the greater uncertainty of cotton returns is that while wheat is harvested by special machinery, cotton is harvested by hand labor. Workers must come from all over the country and there is no assurance that enough men will come or that they will come on time.

There is some evidence that the variability of yields among farmers is less for wheat than for cotton, but data at the farm level is not available to establish this difference. The reasons for this greater variability among farms are very similar to those reasons for the variability among years.

Net returns

Cost data at the farm level is not easily available in the Valley; however, the costs of production for wheat and cotton were calculated in the winter of 1963-1964 (16). From this data the net returns for wheat and cotton were calculated as shown in Table 10.

Table 10. Yaqui Valley, Mexico. Net returns of one hectare of wheat and cotton, expressed in pesos.[a]

	WHEAT	COTTON
Costs		
Land	$ 600	$ 600
Labor	260	1,900
Machinery	880	980
Direct services	660	1,090
Total costs	2,400	4,570
Gross returns	3,065.85	5,538.85
Net returns	665.85	968.85

[a]Source: (16).

Although the data of the costs of production represents only one year, this does not vary significantly from one year to another. Thus we can assume that there is a constant increasing trend in the cost of production of all the crops.

From Table 10, we can conclude that cotton yields higher profits than wheat. However, this crop also has larger production costs and involves more uncertainty than wheat, as discussed in the last section. The higher cost of production of cotton usually means that large sums of money must be borrowed by the farmer, thus reducing his equity.

CHAPTER IV. PRODUCTION RESPONSE FUNCTION FOR WHEAT, COTTON, AND CORN

In this chapter the objective is to find how the different economic, technological, environmental, and structural variables affect the agricultural production of the area. Special attention is given to the economic variables such as prices. Specifically, regression analysis will be used to determine the area response function for wheat, cotton, and corn.

Production model[1]

Production, P, is equal to the number of units of production, N, (acreage in our case) times the average yield per unit of production, Y, (yield per acre).

$$P = N \cdot Y$$

A production model should consist of at least two production relations, one focused on the number of units of production, and the other on yield per production unit.

If the explanation of P is obtained directly or independently of the estimation of N and Y, there should be consistency between both approaches:

(1) $$P = a_o + \sum_{i=1}^{n} a_i X_i + U_p$$

also:

(2) $$N = b_o + \sum_{i=1}^{n} b_i X_i + U_n$$

(3) $$Y = c_o + \sum_{i=1}^{n} c_i X_i + U_y$$

[1] This model is similar to the one used by Oury (12, pp. 6-7).

and assuming perfect consistency, we should have ultimately:

$$(4) \quad P = (b_o + \sum_{i=1}^{n} b_i X_i + U_n)\,(c_o + \sum_{i=1}^{n} c_i X_i + U_y)\ ,$$

where:

a_o, b_o, c_o are constant terms

a_i, b_i, c_i are the parameters

U_p, U_n, U_y are the error terms

A strict consistency would be present if Equations 1 and 4 are identical, but in this model we wouldn't expect them to be the same.

Any of the four equations in the model can be formulated linearly in the following form:

$$(5) \qquad Y = B_o + \sum_{j=1}^{m} B_j X_{j(t)} + U_{(t)}$$

In this model the dependent variable "Y" (production, area, or yield) contains a systematic part that depends linearly on a number m of other variables, X's; and in addition, a random part "U".

The observations of the X's are in the form of time series data; assuming that each production period corresponds to one year and that we have n years: then let the index t that runs from 1 to n, represent the observations, the regression parameters are $B_{j=1,\ 2\ \ldots,\ m}$.

Equation 5 can be estimated by the method of least squares[1].

Response to individual variables[2] We are interested in discovering the response of production to price condition primarily, and secondarily to non-price factors.

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[1]This method is explained in Fox (6, pp. 278-282).

[2]This section is based on Oury (12, pp. 173-179).

The relationship between the relative change in the size of the crop and the relative change in price is called the production price elasticity or production price response.

When all the signs of the coefficients conform to logic and all requirements of statistical theory are met in a satisfactory manner, the regression equations of a model should explain the variations in the data from which they are derived.

From the individual equations, it is possible to derive estimates of percentages changes which occur in the dependent variable (yield, acreage, production); when an independent variable (price, weather, technology) undergoes a change.

Price elasticity of production (or supply) is considered to be the ratio of the percentage change in production (or supply) to the associated change in the price upon which producers based their production plans.

$$e_p = \frac{dq}{dp} \cdot \frac{p}{q}$$

where:

e_p = elasticity with regard to price

dp = change in production

dp = change in price

p = price

q = quantity

The ratio of the unit change in supply and the unit change in price of the commodity involved is equal to the price parameter in the regression equation. By convention we use the average price ($\bar{p}$) and the average quantity ($\bar{q}$) in computing the elasticity. In our case p and q are respectively the sample means values of price and production of the commodity involved.

The mathematical formulation is similar for non-price elasticities. Therefore, for each regression equation the response of the dependent variable to the individual variables involved in its "explanation" can be easily calculated from the following formula which holds only for first degree regression equations:

$$e_i = b_i \cdot \frac{\bar{X}}{\bar{Y}}$$

where: e_i = elasticity with regard to the ith independent variable involved;

b_i = regression coefficient of the ith independent variable involved;

$\bar{X}_i$ = sample mean value of the ith independent variable involved;

$\bar{Y}_i$ = sample mean value of the dependent variable involved.

Production is the product of acreage and yield, then the production response to any individual independent variable should be the sum of both the yield and the acreage responses to the very same variable, had yield, acreage, and production been explained "perfectly."

Yield and production response

After considering the fact that crop yields are mainly a function of technological and environmental variables, and being unable to find a good measure of these variables in the form of time series data, the yield response function was not estimated; neither was the production response for the same reasons.

The area response function was estimated and it can be used as an approximation of the production response. However, it is important to note here that in studying production response, when possible, both area and yield response functions should be estimated as shown in the above model. The elasticity of production with regard to price, or any other factor, is the sum of both elasticities of area and yield with regard to that factor. Only if the elasticity of yield with respect to any variable is zero, then the elasticity of output and area will be one and the same. There is evidence that the economic variables, higher prices, have an encouraging effect in yield increasing practices; therefore, there exists a positive elasticity of yield response with regard to price. However, this effect would not be measured correctly if the effects of the important variables such as weather and technology are not considered. So the yield response to price was not tested.

<u>Area response functions</u>

We have indicated that our dependent variable will be the area planted of a crop. The factors affecting the area planted of a crop can be grouped in the following categories:

(1) Environmental, relevant to geography, geology, climate;

(2) Economic, relevant to market conditions, price relationship;

(3) Technological, relevant to the various forms of technology involved;

(4) Institutional, relevant to law, tradition, and government policy.

The "best" variables representing each category have to be chosen since different variables have been used (Ezekiel and Fox 4, pp. 440-443).

The number of variables is limited by statistical theory by the number of degrees of freedom available, and this number is further limited by the data in form of time series available. Considering this, we will discuss the relevant variables for this study.

Environmental This region can be considered very homogenous topographically speaking; and in general, we can say that the quality of the soils is more or less evenly distributed throughout the Valley.

