SIMULATION MODEL ANALYSIS OF MACHINEY SELECTION FOR COLLECTIVE EJIDOS IN MEXICO

By

Omar Ulloa

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in

Agricultural Engineering Technology

Department of Agricultural Engineering

1987

ABSTRACT

Simulation Model Analysis of Machinery Selection for Collective Ejidos in Mexico.

by

Omar Ulloa

Collective ejidos located in the Yaqui Valley in Sonora, Mexico have high investment in agricultural machinery, but no studies have been made relative to the technical and economical performance of machinery.

This dissertation is focused on the application of a computer model, developed at the Agricultural Engineering Department, Michigan State University, to the simulation of field and economic performance of agricultural machinery for wheat, soybean and cotton production. Data for definition of main parameters were collected in the Yaqui Valley, in order that the model be representative of the ejidos. Model validation was carried out through sensitivity analysis of the model to changes in major parameters, and in comparisons of simulated with actual machinery sets owned by the ejidos. After validation the model was applied to select least cost machinery sets for five crop rotations under conventional and reduced tillage systems, and to compare custom hired vs. owned machinery.

The main conclusions of the study were as follows:

Agricultural machinery management and repair were the most important and urgent topics that needed research, training and technical assistance. This was indicated by ejidatarios, technicians and ejido leaders.

The machinery selection model, MACHSEL, proved to be effective to simulate agricultural machinery systems for wheat, soybean and cotton production in the Yaqui Valley. The sensitivity analysis showed reasonable reactions to changes in size, type of soil, rotations, probability of suitable days, and economic parameters.

The ejidos own more power and machinery than required for least cost at the 0.8 probability level. Cost savings of up to 21.4% could be obtained for a 300 hectare W-S rotation, reducing tillage operations with no yield decrease. The reduced tillage system reduced total cost per hectare by 18.2% as compared with conventional tillage on a 600 hectare W-S-C crop rotation.

Custom hiring machines was a common alternative in the Yaqui Valley. If the ejidos had to pay full prices for their machinery purchases, savings of up to 31% could be obtained by custom hiring cotton pickers and combines. When the real cost of machines declines, due to interest rates below inflation, custom hiring will not be cost effective.

The validated computer model is applicable to Mexico for teaching and technical assistance related to agricultural machinery management.

Approved Merle L. Esmay
Major Professor

Approved
Department Chairman

Dedicated to:

My wife Marina

My daughters

Claudia Vanessa

Maria Soledad

Valentina Isabel

ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude to the following:

Dr. Merle L. Esmay, the author's major professor and committee chairman, for his invaluable guidance during the graduate program, and for his editorial help while writing this manuscript.

Dr. C. Alan Rotz for his guidance with the computer model, and his editorial help while writing the manuscript.

Drs. Robert Stevens and Robert Wilkinson, who served on the author's guidance committee, and for their editorial help while writing the manuscript.

Ing. Agustín Cruz-Alcalá for coordinating the collaboration of CRUNO and Coalition, for data collection in the Yaqui Valley.

The Regional Center of the Northwest and the Agricultural Machinery Department of the University of Chapingo, and the Coalition of Collective Ejidos, for their support for the research project.

Claudia and Soledad for their help in typing the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1. PROBLEM STATEMENT

Agricultural machinery is an important component in Mexican agricultural production systems. This is particularly true in highly productive irrigated lands.

Much effort has been made by the Mexican Government to introduce agricultural machinery since the first tractor imports in 1918 (SARH, 1984). Technical support for those programs have been inadequate, due to lack of trained personel, and little research has been carried out on machinery selection and management.

Approximately half of the agricultural land in Mexico is held by private owners, and half by ejidos or colonists (social property). The mechanization level indicator, of hp/ha, is higher for private farms than for social property. Organizational problems, small holdings and lack of education and/or training have been major obstacles for mechanization efforts in ejidos.

The collective ejido is one type of organization of social property. The ejido is worked as a unit, which can justify the ownership of some tractors and implements. Machinery repair, maintenance, and management problems in collective ejidos of the Yaqui Valley have been described by Cruz et al. (1982). No other studies have been made to better understand those problems.

This dissertation is focused on the application of a computer model, to simulate field and economic performance of agricultural machinery in 45 collective ejidos, located in the Yaqui Valley, in South Sonora, Mexico. Main goals were to analyse the applicable types of machines, methods, field performance and operating costs of agricultural machinery and identify the best agricultural machinery sets.

Data for definition of parameters were collected in the Yaqui Valley in order that the model be representative of the ejidos. Data were collected from measurements, interviews and surveys.

One reason for selecting the Yaqui Valley was the interest of the parties involved. This resulted in good facilities, and resources for collaboration. Another reason was the large parcels of land with similar types of machinery to those used in the United States. This facilitated the application of a computer model developed at Michigan State University. Another important consideration was that shortly after their creation, the ejidos were organized in a Coalition. For the purposes of the study the Coalition facilitated the gathering of required information.

1.2. RELEVANCE OF THE TOPIC

The Yaqui Valley is one of the most productive irrigated regions in Mexico, and the collective ejidos are a significant sector in the Valley. The ejidos have high investment in agricultural machinery, but no studies have been made relative to the technical and economical performance of the machinery.

With the availability of computer hardware and software in developed countries, it was considered desirable to evaluate the appropriateness of using computer models in developing countries. There is interest in determining their usefulness for planning, research and teaching purposes, and to determine the modifications that will be required for their use.

Fifty collective ejidos associated with the Coalition of Collective Ejidos of the Yaqui and Mayo Valleys owned 353 tractors, 90 combines, 142 disk plows, 195 offset disk harrows, 172 planters, and 57 sprayers (Ulloa, 1985). Ejido leaders and technicians have complained of high repair and maintenance expenses, and use problems with machinery. Finding appropriate solutions could mean significant savings and lower production costs for ejidos.

The study is the first one of its kind in the region, and thus a pilot study. Results will be useful for agricultural extensionists, farmers and ejidatarios. For the University of Chapingo, it means a new line of regional research in agricultural machinery management envolving collaboration of faculty, students, local institutions and ejidatarios. The methodology could be applied for similar studies in other regions, furthering agricultural mechanization research in Mexico.

1.3. THE STUDY AREA

The Yaqui Valley is located between 27° 00' to 27° 40' latitude North, and from 109° 45' to 110° 20'longitude. It is on the Pacific coast, South of the State of Sonora, in the Northwest of Mexico (See Figure 1.1.). The main city, Ciudad Obregon, with 250,000 inhabitants, is 1,750 km from Mexico City. Climate is desertic, with minimum temperatures of one degree Centigrade in December and January and maximum of 44 degree Centigrade during July and August. The average annual rainfall is 300 mm. (SARH, 1984).

The Valley, with 225,000 irrigated hectares is the largest irrigation district in the state of Sonora, and one of the most modernized production zones in the country (Freebairn,1977). The area is very level, at an average of 30 m. above sea level. Agriculture is mostly commercial cash crops produced with powered machinery. Animal traction is not used in the Valley. Wheat, the main crop, amounted to 25% of national production in 1970 (Freebairn, 1977). Soybeans and cotton were the next two main crops.

Ejidos are the most important sector in the agriculture of the Valley with holdings of 121,372 irrigated hectares (Castaños, 1982). The "ejido" is an agrarian community that received and held land under Mexico's agrarian reform of 1917. From 1915 to 1969 aproximately 75 million hectares were organized into ejidal lands, with about 2,800,000 beneficiaries (Freebairn,1977). The ejidos could be worked by individual parcels or collectively

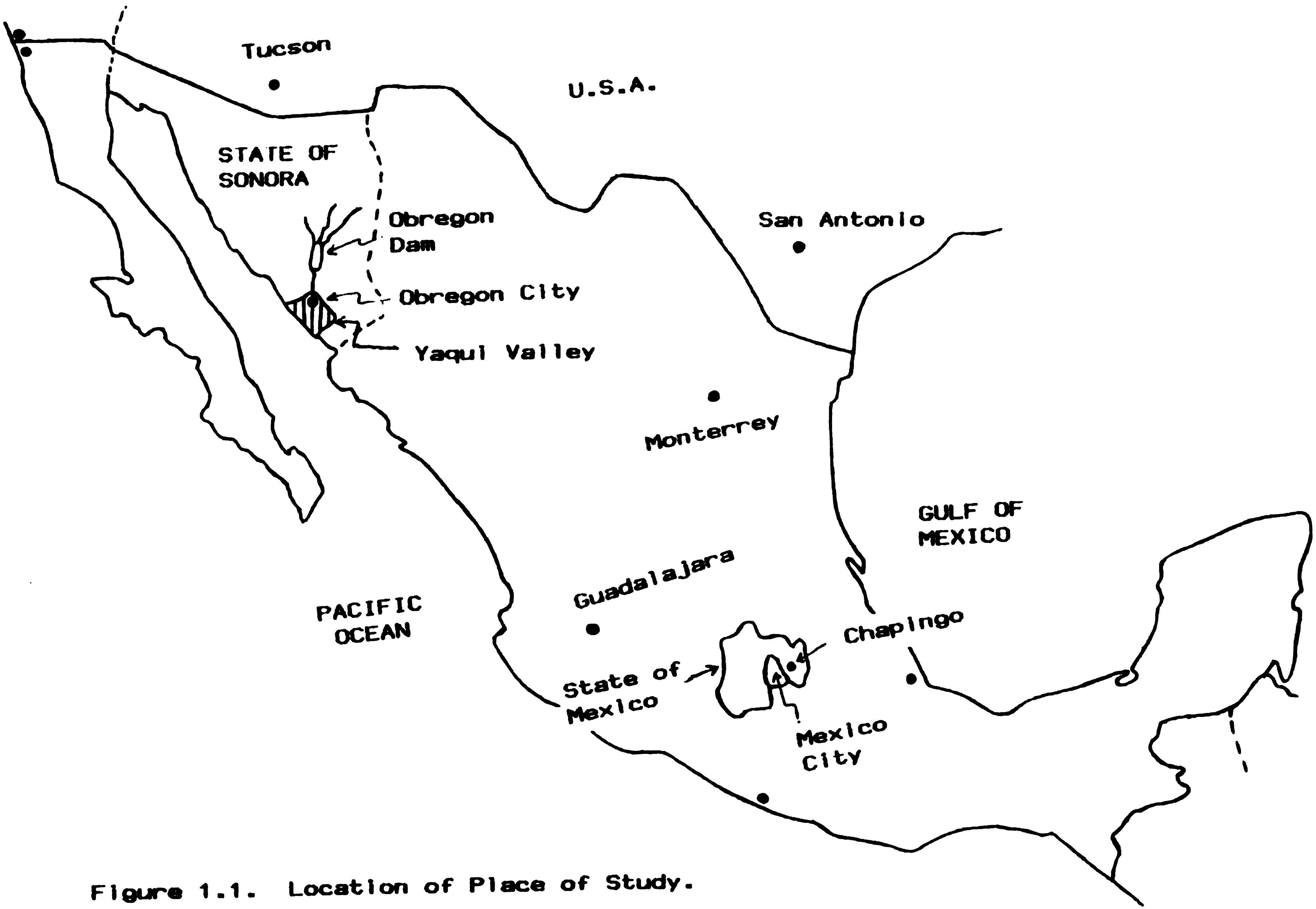


Figure 1.1. Location of Place of Study.

(Article 130, Agrarian Reform Law).

Fernandez (1978) analyzed different types of organizations of ejidos, and pointed out discrepancies in the number of collective ejidos. He cited Mr. J.R. Haro, who wrote in 1976 that only 200 ejidos were functioning collectively, while the Secretary of Agriculture contended that there were 884. This range of numbers of collective ejidos represented only 0.8% and 3.7% of the ejidos in Mexico.

Fourteen collective ejidos were formed in the Yaqui Valley in 1938, with a total of 2159 members. By 1957 only a part of one ejido, with 41 members remained as a collective. Seventy six new collective ejidos, with a total area of 35,472 hectares and 6856 members were created in 1976.

This study deals with 45 of the collective ejidos of 1976, associated with the Coalition of Collective Ejidos of the Yaqui and Mayo Valleys . The University of Chapingo signed an agreement for collaboration with the Coalition in 1979 (Castaños, 1982;Cruz, 1985). One of the problems for ejido leaders was poor management of agricultural machines in their collective ejidos. This project was carried out under an agreement, and was part of a research and training program in agricultural machinery. The participants were: a) The Department of Agricultural Machinery, Subdirection of Regional Centers and Regional Center of the Northwest (All three from of the University of Chapingo), and b) The Coalition of Collective Ejidos.

CHAPTER 2

OBJECTIVES

The general objective of this study was to define viable agricultural mechanization alternatives, and to apply a computer simulation model to select the optimum machinery sets for collective ejidos in the Yaqui Valley, Son., Méx.

Specific objectives of the study were:

1. To identify agricultural mechanization needs, as indicated by ejidatarios, technicians and decision makers.
2. To seek improved agricultural mechanization alternatives for wheat, soybean and cotton production in collective ejido farms.
3. To obtain agronomic, economic and machinery data, and to adapt and validate a computer simulation model developed at the agricultural engineering department, Michigan State University, to determine optimum machinery sets for collective ejidos in the Yaqui Valley.
4. To carry out a sensitivity analysis to check the response of the system to changes in selected parameters.

CHAPTER 3

LITERATURE REVIEW

3.1. AGRICULTURAL OVERVIEW OF MEXICO.

3.1.1. Land

Mexico has a total land area of 1.96 million km^2(196 million hectares). Statistics of the Secretary of Agriculture and Hidraulic Resources (SARH) indicated that there were only 27.5 million hectares of cultivable land, 69.8 million hectares of pasture land, and 18.5 million hectares of forest. North and North Central regions had temperate climate; Pacific and Atlantic Coast, and Southeast regions had tropical climate. Cultivable land was mostly non-irrigated (temporal agriculture) with a total of 21.65 million hectares. Total area seeded during the period 1979 to 1983 varied from 18.07 million hectares to 23.1 million hectares (Table 3.1.).

Irrigation districts were created in 1926 These districts consisted of the most productive lands, and were benefitiaries of the important infrastructure created by the government. Irrigated land amounted a total of 4.73 million hectares, and there were 1.08 million of natural moist land.

Land tenure in Mexico was almost half private land, and half social property (Table 3.2.). The same held for irrigation districts (Table 3.3.). Ejidatarios more than doubled the number of private owners, but the size of their

Table 3.1. Area Seeded From 1979-1983 in Million Hectares

Year	Irrigated Land	Temporal Land	Total
1979	5.26	12.81	18.07
1980	5.21	13.72	18.93
1981	5.5	17.63	23.12
1982	5.1	14.96	20.05
1983	5.27	14.39	19.67

Source: SARH. In Programa Nacional de Tractores Agrícolas, 1985-1988.

Table 3.2. Land Tenure in Mexico.

Type of Tenure	Area Million Ha	Number of			
		Ejidos	Colonies	Millions	
				Private Farms	Users
Social Property	83	24,000	1,497		2.8
Private Property	82			1.2	1.2
National Lands	10.5				
Totals	175.5	24,000	1,497	1.2	4.0

Source: SARH, 1979.

Table 3.3. Land Tenure in Irrigation Districts. 1975/1976.

Type of User	Number of Users	Total Area Million Has	Average Size of Parcel, Ha
Ejidatarios	287,376	1.44	4.9
Private & Colonists	117,267	1.48	12.6
Total	407,450	2.92	7.17

Source: SARH, 1979.

parcels was smaller compared with private owners and colonists.

3.1.2. Main Crops.

Corn, beans, sorghum, wheat and sugarcane, were the five main crops, by area seeded. Corn amounted to one third of area seeded, but the price per ton was one of the lowest paid (Table 3.4.). Corn and beans were the main food in Mexican diet. Commercial crops exported to the U.S., such as; tomato and avocado, had the highest price per ton. (See Table 3.4.).

During 1981, the states of Sonora, Sinaloa, Tamaulipas and Guanajuato made up 47% of the total area seeded in irrigation districts (SESA, 1984).

3.1.3. Labor

Mexico had a total of 71 million habitants in 1970, of which 58.6 were urban, and 41.4 rural. Rural population decreased from 80.6% in 1900, to 66.5% in 1930, 57.4% in 1950 and to 41.4 in 1970. (SARH, 1979).

The working population projected for 1982 was 17.04 million, with a total of 6.26 million in the primary sector. The working population in agriculture represented 26.8% of total working population (Table 3.5.).

Table 3.4. Crop Area, Yields and Value of Production in Mexico.

Crop Name	Hectares Thousands	Metric Ton Thousands	Yield kg/ha	Mex $/Ha Thousands
Corn	6,800	8,500	1,250	2.8
Beans	1,650	1,072	650	3.9
Sorghum	1,475	4,336	2,940	5.6
Wheat	840	2,772	3,300	6.27
Sugar Cane	497	33,796	68,000	8.16
Coffee	374	232	620	7.2
Barley	276	414	1,500	2.6
Sesame	250	362	1,450	3.8
Cotton	242	212	875	8.7
Ajonjoli	240	168	700	4.4
Alfalfa	217	14,335	66,000	15.8
Henequen	192	151	788	4.3
Rice	160	472	2,950	8.5
Chile	67	333	4,961	26.1
Potatoes	54	640	11,900	21.4
Tomato	50	885	17,700	50.4
Avocado	16	312	9,186	42.9

Source: SARH, 1979.

Table 3.5. Economically Active Population in Primary Sector, Mexico.

Concept	Millions	Percent of total active population
Agriculture	4.57	26.8
Animal Production	1.04	6.1
Forestry	0.65	3.8
Total	6.26	36.73

Source: SARH, 1979.

3.2. AGRICULTURE IN THE STATE OF SONORA

3.2.1. General Overview

The state of Sonora, located along the Pacific Coast in Northwest of Mexico, is mainly a desert area. A total area of 182,052 km^2 makes it the second largest in the country. The population of the state was 1,513,731 inhabitants in 1980, with 73% urban (9.3% of territory; 2.3% of population). The economically active population was 458,800 with 32.1% in agriculture (SARH, 1981).

The agricultural area consisted of 713,000 hectares, with 96% irrigated, and 4% rainfed. Only 30% of the total agricultural land of the country (5,063,759 hectares) was irrigated. The state of Sonora had 13.5% of irrigated land of the country. The largest irrigation districts in the state of Sonora were: 1)Yaqui Valley (Irrigation district 041), with 33% of the irrigated land; 2) Costa de Hermosillo, with 23.7% of irrigated land; and 3) Mayo Valley with 13.5% of the irrigated land (See Table 3.6.)

Wheat was the most important crop in the state, of Sonora, representing 40 to 50% of the national production (SARH, 1984). Table 3.7 shows the area and yield of main crops in Sonora.