The total area available has changed in the study period; and to account for this factor two dependent variables will be used in the equations: one, the total area harvested; and the other, the relative area of each crop with respect to the total area available. It was said earlier that there is little, if any abandonment of area planted, therefore, area harvested and area planted is considered equal for the purpose of this analysis.

Water available Being an irrigation district, the most important weather influence can be expressed in terms of the water available for irrigation of each crop.

Farmers do not plant a crop unless they are sure that they will get enough water to irrigate it. Our hypothesis here will be then that the area planted of a crop depends on the water available to irrigate it.

Wheat is the first crop planted in the agricultural cycle, so we will consider the water on the three dams in the first day of the cycle (October 1) as a measure of the water available to irrigate it.

As it was stated before, the cropping plan is changed accordingly to the water available; then, we will take as a measure of the water available to irrigate cotton, the water in the dams on March 1; and for corn, the water in the dams on August 1 will be used.

For corn, we will also use as an independent variable the area harvested of wheat; based on the fact that it can be planted after wheat for double cropping and that the decision on the area planted of corn may depend more on the area of wheat that was harvested than on the water available.

In this variable, we expect a positive significant coefficient; the more water available to irrigate a crop, the larger the area planted of it. And for corn, the larger the area planted with wheat, the larger the area of corn.

Economic The first economic factor that will be considered is the price of products.

Expected prices It is hypothesized that producers respond to the expected price of the product. It is a fact that every producer has his own expected price for any given product.

In this study two hypotheses on expected prices will be used: the first one saying that the expected price of any product is equal to last year's price for that product.

$$P^*_{i_t} = P_{i_{t-1}}$$

where: P^* = expected price of crop i

$P_{i_{t-1}}$ = last year actual price of crop i

The second hypothesis is a little more sophisticated, but more realistic. It assumes that expected prices are a function of actual prices in a series of preceding years. This approach was used by Nerlove (11) and is known as the distributed-lag. It has been used successfully by Krishna (9) among others.

$$(1) \qquad P^*_t = f(P_{t-1}, P_{t-2}, P_{t-3}, \ldots P_{t-n})$$

This approach assumes that farmers do not react only to the price that they received the previous years, but to a set of prices that they have received in a series of years. This assumption is very realistic.

The assumption also is more operational than it looks at first sight. The approach used by Falcon and Gotsch (5) as well as Ladd's Review of Nerlove (10) will be used to show how this assumption can be put into a form useful for empirical work.

Beginning with Equation 1, the output of any crop i (or area harvested, in our case) might then be fitted with the following model:

$$(2) \quad H_t = b_o + b_1 \cdot P_{t-1} + b_2 P_{t-2} + \ldots + b_n P_{t-n} + e$$

In this model, the parameter b_1 may be interpreted as the short-run response to price, while the sum of b_1 to b_n would then be the long-run response (5, p. 11).

This equation would be very difficult to estimate, without making further assumptions because it will require a great number of extra price observations, which are not likely to be available; besides, there are likely to be very high inter-correlations among the lagged price variables (5, p. 11).

But Nerlove (10) further hypothesizes that

$$P^*_t - P^*_{t-1} = C(P_{t-1} - P^*_{t-1})$$

This C, or coefficient of expectation as Nerlove calls it, links all the parameters in Equation 2. Therefore, if observed output H_t is a linear function of P^*_t then we have:

$$H_t = b_o + b_1 P_{t-1} + b_2 CP_{t-2} + b_3 C^2 P_{t-3} + \ldots, b_n C^{n-1} P_{t-n} + e$$

It can be seen that the first hypothesis is only a special case of this more general equation, with the value of C being zero.

After some algebraic transformations, the following estimating equation is derived (4, p. 13):

$$H_t = a_o + a_1 P_{t-1} + a_2 H_{t-1}$$

where: The a's are functions of C and the b's

P_{t-1} = last year's actual price

H_{t-1} = last year's production (or area harvested)

In order to use this approach, only a little additional data is required.

Relative prices Product prices may be regarded as having two meanings to the farmers. One meaning regards prices as affecting the normal pattern of production, which is reflected in the long-run planning by producers; and the other views prices as affecting the yearly shifts in production between crops. This framework implies that producers adjust their output in the long-run with regard to the overall economic indicators and asset fixity, and that they also change this output to a limited extent to take advantage of anticipated changes in prices of competitive crops (12, pp. 160-162). The assumption seems realistic given that producers have fixed as well as variable factors of production and both have to be considered when analyzing possible changes in production.

As it was stated earlier, the government establishes a guaranteed price for wheat, even though this price is usually announced prior to planting, it is hypothesized that farmers react to previous year's prices on the following bases. From 1953 to 1956 farmers did not have enough confidence on the guaranteed price policy mainly because this policy had been in effect for some time but had failed to work properly. From 1956 to 1964 the guaranteed price was constant; therefore, there is no important conflict in those years. In 1965 and 1966 the guaranteed price declined and it is hypothesized here that farmers planned their production according to previous years prices because they did not expect that the government would lower the price so sharply. After the announcement of the price decline, the farmers asked for an extension of the previous price and a more gradual decline over several years. The price of cotton depends on the world price and it changes continually. For corn, as it was said before, there also exists a guaranteed price by the government but the production of this crop has been bought by the government only in specific years. Therefore for these two crops it will also be assumed that the production responds to previous years prices.

Considering the assumption of producers responding to expected prices, and this response being an effect of two different meanings to the farmers of the price variable, price ratio variables were constructed as follows:

The expected price of the crop in question will be used in the numerator under the assumption that an increase in the expected price for that crop will result in an increase in hectares planted. This assumption is what we are most interested on testing, specifically to determine if the farmers react to price when they plan the production of certain crop.

In the denominator of one of the relative price variable, a wholesale price index will be entered under the assumption that the higher this price index; representing input prices, prices of consumption commodities, prices of other production goods - agricultural as well as industrial; the less the planned long-run production of the farmers. This means that they could plan investments outside of agriculture or plan other forms of obtaining income. On the other hand, the lower this price index, the higher the relative price of the crop i in question, then farmers will increase their investments in fixed factors for producing that crop. This variable will be entered for the three crops and is expected to be positive significant, but it is very probable that given that the period considered is very short, the effect of this variable will be unnoticeable.

Other ratios will be entered having the expected prices of the products deflated by the expected price of its most important competitive crops. The competing crop price is used in the denominator under the assumption that an increase in the denominator will cause a decrease in production and vice-versa. Variables factors of production will be shifted to other crops, or from other crops as the case may be. This variable is believed to be more important than the previous one for this study which involves a short period of time.

In the case of wheat a price ratio variable will be entered having the expected price of wheat in the numerator and the expected price of cotton in the denominator. Cotton is the leading competing crop with wheat, for water as well as area, they are the two most important crops in the Valley. The area to be planted of both crops is decided almost simultaneously in making the plan for the agricultural year.

In the case of cotton, two ratios will be entered in the analysis. The first one having the price of cotton deflated by the price of wheat because as it was said, they are the two leading competing crops for the resources of the Valley. But considering that cotton is a summer crop and that corn is planted in the summer while cotton is still standing, there is also an important competition for resources between these two crops that should be considered; therefore, a second ratio will be entered having the expected price of cotton deflated by the expected price of corn.

Corn competes with all the crops of the Valley for the scarce water and it also competes with almost every crop for area because it is planted in the summer and harvested in winter[1], therefore, it competes with both wheat and cotton. Corn is planted while cotton is still standing, therefore both crops cannot be planted in the same area in the same agricultural year; and wheat is planted while corn is still standing, therefore if corn is planted that area cannot be planted with wheat the following agricultural year. This relationship makes possible the two year rotation having wheat-corn-cotton, which makes the three crops also complementary. Considering the above explanation, two price ratios will be entered for corn in the a-

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[1]See Table 4 for the approximated seeding and harvesting periods of the crops in the Valley.

nalysis. One having the expected price of corn deflated by the actual price of wheat[1], and the other one having the expected price of corn deflated by the expected price of cotton.

A significant positive coefficient on the relative price variable is expected if area responsiveness to price exists. Also a positive coefficient is expected on the lagged area variable.

Prices of inputs will not be considered except to the limited extent of being part of the wholesale index price.

Relative yields It is hypothesized here that farmers make their decision on how much area to plant of a certain crop thinking in the returns they expect to receive from it. This expected returns or profit depends on the expected price and on the expected yield. Different farmers may have different expected yields, but for the farmers taken as a whole, it is safe to assume that last year's yield is a measure of this year's expected yield. This is the assumption made here.

In the numerator we will use the expected yield of the crop under the assumption that the higher the yield the more profit that a farmer expects to make; therefore, the larger the area he is going to plant of that particular crop.

For the denominator we will use the expected yield of a competing crop. The competing crops are the same that the ones used in the relative price ratios. This means that for cotton and corn we will have two ratios of relative yields.

For the reasons stated above, the coefficient of this variable is also

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[1]In this case the price of wheat will be used with no lag because the price is known when corn is planted.

expected to be positive.

Returns per hectare The gross returns per hectare wer calculated in last chapter (Table 9) and here they will also be used as an independent variable, specifically, we will use relative returns per hectare. The same reasoning used for relative prices and yields will be used here for the deflating crop.

The coefficient of this variable is also expected to be positive.

Technological The fact that technology has had a great influence in the production of all these crops seems obvious; unfortunately a direct measure of this variable such as fertilizer consumption, or yield increase due to better seeds was not available for this analysis. An increase in technology is reflected in higher relative yields, therefore, technology is represented here through yields and returns per hectare. These variables were already mentioned.

Institutional This analysis covers a short period of time, therefore institutions may be assumed constant. Nevertheless, in our price variables we introduced lagged area as an independent variable. This variable could be considered as a measure of government policy, tradition or fixed factors of production. Then, this variable is measuring two different things: the effect of previous prices, and the effect of some traditional variables. So it can be considered institutional as well as an economic variable.

Variables in the model

Based on the discussion above the following independent variables, X's, were fitted in the multiple regression model.

Wheat

X_1 = price of wheat deflated by the price of cotton, lagged one year.

X_2 = price of wheat deflated by a wholesale price index, lagged one year.

X_3 = area harvested of wheat lagged one year.

X_4 = area harvested of wheat divided by the total area available in the Valley for cultivation, lagged one year.

X_5 = yield of wheat deflated by the yield of cotton, lagged one year.

X_6 = water in the dams October 1.

X_7 = revenue per hectare of wheat deflated by the revenue per hectare of cotton.

Cotton

X_8 = price of cotton deflated by price of wheat, lagged one year.

X_9 = price of cotton deflated by price of corn, lagged one year.

X_{10} = price of cotton deflated by a wholesale price index, lagged one year.

X_{11} = area harvested of cotton, lagged one year.

X_{12} = area harvested of cotton divided by the total area available for cultivation in the Valley, lagged one year.

X_{13} = yield of cotton deflated by the yield of wheat, lagged one year.

X_{14} = yield of cotton deflated by the yield of corn, lagged one year.

X_{15} = water in the dams March 1.

X_{16} = Revenue per hectare of cotton deflated by the revenue per hectare of wheat, lagged one year.

Corn

X_{17} = price of corn lagged one year deflated by the price of wheat with no lag.

X_{18} = price of corn deflated by the price of cotton, lagged one year.

X_{19} = price of corn deflated by a wholesale price index, lagged one year.

X_{20} = area harvested of corn lagged one year.

X_{21} = area harvested of corn divided by the total area available for cultivation in the Valley, lagged one year.

X_{22} = yield of corn lagged one year deflated by the yield of wheat with no lag.

X_{23} = yield of corn deflated by the yield of cotton, lagged one year.

X_{24} = water in the dams August 1.

X_{25} = area harvested of wheat.

X_{26} = revenue per hectare of corn deflated by the revenue per hectare of wheat, lagged one year.

As it was said earlier, there are two dependent variables for each crop: one the relative area; and the other, the total harvested area of the crop. The same independent variables were used for both equations with the exception of variables X_3 and X_4; X_{11} and X_{12}; X_{20} and X_{21}. Only one of these variables, the relevant one, was used for each case.

All the numerical data used for this analysis is the one reported by the Secretaria de Recursos Hidraulicos (2). Most of this data is shown in the preceding chapter. The years included go from 1953 to 1966.

Results and discussion

The equations were solved by the stepwise regression method. It consists in selecting by some criteria a subset of the variables which very often are the most importants. All the variables were not fitted at the same time, several runs were made.

Wheat   All the significant results of the regression analysis for wheat area response functions are shown in Table 11.

Table 11. Yaqui Valley, Mexico. Area response functions for wheat for the years 1953 to 1966

	Y	A	B	s.d.	X	e	R^2
1	Y_1	2639	94535	27502	X_5	.98	.64
2	Y_2	14.1	33.4	12.4	X_5	.74	.52
3	Y_1	60523	113452	56737	X_7	.51	.31
4	Y_2	24	57.7	27.1	X_7	.57	.34

Y = dependent variable.

Y_1 = total area.

Y_2 = relative area.

A = constant term.

B = regression coefficient.

s.d. = standard deviation.

e = elasticity of area response.

X = independent variable.

X_5 = yield of wheat deflated by the yield of cotton, lagged one year.

X_7 = revenue per hectare of wheat deflated by the revenue per hectare of cotton.

R^2 = correlation coefficient.

For all the equations solved for wheat, the only significant coefficients were the ones corresponding to variables X_5 and X_7, which are respectively relative expected yields and relative expected returns per hectare. In both cases the deflating commodity is cotton.

The correlation coefficients in Equations 1 and 2, the equations having variable X_5, were .64 and .52 respectively. They are not so low if we consider the fact that there is only one variable in those equations. The elasticity of Equation 1 is almost equal to the unity, this means that the farmers are yield responsive, and if yield is also a measure of income, they are income responsive.

The fact that the coefficient of variable X_7 was significant further proves that wheat producers are income responsive.

The coefficient of the relative price variable did not come out significant in any of the runs. By observing the data we can see that when the relative price goes up, the area harvested of wheat increases, but there is no responsiveness to downward price movements except when they are accompanied by a relative yield decline.

The variables representing the lagged dependent variables did not enter the solution, not only for wheat, but for any crop. This could be interpreted as meaning that producers do not react to prices lagged more than one year. This means that if there is price responsiveness is only in the short-run and not in the long-run. It also means that for this period of time institutional variables such as government policy, tradition, etc. may be assumed constant or that their changes have not been significant to affect the area harvested of the crops.