3.2.2. The Yaqui Valley.

Esquer (1982), and Freebairn (1977) refered to the development of irrigation and agriculture in the Yaqui Valley. This valley, in south Sonora, was a region that

Table 3.6 Irrigation Districts and Land Distribution in the State of Sonora. 1980.

Name of Irrigation District	Private Farmers Number	Private Farmers Hectars	Colonists Number	Colonists Hectars	Ejidatarios Number	Ejidatarios Hectars	Total Users	Total Hectars
Yaqui Valley	3,198	89,505	661	14,132	13,768	121,372	17,627	225,009
Coast of Hermosillo	1,205	123,527	1,122	34,600	191	3,971	2,518	162,098
Mayo Valley	3,669	47,721			7,760	44,452	11,429	92,173
Caborca Valley	583	41,157	968	6,593	2,054	10,126	3,605	57,876
S.L. Río Colorado	2	100	889	14,124	708	12,533	1,599	26,757
Guaymas Valley	108	12,120	163	598	1,936	11,220	2,207	23,938
Yaqui Colonies					2,415	24,611	2,415	24,611
Cuchuta	1,964	8,817			990	6,039	2,954	14,856
Sonoyta	418	6,762			680	1,701	1,098	8,463
Urderal	2,977	18,790			7,551	28,758	10,528	47,540
Total	14,124	348,499	3,803	70,047	38,053	264,783	55,980	683,329
Hectars/User	24.67		18.42		6.96		12.21	

Source: SARH. Subsecretaría de Planeación.

Table 3.7. Main Crops in the State of Sonora, 1979/1980

Crop	Harvested Hectars	Yield Ton/Ha
Wheat	281,893	4.4
Cotton	94,444	3.4
Saffon	60,838	1.7
Soybean	44,015	2.2
Sesame	36,437	0.7
Chickpea	35,306	1.6
Corn	20,269	2.8
Alfalfa	18,440	11.4
Grapevine	17,571	11.2
Sorghum	12,568	3.3
Total	621,781	

Source: SARH, Subsecretaría de Planeación. 1981.

reflected many aspects of Mexico's modern development. Until 1533 it was only habited by the Yaqui tribe; its emergence as an important agricultural region dated back only about ninety years. Since then, substantial investment in resource development was made. In 1970, 25 % of national wheat production and 10 % of cotton production originated in the Valley.

The land of the Valley was divided in squared sections of 400 hectares (200 x 200 m), with roads every 2 kilometers oriented from north to south and from west to east. The Richardson Company (1904 - 1928), a California-based construction and land development company, laid out the grid of land divisions, roads, canals and town borders that mark the region to this day.

The most important factor in the growth of the Yaqui Valley has been the development of the region's water resources. The two major storage dams were the Angostura, finished in 1941 (864 million m^3) and the Alvaro Obregon, finished in 1952 (3,227 million m^3 capacity). A third one, the Plutarco Elías Calles dam (1963-65; 3,020 mill m^3) was mainly to generate electricity.

The water distribution net work consisted of two main canals with a total length of 220.95 Km. Secondary and terciary canals totaled 2,231.22 Km. of legth, and drains totaled 2,290.69 Km. Including subterranean waters (339 wells) and water pumped from drains, the average usable water totaled 3,329 million m^3, per year. Total irrigated area was 225,009 hectares (Esquer, 1982).

3.3. AGRICULTURAL MECHANIZATION IN MEXICO.

Of the 23.1 million hectares "open to cultivation", SARH estimated that mechanization was feasible in 16 million hectares (4.8 million irrigated; 11.2 million temporal) (SARH,1985)

Grain drills, mowers and treshers, imported from the United States since 1880, were the first initiatives of agricultural mechanization in México (Gómez, 1983). The Government imported 112 tractors in 1918, which were sold to producers at a reduced price, to promote the use of machinery (SARH, 1985). During that period the Government set up the "train of the North" and the "train of the South", both loaded with farm machines. The trains started from Mexico City, and stopped at main points along their routes, to demonstrate the use of modern machinery. Since then, the Government, with the support of machinery dealers and manufacturers, organized national and regional programs of agricultural machinery. Tractor manufacture started in 1966.

Importing, manufacturing and commercialization of machinery, was not matched with effective research and training efforts. During the 70's there was some increased concern for research and training in mechanization, at engineering and agriculture colleges of some Mexican universities (Ulloa, 1980). This resulted in the establishment of four agricultural machinery/mechanization curricula in about 1976 (Salamanca, Guanajuato; Mexicali, Baja California; Saltillo, Coahuila; Cuatitlán, México). The University of Chapingo started a professional specialty in agricultural machinery in 1983.

A research program in agricultural engineering and mechanization was initiated, by the National Agricultural Research Institute(INIA), in 1978. The main objective of the program, located in Cotaxtla, Veracruz was to design simple implements and machines, for small farmers (Gómez, 1983).

3.3.1 Existence of Machinery

Tractors and equipment were registered by the national agricultural census, every 10 years, since 1930. The number of tractors increased from 3,880 in 1930 to 91,350 in 1970 (Table 3.8). Statistics of SARH (Gomáz, 1983) indicated a total of 158,964 tractors in 1981 (80,644 in irrigated areas, and 78,320 in temporal areas).

There were notorious differences in the amount and type of agricultural mechanization between regions. Temperate North and North Central regions practiced a more modern, cash-crop type of agriculture. Tropical South and South East regions practiced more traditional, subsistence agriculture. Central regions were intermediate. Tractors, combines and tractor-implements were concentrated in Northern regions (Tables 3.9 and 3.10). Animal-traction implements and hand operated machines were concentrated in Central and Southern regions (Table 3.11).

Table 3.8. Existence of Agricultural Machinery in Mexico(in thousands). 1930-1970.

Type of Machinery	Year				
	1930	1940	1950	1960	1970
Tractors	3.9	4.5	23	54.5	91
Plows	904	1,651	2,173	2,386	2,207
Moldboard,iron		1,188	1,135	1,224	948
Wood plow			1,128	1,110	916
Disk plow				62	132
Harrows,iron		34	65	84	106
Seeders	22	26	60	93	177
Cultivators		69	175	224	370
Mowers	8	5	7.5	10	12
Balers		2	2.7	4.8	5.8
Treshers	4			5.4	3.1
Combines				3.8	7

Source: Agricultural Census.

Table 3.9. Tractors and Laborable Land on Main Regions in Mexico. 1981.

Region	Laborable Hectares	Number of Tractors	Hectares per Tractor
North Pacific	2,832,075	31,378	90.3
North East	1,073,841	11,844	90.7
North-Center	2,577,621	30,536	84.4
Center	11,011,959	61,699	178.5
South	5,642,910	7,621	740.4
Mexico	23,138,405	143,078	161.7

Source: Información Agropecuaria y Forestal, 1981.
SARH, Dirección General de Economía Agrícola.

Table 3.10. Existence of Machinery in Irrigation Districts by Regions.

Region	Tractors	Seeders	Mowers	Tresher	Combines
North Pacific	26,016	17,788	3,616	1,391	4,192
Northeast	5,773	4,670	110	153	1,026
North Central	7,548	4,858	2,313	293	641
Center	14,253	6,548	1,281	636	989
South	852	156	41	88	48
Total	54,442	29,020	7,361	2,561	6,896

Source: INIA, 1981.

3.3.2. Machinery Manufacture.

Machines from over 12 different manufactures were imported up intil 1964. Tractors were manufactured in México since 1966. At the time a minimum integration of 55% of national components was required by law, and importation of tractors under 85 H.P. was prohibited (SARH, 1985). International Harvester, John Deere, Ford (Sidena) and Massey Ferguson manufactured tractors and equipment during the period of 1966-84. During 1983/84 M.F. and I.H. sold their assets to Ford and J.Deere, respectively. Tractor production varied from 467 in 1966 to a peak 15,965 in 1980. Table 3.12 shows locally, manufactured and imported tractors from 1966 to 1980. Estimated demand for the period 1985-1988 was a total of 181,523 units (SESA, 1984).

Most implements were manufactured in México. In 1975 there were 365 mostly small implement manufacturers. The Five largest implement manufacturers had 52.1% of value of sales (Gómez, 1983). Combines, cotton pickers, grain drills and most forage equiment were imported. Also tractors of more than 140 H.P.

3.3.3. Agricultural Machinery in the State of Sonora.

Agriculture in the state of Sonora is considered "modern". Farmers and ejidatarios have been more receptive to new methods developed by agricultural experiment stations, or promoted by representatives of private companies. Processing of agricultural products was also one of the main activities in the state.

Table 3.11. Existence of Small Implements and Animal Drawn Plows, by Regions.

Region	Number of Plows Iron	 Wood	Hand Shellers
North Pacific	69,541	58,406	734
North East	75,827	31,796	1,437
North Center	122,166	82,965	2,124
Center	603,238	565,487	4,306
South	81,738	177,737	3,334
Total	952,510	916,391	11,929

Source: Gómez, 1983.

Table 3.12. Tractor Manufacture & Imports in Mexico. 1966 to 1980.

	Number of Tractor/year		
Concept	Manufacture	Imports	Total
Maximum	15,965 (1980)	19,655 (1980)	35,620 (1980)
Minimum	467 (1966)	2,999 (1973)	6,485 (1966)
Average	7,732	7,786	15,518

Source: J. Gutiérrez in Gómez, 1983.

Mechanization in the region was based on the use of self-propelled and tractor-operated machinery, with no animal traction. Hand labor was available, but not as abundant as in Central and Southern regions. SARH (1981) indicated a total of 812,741 cultivable hectares for the state of Sonora. Tractors were 8,379, with a relation of 97.0 hectares per tractor.

Mechanization in the Yaqui Valley is shown in Table 3.13. During the period 1984/85 the number of combines totaled 951, which represented 13.8% of the combines in all the irrigation districts in the country. Seven percent of the tractors and 5.4% of seeders were also in the Valley.

An average of 59.3 hectares per tractor was calculated for 1981. This was a more favorable relation than the rest of the states (97 hectares/tractor), and the country (161.7 hectares/tractor). The average size of tractors in Mexico was estimated at 70 H.P. by Gômez (1983).

Main offices or headquarters of two regional mechanization programs were located in Obregôn. In the private sector, there were offices of major machinery dealers, and custom-hired services. One of the largest implement manufacturers in the country was also located in Obregon City.

3.4. CROP PRODUCTION SYSTEMS IN THE YAQUI VALLEY

Wheat, soybean and cotton were the main crops in the Valley, as shown in Table 3.14. Moreno, Ortega and Samayoa

Table 3.13. Machinery in the Yaqui Valley (Irrigation District 41) 1984-85.

Type of Machinery	Type of User		Not Owned by user[1]	Total
	Ejidatario	Farmeres Colonists		
Tractors	1,163	1,808	352	3,793
Combines	367	401	183	951
Cotton Pickers	70	113	29	212
Trucks	170	196	3	396
Stalk Shredder	278	298	3	369
Fertilizer eq.	483	517	3	1,003
Subsoiler	246	315	87	648
Disk Plows	638	652	183	1,473
Disk Harrows	812	898	199	1,909
Land Plane	177	290	64	531
Diggers	324	359	4	687
Bedders	442	498	2	942
Shovels	191	255	166	612
Seeders	721	810	25	1,556
Row cultivator	712	774	22	1,508
Wagons	244	538	17	799

[1] Cooperatives, custom-hired services.

Source: SARH, Irrigation District 041. Area de Estadistica. 1986.

(1983) indicated that 40% of area seeded in the Yaqui Valley used the wheat-soybean rotation. When water was available this rotation was up to 60% of area seeded. The wheat-soybean rotation was the only one which allowed two crops in one year. The area seeded with rotations including wheat was 85% of total in the Valley (Table 3.15).

Crop production systems in the Valley have been studied by the Agricultural Experiment Station Yaqui Valley (CAEVY). This station is a part of the Agricultural Research Center for the Northwest (CIANO-INIA). Seeding and harvesting schedules for wheat, soybeans and cotton are shown in Figure 3.1. Loss of production will occur (timeliness cost) if planting or harvesting are delayed (See Table 3.16).

3.4.1. Wheat Production

Wheat was the main crop in South Sonora, as it match up 40% of the area seeded. Total area seeded with wheat in the Yaqui Valley during 1982-83 was 117,135 hectares with an average yield of 4.9 ton/hectare (SARH, 1984).

Seeding dates were from November 15 to December 15, with a growing period of about 140 days. Harvest was from April 15 to May 30 (SARH, 1984). Experiments carried out at CIANO from 1969-1981 (Moreno, 1986) showed that the optimum beginning seeding date was around December 1. Seeding between November 1 to December 15 was very close to the optimum (See Figure 3.2). Seeding after December 15 resulted in a 1% per day decrease in yield (Table 3.16).

Table 3.14. Harvested Area, Production and Value of Crops. Yaqui Valley. Sonora, Mex. 1980/81.

CROP	Hectares HARVESTED	Yield TON/HA	Total PRODUCT TONs.	Crop value, Mex.$ $/Ton	Total Million
Wheat	116,414	4.4	510,563	4,600	2,349
Soybeans	56,059	1.9	109,529	10,800	1,183
Cotton	41,531	2.6	105,828	11,500	1,217
Saffon	24,439	1.6	38,028	8,000	304
Maize	22,751	3.9	89,195	6,500	580
Alfalfa	4,062	17.2	69,839	2,800	106
Sorghum	3,649	4.3	15,534	3,930	61
Beans	2,121	0.8	1,787	16,000	29
Flax	767	1.7	1,329	8,000	11
Fruits	335	13.1	4,375	5,000	22

Source: SARH, Subsecretaría de Planeación.

Table 3.15. Rotations in the Yaqui Valley.

Type of rotation	Percent of area
Wheat - Soybean	40
Wheat - Wheat	20
Wheat - Soybean - Cotton	10
Wheat - Sesame	10
Wheat - Corn - Cotton	5
Cotton - Cotton	5
Others	10

Source: Moreno, Ortega, Samayoa. 1983.

Table 3.16. Timeliness Cost for Planting and Harvesting in the Yaqui Valley.

Crop	Planting Loss %/day	Penalty[1] $/ha/wk	Harvesting Loss %/day	Penalty $/ha/wk
Wheat	1.0 after Dec 15	17.5	0.5 after May 5	8.9
Soybean	1.4 after Jun 1	24.5	1.5 after Sep 30	25.7
Cotton	0.6 after Apr 1	19.0	0.75 after Aug 25	22.0

[1] Calculated based on guaranty prices in Thousand Mexican pesos per metric ton, 1985 (wheat: 37,000, soybean: 64,000, cotton: 103,000).

Source: Experimental data from CIANO-INIA.

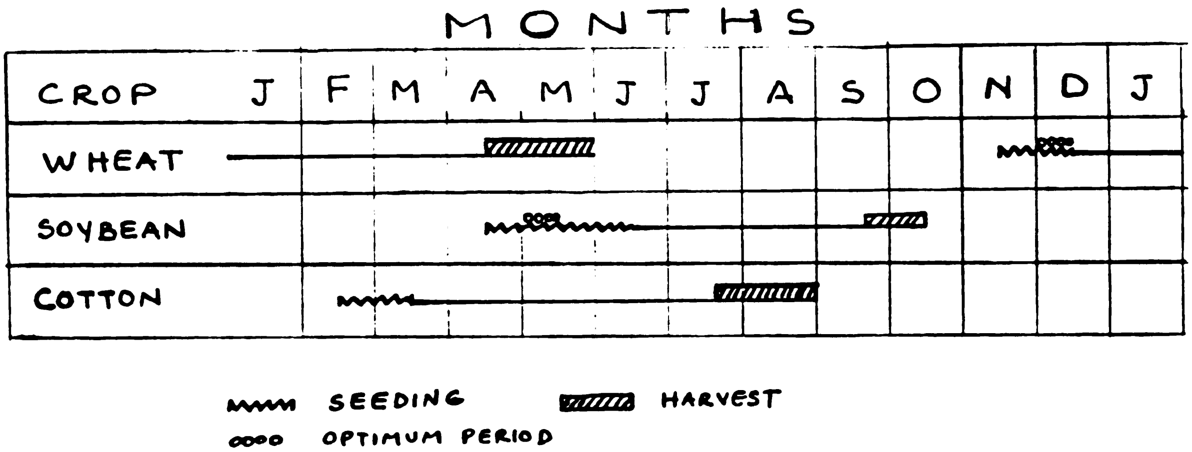


Figure 3.1. Operation schedules for wheat, soybeans and cotton production in the Yaqui Valley

Tillage operations for wheat included disk plowing, two passes with the offset disk harrow and land leveling. Ninety five percent of this seeding was done with the grain drill (Ramírez, 1985). The other 5% was done with a new row-seeding method in the Valley. Dry soil seeding was most common. Wet soil seeding was used only when there were too many weeds.

Grain was irrigated 4 or 5 times during the growing season. The first one was for germination just before or after seeding with the last one 105 days after seeding. Crop protection was required for weed, insect and pest control. Ground or aerial spraying was used. Combines, trucks and wagons were used to collect and transport the grain to elevators in Obregon City. The straw was usually burned, to facilitate tillage operations, particularly if soybeans followed in the rotation.

3.4.2. Soybean Production

Soybean production in the Yaqui Valley started in 1959, and is now the second most important crop. The average area seeded in the Valley from 1959-1983 was 48,658 hectares, with an average yield of 2.1 ton/ha (SARH, 1984). The area seeded increases and average of 8.3% per year from 1961-1980, and its yield increased 4.7% yearly.

Moreno (1986), reported results of four years of experiments on planting dates, and reported that the best period was from May 01 to May 15 (Figure 3.3). Planting after June 01 resulted in a 1.4% per day decrease in crop yield.

Time limitation was the main problem of planting soybean after wheat. Alternative methods tried to reduce time included conservation tillage, minimum tillage or zero tillage (Moreno, Ortega and Samayoa, 1984). Other things tried were to seed wheat in furrows, burn the straw after harvest, irrigate, raise the furrows and seed soybeans. This could allow a gain of up to 10 days. Dry soil seeding was another alternative, which allowed a gain of 8 to 15 days. Direct seeding was proposed in 1982.

The experiment station for the Yaqui Valley, recommended planting soybeans between April 15 to June 15. Tillage operations recommended were, disk plowing, two passes with the offset disk harrow and land leveler. Broadcast spreading of fertilization should be done previous to planting, with the disk harrowing operation.

Preparation for irrigation included; furrowing, and forming irrigation canals and drains. Planting was done 8 to 10 days after irrigation using 4-row planters. Row spacing was commonly 70 cm. (Ramirez, 1985), (SARH,1984).

Crop care practices might include, cultipacking to seal in moisture, furrowing before each irrigation and two row-cultivation combined with manual weeding. Two or three aerial sprayings were necessary for insect control. Six irrigations were required during the growing period. Canals

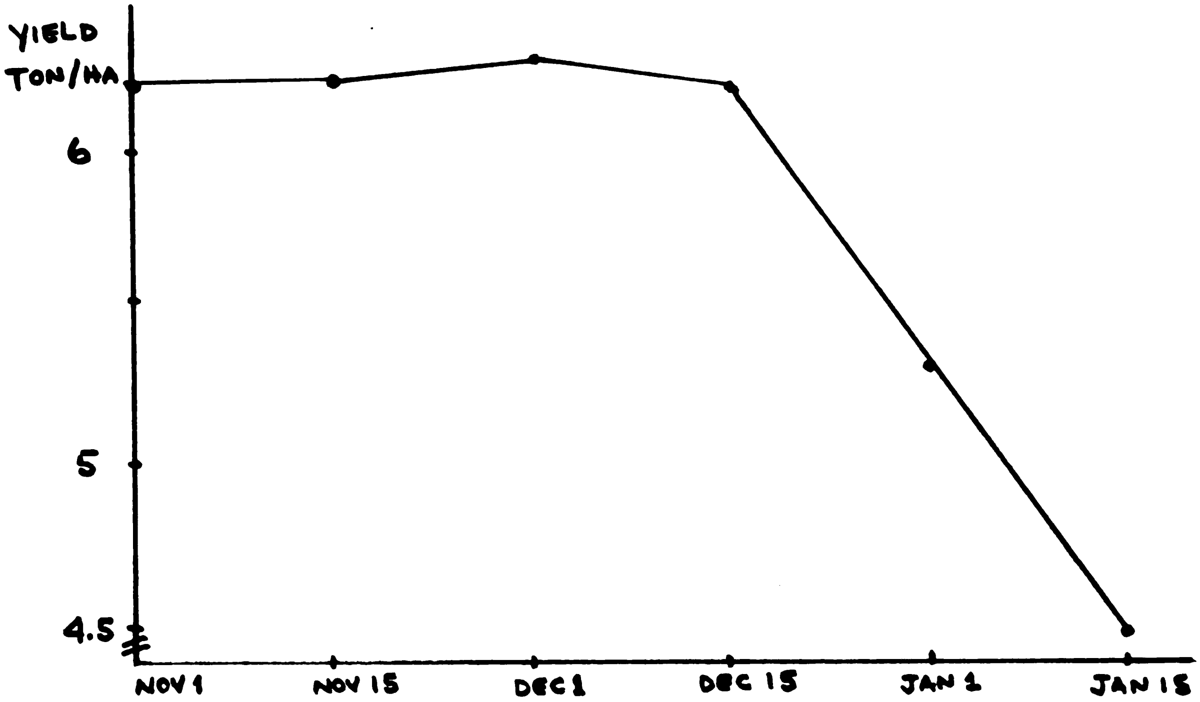


Figure 3.2. Date of Seeding and Yield for Wheat Production

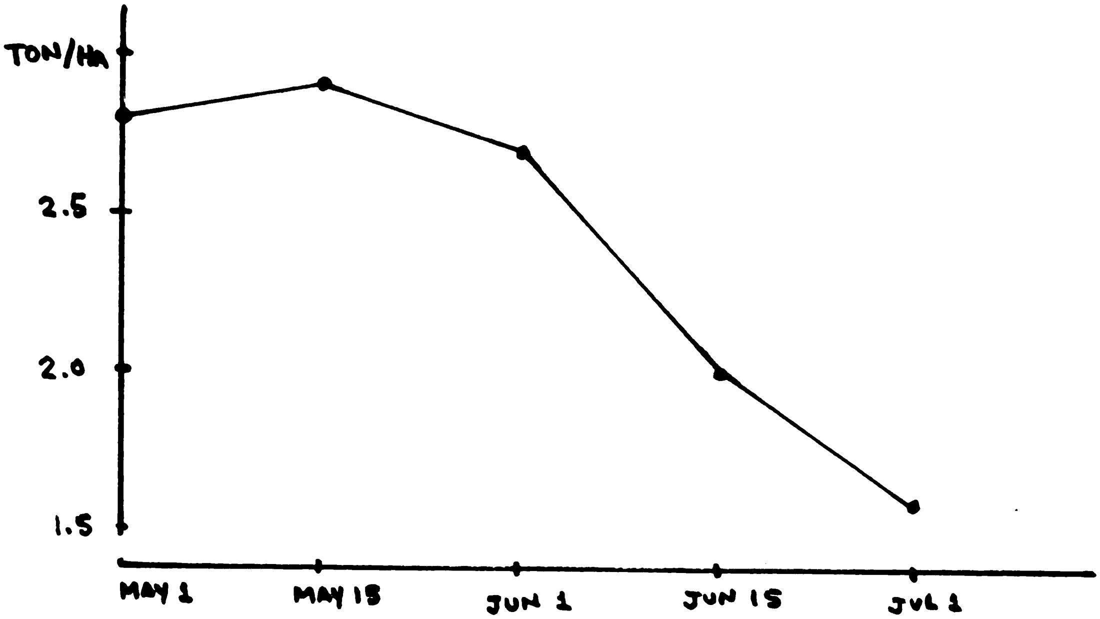


Figure 3.3. Seeding Dates and Yield for Soybean Production.

and drains were eliminated before harvesting. Soybeans were combined at 12 to 14% moisture.

3.4.3. Cotton Production

Cotton production in South Sonora represented about 15 percent of national production (SARH, 1984). Cotton has been grown in the Yaqui Valley since the 30's. With the completion of the Alvaro Obregon Dam in the 1950's, cotton production in the Valley became important regionally and nationally. The area seeded had peaks and lows due to the foreign contracts in the region, that varied from year to year. The average area seeded from 1955 to 1984 was 45,103 Ha with a peak of 78,975 Ha in 1975. Average yield for the period 1955-1984 was 2.64 ton/ha (Ramírez, 1985). From 1961-1980 yields increased at a rate of 1.75% per year, and area seeded decreased at a rate of -2.09% per year.

Recommended seeding dates were from February 15 to March 15. The recommendation of CAEVY for cotton production operations were: disk plowing from 15 to 25 cm. depth; chiseling in some cases; offset harrow, usually 3 passes; land plane or wood frame. Fertilizer application was with the disk harrow (with wood table); furrowing; and set up canals and drains. Planting was in either wet or dry soil, with a row spacing of 100 cm.

Plants were hand thinned when they were 20-25 cm. high, to 4 to 7 plants per meter.

Weeds were controled by spraying herbicides or with row-cultivation. Three or four cultivations were required, depending the planting date.

Cotton picking was by hand or with mechanical cotton pickers. Stalk shredding and disk plowing were required by law after harvest.

3.5. COLLECTIVE EJIDOS OF THE YAQUI VALLEY.

The work in collective ejidos is divided between the members, and for each work-day an anticipated payment is made , as a salary, depending on the type of job. The profits at the end of the season are distributed between the members, substracting the anticipated payments and some funds to create capital (Fernández, 1978).

The first collective ejidos were formed in the Yaqui Valley in 1937, when 17,000 ha of irrigated land and 36,000 ha of non-irrigated (pasture) land were assigned to 2160 ejidatarios (Castaños, 1982). The first division of these collective ejidos ocurred in 1948, and by 1952 all but one ejidos had divided. Only a part of the ejido Quechehueca continued as collective (Castaños, 1982; Freebairn, 1977).

Seventy six new collective ejidos were created on November 19, 1976, with 35,472 irrigated ha of land and 6,856 users. Later four ejidos were added with 1,102 ejidatarios and 5,500 ha. By 1980, 54% of the area of the Yaqui Valley, and 78% of users were assigned to ejidos. Private farmers owned 40% of the land, and colonists owned 6% of the land (See Table 3.17).

The ejidos created in 1976 were under great external pressure and most observers predicted their failure. To counteract internal and external problems, the ejidatarios decided to organize with their own credit, insurance and technical assistance services. That was the origin of the Coalition.

The Coalition of Collective Ejidos of the Yaqui and Mayo Valleys (CECVYM), started in October 1978 (Castaños, 1982). The organization of the Coalition is depicted in Figure 3.4. Important units or areas were:

1. Common Fund to handle crop insurance was initiated in October 1979.
2. Credit Union to handle credits was started in 1980.
3. Technical Assistance Area (Coalition's own extension service)

The ejidos were free to join the Coalition, and at the beggining most ejidos were associated. During the period of this study, the collective ejidos associated with Coalition varied between 52 to 49.

Organizational problems in the collective ejidos created in 1976 were studied by Camarena and Encinas (1982). Fifty percent of the ejidatarios interviewed stated that they would like to work their portions of land individually, or in small groups. Some ejidos had already subdivided their land into smaller work groups, while still maintaining the collective structure for administrative purposes.

Agricultural machinery purchased and utilized by collective ejidos associated with Coalition did not receive

Table 3.17. Changes in Area and User in the Yaqui Valley (In Percent).

Tenure System		1960	1970	1980
Colonists	Users	14	8	4
	Area	11	7	6
Private Farmers	Users	26	38	18
	Area	55	59	40
Ejidos	Users	60	54	78
	Area	34	34	54
Total	Users	8,861	8,043	17,627
	Area(ha)	221,231	215,169	225,010

Source: Castaños, 1982.

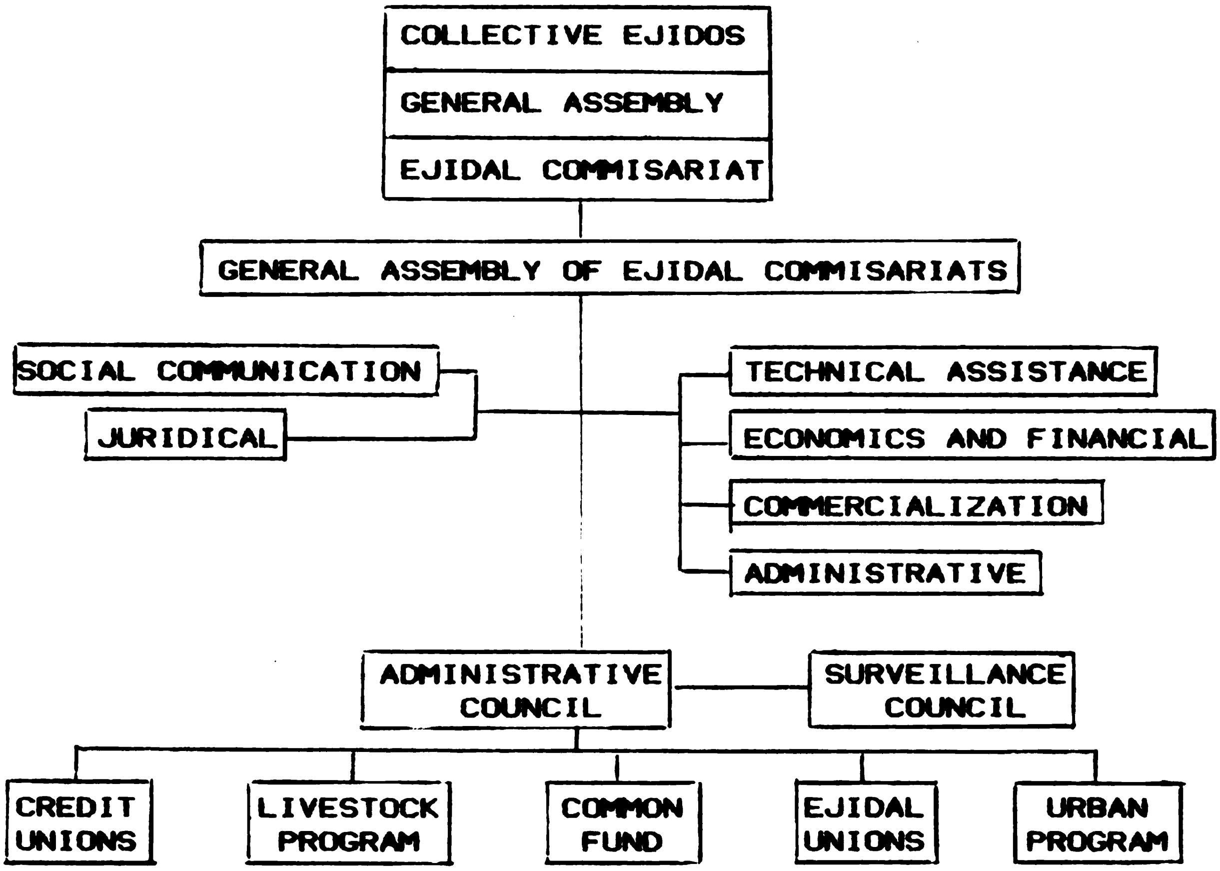


Fig. 3.4. Organigram Coalition of Colective Ejidos.

adequate maintenance, and was poorly managed and operated (Cruz et. al, 1982).

3.6. SYSTEMS APPROACH FOR AGRICULTURAL MACHINERY SELECTION

3.6.1. Systems Approach

Complexity of the modern systems of crop production leads to the application of system analysis. Systems approach or systems analysis is a problem solving methodology which begins with a tentatively identified set of needs and has as its results a simulation of a real system for efficiently satisfying a, perhaps redefined, set of needs which are acceptable or "good" in light of trade-offs among needs, and the resource limitations that are accepted as constraints in a given setting (Manetsch and Park, 1977).

System analysis may be expressed by the following mathematical statement:

$$\text{SYSTEMS APPROACH} \underset{\uparrow}{>} \overset{N}{\underset{i=1}{}} X_i \text{, where:}$$

Includes but is greater than

X1 = A methodology for planning and management.

X2 = A multidisciplinary team.

X3 = Organization.

X4 = Mathematical modeling techniques.

X5 = Disciplined non-quantitative thinking.

X6 = Simulation techniques.

X7 = Optimization Techniques.

X8 = Application of computers.

Simulation usually refers to a computer program or other functioning model that represent a system of different design and management strategies. Optimization refers to maximizing or minimizing some criterion of performance of the system while satisfying other constraints of a physical or social environmented nature (Manetsch and Park, 1977).

Major phases of the systems approach are; (1) feasibility evaluation; (2) abstract modeling; (3) implement design; (4) implementation; and (5) system operation.

Feasibility evaluation is a critical phase, aimed towards the generation of a set of feasible system alternatives, capable of satisfying identified needs. Abstract modeling has as its output, the broad specifications for a system design and/or management strategy to be implemented in the real world. Implementation design completely specifies the details of system and/or management strategy. Implementation is to give physical existence to the desired system. Operation is the only valid test of the system's adequacy.

Application of system analysis to agricultural engineering problems are summarized by Hetz (1982). Esmay (1974), described an applicable system analysis approach and proposed a flow for development of a standarized approach for engineers involved in feasibility studies.

Farm machinery is a major subsystem of the agricultural production system. Rumsey, Gantz and Chancellor (1986), pointed that a great body of generic and situation-specific literature exists concerning the optimization of cost-effectiveness of farm machinery.

Wolak (1981), Muhtar (1982) and Rotz et al. (1983), discussed four methods of approach for selection of machinery requirements and associated costs: (1) enterprise budgets and custom hire rates, (2) whole farm profit maximizing with linear programming models, (3) least cost models which seek a minimum machinery cost complement for a given management structure, and (4) heuristic models for selecting multiple interprise machinery sets.

3.6.2. Information Requirements for Machinery Selection

Machinery selection information may be generically categorized into three areas: (1) machinery data, (2) environmental data, and (3) economic data (Rumsey, Gautz and Chancellor, 1986). Four major blocks of information for machinery selection were identified by Rotz and Black (1985) as: (1) farm parameters, (2) crop and weather parameters, (3) machine parameters, and (4) economic parameters.

The availability and accuracy of data, and the sensitivity of the model to changes in the data were further discussed by Rotz and Black (1985). Farm parameters included size or total land area, crop rotation, and predominant soil type.

Timeliness cost and suitable work time available during the working season are main crop and weather parameters. Timeliness data are usually obtained from experiment stations. Suitable work days are difficult to obtain, because records have not been kept. Computer simulation has been used for generation of suitable work day probabilities from weather data for a specific location (Rosenberg et al., 1982; Hetz, 1982).

Machinery parameters required for a computer model simulation included commercial sizes available, field efficiency, field speed, and power requirements (Rotz and Black, 1985), Hunt (1977), Bowers (1975). Machinery sizes are obtained from manufacturers or dealers of farm equipment. Machinery performance data may be obtained from direct measurements or from publications, such as; machinery text books, extension bulletins and the Agricultural Engineers Yearbook.

Economic parameters include: initial cost of machinery; tax benefits; interest, discount and inflation rates; remaining values of machines; and fuel and labor prices.

Rumsey, Gautzand and Chancellor (1986) pointed that in reality, generic information for machinery, environmental and economic data are often used, due to lack of machine-site, and crop specific information.

3.6.3. Data Collection for Agricultural Machinery Selection

Machinery operation data should be obtained by direct measurements for the most releability. Other methods include farm surveys and gathering published information.

Information is the foundation upon which research is based. Published data are considered to be secondary data; any data generated by the researcher are primary data (Andrews and Hilderbrand, 1976). Any observation or investigation of the reality about a situation may be called a survey (Ferber et al., 1980). Data collection methods are described an/or analyzed by various authors. Dillon and Hardaker (1980) indicated that there are three methods by which farm survey data can be gathered: (1) direct observation, including measurements; (2) interviewing respondents; and (3) records kept by respondents.

Data collection is almost always an expensive operation (Casley and Lury, 1981). Paucity of resources for data collection in developing countries is pointed to by Zarkovich (1983). Under such conditions, efficiency becomes a serious problem. Rapid rural appraisal could be a starting point for data collection (Chambers, 1981).

Sample data collection is widely accepted as a means of providing statistical data (Kalton, 1985). Types of sampling, their advantages and disadvantages, are discussed by Dillon and Hardaker (1980), Ferber et al. (1980), Kalton (1985), Bullmer (1983), and Casley (1981). The most critical phase in data collection is that period during which data are actually collected (Bullmer, 1983).

CHAPTER 4

DATA COLLECTION

4.1. TYPE OF DATA AND PROCEDURE

The Yaqui Valley crop production conditions were identified in order to obtain main parameter values for the computer model. These existing characteristics of the ejidos (area, crops, rotations, type of soils, operations schedule, suitable days,etc.) were used to validate the model.

A data collection process was carried out in the Yaqui Valley, in March 85 (2 weeks), July 85 (4 weeks), August and December 85 (one week) and May 86 (3 weeks) for the purpose of obtaining such information.

4.1.1. Type and Source of Data Collected

Data were collected to obtain the information required by the computer model, as specified by Rotz and Black (1985). Crop and weather data were obtained at CIANO (Agricultural Research Center of the Northwest) of the National Agricultural Research Institute of Mexico (INIA), from the Technical Area (Agric. Extension Service) of the Coalition of Collective Ejidos of the Yaqui and Mayo Valleys (CECVYM), and from the ejidos.