The coefficient of variable X_2, the price of wheat deflated by a wholesale price index, was not significant. This variable was not significant either for any of the two other crops. The "real" price of the three crops has had a decreasing trend while the area has been increasing. The reason for this could be that the effect of this variable is overwhelmed by the effect of increasing technology for growing the crops; so even though the "real" price is declining, profits may be constant or even increasing a little.

We can conclude from the regression analysis results and by close observation of the data that wheat producers do not, in the short-run or in the long-run reduce plantings significantly in response to small relative price reductions; and there is no evidence that they will increase plantings due to relative price increases if relative yield increases are not present. But I think that it would be incorrect to conclude that price was not an important consideration in farmers decision making process, but the direction and extent to which farmers respond is influenced by a most diverse set of conditions. If a small reduction of relative price exist, farmers may want to plant the same area of wheat because they still could make more money than from other crops or could balance their rotation better, or because of the greater yield certainty.

The coefficient of water supply was not significant, this means that the quantity of water in October 1 has not been an important determinant of the area planted to wheat.

Cotton The area response functions for cotton are shown in Table 12.

Cotton producers were found price, yield, and revenue responsive. The coefficients of the variables X_8, X_{13}, and X_{16} were highly significant. These variables represent: price of cotton deflated by the price of wheat, lagged one year; yield of cotton deflated by the yield of wheat, lagged one year; and revenue per hectare of cotton deflated by the revenue per hectare of wheat, lagged one year.

Equation 3, the one having total area planted of cotton as the dependent variable, has a significant coefficient corresponding to variable X_{15} which represents water on the dams on March 1. This is consistent with the fact that the area of cotton is sometimes restricted because of the high requirements that this crop has for water.

Table 12. Yaqui Valley, Mexico. Area response function for cotton for the years 1953 to 1966

	Y	A	B	s.d.	X	e	B	s.d.	X	e	R^2
1	Y_1	-23354	101098	23511	X_{13}	1.4					.76
2	Y_2	- 11.3	46.9	10.8	X_{13}	1.4					.77
3	Y_1	-46200	32818	7693	X_8	1.4	.0103	.0033	X_{15}	.41	.75
4	Y_2	- 1.8	11.9	3.7	X_8	1.1					.61
5	Y_1	20565	19183	4848	X_{16}	.66					.61
6	Y_2	8.8	9.1	2.1	X_{16}	.68					.64

Y = dependent variable.

Y_1 = total area.

Y_2 = relative area.

A = constant term.

B = regression coefficient.

s.d. = standard deviation.

e = elasticity of area response.

X = independent variable.

R^2 = correlation coefficient.

X_{13} = yield of cotton deflated by the yield of wheat, lagged one year.

X_8 = price of cotton deflated by the price of wheat, lagged one year.

X_{15} = water in the dams March 1.

X_{16} = revenue per hectare of cotton deflated by the revenue per hectare of wheat, lagged one year.

The coefficient of the relative price variable and of the relative yield variable having the price and yield of corn in the denominator were not significant, this further proves that the real competing crops in the Valley are wheat and cotton.

The coefficients of water available in the equations of relative area were not significant; and they were not significant for the cases of wheat or cotton either. This means that the relative area planted of these crops does not depend on the water available on those specific dates. But the possibility is still open for the fact that another measure of the water would prove significant.

The correlation coefficients of Equations 1 and 2 are .76 and .77; they are rather high considering that only one variable, X_{13}, is explaining three fourths of the variations in hectares planted. The elasticity of this variable is greater than one, emphasizing the importance that relative yields have in the production of the crops in the Valley.

Corn   For corn only one equation for each dependent variable was found significant, but each of those equations contains two variables. This is seen in Table 13.

The coefficient of variable X_{17}, price of corn deflated by price of wheat, was highly significant for both equations. Therefore, corn producers are also price responsive.

The variable representing the area harvested of wheat, X_{25}, has a significant coefficient; and the water on the dams variable did not enter the solution. This means that the main decision to grow corn depends on the area that can be double cropped after wheat. This is consistent with the

Table 13. Yaqui Valley, Mexico. Area response functions for corn for the years 1953 to 1966

	Y	A	B	s.d.	X	e	B	s.d.	X	e	R^2
1	Y_1	-85151	81396	17266	X_{17}	3.2	.3213	.1071	X_{25}	1.8	.83
2	Y_2	- 38	36.5	7.9	X_{17}	3.1	.0001	.0000	X_{25}	1.2	.82

Y = dependent variable.

Y_1 = total area.

Y_2 = relative area.

A = constant term.

B = regression coefficient.

s.d. = standard deviation.

e = elasticity of area response.

X = independent variable.

R^2 = correlation coefficient.

X_{17} = price of corn lagged one year, deflated by the price of wheat with no lag.

X_{25} = area harvested of wheat.

fact that corn is mostly used as a double crop in a wheat-corn-cotton rotation.

The coefficients of the yield and revenue variables were not significant. The variability of both of these variables is very large; this is a consequence of fast increasing yields and of some drastic changes in yield in some years due to weather conditions. This very large variability made the effect of variables X_{22}, X_{23}, and X_{26} very inconsistent and not significative in the area harvested of corn.

The correlation coefficients of .83 and .82 found for the corn equations were the highest found for any equation, and with one exception for Equation 3 of cotton they were the only equations with two variables.

The significant independent variables explaining the changes of the dependent variable total area were the same explaining the changes in relative area; with only one exception, Equations 3 and 4 of cotton. So in this sense the results are fairly consistent.

A time series model cannot explain completely the agricultural production behavior. Cross-section analysis based upon farm size, farm specialization, and land tenure system should also be conducted to understand better the response pattern of the different producers to the various economic as well as other categories of independent variables.

CHAPTER V. IMPROVING THE VALUE PRODUCTIVITY OF THE VALLEY

There is a need for planning at the regional level in accordance with national goals in order to maximize the production of the Valley, and to maximize the utilization of fixed scarce resources of the Valley such as land and water. There is also a need for optimizing the production at the farm level, i.e. planning the production of each farm considering the resources of each individual producer.

The objective of this chapter is to make some recommendations about research needed to help maximize the value of the agricultural product of the Yaqui Valley.

National goals

Mexico's agricultural goal is no longer merely to increase total production. Now there is a need to adjust the supply of each agricultural commodity to its market demand. There is also a need to increase the productivity of the different resources such as labor, irrigation water, and capital. Each region should produce that commodity in which it has a comparative advantage, i.e. regions with abundant labor should produce labor-intensive products, regions in which irrigation water is expensive should produce crops which yield a high marginal value product for water. This rationale should be used for all the resources.

To better understand the importance of the problem mentioned above, we will briefly review some findings of a study of the projected supply and demand for agricultural commodities for the years 1965, 1970, and 1975[1] (13).

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[1]The study was carried out under agreement signed by the Mexican Ministry of Agriculture, the Economic Research Service of USDA, and the Bank of Mexico, and was sponsored additionally by the Mexican Ministry of finance.

Table 14 shows that supply and demand for crop output as a whole in 1970 and 1975 will be very similar. Therefore, it can be said that crop production taken as an aggregate will be sufficient to meet the projected domestic and foreign demand.