Machinery data were obtained from agricultural machinery dealers in Obregon City, from the ejidos, and from custom-hired enterprises. The data included available sizes and prices of machinery, speed, field capacity, efficiency, power requirements, operating cost, resale value and others.

Economic information, such as; inflation, price of crops, labor and fuel, were obtained from the Credit Union of Coalition, from the ejidos, and from the Agricultural Economics Center of the Postgraduate College in Chapingo.

4.1.2. Preliminary Activities

4.1.2.1. Rapid Appraisal. The process of data collection was initiated with a rapid appraisal in May 1984. This consisted of a 7-day trip to the Yaqui Valley, to visit ejidos, private farms, agricultural machinery dealers, private and governmental custom-hired machinery enterprises, and the experiment station at CIANO. Questionnaires, prepared at CRUNO (Regional Center of the University of Chapingo, for the Northwest) and Coalition were also tried during the initial visit to the ejidos.

4.1.2.2. Training course. A training and research project was submitted for approval to the Agricultural Machinery Department and Subdirection of Regional Centers of the University of Chapingo, and to the Coalition. A training course on machinery maintenance for ejidatarios was done in September 1984.

4.1.3. Data Collection and Procedure

4.1.3.1. Type and Price of Machinery. The first activity in data collection was done in March 85. Information was collected on the type and prices of machinery commercialized in the Yaqui Valley, and about custom-hired machinery enterprises. A direct questioning procedure was used to obtain price lists on equipment from local dealers.

4.1.3.2. Data Collection in Summer 1985. The next stage of data collection was carried out during the summer of 85. A new questionnaire prepared at the Agr. Machinery Department of Chapingo was used. A technician and 6 senior students of agronomy, assisted in visiting the 50 ejidos with Coalition. An inventory of machinery, was developed. The information obtained was summarized in Table 4.11. A survey on the management, use and problems with the machinery at the collective ejidos was also carried out during the summer of 86. Persons interviewed were work foremen, machinery foremen and ejido authorities. The data obtained during summer surveys were processed and reported in December 85 (Ulloa, 1985).

4.1.3.3. Direct measurements. In August 85, two technicians from CRUNO and Coalition carried out measurements of speed and losses of cotton pickers, and in December the author made field measurements of sedbed preparation and seeding of wheat.

The candidate returned to MSU, in January 86, for a period of one year. Preliminary field research results were presented to the Guidance Committee in January.

4.1.3.4. Data Collection in May 1986. The gathering of field data was completed during a trip to the Yaqui Valley in May 86 when harvesting of wheat and planting of soybeans were taking place. These are the most critical periods for machinery operations. In preparation for this stage of data collection, the course AEC 868, Data Collection in Developing Countries was taken at Michigan State University . The methodology considered elaborating questionnaires, selection and training of enumerators, pretest and data collection.

The field work was carried out in the Yaqui Valley from May 12 to June 2, 1986, with the support of one agronomist of CRUNO and 4 enumerators hired for this project. The data collection work on the collective ejidos consisted of:

a) A group interview about training, technical assistance, and research needs with respect to agricultural machinery.

b) A survey on a sample of representative ejidos to obtain data on machinery management.

c) Measurements of; operating speed, time losses and effective field capacity, and traction power requirements.

The sample population for this study were 45 collective ejidos. Four ejidos located in the Mayo Valley, which was another irrigation district, were left out of the original list of 50; another ejido was left out because it was no longer associated with Coalition.

Inasmuch as the type and number of machines as well as the organization for use depended on the size of the ejidos, a stratified sampling was used. Five strata of 9 ejidos each was used. The first strata included the largest ejidos, and so on, down to the smallest in the last strata. Two ejidos were selected for each strata for measurements and 3 ejidos for interviews and survey. The ejidos selected were coded, with a Roman number representing the strata. The following digits 1 and 2 were assigned to those ejidos in which surveys, interview and measurements were carried out. The number 3 indicates that no measurements were made. The list of ejidos selected for this in depth studies is shown in Table 4.1.

4.1.4. Shortcomings of the Data Collection

There were some limitations in the collection of agricultural machinery data. No previous studies had been made in the Yaqui Valley, and therefore no published information about machinery performance or management was available for this region. Most ejidos had not kept records on machinery use and management other than for accounting purposes. Only a few ejidatarios (authorities, work foreman, surveillance council) work the year round in the ejido. They are elected for 3 year periods and many of the records they kept were no longer with the ejidos. Most of the ejidos had elected new authorities at the beginning

Table 4.1. List of Ejidos Selected for Data Collection

Ejido Code	Ejido Name
I1	Felipe Neri
I2	Yucuribampo
I3	Ignacio Zaragoza
II1	Bachomobampo
II2	Genovevo de la O
II3	San José Bacum
III1	Belisario Domínguez
III2	Estación Luis
III3	15 de Mayo
IV1	Héroes de Cultaca
IV2	Precursores de la Revolución
IV3	2 de Abril
V1	Plano Oriente
V2	Vicente Padilla
V3	6 de Enero

of the year, thus this was a major problem.

There was good collaboration and interest shown by the ejidatarios in a majority of cases. The data obtained, although not as complete as desired, provided an adequate information base for the simulation model validation and analysis.

4.2. AGRICULTURAL MECHANIZATION TRAINING, TECHNICAL ASSISTANCE AND RESEARCH NEEDS

A group interview technique was used on collective ejidos of the Yaqui Valley in May 86. The group of ejidatarios interviewed at each ejido included one ejido authorithy, the work foreman or machinery foreman, and a machinery operator.

The ejidatarios and technicians interviewed agreed that there were needs for training, technical assistance and research on general and specific aspects of agricultural mechanization.

4.2.1. Training Needs

Of 15 groups interviewed, 12 responded that there was a need for agricultural machinery training in the collective ejidos. The main reasons given for the need were: the ejidatarios had low knowledge about machinery in seven cases, to do a better job in seven cases, and the ejido needed more trained persons in seven cases.

Only one ejido had requested a course to Coalition to improve the training about machinery. Three ejidos had requested a training course to machinery dealers, and one to the technicians of Coalition.

Two training courses for ejidatarios had been offered by the Agricultural Machinery Department of the University of Chapingo. There were some questions asked about the reasons for the low attendance to these courses. Detailed answers are shown in Appendix A

4.2.2. Technical Assistance Needs

The need for more technical assistance on agricultural machinery was expressed by 12 of 15 groups interviewed. The main topics indicated were: machinery repair by 13 groups, use of workshop equipment by 11 groups, studies on how the ejido is using the machinery by 10 groups, to keep records of expenses and to calculate operating costs by 10 groups. Nine groups would like to have assistance for machinery maintenance, and seven for selection of tractors and equipment for the ejido.

4.2.3. Agricultural Machinery Research Needs

Eleven groups interviewed responded that research or studies were very important, and three that were important. The main reasons were: to know which equipment or new methods would be better for the ejidos in 11 cases, because the ejidatarios and technicians are awaiting research results in 9 cases. Six groups expressed that little was known on how the machinery was being used in the ejido.

The groups interviewed were asked to assess the importance and urgency of seven research or study topics. The answers were weighted using the following scale:

Very important or very urgent need	:	10 points
Important or urgent topic	:	7 points
Little important or little urgent	:	3 points
Not important or not urgent topic	:	0 points

The groups interviewed were asked which of the seven research topics should be studied in the first place, and so on, down to the seventh place for the topic with lower priority). The weights assigned to the answers were:

Topic in first place:	20 points
Topic in second place:	15 points
Topic in third place:	10 points
Topic in fourth place:	5 points
Topic in fifth place:	3 points
Topic in sixth place:	1 point
Topic in seventh place:	0 points

Management and repair of machinery resulted in the first places, when the aspects of importance, priority and urgency were considered together. Machine design and tillage methods resulted in the last places (See Table 4.2).

4.3. EJIDO AND CROP PRODUCTION DATA

4.3.1. Ejido Size

The size of ejidos varied form 19 to 1583 cultivable hectars. The most common sized were 101-400 hectares (25

Table 4.2. Relative Importance, Priority and Urgency of Agricultural Machinery Research Topics in Collective Ejidos.

Research topic	Importance	Priority	Urgency	Average
Mach. Management	98	100	99	99
Mach. Repair	94	98	100	94
Operating costs	100	83	93	92
Machine shop	91	80	96	89
Calibration on mach.	91	78	88	86
Tillage methods	90	55	87	77
Machine design	87	45	77	70

Source: Group interviews in collective ejidos, Yaqui Valley, Son. Mexico, May 1986.

ejidos) and 401-1000 hectares (21 ejidos), with 2 ejidos less than 100 hectars and 2 ejidos over 1,000 hectars.

4.3.2. Parcel Size

The size of parcels within the ejidos varied from 11 to 30 hectars (19 parcels) and from 76 to 100 hectares (13 parcels). Fifty percent of the parcels were less than or equal to 50 hectares, with decreasing percentage of medium (51-100 hectares) and large size parcels (over 100 hectares) as shown in Figure 4.1. The land was very level, with almost no obstacles (trees, stones).

4.3.3. Crop Rotations

1) Wheat-Soybean rotation was used in 12 of the ejidos surveyed, being the most important in 10, and second most important in the other two.
2) Wheat-Soybean-Cotton rotation was used in 7 of 13 ejidos, being the most important in one, and second most important in the other 6 ejidos.
3) Wheat-Maize-Cotton rotation was used in 7 of 13 ejidos, being the second most important in 3, and third most important in 4.

Other rotations were wheat-sesame (4 ejidos), wheat-wheat (3 ejidos), wheat-sorghum (1) and wheat-soybean-sorghum (1). (See Table 4.3).

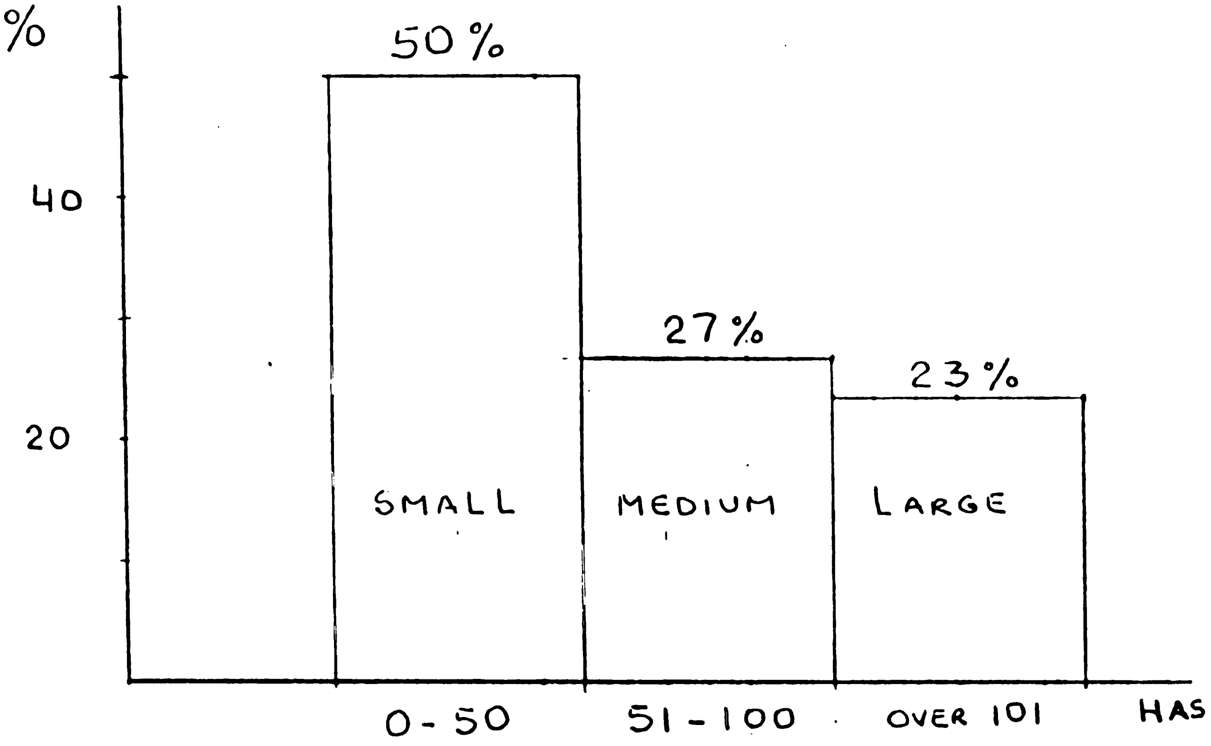


Figure 4.1. Distribution of Size of Parcels in Collective Ejidos.

Table 4.3. Crops Rotations Used in Collective Ejidos.

	Crop Rotations					
Strata	W-S	W-S-C	W-M-C	W-S-S	W-W	OTHERS
I	3	2	2	1	1	0
II	2	0	3	1	0	1
III	2	2	0	1	0	0
IV	3	3	1	0	1	0
V	2	0	1	1	1	1
Total	12	7	7	4	3	2

Source: Survey in 13 ejidos of the Yaqui Valley, May 1986.

W = Wheat; S = Soybeans; C = Cotton
M = Maize; SS = Sesame

4.3.4. Crop Area and Yield

In the Yaqui Valley there were two main croping seasons: The winter season, during which the main crop was wheat, and summer season, during which soybeans and cotton were the main crops.

Wheat was the main crop on the collective ejidos. The average area seeded from seasons 1981/82 to 1985/86 were 15,180 hectares per year, which represented 68% of the total cultivable hectares of the collective ejidos associated with Coalition. The average area with soybeans and cotton, from 1981 to 1985, were 13,238 hectars and 1,803 hectars per year, respectively, which represented 59% and 8% of the cultivable area of the collective ejidos (See Tables 4.4 and 4.5)

The yields for wheat varied from 4.8 to 5.3 ton/ha, from 1.7 to 2.0 ton/ha for soybean, and from 2.0 to 2.28 ton/ha for cotton.

Approximately 70% of the cultivable area in larger ejidos (strata I and II) was seeded with wheat, and 82% to 84% in medium and small ejidos. The area seeded with soybeans was less than the wheat area and varied from year to year because it depended on the water remaining in the Alvaro Obregon dam. The area seeded with soybean has been up to 47 to 58% of the total cultivable land on larger ejidos, and up to 67 to 82% on medium and small ejidos. The area seeded with cotton was low and has been decreasing from past years, due to high production costs and low international price of cotton (Figure 4.2).

Table 4.4. Area and Yield of Wheat in Collective Ejidos of the Yaqui Valley.

YEAR	AREA HECTARS	YIELD TON/HA
1981/82	17,390	5.3
1982/83	15,598	5.0
1983/84	13,245	5.3
1984/85	14,209	4.8
1985/86	15,462	NA
AVERAGE	15,180	

Source: Technical Assistance Area, Coalition. Unpublished data.

TABLE 4.5. Area and Yield of Soybean and Cotton in Collective Ejidos of the Yaqui Valley.

YEAR	SOYBEAN		COTTON	
	HECTARS	TON/HA	HECTARS	TON/HA
1981	15,117	--	--	--
1982	12,891	2.0	858	--
1983	13,749	1.84	1,277	2.8
1984	9,393	1.7	4,135	2.0
1985	15,040	1.7	2,745	2.5
AVERAGE	13,238		1,803	

Source: Technical Assistance Area, Coalition, Unpublished data.

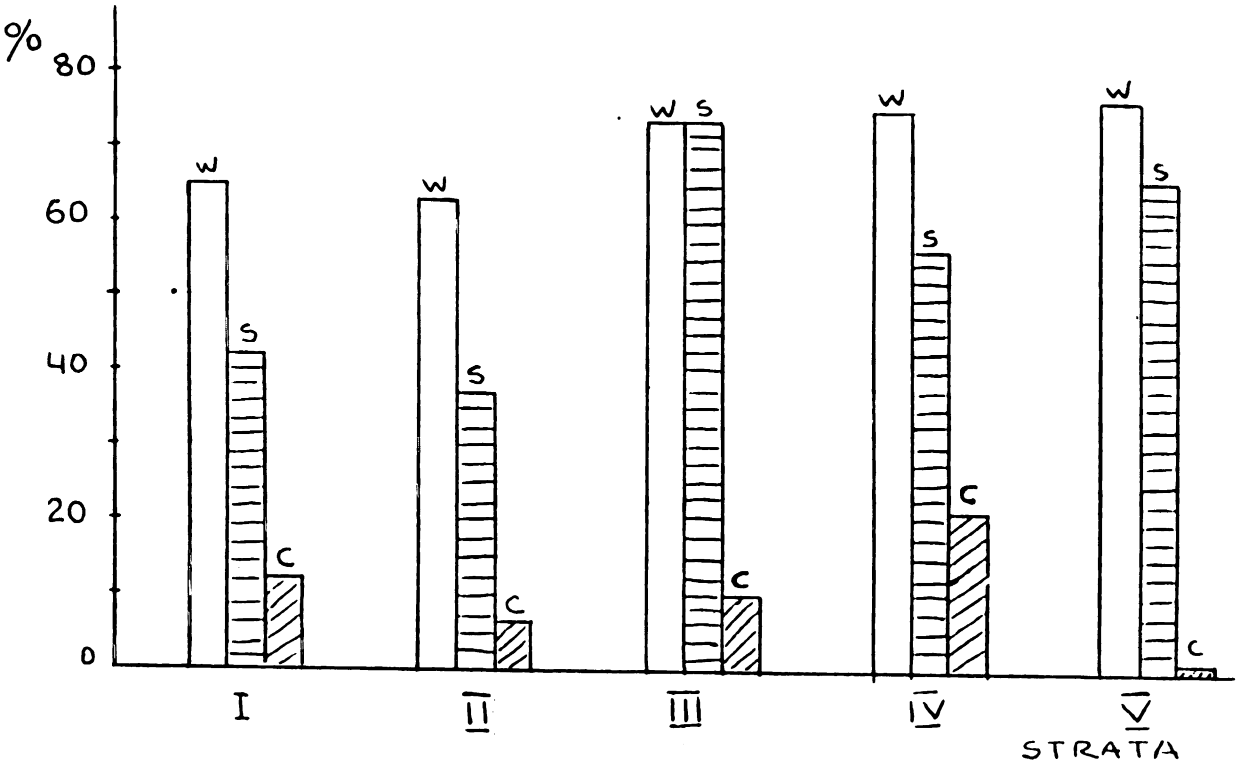


Figure 4.2. Percent of Total Area Seeded with Wheat, Soybeans and Cotton in Collective Ejidos.

4.3.5. Crop Production System

The crop production systems for wheat, soybeans and cotton were relatively uniform in the collective ejidos. The ejidos had to proceed according to schedules of the irrigation district, and followed the recommendations of the field technicians of Coalition to receive their allowances from the Credit Union or Banks.

The July 85 and May 86 surveys , indicated variation in the type of operations and equipment. The number of tillage, fertilizer application and plant protection operations are shown in Tables 4.6, 4.7 and 4.8 for all the ejidos of Coalition.

The main variation for the mechanization of the 3 main crops from 1983 to 1985 are shown in Table 4.9. Typical mechanized systems for wheat, soybeans and cotton are shown in Table 4.10.

4.3.6. Workable Days

The ejidatarios did not register or recall the number of suitable days for field operations. Records of 27 years (1959-1985) of daily precipitation were obtained from the agroclimatology area of CIANO, along with the criteria to decide non-suitable days. The procedure to generate suitable days on a weekly basis is described in Chapter 5, Section 5.3.1.3.

Table 4.6. Operation and Dates for Wheat Production in Collective Ejidos of the Yaqui Valley

Operation	No. of Ejidos Doing Operation	Date of the Operations[1]			
		Earlier	Most Common		Latest
		Date	Date	No. Ejidos	Date
Subsoiling	6	09-1	09-4	3	12-1
Chiseling	12	09-1	10-1	5	12-1
Disk Plowing	34	07-1	10-2	11	12-1
Disk Harrow-1	41	07-1	10-3	13	12-2
Disk Harrow-2	41	07-1	10-4	14	12-4
Disk Harrow-3	20	07-1	10-4	9	12-4
Land Leveling	35	09-4	11-1	16	01-1
Furrowing	25	10-1	11-1	8	01-1
Bedding	17	10-3	11-4	6	12-3
Seeding	36	11-1	12-1	13	01-1
Applic. Solid Fertilizer	36	09-1	11-1	15	02-1
Applic. Liquid Fertilizer	30	09-4	01-1	5	03-4
Ground Spraying	10	12-1	01-4	3	03-4
Aerial Spraying	35	12-2	01-4	7	04-3
Harvest	41	04-1	05-1	26	07-1
Straw Burning	38	05-1	05-3	11	07-2

---

[1] First two digits indicate month; last digit indicates which week in that month.

Source: Survey in the Yaqui Valley, July 85.

TABLE 4.7. Operation and Dates for Soybean Production in Collective Ejidos of the Yaqui Valley.

Operation	No. of Ejidos Doing Operation	Date of The Operations[1]			
		Earlier Date	Most Common Dates	Most Common No.	Latest Date
Subsoiling	8	02-1	05-1	3	05-4
Chiseling	7	02-1	05-1	2	06-1
Disc Plowing	19	02-1	06-1	6	07-3
Disc Harrow-1	42	02-1	06-1	10	07-3
Disc Harrow-2	40	02-1	05-4	19	07-1
Disc Harrow-3	23	02-1	06-1	6	06-4
Land Leveling	21	02-2	05-1	7	07-1
Furrowing	40	02-2	05-3	10	07-2
Seeding	43	04-1	06-1	21	07-4
Cultipacker	23	05-2	06-4	5	08-1
Applic. Solid	--	----	----	--	----
Fertilizer	28	03-3	05-1	10	07-1
Applic. Liquid	--	----	----	--	----
Fertilizer	8	05-1	05-4	4	06-3
Cultivation-1	34	05-4	07-1	7	08-2
Cultivation-2	23	05-4	07-1	8	07-4
Ground Spraying *	3	05-1	----	--	08-4
Aerial Spraying *	4	06-2	----	--	08-1
Defoliation *	1	----	----	--	----

---

[1] First two digits indicate month; last digit indicates which week in that month.

* These operations had not been done at the time of the survey.

TABLE 4.8. Operation and Dates for Cotton Production in Collective Ejidos of the Yaqui Valley. 1985.

Operation	No. of Ejidos Doing Operation	Date of the Operations[1]			
		Earlier	Most Common		Latest
		Date	Dates	No. Ejidos	Date
Subsoiling	15	12-1	01-1	9	02-3
Disc Plowing	18	11-4	01-1	8	02-4
Disc Harrow-1	24	12-1	02-1	6	03-1
Disc Harrow-2	24	12-1	02-1	6	03-2
Disc Harrow-3	17	12-1	02-1	4	03-1
Land Leveling	11	12-4	01-1	4	04-1
Furrowing	23	01-1	02-1	6	04-1
Seeding	23	02-1	02-4	61	04-4
Cultipacker	6	02-4	---	-	05-3
App. Solid Fert.	19	01-1	02-1	4	04-4
App. Liquid Fert.	15	01-1	04-1	3	05-4
Manual Thinning	19	03-1	04-4	3	06-1
Cultivation-1	20	02-4	03-3	4	06-1
Cultivation-2	18	02-4	04-1	4	06-4
Ground Spraying *	12	02-1	04-2	4	05-1
Aerial Spraying *	13	05-1	06-4	6	07-4
Defoliation *	9	05-4	07-3	3	08-2
Harvest *	6	07-4	08-1	-	08-1
Rotary Cutter *	4	08-2	---	-	---

[1] First two digits indicate month; last digit indicates which week in that month.

* These operations had not been done at the time of the survey.

Table 4.9. Number of Passes and Cases Reported for Field Operation on Wheat, Soybean and Cotton in Collective Ejidos.

Operation	Wheat		Soybean		Cotton	
	Passes	Frec	Passes	Frec	Passes	Frec
Chiseling	0	24	0	24	0	4
	1	10	1	1	1	6
Disk Plowing	0	10	0	20	0	6
	1	23	1	5	1	6
Disk Harrow	2	5	2	14	2	2
	3	25	3	12	3	8
	4	2	-	--	4	2
Land Plane	0	11	0	20	0	5
	1	14	1	2	1	6
	2	1	-	--	-	-
Wood Frame	0	2	1	22	1	9
	1	21	2	3	2	3
	2	9	3	1	-	-
Furrowing	0	6	1	14	1	9
	1	21	2	9	2	2
	2	2	-	--	-	-
Broadcasting Fertilizer	0	6	0	3	0	1
	1	17	1	18	1	8
	2	11	2	5	2	3
Field Fertilization	0	16	-	--	0	6
	1	5	-	--	1	4
Row-Cultivator	-	--	2	8	3	5
	-	--	3	11	4	7
	-	--	4	4	-	-
Ground Spraying	0	18	0	16	0	3
	1	9	1	5	1	8
	2	1	-	--	-	-
Aerial Spraying	0	8	0	3	1	2
	1	14	1	12	2	6
	2	7	2	9	3	4
	3	3	3	2	-	-

Source: Survey on 14 Collective Ejidos, May 1986.

Table 4.10. Operations and Number of Passes for Wheat, Soybeans and Cotton Production in Collective Ejidos of the Yaqui Valley.

Field Operation	Wheat	Soybeans	Cotton
Chiseling	0	0	1
Disk plowing	1	0	0,1*
Disk harrowing	3	2	3
Fertilizer spreading	1	1	1
Land plane	1	0	1
Wood frame	1	1	1
Furrowing	1	1	1
Row cultivation	0	3	4
Ground spraying	0	0	1
Aerial spraying	1	1	2
Stalk cutter	0	0	1

Source: Survey in Collective Ejidos, May 1986.

* 50% disk plowed; 50% did not disk plowed.

4.4. AGRICULTURAL MACHINERY IN COLLECTIVE EJIDOS

4.4.1. Inventory of Agricultural Machinery

Fifty ejidos associated with Coalition had a total of 353 tractors in July 85. This was an average of 7 tractors per ejido, and one tractor per 61.7 cultivable hectares. The number of combines was 90, with an average of one combine per 242 cultivable hectares. Table 4.11 presents a summary of the equipment in the collective ejidos. Besides, 18 of the 50 ejidos associated with the Coalition, created the Union "19 de Noviembre", an ejidal cooperative that owned and operated 3 planes for aerial spraying, 10 combines, 8 2-row cotton pickers, 26 equipment for ammonia injection and 33 for aqua-ammonia application.

4.4.2. Experience in Agricultural Machinery

In July 85 there were 3861 active members (ejidatarios) of which 702 were tractor operators, 144 combine operators, and 99 truck drivers. The majority of these operators had more than 10 years of experience. There were only 17 mechanics and 18 welders for 8 ejidos workshops. The other ejidos had no workshops. This explains why the Coalition leaders complained about poor maintenance and high expenses for machinery repair.

Table 4.11. Agricultural Machinery in Collective Ejidos. Yaqui Valley, Sonora, Mexico

Ejido Name	Cult. Has	Ejida- tarios	Number of Machines					
			Tract No.	Comb No.	Disk Plow	Disk Harrow	Plant. Equip	Spray. Equip
Alfredo Bonfil	1583	207	17	6	6	7	6	-
El Rodeo	1089	189	14	3	5	6	4	1
Felipe Neri	987	163	14	4	3	6	6	1
Mariano Escobedo-1	941	177	11	4	5	8	5	1
Yucuribampo	914	156	13	1	5	6	5	3
Guillermo Prieto	906	155	18	4	5	8	9	1
Col. Allende (Fl. Madero)	881	178	20	7	4	8	6	2
Constituyentes	825	132	11	2	4	6	3	2
Ignacio Zarogoza	773	110	8	4	3	5	5	2
Mariano Escobedo-2	694	135	11	4	5	5	3	2
Nazario Ortiz Garza	672	115	10	4	4	6	7	-
San Isidro	625	118	3	-	1	2	2	-
Plan de Ayala	590	118	8	4	3	5	5	3
San Jose Bacum	553	123	7	1	2	4	-	1
Otilio Montaño	552	82	9	2	2	4	2	-
23 de Octubre	532	98	10	2	4	4	5	1
Bachomobampo	525	117	10	-	4	3	3	1
Genoevo de la O	521	104	9	3	3	6	4	1
5 de Junio	475	85	7	2	6	5	-	4
El Pensador	438	74	8	3	4	4	6	2
Romero Palacios	396	78	6	1	3	5	4	1
15 de Mayo	394	66	7	2	3	4	3	5
Estación Luis	392	66	10	1	3	4	3	-
Raymundo Saravia	388	85	5	2	2	2	3	1
Belisario Domínguez	385	68	7	2	2	4	2	-

Table 4.11. (Cont'd)

Ejido Name	Cult. Has	Ejida- tarios	Number of Machines					
			Tract No.	Comb No.	Disk Plow	Disk Harrow	Plant. Equip	Spray. Equip
Primero de Abril	370	37	7	2	3	4	3	1
A. Ruiz Cortínez	364	72	10	2	3	4	2	2
Veteranos de la Revolución	364	77	8	3	3	4	3	2
Severiano Talamante	340	50	6	2	1	3	2	2
Cuauhtemoc Càrdenas	307	61	7	2	1	2	2	1
Jacinto Lopez	290	47	5	-	2	3	3	2
Hèroes de Cuitaca	270	28	4	2	4	3	4	-
2 de Abril	264	32	6	-	2	2	2	-
Ignacio Pesqueira	251	39	4	2	3	4	4	2
El Chamizal	225	44	2	-	1	1	1	-
Fco. J. Mujica	222	32	5	1	3	4	4	1
El Porvenir	219	46	4	2	2	4	3	-
Precursores de la Rev.	195	38	4	1	2	2	1	1
Plan Oriente	183	37	4	-	2	4	2	2
Abelardo L. Rodríguez	167	25	4	-	2	5	2	1
Ignacio Soto	157	30	4	-	2	3	2	1
Vicente Padilla	152	26	4	-	3	3	2	1
Benito Juarez	145	24	3	-	3	3	2	-
8 de Febrero	145	14	3	2	2	1	2	1
Francisco de Bocanegra	140	26	3	-	2	2	3	-
6 de Enero	134	13	2	-	2	2	2	-
Rio Yaqui	123	24	3	-	2	2	2	1
Pascual Acuña	110	20	2	-	2	1	2	2
Màrtires de Cananea	99	14	2	1	2	2	1	-
El Individual	19	4	-	-	-	-	-	-
TOTALS	22,286	3,861	353	90	142	195	172	57

Source: Survey on Collective Ejidos. July 1985.

4.4.3. Responsibles for the Machinery

Machinery maintenance and repair, programming and controling was in the hands of a work foreman in 22 ejidos , a machinery foreman in 16 ejidos and the surveillance head in 16 ejidos .

Records of maintenance and repair expenditures were kept globally for all the machinery in 42 ejidos. Individual or per machine records were maintained only in 5 ejidos, and 9 ejidos kept both types of records.

4.4.4. Working Day

A working day for machinery operators was normally 8 hours in 39 ejidos , 12 hours in 5 ejidos, 7 hours in 3 ejidos and 6 hours in 2 ejidos. There were urgent operations (very common for the wheat-soybean rotation), where one operator would work continously up to 16 hours (double shift) or 24 hours (triple shift). The operations most often done with longer working days were disk plowing, disk harrowing and land leveling.

In the survey of May 86 (See Table 4.12), tillage was reported as being done for up to 24 hours with the same operator (approximately 20 effective hours). Other operations could be up to 10, 12 or 18 hours per day on some ejidos. For example, spraying could be done up to 18 hours per day, when the operation was done during noon and night.

Table 4.12. Range of Working Hours per Day.

Field Operation	Hour/day
Tillage, seeding wheat	8 - 24
Spraying	6 - 18
Row cultivation	8 - 16
Furrowing, planting soybean and cotton	8 - 12
Cotton picking (machine)	7 - 10
Harvesting wheat and soybeans	6 - 10

Source: Survey in Collective Ejidos, May 1986.

4.4.5. Operator Wages.

Operator wages varied between ejidos, as they were free to decide how much to take for labor from the credit received for crop production. Most of the ejidos paid a fixed amount per day or a percentage of the rate established in the credit for a given operation. Payments for tillage, seeding , cultivation and spraying were on a per day basis, varying from 1800 to 3000 Mexican pesos per 8 hours. Payments were proportionally higher for longer working days. For harvest the payment was higher on a per day basis; and around 10 % of the authorized price per hectare harvested.

4.4.6. Programming of Machinery Operations.

Machinery use was programmed by the work foreman in 16 of the 50 ejidos, or between 2 or 3 persons including the work foreman, surveillance head or somebody from the ejido authorities. In 6 ejidos, the General Assembly made decisions about the programming.

Usually the programming was done with a one month lead time. Ten types of programming problems were reported. The most frequent problems were; machinery failures in 11 cases, delay in supplies in 7 cases, and bad weather in 6.

Records of variable accuracy were maintained on the use of machinery, mainly for the purpose of paying the operators, and for crop expenses . No specific data were kept for particular machines or land parcels.

4.4.7. Purchase of Machinery.

Machinery purchases were made by the ejidos without data on machinery use. Decisions were based on practical experience, and the need of more machinery to complete the field work on time.In all cases the purchase of new machinery had to be approved by the Assembly.

Most of the ejidos purchased new machinery because of the guaranty and service given by dealers. A few ejidos purchased used machinery when there were good opportunities, low prices, or when the ejido did not have enough money.

The majority of the ejidos purchased machinery through the Credit Union of Coalition (34 ejidos), 15 ejidos purchased directly from dealers and 10 through Banrural. Forty one ejidos used special credits for durable assets (creditos refaccionarios), 11 obtained price reductions in direct purchases, 11 used private loans, and 7 obtained payment facilities.

By July 85, the ejidos indicated the need of the following equipment: 39 tractors, 18 combines, 2 cotton pickers, 13 trucks, 4 sprayers and 33 other implements. This is not a large amount of machinery considering the 50 ejidos. This infers general satisfaction with the present machinery for their needs. It was also reported that they would sell 44 tractors and 8 combines.

4.4.8. Custom-Hired Operations.

The survey of July 85 indicated that the ejidos have used custom-hired machinery since they were created in 1976. For the last season they recalled 18 cases of custom-hired work for seeding, 15 cases of disk harrowing, 15 for harvest, 14 for spraying, and 11 for disk plowing. The area custom-hired per ejido varied from 40 to 860 hectares for seeding, 60 to 860 hectars for disk harrowing, 19 to 860 hectares for disk plowing and harvest, and 30 to 440 hectares for spraying. The quality of custom-hired work was largely reported as good and timely; only seven cases were reported as defficient and 3 and as not timely.

Custom-hired operations reported on the survey of May 86 were: disk harrowing and land leveling in 3 ejidos, furrowing in one, wheat seeding in two, soybean planting in three, wheat harvest in six, and soybean harvest in four. The area custom-hired was incompletely reported because of poor recall and lack of accurate records. Some data obtained were: disk harrowing: 245 hectars; land leveling: 158 hectars; wheat seeding:50 hectars; soybean seeding: 389 hectars; wheat harvest: 1780 hectars; soybean harvest: 784 hectars.

4.5. MACHINE PARAMETERS

4.5.1. Duration of Machinery

Much of the machinery purchased new since the collective ejidos were created in November 1976, was still in operation. Therefore, at the time of the study there were machines with 10 years of use. The total hours worked for specific tractors and implements was not kept, nor could be recalled accurately by ejidatarios.

Experienced dealers of Ford, John Deere and Industrias Vazquez in Obregon City (May 86), indicated that duration of machinery in the Yaqui Valley depends on maintenanace and operating conditions. There were tractors 20 years old, and combines 15 years old still running. Dealers considered that with good care and maintenance the duration of tractors in private farms could be up to 14,000 hours, 12 to 15 years for combines and 6 to 10 years for implements such as disk plows, disk harrows, cultivators, planters, etc. Dealers beleive that there was a lower duration on collective ejidos (with good care) of about 8,000 to 10,000 hours for tractors, and 10 years for combines (no indications of hours of use). Better care, maintenance and operation in private farms, were considered among the reasons for longer useful life of machinery, as compared with collective ejidos.

4.5.2. Resale Value

Selling or buying used equipment was not a common practice in the collective ejidos, although it existed in the Yaqui Valley. Resale prices depended on the conditions of the machines, need and opportunity and ability to negotiate with potential clients. According to machinery dealers consulted, 10 year old operating tractors and combines sold for about 10% of new equipment price. Scrap values could be; 5 to 10% for tractors, while implements had practically no scrap value.

4.5.3. Annual Use of Machinery

Practically no detailed data on machinery use were available. The ejidatarios did not emphasize the use of hourmeters for the evaluation of machinery performance. On the survey of July 85, 34 ejidos estimates of annual tractor use varied from 15 to 360 days/year, and combines (22 cases) from 15 to 120 days/year. For tractors, 14 ejidos estimated an annual use of less than 60 days/year, 9 from 61 to 120 days/year, 5 ejidos estimated an use of 121 to 240 days and 5 more than 241 days. Therefore, the majority used the tractors less than 1000 hours per year (120 8-hour days/year).