Table 14. Mexico. Balance of output and demand for crop products for the years 1960, 1965, 1970, and 1975[a]

OUTPUT AND DEMAND	MILLIONS OF PESOS[b]			
	1960[c]	1965	1970	1975
Crop output	16,464	20,004	24,367	28,214
Crop demand	16,714	19,860	23,921	29,055
Surplus or deficit	- 250	+ 144	+ 445	- 841
Surplus or deficit as a percentage of total demand	-1.50	+ .73	+1.86	-2.89

[a]Source: Bank of Mexico, office for the study of agricultural projections. In (13).

[b]Average 1958-1960 farm prices.

[c]1959-1961 average.

If we look at the projected supply and demand for specific crops (Table 15) we see that there are very significant imbalances.

Transforming the deficits and surpluses of projected output in terms of area harvested (Table 16), we find that, given the foreseeable changes in average yields, there would be enough land available for deficit crops if taken away from surplus crops. This allocation is subject to the restrictions deriving from technical (agronomic) as well as economic and social factors.

It has been shown that the three most important crops in the Yaqui Val-

Table 15. Mexico. Surplus (+) or deficit (-) of specific products or group of products of projected supply. Numbers represent the percentage of total demand[a]

PRODUCTS[b]	1970	1975
Vegetables	- 15	- 24
Fruits	- 16	- 25
Oilseeds	- 8	- 19
Sorghum	- 9	- 11
Chickpeas	- 26	- 36
Barley	- 16	- 15
Wheat	+ 37	+ 32
Rice	+ 10	+ 22
Beans	+ 10	+ 19
Coffee[c]	+ 17	+ 10

[a]Source: (13).

[b]Corn and cotton do not appear because the relatively small surpluses of these two products are not considered significant.

[c]Allowance has been made for foreign demand.

Table 16. Mexico. Surplus (+) and deficit (-) of crop output expressed in hectares harvested in 1970 and 1975[a]

	1970	1975
Surplus	1,044,000	960,000
Deficit	379,000	675,000
	+ 665,000	+ 285,000

[a]Source: (13).

ley are wheat, cotton, and corn. Corn and cotton will not have significant surpluses, but it will be interesting to take a close look at the projections for wheat. This is important because of the effect that the national projections of this crop can have on the production pattern of the Valley.

Area harvested of wheat, according to the projections (13), will exceed the requirements for domestic demand by 291,000 hectares in 1970 and by 272,000 hectares in 1975. In tons, this surplus is equal to 734,600 tons and 794,000 tons respectively.

The possibilities of exporting this crop are not good because some countries (such as Pakistan and India) which were potential importers are becoming self-sufficient and may even export wheat in the future. Also other countries (such as Canada and the United States) can produce this crop at a lower cost and export it with more favorable economic conditions than can Mexico.

Planning at the national level

We have seen that there are projected deficits and surpluses of agricultural products and that the possibility of exporting that commodity, wheat, with the largest surplus, is not good. Therefore, technological and economic resources must be allocated among regions and among crops to adjust the future supply of agricultural commodities to meet their projected market demand.

It is suggested here that production should be allocated among regions by some method. This can be a simple method, or a more sophisticated linear programming method. Whatever the method, the ideal would be one consistent with the comparative advantages of the different agricultural producing regions. Optimal allocation demands concentration of inputs to the more responsive crops, regions and producers. This may cause welfare problems of income distribution. However, other methods of achieving social justice and general welfare should be considered in order that departure from economically optimal allocation of resources can be minimized.

Maximizing the production of the Valley

We have seen in a general way what are the national goals, and we can conclude that it is important that production of the Yaqui Valley be planned in accordance with these goals. It was also suggested that national agricultural production be planned by some method considering the comparative advantage of each specific region.

The results of such a plan cannot be anticipated due to a lack of information about production possibilities in the different regions and to the restrictions dictated by social factors. Such a plan could call for either increasing or decreasing the area of any commodity in the Valley, including wheat, cotton, and corn. It could call for increasing the production of other commodities with foreseeable deficit such as feedgrains, oilseeds, and vegetables. Most of these crops have been grown in the Valley at one time or another as shown in Table 2; therefore, there is no agronomic reason to impede an increase in their production if the economic analysis suggests it.

Planning the production of the Valley

It is of common knowledge that one cannot fully control the level of agricultural production. The output of different crops is greatly affected by weather, pests, and other factors not completely under human control.

But by having a notion of the production response of the different agricultural regions, it is possible, in accordance with a plan, to find ways to increase or reduce the area and output of any particular crop especially those crops which are more responsive to economic factors.

Based on the analysis of the production of the Valley in previous chapters and in other observations and deductions, we will discuss some alternatives for influencing the production of the Valley. This analysis, however, is not exhaustive - other alternatives are available.

Increasing the production of any crop can be achieved by increasing yields, area, or both. To increase the area harvested of a specific crop, we may increase the total harvested area of the Valley or increase the proportion of the area planted with that crop, i.e. decreasing the area of other crops; this relative area of any crop can be influenced through relative yields and relative prices, as we have seen in our analysis in the preceding chapter. Increasing yields has a two-fold effect in the production of a crop - one direct, and the other indirect (by increasing the relative yield of a crop and thus the area harvested of that crop.)

We will look with a little more detail at these possible alternatives.

Increasing total area harvested There is no foreseeable possibility of opening new land in the Valley, but there is the possibility of increasing the total harvested area by double cropping a larger portion of the available irrigated area. The limiting factor is water. We need to use and allocate this scarce factor in the best way possible.

In allocating this scarce factor, the choice is to use it either to increase yields or to extend the area of double cropping. There is also the choice of growing crops with different requirements of water.

The production function is not known to us and no exact conclusions can be drawn at the moment with respect to water for any specific crop grown in the Valley. Nevertheless, it will be useful to look at the following analysis based on the fact that theoretical and empirical evidence suggests that the most appropriate function for relating yields to successive increments of water is one of the general forms shown in Figure 1[1].

Production functions of this classical type which include ranges of increasing, decreasing, and negative marginal returns can be divided into three stages as shown in Figure 1.

If the resources are used in such a way that production takes place in Stage 1, then this is an irrational production in the economic sense because returns can always be increased by applying a greater quantity of variable resources to the fixed factors. If more variable inputs are not available, we still can increase the product by leaving idle part of the fixed factors i.e. land. In Stage 3, production is also irrational for the same reasoning resources (In this case the variable resources) can be left idle with the effect of increasing total product; in other words, variable factors should not be applied in excess. Even without prices for the inputs and products, it is evident that Stage 2 is the economically rational area of production (8, pp. 90-92).