On the survey of May 86 one ejido provided the following figures: 1000 hr/year, average of 8 years for a large tractor (IH 966); 350hr/year, average of 8 years for a small tractor (MF 165); 315 hr/year, average of 6 years for a combine (JD 7700); 500 hr/year for a disk harrow;

300 hr/year for a grain drill, and 280 hr/year for a row-crop planter.

4.5.4 Failures & Repairs Costs

The most common expressed problem with machinery was the high cost of repair. However no records were kept for each machine in the ejido, not even the largest ones. Accounting included only costs of fuel, labor, repairs, etc. for the ejido as a whole.

Some machines did have critical failures that kept them down a significant length of time. The recall was only on the large machines, but this could be a problem with implements as well.

There were 3 cases of tractors and 2 combines for which failure was an engine break-down. These resulted in the keeping the machines out of action for 15 to 240 days. In 6 cases the unavailabity of repair parts was a cause for the delay in repairing the machinery. In one ejido, payments for a major repair for a tractor represented about 10% of the price of a new tractor.

Machinery dealers had a few records of tractor and combine repair, but not complete.Table 4.13 depicts payments for repair of two tractors given by the John Deere dealer in Obregon City.

4.5.5 Speed, Field Capacity, and Field Efficiency of Machinery

The July 85 survey produced limited data on operating speeds, field capacity and field efficiency. Operators knew the tractor gear for a given operation, but not the speed in kilometers per hour. Effective field capacities were recalled in hectars per day, but this could be inaccurate, when different tractors, implements and operators were used on the same parcel.

In May 86 the majority of the ejidos worked at third gear for disk plowing; third and fourth gear for disk harrowing; third, fourth and fifth gear for seeding. Cultivation varied from first to third gear for the first pass, and up to fourth gear for the second cultivation. This information is consistent wih that obtained in July 85.

Effective field capacity data obtained were reliable in some cases, but in others was inaccurate, due to poor recalling or poor estimation of hours spent on a given parcel. Field efficiency was calculated from the few reliable values as: 0.6 to 0.8 for disk plowing, 0.6 to 0.84 for disk harrowing, 0.5 to 0.7 for soybean and cotton planting, and 0.5 to 0.7 for wheat and soybeans harvest.

Direct measurements of operating speeds and time losses were carried out in August, December 1985, and May 86. An average speed of 3.7 km/hr and a field efficiency of 0.77 were calculated for cotton picking. Manual picking of cotton required an average of 83.6 person-hour per hectare. Average speeds in km/hr for wheat seedbed preparation and seeding, wheat harvesting, and tillage and planting for soybeans are shown in Table 4.14.

4.5.6 Draft Force Measurements

Draft forces were measured for disk plow, disk harrow and chisel plow, in May 86. An hydraulic dynamometer (Towner pull- meter), with a pulling capacity of 30,000 pounds was used for measurements. The pullmeter was borrowed from Maquinaria General de Occidente, dealers of Caterpillar in Obregon City.

An average of 24.7 drawbar kilowatt per meter (10.1 DBHP/ft) was measured for disk plow. Measurements were made in 5 ejidos with 10 replications per trial. For disk harrow there were measurements in 7 ejidos, with an average of 8.1 drawbar kilowatt per meter of width (3.3 DBHP/ft). Average depths and speeds for disk plowing, were 25.2 cm and 5.3 km/hr, and 14.7cm and 6 km/hr for disk harrow.

4.6. AGRICULTURAL MACHINERY AVAILABLE IN THE YAQUI VALLEY.

4.6.1. Agricultural Machinery Manufacture.

Agricultural machinery manufacturing in Mexico was concentrated around the main industrial centers. In the Yaqui Valley, the only manufacturer was Industrias Vazquez, the largest in the northwest and one of the

Table 4.13. Payments for Tractor Repair

Year	J. D. 4235[1] Payments, M.$	J.D. 4440[2] Payments, M.$
1982	6,014	58,111
1983	10,697	95,906
1984	25,770	534,706
1985	622,679	33,560

[1] Tractor sold Jan.17, 1974
[2] Tractor sold Feb.29, 1980
Source: Equipos Agrícolas del Yaqui, Obregón City.

Table 4.14. Operating Speeds in Collective Ejidos.

Operation	Km/hr Average	No. of Ejidos
December 85[1]		
Disk Harrowing	7.1	4
Wheat Seeding	10.9	3
Furrowing	9.4	1
May 86[2]		
Wheat Harvesting	4.0	1
Disk Plowing	5.6	8
Disk Harrowing	5.9	7
Furrowing	7.7	4
Soybean Planting	9.3	2

[1] Seedbed preparation and seeding wheat.
[2] Wheat harvest; Tillage and planting soybean
Source: Direct measurements in the Yaqui Valley

largest implement manufacturers in Mexico. Sales were directly at the Obregon City factory and through established dealers in the region, and country.

4.6.2. Agricultural Machinery Dealers.

Prominent dealers of agricultural equipment in the Yaqui Valley were: Sonora Agrícola, a representative of Ford; and Equipos Agrícolas del Yaqui,a representative of John Deere. Both had main offices in Obregon City.

Smaller dealers were: Grupo Promansa, representatives of Sidena, Canota and Hass; Servicios Agrícolas, representing New Holland; and Combinadas, Tractores y Montacargas, S.A., a representative of Allis Chalmers.

Large dealers of industrial machinery, which also sold crawler tractors for agricultural operations were: Maquinaria General de Occidente for Caterpillar; and DIMAKO, selling crawler tractors and industrial machinery. Both sold mostly imported machinery.

4.6.3. Available Sizes and Prices of Equipment.

The collective ejidos purchased new machinery, generally from the dealers in Obregon City. Only for some special imported machinery, such as combines or cotton pickers would purchases be made directly from the U.S. The equipment available, and the prices for April 1985 is detailed in Appendix B.

4.6.4. Custom Hire Machinery Services.

The intensive use of the irrigated land of the valley, with two crops per year in most cases, with critical periods for seeding, crop protection practices and harvesting, demanded the use of large machinery. Custom-hire machinery operations were used for high capacity jobs requiring high capacity (usually imported) machines, which small or medium holders could not afford to own.

Custom-hired services were provided by both governmental and private enterprises. There were two governmental services; one, was the Program for Agricultural Mechanization for small private farmers, and two, was the Machinery Central of the Rural Bank for the reservation of the Yaqui tribe (Irrigation District 018). Both had their main offices in Obregon City. The larger private enterprises were: Aerofumigadores Unidos del Yaqui y Mayo, with 71 planes; and Fumigaciones e Insecticidas Union del Yaqui (FUMEI), with 44 aqua-ammonia applicators and 48 nurse trailers, 9 anhydrous ammonia applicators and 34 nurse trailers and 6 nurse trailers for calcium polisulphurum.

4.6.5. Price of Custom-Hired Operations

Prices for custom hire operations were established by a committee, chaired by the representative of the Secretary of Agriculture and Hydraulic Resources (SARH), with members of other agricultural related institutions. Prices established were to be charged by government and private custom-hire services. The list of prices for custom-hire operations is presented in Table 4.15.

4.7. ECONOMIC PARAMETERS

Economic factors were critical for the simulation model, since the objective was to obtain the most economical machinery sets for collective ejidos. Information was obtained on inflation in Mexico, and the prices of crops, machinery, fuel and labor.

4.7.1. General Inflation in Mexico.

Information of the Bank of Mexico in Chalita (1986), showed that the general inflation in Mexico during the last 15 years varied from a low 4.5 % in 1970 to a peak 98.8 % in 1982. Table 4.16 depicts the values of inflation in Mexico for the last 15 years. It will be noted that there are 3 main periods:

1) 1970 - 1972 with low inflation rates of 4.5, 4.4 and 4.5 %.
2) 1973 - 1981, with medium inflation varying from 12.3 to 29.7%.
3) 1982 - 1985, with high inflation rates, varying from 98.8% in 1982 and decreasing to 63.7% in 1985. This reflects Mexico's economic crisis, which is still present.

Table 4.15. Prices for Custom-Hired Services in the Yaqui Valley. April, 1985.

Operation	Mex $/ha
Disk plowing	7,350
Subsoiling	5,700
Disk harrowing	2,950
Land leveling	3,250
Land leveling (tablon)	1,900
Fertilizing	1,800
Furrowing	2,150
Row-cultivation	1,800
Seeding	2,400
Cultipacker	1,100
Rotary shredder	3,500
Aerial spraying	3,000
Aqua ammonia aplic.[1]	9,200
Anhydrous ammonia aplic.[1]	35,600
Combine	12,000
Cotton picker	16,000
Tractor, one hour	3,600

[1] Price per metric ton., product included.

Source: Agricultural Mechanization Program, Aerofumigadores Unidos del Yaqui y Mayo, FUMEI.

4.7.2. Credits Loans for Agricultural Machinery Purchases

The collective ejidos associated with Coalition purchased their machinery through the Credit Union of Coalition, which had similar functions as Banrural, the government bank for rural development. The conditions for purchasing machinery with the Credit Union were very favorable for collective ejidos, as compared to the private banks. Table 4.17 shows the interest rates for machinery purchases as low as a half or a third (1982, 1983) of general inflation.

Dealers did not handle credit for their potential clients as they did before the economic crisis, because of the high interest rates charged by the banks for private loans.

4.7.3. Price of Machinery

The price of tractors, combines and implements increased at different rates during the last years. Combines had the largest increase: 46 times the initial price, from August 1980 to May 1986, while inflation increased by a factor of 17.4. A utility tractor increased by a factors of 23.6 and a tillage tractor 28.6; disk plows 13.5 times; and disk harrows 12.76 times over the same period (See Tables 4.18 and 4.19).

Prices of domestic made implements increased less than inflation. Imported machinery such as combines varied largely above inflation, reflecting the variation of the exchange rate (Mexican pesos per one US dolar) since

Table 4.16. Percent of Inflation in Mexico.

Year	Inflation %
1970	4.5
1971	4.4
1972	4.5
1973	12.3
1974	24.0
1975	18.1
1976	19.4
1977	20.7
978	16.2
1979	19.9
1980	29.7
1981	28.9
1982	98.8
1983	80.8
1984	66.0
1985	63.7

Source: Luis E. Chalita, 1986.

Table 4.17 Interest Rates for Ejidos for Credits to Purchase Machinery.

Year	Interest Rate
1980	13
1981	15.5
1982 - Jun 83	19
Jul - Dec 83	23
1984	27.5
1985	32
1986	38

Source: Credit Union, Coalition. May 86.

Table 4.18. Price Variations of Tractors. Mex. Pesos x 1000

Date	Ford 6600	MF 285	MF 290	IH 784
January 81	403	396	--	404
July 81	459	454	--	432
March 82	539	590	--	592
September 82	796	841	--	820
February 83	1,170	1,235	1,392	1,205
May 83	1,474	1,555	1,754	1,518
October 83	1,816	1,912	2,197	discont.
May 84	2,588	2,174	2,498	--
August 84	--	2,742	3,150	--
March 85	3,310	--	--	--
January 86	4,799	--	--	--
May 86	7,883	--	--	--

Source: Sonora Agrícola, Obregón City. June 1986.

Table 4.19. Price Variations of J. Deere Machinery, Aug. 80-May 86. Thousand of Mexican pesos.

Date of Price	Tractor 2735	Tractor 4235	Combine 7720*	Plow 3745	Harrow 32
Aug 80	410	621	1,085	119	186
Aug 81	527	684	2,003	160	196
Aug 82	665	1,110	3,507	217	288
Aug 83	1,722	3,046	12,147	318	481
Aug 84	2,980	5,673	15,172	550	913
Aug 85	4,229	8,017	19,500	956	1,415
May 86	9,680	17,776	50,000	1,606	2,370

*1980,1981 Combine 6620

1982. Tractors up to 140 HP, manufactured in Mexico (with around 50% of imported parts), were in an intermediate situation, with a price variation a little above the general inflation.

Prices of locally manufactured equipment are shown in Table 4.20. The variation factor in price from Sept 81 to May 86 was near the general inflation for a shovel and a disk harrow. The increase of a fertilizer spreader was about half the inflation for the same period (See Table 4.21).

The lower price increase of implements reflected price control regulations of domestic manufactured equipment and/or a low demand for equipment due to lack of money by producers.

4.7.4. Price of Fuel and Wages

During 1985 fuel prices increased 143 %, and for the period of January 86 to August 86 the increase was 83.5%. Monthly variations of fuel price from January 1985 to September 86 are shown in Table 4.22.

Variations of minimum wages were obtained for the period 1976 to 1986. Minumum wages for machinery operators were 46.7% higher than the general wages for farm workers (Table 4.23).

Table 4.20. Price Variation for Implements. Thousand Mexican Pesos.

Date	Offset Disk Harrow	Shovel 10" w/wheels	Fertilizer Spreader
Sept 81	234	83	--
Sept 82	369	150	64
Nov 83	677	283	120
Febr 84	934	290	150
Jun 84	1,120	377	187
Dec 84	1,271	483	178
Febr 85	1,462	537	207
Jun 85	1,571	642	248
Febr 86	2,577	1,192	392
May 86	2,620	1,210	398

Source: Industrias Vazquez. Obregon City, Sonora.

Table 4.21. Inflation and Price Variation for Implements. Sept 81 - May 86.

Concept	Mex $ Sept 81	Mex $ May 86	Factor of Increase
Inflation	100	1,319.3	13.2
Shovel, 10'	83,592	1,210,000	14.5
Offset harrow	234,286	2,620,000	11.2
Fertilizer	64,000	398,000	6.2

Table 4.22. Price of Fuel. January 1985 to September 1986. Mexican $/liter.

Month	1985	1986
January	26.0	63.2
February	32.0	65.5
March	32.8	67.8
April	33.6	70.1
May	34.5	72.6
June	35.3	75.1
July	36.2	77.8
August	37.1	94.2
September	38.0	116.0
October	39.0	--
November	40.0	--
December	50.9	--

Source: Fuel Stations, Texcoco Mexico.

Table 4.23. Minimum Wages per 8-hour Day in Mexican Pesos. Yaqui Valley

Year	General Worker	Farm Worker	Machinery Operator
1976	69	66	97
1977	93	89	137
1978	105	100	147
1979	120	120	176
1980	145	145	213
1981	190	190	279
1982	255	NA	NA
1983	415	NA	NA
1984	625	625	917
1985	975	975	1430
1986	1520	NA	NA

Source: Diarios Oficiales de la Federación.

4.8. DISCUSSION OF RESULTS OF DATA COLLECTION

The needs analysis showed that the ejidatarios, technicians and ejido leaders emphasized the need for training, technical assistance and research in agricultural mechanization. Eighty percent of the answers were positive for training, 80 % for technical assistance, and 93 % for research needs. Machinery management and repair were the topics indicated as more important and urgent.

The data collection process included all information kept by the ejidos, and other resources available for the study. Data on size of ejidos, size of parcels, area seeded and yields were quite accurate, because good records were kept on these items at the ejidos and/or Coalition's offices. Crop production systems and schedules varied within the ejidos (Tables 4.6 to 4.10), but in general the field operations were within the (broad) recommendations of the CAEVY.

Machinery data collection presented some problems due to lack of records kept by the ejidos. The results of field surveys and measurements were used to establish such parameters as operating speeds, field efficiencies, and sizes and prices of equipment. The information obtained was used to formulate rotation files and the external file CONTIL which contained machine and economic parameters. Both files were required by the computer model.

The information on machinery sizes and prices collected in 1985 was limited to the few sizes of machines available from local dealers. The model needed more options to provide greater flexibility of selection. To solve this, it was assumed that machinery could be ordered from other places in Mexico, or imported by local dealers.

Official prices of custom hired operations were obtained and used in the model. Data on prices paid by the ejidos was not considered reliable, because of poor record keeping. The limited data obtained was presented in section 4.4.8. Results of the survey indicated that custom hiring was an option that should be compared with owning the machinery by the ejidos.

Economic parameters included in the model varied with the difficulty of obtaining data and/or reliability. General inflation and parameters related to machinery purchase were readily obtainable and reliable, since official information was available. Cost of labor varied in the ejidos, therefore the most common price paid to machine operators was used for model validation. Prices of machinery fuel and wages were obtained for the previous two to ten years. Since there was no clear pattern of price changes, and it was difficult to predict any trend in price increases, zero inflation of fuel, machinery and wages were used in the model validation.

4.9. DATA USED IN THE COMPUTER MODEL

Agronomic, economic and agricultural machinery operational data collected; in the collective ejidos, and/or from machinery dealers, Coalition's office and government offices, were used to formulate values for the parameters in the input data files, or in the data block of the computer program.

Sizes and prices of agricultural machines for the Yaqui Valley replaced values for Michigan in the original computer program and/or in the machinery data file. Price for machinery were obtained from agricultural machinery dealers.

Timeliness costs for planting and harvesting of wheat, soybeans and cotton were calculated from crop yields and crop values, according to information from the Experiment Station in the Yaqui Valley (Table 3.16). Prices of crops for 1985 were obtained from Coalition. Timeliness cost occurs when a machine is not capable of doing the job on the optimum crop yield period (Figures 3.2 and 3.3).

Operation speeds and field efficiencies of machines were estimated from measurements made in the collective ejidos, and used in the machinery data file. Maximum widths of machines sold by dealers in the Yaqui Valley were also used in the machinery data file.

Data obtained on repair, resale value of machines and draft forces were not sufficient and/or reliable. Therefore, the values for Michigan and already in the model were used for this study. The usable life of machinery was assumed to be 10 years. Most machinery purchased by the ejidos ten years ago was still in use, so ten years would be a minimum. running. Dealers also indicated an average duration of 10 years for machinery owned by ejidos.

Suitable days for field operations were calculated from daily rainfall records (Section 5.3.1.3.) because there were no records kept by ejidos. Machinery file data on suitable hours machinery file depended on the hours per days for different field operations. Length of working days varied on the ejidos, therefore an average was estimated from the results of the surveys, as follows:

Tillage Operations: 12 hours/day.

Seeding, Cultivation and Spraying: 10 hours/day.

Harvesting: 8 hours/day.

Average wages for machinery operators in collective ejidos, and the price of fuel for 1985 were used in the model. Tax, insurance and shelter costs were assumed to be 1% of the price of new equipment, same as was already in the model, because no specific data for the Yaqui Valley were obtained.

Income tax, discount rates, and inflation rates were assumed to be zero. The ejidos do not pay income taxes, and the costs of wages, fuel and machinery were fixed by the government according to the general inflation rate. A low interest rate (1%) was assumed in the model reflecting the conditions for most ejidos that obtained subsidized credit loans for machinery purchases. For those loans, a zero downpayment with 5 years to pay were used, according to information given by the Credit Union of Coalition for the last 7 years.

The recommended dates for planting and harvesting, as recommended by the Experiment Station of the Yaqui Valley, were used to set up the crop rotation files. The five most representative rotations (including wheat, soybean and cotton) and used by the ejidos were included in the rotation files. Sequence of field operations and number of passes correspond to those obtained from the surveys of the collective ejidos.