In the special case of a resource having a zero (or almost zero) opportunity cost, then the economic price of this resource is zero and to maximize profits we should equate its marginal product to zero. Therefore, if water were a free good, production should take place at the end of Stage

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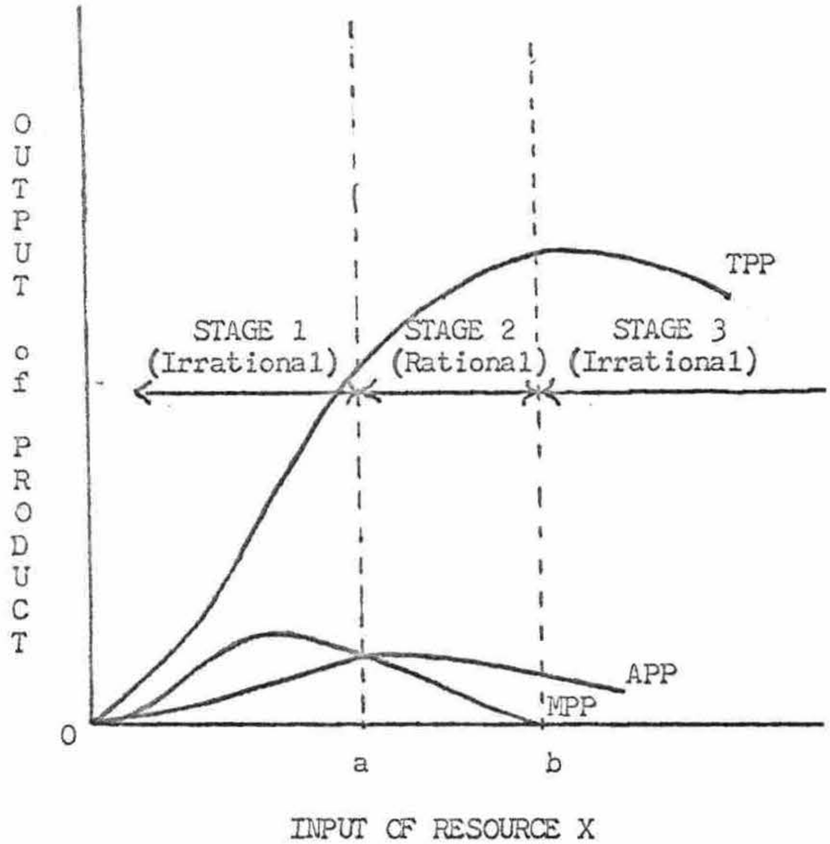
[1]This analysis is similar to the one used by Falcon and Gotsch (5, pp. 21-27).



TPP = Total physical product curve

APP = Average physical product curve

MPP = Marginal physical product curve

Figure 1. Production function which includes increasing, decreasing, and negative marginal returns

2, Point b. A similar argument holds for the fixed resource; and its marginal product is equal to zero at the beginning of Stage 2, Point a, or the point of maximum average product of the variable input. If land were a free resource, production should take place at Point a.

In situations where large areas are left without being double cropped each season for lack of water, land is a relatively "free" input during that season. Then it can be argued that in the Valley the amount of water applied per hectare should be restricted in order that more hectares can be harvested (double cropped).

The usefulness of the preceding analysis requires knowledge of the production function of the specific crop with respect to water. Research done by agronomists has been concerned mainly with the problem of determining the amount of water required by plants to maximize yields per hectare (Point b). The economic allocation of water in the Valley has to be studied with more detail. The salinity problem which can be created by the restricted use of water should also be considered.

<u>Increasing relative area of specific crops</u> The following alternatives for increasing the relative area of specific crops will be considered:

1) direct, restricting the area planted of some crops by controlling irrigation water,

2) influencing relative profitability through:

   a) relative prices
   b) credit
   c) input prices
   d) relative yields

<u>Direct</u> It was pointed out earlier that water is essential for growing any crop in this area. With the exception of a few irrigation wells,

all the water comes from the dams and is controlled by the Comite Directivo Agricola. The maximum area harvested of any crop in the area can be controlled with a very close degree of precision. The committee has in fact used this water power to control production in the area; and it seems that this mean is going to be used frequently in the future. If this is so, then the Comite Directivo Agricola should be a democratically based local body so local interests of every type of producer be considered when influencing production to achieve national goals.

Relative price of products Another alternative for influencing production, or more specifically changing the relative area planted of each crop, is changing the relative prices of the products. It was mentioned before that support prices exist or have existed for some products in the Valley; therefore, we can say that this policy has been used in Mexico with fair results.

The relative price of some specific products can be increased by lowering the support prices of other crops; for this region, it would be specifically to lower further the support price for wheat which is the only one of the major crops with a support price. The immediate impact of this action would be that the farmers in the Valley will be faced with sudden losses due to the low flexibility of some factors of production such as special machinery for wheat harvesting and the knowledge of the farmers to grow this crop. The long-run impact of this policy would be that a region which has been proved relative efficient for producing wheat will not produce this crop at a large scale anymore.

The relative prices may also be increased by providing relative high support prices for the specific crops for which we want an increase in production. In the case of the Valley, it would specifically mean to set a high support price of feedgrains, vegetables, oilseeds, etc. Or if the wheat production is wanted to be increased this would call for raising its price again.

When the national plan was discussed, it was said that the allocation of resources should be made in accordance with the comparative advantage of each region. The same principle applies to the allocation of incentives between regions. Economic incentives such as support prices should be used to allocate in an economically efficient manner agricultural production. Some other ways of distributing income may be used to increase social welfare. Otherwise efficient production of a given crop in a given area is discouraged while it is being encouraged in some other region that may have a comparative advantage in producing some other crop, or may use its resources to produce some non-agricultural product.

To give more emphasis to the preceding discussion, it is important that we state again the fact that the guaranteed price for wheat has been lowered in the Yaqui Valley, and in all the Northwestern region of Mexico. This measure which was probably aimed at obtaining more equitable distribution of income as well as lowering the production of wheat may have some economic consequences which are not desirable to the country. The agricultural region of El Bajio[1] which is closer to Mexico City than the Northwestern region, probably has a comparative advantage for producing fruit and vegetable crops. But contrary to economic principles, wheat production is be-

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[1]This region is in the central part of Mexico, includes mainly the states of Jalisco, Guanajuato; and parts of other central states.

ing encouraged through higher relative prices as compared to the prices in the Northwestern region; and as a consequence of this policy, vegetable and fruit production is being discouraged.

If wheat production is wanted to be lowered to keep surpluses at a minimum level then the guaranteed price for this crop should be lowered in the Bajio, or raised in the Northwestern or a combination of both policies that will give higher relative price for this crop in the Northwest. This action would not only result in an increase in production of wheat in the Northwest where the yields of this crop have been higher, but it will lower the wheat production in the Bajio thus keeping the surpluses of this crop at a minimum. It will also encourage an increase in vegetables and fruits production in the Bajio and these products have a very good potential market in all the central area of Mexico.

There are great possibilities of influencing production by the use of guaranteed prices to change the relative prices of the different crops and of the different regions; but the production possibilities of each region should be studied better so production is guided in the proper direction. Production response studies of different crops in different regions and by different groups of producers are urgently needed in order that relative prices can be more efficiently used to influence production.

Credit The use of credit facilities and promotion programs to encourage the production of specific crops can be more intensively used than it has been. These policies have the greatest potential use in the ejido and small farm sectors, few if any of the farmers in these sectors are able to finance completely their farming operations and their sources of credit are limited. The principal sources of credit of these two sectors are the Banco Nacional de Credito Ejidal and the Banco Nacional de Credito Agricola y Ganadero. These two federal banks can use the credit policy to increase the production of certain crops by giving special credit facilities for the growing of specific crops thus increasing the area planted of those crops; they can also encourage the adoption of yield increasing technologies which will also increase the production. The long-term credit for investments that will not yield immediate returns have been neglected; this kind of credit will have to be carefully considered if the production of fruits or dairy and poultry products is wanted to be increased.