CHAPTER 5

DESCRIPTION OF THE MODEL AND ASSOCIATED FILES

5.1. MACHINERY SELECTION MODEL

The machinery selection model (MACHSEL) was developed by Muhtar (1982), as an extension of work by Wolak (1981). It is a heuristic model designed to provide the most economic machinery complement. The program was intended for interactive use or with computer cards.

Rotz et al. (1983), and Rotz & Black (1985) developed modifications and further validation of the model. Minimum capacity for each machine was calculated based upon the operations required, the area to be covered, and time constraints for the operation. Minimum capacities needed to complete all field operations within the time available were determined first. Tractor sizes were determined based upon maximum power requirements for implements. Row machines were matched i.e, the size of the planter, row cultivator and ammonia application were set either equal or double the size of the combine. Figure 5.1. shows the flow diagram of the modified program MACHSEL.

After the first set of machines and associated costs were determined, a check was made to determine if a lower cost set of machines could be determined. Implements or combine sizes were increased and the entire process was repeated.

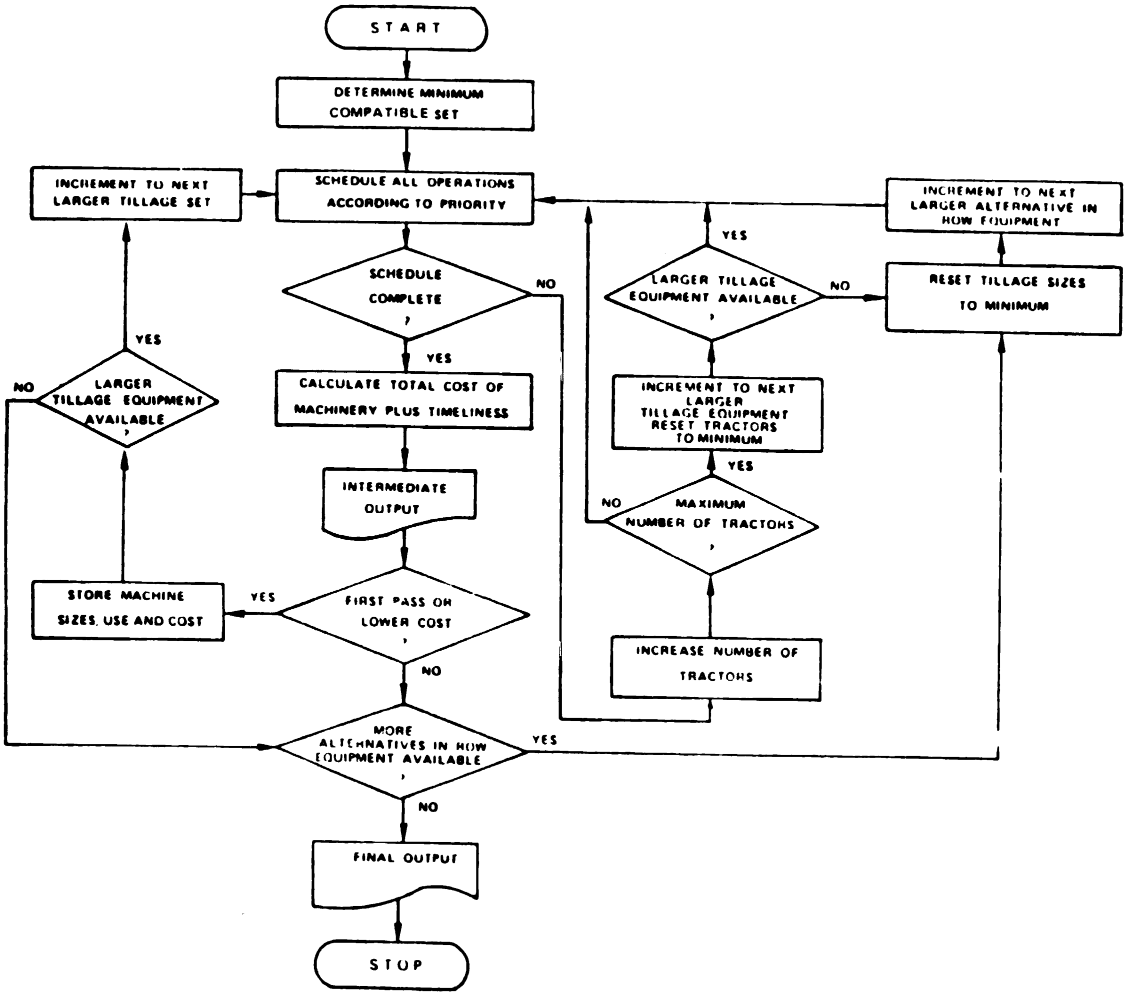


Figure 5.1. Flow Chart of Modified Program MACHSEL

5.2. MICROCOMPUTER VERSION OF MACHSEL

A microcomputer version of MACHSEL was developed by Rotz in March of 1986. The program was compiled in Lahey, F77L version of Fortran.

Data required by the model were stored in six input files. Two files contained machinery data and suitable hours for field work, for conventional and no tillage systems. The other four files contained operation sequences for four tillage methods and 12 crop rotations.

The microcomputer version of MACHSEL was validated, as a part of this study, to select best machinery sets for wheat, soybean and cotton production in the Yaqui Valley, state of Sonora in Northwest Mexico.

Modifications in the computer program and input data files were required for the adaptation of MACHSEL to this study. Timeliness costs for wheat, soybeans and cotton (Table 3.16) and sizes of machines replaced Michigan data in the computer program. The machines included in this model were those; currently available in the Yaqui Valley, available by order from other locations in Mexico, or could be imported. The list of machines and sizes considered are shown in Table 5.1. Row machines varied in size from 2 to 12 rows, except for sprayers that could be up to 24 rows in width.

Subroutines; IMPSEL for selection of a minimum set of machines, and IMPINC for incrementation of machine sizes

Table 5.1. Equipment and Sizes Used for Wheat, Soybean and Cotton Production in the Yaqui Valley.

Code	Equipment	Unit	Sizes
1	Combine	row	4,6,8,12
2	Cotton Picker	row	2
3	Self Prop. Sprayer	row	8,12,26,24
4	Stalk Cutter	ft.	6,7
5	Cultipacker	ft.	10,12,15,18
6	Subsoiler	ft.	4,6,8,10,12,15
7	Fertilizers	ft.	20,30,40
8	Land Plane	ft.	10,12,14,15,18
9	Disk Plow	disk	2,3,5,6,7,9
10	Disk Harrow	ft.	5.3,7,8,11,12.5,15.5, 18,22.5
11	Offset Harrow	ft.	5.3,8,11,12.5,13.5, 15.5,17.5
12	Wood Frame	ft.	8,10,12,14,15
13	Grain Drill	ft.	8,12,14,16,20,24
14	Row Planter	row	2,3,4,6,8,12
15	Furrower	row	2,3,4,6,8,12
16	Sprayer	row	4,6,8,12,16,24
17	Row-cultivator	row	2,3,4,6,8,12

Source: Machinery dealers, Ciudad Obregón, Sonora.

were slightly modified, for different sets of machines considered. For example; the size equalization of beet toppers with beet lifters, and combine headers with bean pullers were canceled, because these machines were not used in the Yaqui Valley. Cotton pickers, self-propelled sprayers, stalk cutters and cultipackers replaced bean pullers, mower-conditioners, beet toppers and beet lifters. For tillage; land planes and wood frames, replaced chisel plows and field cultivator, and furrowers replaced min-till planters.

Ten selected combinations of row-equipment were considered in the model. An eleventh alternative in the original MACHSEL was not included because it contained a 24-row planter, which was assumed not a realistic option in in the Yaqui Valley.

5.3. INPUT DATA FILES

Agronomic, economic and machinery data, presented in Chapter 4, were used to validate the model for the conditions of the Yaqui Valley. Three input data files were set up: One, was a machinery data file, CONTIL. Two, was a rotation file COVEN, for conventional tillage. Three, was a rotational file REDUC, for reduced tillage.

5.3.1. Machinery Data Files

The Machinery file CONTIL contains machinery and economic parameters, and suitable hours for field operations. The detailed content of the file CONTIL is presented in the User's Guide for the model (Appendix C).

Input data for machinery parameters were obtained from direct measurements, secondary data or estimations (speed, efficiencies, price of equipment and custom-hire). Parameters for power requirements, repair and resale values were assumed to be equal to those used in the original model.

Economic parameters included cost of fuel and labor along with the relative inflation for machinery, labor and fuel. Values for these parameters were those in effect in 1985 in the Yaqui Valley or in the collective ejidos. Interest was assumed at 1%, because no real interest was charged to machinery. In fact, real interest was negative, because credit was subsidized for ejidos at a rate below the inflation. The periods for payment of loan on machinery purchases were 5 years, with zero down payment.

Time available for field work was calculated based on records of daily rainfall, and the hours per day for specific field operations in the ejidos (Table 4.12, Chapter 4).

A new computer program was developed to calculate suitable climatic days per week, based on 26 year records of daily rainfall. The flow chart of the computer program is presented in Figure 5.2.

Relationships for estimation of non-suitable climatic days were developed with the assistance of Francisco López Lugo of CIMMYT, Mexico; field personnel of CAEVY and consultation with researchers of CAEVY and CIMMYT. Two predominant soil types of clay and loam were considered.

The procedure for determination of non-suitable climatic days for specific operations was based on the following criteria:

a) Maximum precipitation that allows machinery to operate in the field (Table 5.2.)

b) Range of daily rainfall that impedes the operation of machinery in the field the same day (Table 5.2.).

c) Empirical relationship between daily rainfall and non-suitable days when rainfall exceded the limit in point b) (Table 5.3. and Table 5.4.).

d) Maximum non-suitable days that can occur due to heavy rains during one day, or continous rain periods. These periods were obtained from the 26-year record of daily precipitation (Table 5.5.).

The computer program consisted of various steps. First, a file RAINFIL was formulated which contains daily rainfall in millimeters, along with the day it occurred for the years 1960 through 1985. Second, the file RAINFIL was used to calculate non-suitable days for each week, during 26 years. An intermediate file DAYSPWK was created for

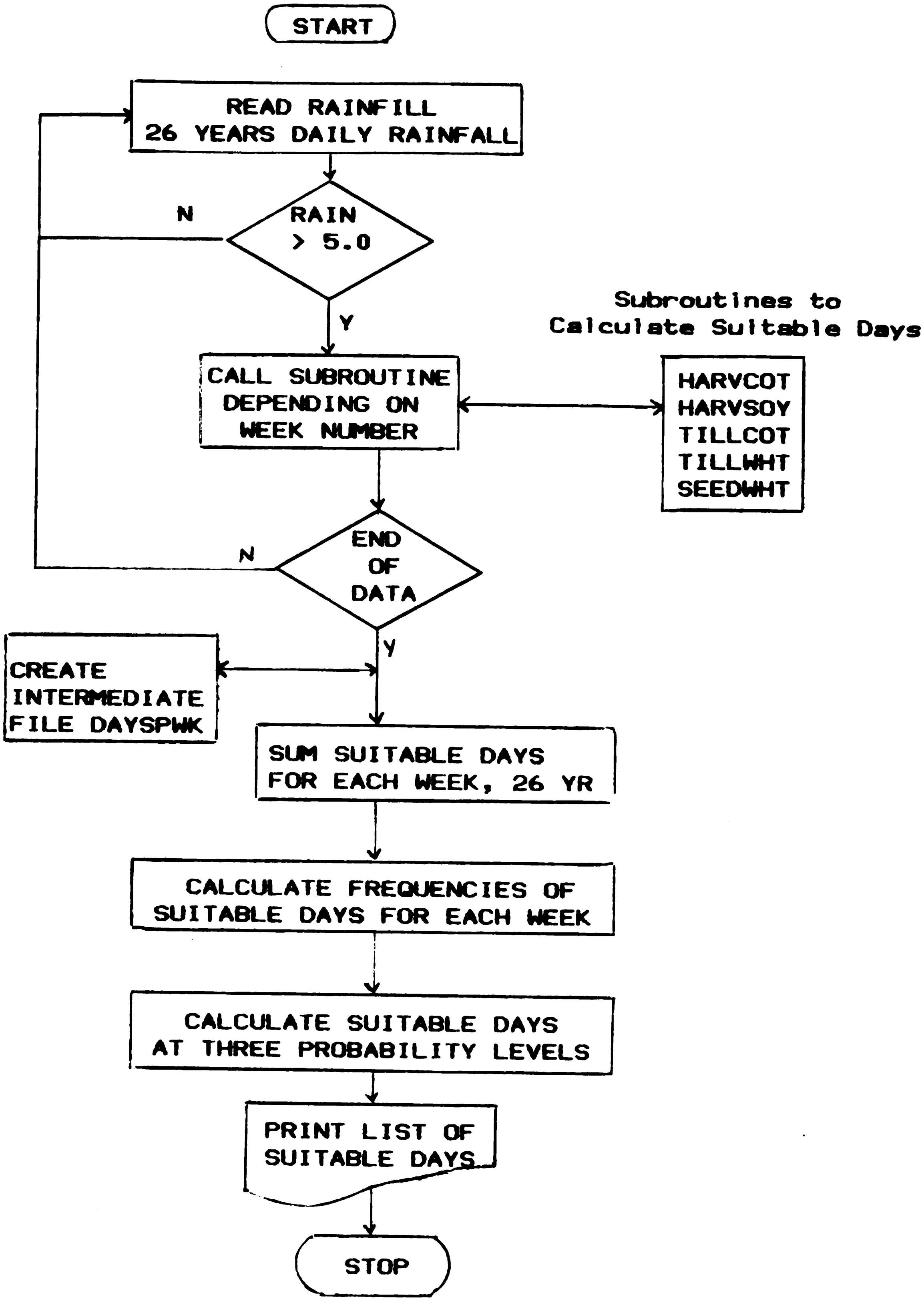


Figure 5.2. Flow Chart for Suitable Days Program.

Table 5.2. Non-Suitable Days as Determined by Daily Precipitation.

	Clay		Loam	
WHEAT	A[1] mm	B[2] mm	A mm	B mm
Spraying(Jan)	< 5	6-8	< 6	7-9
Tillage(Oct-Nov)	< 5	6-8	< 8	9-12
Seeding(Nov-Dic)	< 6	6-12	< 10	11-15
SOYBEAN				
Row-Cultivator (Jun-Aug)	< 8	9-15	< 10	11-15
Harvest(Sep-Oct)	< 5	6-19	< 8	9-12
COTTON				
Tillage(Jan-Feb)	< 5	6-8	< 7	8-10
Cotton Picker (Jun-Aug)	< 8	9-10	< 10	11-15

[1] A: Maximum rainfall(mm) that does not affect the operation the same day.

[2] B: Range of rainfall that impedes the machine if it enters the field the same day of rain.

Source: Francisco López Lugo, CIMMYT, México. Personal Communication.

Table 5.3. Number or Non-Suitable Work Days Caused by a One-Day Rain for Clay Soil.

WHEAT	Relationship between precipitation and number of non-suitable days.							
Spraying(Jan)	mm[1]	10	12	14	17	21	25	
	days[1]	2	3	4	5	6	7	
Tillage(Oct-Nov)	mm	8	10	12	14	16	18	20
	days	1	3	4	4	5	5	6
Seeding(Nov-Dec)	mm	15	20	23	25	27	29	30
	days	2	3	4	5	6	7	8
SOYBEAN								
Row-Cultivator (Jun-Jul-Aug)	mm	17	20	23	25	27	29	30
	days	2	3	4	5	6	7	8
Harvest(Sep-Oct)	mm	13	16	19	22	26		
	days	2	3	4	5	6		
COTTON								
Tillage(Jan-Feb)	mm	10	12	14	16	18	20	
	days	2	3	4	5	6	7	
Harvest(Jul-Aug)	mm	14	17	20	24	28		
	days	2	3	4	5	6		

---

[1] Precipitation in a single day, mm

[2] Non-suitable days due to above rainfall.

Source: Francisco Lopez-Lugo, CYMMYT, Mexico. Personal communication.

Table 5.4. Number of Non-Suitable Work Days Caused by a One-Day Rain for Loam Soil.

WHEAT	Relationship Between precipitation and non-suitable days.					
Spraying(Jan)	mm[1]	12	16	20	24	28
	days[1]	2	3	4	5	6
Tillage(Oct-Nov)	mm	14	17	20	24	28
	days	2	3	4	5	6
Seeding(Nov-Dec)	mm	18	22	26	30	34
	days	2	3	4	5	6
SOYBEAN						
Row-Cultivator (Jun-Jul-Aug)	mm	20	24	28	32	36
	days	3	4	5	6	7
Harvest(Sep-Oct)	mm	17	20	24	28	32
	days	3	4	5	6	7
COTTON						
Tillage(Jan-Feb)	mm	14	17	20	23	26
	days	2	3	4	5	6
Harvest(Jul-Aug)	mm	17	22	26	30	35
	days	2	3	4	5	6

---

[1] Precipitation in a single day, mm

[2] Non-suitable days due to above rainfall.

Source: Francisco Lopez-Lugo, CYMMYT, Mexico.
Personal Communication.

Table 5.5. Maximum Delay(days) Due to Heavy Rains During Two or More Days.

Month	Operation	Rainfall mm.	Type of Soil	
			Clay	Loam
January	Tillage (cotton)	89	30	25
	Spraying	89	30	25
July	Cultivation (soybean)	90	27	24
	Cotton Picking	90	29	26
August	Cotton Picking	140	35-40	30-35
September	Tillage	70	27-31	24-28
	Soybean Harvest	70	26-30	22-26
October	Tillage	105	25-30	21-24
November	Tillage and Seeding Wheat	120	30-35	25-30
December	Tillage and Seeding Wheat	65	24-27	20-23

Source: Francisco Lopez Lugo. CIMMYT, Mexico. Personal communication.

determining suitable days per week for each year. Fourth, after analyzing file DAYSPWK and checking with the real data, suitable days for clay and loam soil, at 0.8, 0.7 and 0.5 probability levels were determined, using cumulative distribution functions for the 26 years for each calendar week (Shown in Table 5.6.).

To obtain suitable climatic hours per week, the suitable days were multiplied by the number of hour per day for specific periods. The main operations at different time periods were considered in assigning hours per day to a given week. Hours per day were based on results presented in Chapter 4, Section 4.4.4. Suitable hours per week, for clay and loam soil, at 0.8,0.7 and 0.5% probability level are shown in Appendix C.

5.3.2. Rotation Files

Crop rotation files contain sequences and calendar dates within which an operation should be completed. Two tillage systems, with 5 rotations each were designed for this study. These files were:

COVEN, for conventional tillage system.

REDUC, for reduced tillage system.