Input prices Changing the relative price of inputs to raise the production of some specific crops would almost necessarily mean to lower the price through subsidy of some non-traditional inputs, such as fertilizers and improved seeds. However, the extent to which farmers use these relatively new forms of input is not only dependent on their relative price, but it depends on their physical productivity and the price of the products as well. This will be discussed with more detail latter in this chapter. The path of action which has been followed and should be continued is to increase the productivity of these inputs through research and technical improvements. This policy has included subsidization of price of products but the prices of inputs have not been subsidized. The results have been good viewed by the fact of the increase in yields due to the wide use of fertilizer, pesticides, and improved seeds in the Valley. Therefore, research on increasing the productivity of these inputs should continue and prices should not be subsidized in order that they are used in the proper amount.

The price of water offers a possibility for controlling production; it could be lowered for some crops to encourage their production, however, the direct approach of influencing production through the use of water, which has already been discussed, is preferred because it is easier to administer and does not affect the cost relationships which may lead to inefficient production. The price of water represents a good medium for the government agencies to collect taxes or other forms of payments for different investments done to improve the productivity of the Valley. It is important to emphasize the fact that this resource should receive the proper economic price for its use to be optimal. It should be priced considering its best use and its marginal productivity. In other words the opportunity cost of this resource should not be neglected when the price is decided. To set this price, specific research on the productivity of water considering the different products and the different combination of inputs should be conducted. Linear programming studies of the use of water and other scarce inputs would yield the "shadow price" or marginal value product of these inputs and thus an economic proper price can be set.

Increasing total and relative yields We have mentioned that yield has a double effect in production and we will discuss both in this section.

We have to start by accepting the fact that the yield trend will continue to go up because of the agronomic possibilities for researh and improvement of crops; and because of the economic infrastructure of the region and the market oriented producers. The reasoning is as follows: crop yields are mainly a function of technology and weather in the short-run, therefore, the farmer has a few possibilities of controlling year to year changes in response to changes in economic factors. In the long-run, yield increasing techniques lower the cost per unit produced, then farmers will continue to use them. Assuming that research continues in some crop the higher yield trend will also continue.

If production of specific crops is wanted to be increased through higher relative yields, then research in techniques that will increase the relative yields of that crop should be conducted. Specifically for the Valley if the production of feedgrains, oilseeds and vegetables is wanted to be increased then the approriate research should be done to make the yields of these products economically acceptable when they are compared with those of wheat or other accepted crops in the area.

It was said that the yield increasing trend can be assumed to continue to go up if research is continued. But this would not have to be true if research is oriented towards another direction, such as lowering the cost of production per hectare, even if this means lowering yields. This measure would help to lower production without lowering the area harvested. For wheat some of these cost and production reducing techniques would be: The limited use of water per unit, as explained before, or the use of chemical substances instead of some more expensive mechanical practices for tillage. The research in CIANO could be oriented toward this way without significantly greater increase in research resources.

Planning the production at the farm level

To improve the value productivity of the Valley, the profits of each producer should be maximized. The production of a farm should be planned by some method to allocate as best as possible the resources of each producer.

The scarce resources or restraints of the different producers do not necessarily have to be the same. In some cases the limiting factor would be good management; in other, capital or both, and so on. A linear programming model would probably yield the right allocation of these resources among competitive enterprises. There is also need for better use of fertilizers, not use it to maximize physical product but to maximize profit.

Linear programming model There are a number of different rotations in the Valley that can be used by the individual farmer and because the possibility of double cropping the interrelations of the different crops is not well defined. It may be that the only way that farmers could plan their production to take advantage of the different combinations of products would be by the use, at the farm level, of linear programming methods. To use these methods, it is required that meaningful coefficients for each producer be available and it is also necessary the use of some computer device to perform the calculations. If the use of these methods are introduced and partially subsidized by some government agency, and they prove to be successful, then the method will spread throughout the Valley like the use of fertilizers and improved seeds have. When this happens, farmers will have an incentive to obtain meaningful coefficients and they will become more available. Also the total fixed cost of an electronic computer will be spread through a large number of farms, thus lowering the per unit cost.

Use of fertilizer, water, and other variable inputs The use of fertilizer, insecticides, herbicides, and other variable inputs such as these are widespread in the Valley. When the economic use of them is discussed, the same principle applies as for the use of other variable inputs such as hired labor and water.

The production function shown in Figure 1 and the discussion given of it applies to these inputs; therefore, we know in what stage we should use them to be rational. Nevertheless, we donot know in what point of Stage 2 we should produce. We will use a hypothetical example to show how fertilizer (or other variable input) should be used when the law of diminishing returns holds.

Let us suppose that the following data was available showing the production function of one hectare of wheat with respect to additional equal amounts of fertilizer application. See Table 17.

Table 17. Hypothetical data of cost and value added by increasing the amount of fertilizer in one hectare of wheat

COLUMN	2	3	4	5	6	7
	AMOUNT OF FERTILIZER KG./HA.	YIELD OF WHEAT KG./HA.	AMOUNT ADDED TO YIELD[b] KG./HA.	COST OF FERTILIZER ADDED[c] PESOS	VALUE ADDED[a]	
					PRICE I[d] PESOS	PRICE II[e] PESOS
	0	1000				
1	20	2000	1000	180	500	1000
2	40	2700	700	180	350	700
3	60	3150	450	180	225	450
4	80	3450	300	180	150	300
5	100	3650	200	180	100	200
6	120	3800	150	180	75	150

[a]Marginal revenue.

[b]Marginal physical product.

[c]Marginal cost.

[d]Price I = \$500 pesos per ton of wheat.

[e]Price II = \$1000 pesos per ton of wheat.

Two different hypothetical prices for wheat are used to show the importance that the price of the product has over the use of the input.

If the farmer in question has unlimited capital, i.e. he can buy all the fertilizer he wants, then he will want to use the amount that maximizes profits for him. He will then add fertilizer as long as the revenue is greater than or equal to the cost of doing so. The first 20 Kg. of fertilizer with the price at $500 pesos per ton of wheat adds $500 pesos (Column 6) with a marginal cost of only $180 pesos (Column 5); then the second 20 Kg. adds $350 pesos with the same marginal cost, the third 20 Kg. adds less with still the same cost. The reason of this is that we are assuming constant cost of the input and diminishing marginal returns. With the same price, $500 pesos per ton, the fourth package of 20 Kg. adds only $150 pesos with a cost of $180 pesos. So, with these given prices, it is not profitable to add any more fertilizer even if the total product is still increasing. The point of maximum economic efficiency is between 60 and 80 Kg. of fertilizer where the value added (marginal revenue) is equal to the cost added (marginal cost). However, if the price for wheat were $1000 pesos per ton, not only the 80 Kg. are profitable but even 100 Kg. because the value added is $200 pesos (Column 7) with a cost of only $180 pesos. Therefore, no standard rate of fertilizer can be recommended for all time; this will depend on the yield response to fertilizer that each producer obtains in its farm as well as in the price of the crop in question and the cost of the fertilizer and its application. When the price of the product or the price of the input changes, the rate of application of fertilizer should be changed accordingly.

The same principle applies for the fertilization of any crop as long as the capital is unlimited for the farmers. And the same principle also applies to the use of other variable inputs such as water and labor as long as the amount of it is not fixed.

In a preceding analysis we discussed the water as being a fixed factor and this is true for the region as a whole; but here when the use of it is discussed for each individual, it can be considered a variable input such as fertilizer because once the farmer is permitted to grow a crop by the Comite Directivo Agricola, he has the right to use all the water necessary to irrigate it.

If the capital of a farmer is limited, then the allocation principle changes to some degree. The limited fertilizer that the farmer can buy should be spread among all the hectares of that crop, and among all crops in a way that total value of production is maximized for the given fixed amount. Then the fertilizer should be allocated in the places where the value added (marginal revenue) is greater; this is the principle of opportunity cost which tells you always to use a unit of resource where it makes the greatest addition to the value of production. This principle not only holds for fertilizer but for the allocation of any scarce resource among all competitive activities. Included here is the allocation of the farmer's time among all the enterprises that he can perform.

The fact that the law of diminishing returns holds in the Valley should not be a surprise to anybody; nevertheless, there are producers who insist in obtaining the maximum yield without considering the cost of doing it. Maximum product should be obtained when the amount of resources is fixed, or when the variable resource is a free good; but when this resource has a price such as fertilizer, the value added of each unit should always be weighted against the cost added.

We mentioned the fact that the optimal rate changes with change in prices, the same is true for a change in the production function; and this function changes constantly with changes in weather, technology, and changes in other inputs.

The study of the production functions of different crops with regard to different inputs would help the farmers as well as the extensionists to know the amount of fertilizer, water, and other variable inputs that should be used to maximize profits.

Structural restrictions

We plan to discuss here the land tenure system as a structural restriction for efficient allocation of resources.

Even in a commercialized and progressive type of agriculture such as the Yaqui Valley, good farm management is a scarce factor. Good management is not only scarce, but the opportunity cost of his labor is very low given that hired farm labor is not expensive and that it is able to perform most of the farm work, including the operation of machines.

This problem of scarce "good management" can be solved considering it as any other input. Then, the solution would be either to spread this scarce factor in order that productivity can be maximized, or to increase the supply of it.

In the second chapter we mentioned the forms of land tenure in the Valley and the definition of ejido implies that it cannot change managers. An ejidatario, even if he is inefficient, is going to stay in agriculture. The only possibility of improving farm management in the ejido is by training the ejidatarios and their sons, who are going to be the future managers, as best as possible. If there is excess good management in any ejido, then it is wasted because it cannot expand in area. Their farms can grow in other senses, but this is also restricted by the limited capital restriction on the credit policy by the Banco de Credito Ejidal.

In the private ownership form of land tenure, we have the same problems for spreading "good management," farms can not extend over the area set by the law. There is also a problematic situation for the farms to change owners or managers due to the very high rent of the land. This high rent was partially created by the irrigation projects and support prices. So here we also have the problem of inefficient managers staying in agriculture even though the problem is not as accute as in the ejidal sector. The possibilities for excess "good management" to extend is to intensify the production pattern of the farm while this intensification is profitable. There is also the possibility of engaging in other enterprise, but there is always the problem that farmers that are very efficient as crop growers will not be as efficient in some other enterprise.

It also can be argued that increasing returns to scale to the use of specialized machinery exist. The use of machinery is necessary in the Valley to harvest wheat and other winter crops in order that the area may be available for double cropping. This machinery can be used more efficiently over large and continuous extensions of land.

We can conclude then that the rigidity of the land tenure system restricts the efficient allocation of the scarce factor, "good management," in the Valley. It also fails to take advantage of the increasing returns to scale that can be created by extending the area harvested by the use of specialized machinery. Some possibilities of changing this existing law should be studied and discussed in detail and then presented to the federal government so the right actions are taken to remove this obstacle for obtaining efficiency.[1]

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[1]It is a fact that some actions outside of the law are being taken to remove this inefficiency. Ejidal land is being leased to private proprietors and there are private holdings which exceed the area dictated by the law.

CHAPTER VI. SUMMARY AND CONCLUSIONS

This represents a case study of the factors underlying changes in agricultural production in the Yaqui Valley.

The production of this area has had an impressive growth and, generally speaking, production is highly commercialized and based on advanced technology. Throughout the history of the Valley, a wide variety of crops has been grown but in the last fifteen years the most important ones have been wheat, cotton, and corn.

The growth trend of the three crops mentioned above was calculated as well as the factors affecting their growth. This trend was found to be positive and significant. It was also found to be a consequence of increase in area harvested as well as of higher yields. The increase in area was a result of a large irrigation project. The factors affecting the increase in yields were identified as being: improved seeds, fertilization, plant protection practices, irrigation, and better cultural practices. Unfortunately, the specific effect of each factor was not measured because of lack of proper data. The economic climate that promoted the production growth was created by various government policies which found the righ environment in the Yaqui Valley.

A statistical analysis of the production response, as well as of the yield and area response was intended; however, the available data only permitted the area response function to be estimated.

Multiple regression analysis was used to estimate the area response function for wheat, cotton, and corn. The results were not completely satisfactory; nevertheless, the production, approximated by the area harvested, of the three crops was found responsive to at least one economic variable. This means that the agricultural producers are income responsive, when income is measured by prices, yields, or monetary returns. Cross-section analysis is necessary to complement this type of study.

There are various possibilities for improving the economic productivity of the region. The first step is to plan the agricultural production of the Valley in accordance with the national goals and plans. The national planning should be done in a way that the comparative advantage of each region is considered. To do this, studies of the production response as well as the production possibilities of the different regions are required.

In the Yaqui Valley, the producers were found income responsive, especially for crop yields; therefore, production can be manipulated to adjust to a given plan by the use of technological research. There are also other alternatives to influence the production of specific crops, but the various consequences that all of these alternatives may have in the different producers should be carefully considered before using them.

The allocation of the irrigation water deserves a detailed economic study. It is a very important and very scarce factor and it should be considered as such. A simple economic analysis for the allocation of this resource was shown, but specific conclusions can not be derived without the proper water production functions.

The different possible crop rotations offer a very wide range for allocating the scarce resources. A linear programming model would be useful for choosing the most profitable enterprises of this wide range. However, for this method to be efficient, an electronic computer is required. Meaningful technical coefficients at the farm level are also needed and studies as well as incentives should be directed to obtain them; they are always useful regardless of the planning method used.

A necessary condition to maximize profits at the farm level is that fertilizer and other variable inputs are used in the appropial amount. Proper research should be conducted to find the input-output relationships that exist in the area for the different inputs and crops; and economic principles should be applied to obtain the most profitable allocation of the resources.

The lack of flexibility of the present land tenure system may be considered as a restriction for an efficient use of resources, and should be studied to adjust it to the needs of the region.

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ACKNOWLEDGMENTS

I wish to thank Dr. Lehman B. Fletcher for his guidance, not only in the research and writing of this thesis, but during my stay at this University; Dr. Herman M. Haag for his encouragement to come to this country to study Agricultural Economics; and the Ford Foundation for granting me a scholarship to obtain my M.S. degree.

Private communication throughout all my life with my father, Roberto Donnadieu a farmer of the Yaqui Valley, was the main source of my knowledge about the history and present structure of this region. For this among many things I am deeply indebted to him.

A special thanks to my wife, Rosa Maria, for all her help in writing this thesis and in all the various faces of my graduate work, but mainly for her encouragement and company.

Ames, Iowa
May 1968