The content of the two rotations files used for validation of the model are described and shown in the User's Guide (Appendix C).

The tillage systems were prepared, based on data collected in the Yaqui Valley and presented in Chapter 4. The conventional tillage system is commonly used in the

Table 5.6. Suitable Days Each Week of the Year at Three Probability Levels for Clay and Loam Soil. Yaqui Valley

WEEK[1]	Type of Soil					
	Loam Soil			Clay Soil		
	80%	70%	50%	80%	70%	50%
1	6.2	7.0	7.0	5.2	7.0	7.0
2	7.0	7.0	7.0	6.7	7.0	7.0
3	7.0	7.0	7.0	6.1	6.9	7.0
4	7.0	7.0	7.0	5.2	7.0	7.0
5	4.7	7.0	7.0	3.2	7.0	7.0
6	7.0	7.0	7.0	6.6	7.0	7.0
7	7.0	7.0	7.0	7.0	7.0	7.0
8	7.0	7.0	7.0	7.0	7.0	7.0
9	7.0	7.0	7.0	7.0	7.0	7.0
10	7.0	7.0	7.0	7.0	7.0	7.0
11	7.0	7.0	7.0	7.0	7.0	7.0
12	7.0	7.0	7.0	7.0	7.0	7.0
13	7.0	7.0	7.0	7.0	7.0	7.0
14	7.0	7.0	7.0	7.0	7.0	7.0
15	7.0	7.0	7.0	7.0	7.0	7.0
16	7.0	7.0	7.0	7.0	7.0	7.0
17	7.0	7.0	7.0	7.0	7.0	7.0
18	7.0	7.0	7.0	7.0	7.0	7.0
19	7.0	7.0	7.0	7.0	7.0	7.0
20	7.0	7.0	7.0	7.0	7.0	7.0
21	7.0	7.0	7.0	7.0	7.0	7.0
22	7.0	7.0	7.0	7.0	7.0	7.0
23	7.0	7.0	7.0	7.0	7.0	7.0
24	7.0	7.0	7.0	7.0	7.0	7.0
25	7.0	7.0	7.0	7.0	7.0	7.0
26	7.0	7.0	7.0	7.0	7.0	7.0
27	6.1	6.9	7.0	6.1	6.9	7.0
28	5.1	5.9	7.0	5.1	5.9	7.0
29	4.2	6.2	7.0	4.2	6.1	6.9
30	1.2	3.4	6.3	1.2	3.4	6.3
31	1.6	3.8	4.7	1.1	2.4	4.4
32	2.7	3.9	5.3	2.0	2.7	5.0
33	0.9	3.8	6.0	0.7	3.3	5.7
34	5.0	5.7	6.8	4.1	5.3	6.8
35	3.4	5.3	7.0	2.7	3.9	7.0
36	2.1	3.4	6.2	1.2	2.9	6.2
37	0.6	0.9	4.5	0.5	0.7	4.5
38	2.6	4.9	6.6	1.2	2.4	5.0
39	4.1	4.9	7.0	1.2	4.3	6.0
40	4.2	6.3	7.0	4.1	5.4	7.0

Table 5.6. (Cont'd)

WEEK[1]	Type of Soil					
	Loam Soil			Clay Soil		
	80%	70%	50%	80%	70%	50%
41	5.2	6.9	7.0	3.2	6.4	7.0
42	5.2	7.0	7.0	3.7	6.8	7.0
43	6.6	7.0	7.0	6.2	7.0	7.0
44	7.0	7.0	7.0	7.0	7.0	7.0
45	7.0	7.0	7.0	3.6	7.0	7.0
46	7.0	7.0	7.0	5.6	6.9	7.0
47	7.0	7.0	7.0	6.2	7.0	7.0
48	7.0	7.0	7.0	6.6	7.0	7.0
49	7.0	7.0	7.0	7.0	7.0	7.0
50	7.0	7.0	7.0	6.6	7.0	7.0
51	7.0	7.0	7.0	7.0	7.0	7.0
52	6.7	7.0	7.0	6.3	6.9	7.0

[1] Weeks or year beginning January 1.

ejidos, based on recommendation of CAEVY and the Technical Assistance Area of Coalition. Reduced tillage was an alternative system which does not include subsoiling and/or disk plowing. Disk harrow, furrower and land leveling are reduced by one or two passes each. It was designed based on field experiments carried out at CAEVY. Dates for operations are based on results of survey on 15 ejidos, and information from the CAEVY. Tables 5.7, 5.8. and 5.9. show the list of operations and recommended dates.

5.4. MODEL ASSUMPTIONS

The following assumptions were made for the model analysis:

-Size of ejidos between 100 to 1200 hectares.

-Economic assumption: Zero real relative inflation for machinery, fuel, and wages was considered. Credit for purchasing machinery was 1%.

-Prices and costs in the computer model are in thousand Mexican pesos for the period May-August 1985, when the major part of economic information was obtained (Exchange rate at that time was about 250 pesos per dollar).

Two type of tractors were considered in the model:

1) Primary or tillage tractors were assigned to disk plowing, disk harrowing, land plane and subsoiling. Minimum size assumed was 37 kw.

2) Utility or secondary tractor were assigned to planting,

Table 5.7. Recommended Dates for Wheat After Soybean Field Operations.

Code	Machine Operation	Date Range Initial-Final	Week Number Initial-Final
1	Combine Soybean[1]	9/20-10/15	38-41
6	Subsoiler	10/01-10/30	40-44
9	Disk Plow	10/15-11/30	42-48
11	Disk Harrow	10/15-11/30	42-48
11	Disk Harrow	10/15-11/30	42-48
8	Land Plane	10/15-11/30	42-48
7	Fertilizer Applic.	10/20-11/30	43-48
10	Disk Harrow	10/20-11/30	43-48
12	Wood Frame	10/25-11/30	44-48
13	Seeding[2]	11/14-12/15	46-50
15	Furrowing	11/15-12/15	47-50
16	Ground Spraying	01/07-01/30	2-4

[1] Optimum date for combine soybeans: weeks 38-39.

[2] Optimum date for seeding: weeks 47-50. Seeding was assumed on Dec. 1.

Source: Centro Agricola Experimental del Valle del Yaqui.

Table 5.8. Recommended Dates for Soybean After Wheat Field Operation.

Code	Machine Operation	Date Range Initial-Final	Week Number Initial-Final
1	Combine Wheat[1]	4/15-5/30	16-21
11	Disk Harrow	4/20-5/31	17-22
12	Wood Frame	4/20-5/31	17-22
7	Fertilizer Applic	4/20-5/31	17-22
10	Disk Harrow	4/20-5/31	17-22
15	Furrowing	4/20-5/01	17-22
15	Furrowing	4/30-6/14	18-23
14	Planting[2]	5/01-6/15	18-24
5	Cultipacker	5/15-6/30	20-26
15	Furrower	6/05-7/10	23-28
17	Row-Cultivator	6/20-7/25	25-29
15	Furrower	7/10-8/15	28-33
17	Row-Cultivator		

[1] Optimum date for combine wheat: weeks 16-18.

[2] Optimum date for planting: weeks 18-22.

Source: Centro Agricola Experimental del Valle del Yaqui.

Table 5.9. Recommended Dates for Field Operation for Cotton Production After Soybean.

Code	Machine Operation	Date Range Initial-Final	Week Number Initial-Final
1	Harvest Soybean	9/20-10/15	38-41
6	Subsoil	1/01-2/15	1-76
9	Disk Plow	1/01-2/15	1-7
11	Offset Harrow	1/01-2/15	1-7
11	Offset Harrow	1/15-3/04	3-9
8	Land Plane	1/15-3/04	3-9
7	Fertilizer Applic.	1/22-3/04	4-9
10	Disk Harrow	1/20-3/04	4-9
15	Furrowing	2/04-3/04	6-9
15	Furrowing	2/14-3/14	7-10
14	Planting	2/15-3/15	8-12
17	Row-Cultivator	4/05-5/05	14-18
15	Furrowing	4/05-5/05	14-18
17	Row-cultivator	5/01-6/01	18-22
15	Furrowing	5/01-6/01	18-22
17	Row-cultivator	5/11-6/15	20-24
16	Ground Spraying	3/01-4/01	10-13
2	Harvest Cotton	7/20-8/30	30-35
4	Rotary Shredder	8/01-9/30	31-39

Sources: Centro Agrícola Experimental del Valle del Yaqui.
Survey on Collective Ejidos.

furrowing row cultivation, spraying, wood framing and stalk cutting. Minimum size for utility tractors was 22 kw.

CHAPTER 6

MODEL VALIDATION

Two types of analysis were made for the validation of the model for the conditions of the Yaqui Valley. The first analysis pertained to the sensitivity of the model. This was to verify that the model responded reasonably to changes in major parameters. Secondly, machinery sets selected by the model were compared with selected actual machinery sets in representative sizes of ejidos.

6.1. SENSITIVITY ANALYSIS

Specific hypotheses for main parameters were formulated for validation of the model, based on practical experience or previous studies.

Ejidos sizes of 300, 600 and 1,200 hectares were chosen as representatives of small, medium and large ejidos. The wheat-soybean crop rotation was most popular in the ejidos, so it was used for validation. Conventional tillage on clay and loam soils were considered in the validation of the wheat-soybean rotation in the model.

6.1.1. Probability of Suitable Weather.

Hypothesis: Use of a lower probability level for suitable weather will allow more available days smaller for field operations and decrease the machinery requirement.

Three probability levels for suitable weather were compared: 0.8, 0.7 and 0.5. An 0.8 probability level means that the ejidatarios could expect these results in 8 out of 10 years.

Tables 6.1 to 6.3 present results of computer model runs for 300 and 600 hectares of the wheat-soybean rotation on clay soil. As was expected the model selected larger machines at 0.8 level. As the probability level decreased, there was more time available for a given operation, so the model selected fewer and/or smaller tractors and machines. Timeliness cost decreased as probability level changed from 0.8 to 0.7, and was zero at 0.5 level for all example runs, because the model allowed more time to complete operations within the optimum dates.

For 300 hectares of wheat-soybean rotation with conventional tillage, the model selected the same utility tractors, combines, fertilizer spreaders, wood frames and row equipment at 0.8 and 0.7 levels. Other machines were larger at 0.8 level (Table 6.1)

The model selected the same machinery set at 0.8 and 0.7 level for 300 hectares of W-S, with reduced tillage on clay soil (Table 6.2). The set selected at 0.5 level was smaller, and had zero timeliness cost, resulting in a 28% and 10% reduction in total cost, with respect to 0.8 and 0.7 levels.

Table 6.1. Machinery Selection for Three Levels of Probability for Suitable Weather for 300 Ha Wheat-Soybean Rotation with Conventional Tillage on Clay Soil.

	Probability of Suitable Weather					
	0.8		0.7		0.5	
Machines	Size[1]	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	2*96	316	2*84	364	119	547
Utility Tractor (kw)	2*57	313	2*57	318	45	681
Combine (row)	8	163	8	163	6	217
Fertilizer Spreader (m)	9.1	58	9.1	58	12.2	44
Land Plane (m)	3.7	85	3.7	85	4.3	73
Wood Frame (m)	3.0	191	3.0	191	3.7	159
Disk Plow (disk)	2*5	195	2*4	119	6	159
Disk Harrow (m)	3.8	128	3.4	145	4.7	103
Offset Harrow (m)	3.8	229	3.4	260	4.1	212
Grain Drill (m)	4.3	56	3.7	65	4.9	49
Row Planter (row)	8	43	8	43	6	57
Furrower (row)	8	153	8	153	6	204
Sprayer (row)	16	24	16	24	12	31
Row-cultivator (row)	8	103	8	103	6	138
Cost $/ha						
Machinery	23.53		22.84		19.99	
Fuel	8.56		8.60		8.64	
Labor	1.56		1.68		1.59	
Timeliness	8.57		2.11		0.00	
Total	42.23		35.23		30.22	

---

[1] Number and size indicated. For example 2*57 means 2 tractors of 57 kw. each.

Table 6.2. Machinery Selection for Three Levels of Probability for Suitable Weather for 300 Ha Wheat-Soybean Rotation with Reduced Tillage on Clay Soil.

	Probability of Suitable Weather					
	0.8		0.7		0.5	
Machines	Size[1]	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	84.7	331	84.7	331	96.2	301
Utility Tractor (kw)	57.3	407	57.3	407	43	492
Combine (row)	8	163	8	163	6	217
Fertilizer Spreader (m)	9.1	58	9.1	58	9.1	58
Land Plane (m)	3.7	85	3.7	85	3.7	85
Disk Harrow (m)	3.4	73	3.4	73	3.8	64
Offset Harrow (m)	3.4	173	3.4	173	3.8	153
Grain Drill (m)	3.7	65	3.7	65	4.3	56
Row Planter (row)	8	43	8	43	6	57
Furrower (row)	8	115	8	115	6	153
Sprayer (row)	16	24	16	24	12	31
Row-cultivator (row)	8	103	8	103	6	138
Cost $/ha						
Machinery	18.11		18.11		17.11	
Fuel	5.53		5.53		5.66	
Labor	0.99		0.99		1.11	
Timeliness	8.57		2.11		0.00	
Total	33.20		26.74		23.88	

---

[1] Number and size indicated. For example 2*57 means 2 tractors of 57 kw each.

Comparisons for a 600 hectares ejido resulted in larger number and/or size of machines selected at 0.8 level than the equipment selected at 0.7 and 0.5 levels (Table 6.3). A timeliness cost factor was present at the 0.7 probability level, while it was zero at 0.5 level. It doubled between the 0.7 and 0.8 probability levels.

The results presented confirm the hypothesis for the parameter that a lower probability level allows more available time and decrease the machinery requirements.

6.1.2 Ejido Size

Hypothesis: As the size of ejidos increase the efficiency of machinery use increases thus reducing costs.

Various ejido sizes were compared under different conditions. A summary of the total costs for machinery sets selected at 0.8 probability level for a wheat-soybean rotation is presented in Table 6.4. Two tillage systems, on clay and loam soils were compared. The following relationships were found: a) The total cost machinery cost/ha decreased as the crop area increased for clay soil, while for loam soil the total cost/ha decreased from 150 to 600 hectares, but increased from 600 ha to 1,200 hectares. b) The machinery costs for reduced tillage were lower than for conventional tillage. And c) machinery sets for clay soil had greater cost than for loam soils. Details of these comparisons follow.

Table 6.3. Machinery Selection for Three Probability Levels for Suitable Weather for 600 Ha Wheat-Soybean Rotation with Conventional Tillage on Clay Soil.

	Probability of Suitable Weather					
	0.8		0.7		0.5	
Machines	Size[1]	Hrs	Size	Hrs	Size	Hrs
Primary Tractors (kw)	3*119	365	2*119	547	2*119	547
Utility Tractor (kw)	2*57	574	48	682	2*48	682
Combine (row)	2*8	163	2*6	217	2*6	217
Fertilizer Spreader (m)	12.2	87	12.2	87	12.2	87
Land Plane (m)	2*4.3	73	4.3	146	4.3	146
Wood Frame (m)	2*3.7	159	2*3.7	159	2*3.7	159
Disk Plow (disk)	3*6	106	2*6	159	2*6	159
Disk Harrow (m)	4.7	205	4.7	206	4.7	206
Offset Harrow (m)	2*4.1	212	2*4.1	212	2*4.1	212
Grain Drill (m)	4.9	98	4.9	98	4.9	98
Row Planter (row)	8	86	6	114	6	114
Furrower (row)	8	306	6	408	6	408
Sprayer (row)	16	47	12	63	12	63
Row-cultivator (row)	8	207	6	275	6	275
Cost $/ha						
Machinery	21.72		19.21		19.21	
Fuel	8.56		8.66		8.66	
Labor	1.41		1.59		1.59	
Timeliness	8.59		4.81		0.00	
Total	40.28		34.26		29.45	

---

[1] Number and size indicated. For example 2*57 means two tractors of 57 tractors of 57 kw each.

Table 6.4. Effect of Size, Soil Type and Tillage System Upon Machinery Cost (Thousand Mex. $) for Wheat-Soybean Rotation at 0.8 Probability Level.

Ejido Size (Ha)	Type of Tillage			
	Conventional		Reduced	
	Clay	Loam	Clay	Loam
150	43.97	34.52	37.00	28.66
300	42.23	34.30	33.20	26.16
600	40.28	31.78	32.64	25.29
900	39.93	32.24	32.16	25.32
1200	40.06	33.32	31.89	26.45

Machinery sets selected for four ejido sizes and their costs, for conventional and reduced tillage, are shown in Tables 6.5 and 6.6. For conventional tillage the cost per hectare was higher for 150 hectare ejido, and decreased for a 300 and 600 hectare ejido. No important cost variation resulted from increasing the size from 600 to 1,200 hectares. There was no constant increment between ejido size and number and size of machines selected, i.e, doubling the area in most cases did not result in doubling machines sizes or capacity. Depending on the operations and time available, the model increased the number of machines or incremented the size thus, changing the annual use of machines. For conventional tillage where there are more time constraints, the larger ejidos had more flexibility (more options) for selecting different combinations of size and number of machines, resulting in less machinery cost.

The results presented in this section, in general confirm the hypothesis for this parameter; although machinery reductions due to increased size were not great nor always consistant.

6.1.3. Rotations.

Hypothesis: a) The inclusion of more crops in a rotation will increase machinery efficiency and lower costs.

b) Rotations that include crops with a high demand for field operations (for

Table 6.5. Machinery Selected for four Ejido Sizes for Wheat-Soybean Rotation, with Conventional Tillage, on Clay Soil, at 0.8 Probability Level.

	Size of Ejido in Hectars							
	150		300		600		1200	
Machines	Size[1]	Hours	Size	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	56	567	2*96	316	3*119	365	7*96	362
Utility Tractor (kw)	40	624	2*57	313	2*57	574	5*43	588
Combine (row)	6	116	8	163	2*8	163	6*6	145
Fertilizer Spreader (m)	6.1	44	9.1	58	12.2	87	9.1	233
Land Plane (m)	3	51	3.7	85	2*4.3	73	3*3.7	113
Wood Frame (m)	2.4	119	3.0	191	2*3.7	159	4*3.0	191
Disk Plow (disk)	5	95	2*5	95	3*6	106	7*5	109
Disk Harrow (m)	1.6	151	3.8	128	4.7	206	3*3.8	171
Offset Harrow (m)	1.6	270	3.8	299	2*4.1	212	3*3.8	306
Grain Drill (m)	2.4	49	4.3	56	4.9	98	2*4.3	112
Row Planter (row)	6	31	8	43	8	86	2*6	114
Furrower (row)	3	218	8	153	8	306	3*6	272
Sprayer (row)	12	17	16	24	16	47	12	125
Row-cultivator (row)	3	147	8	103	2	207	3*6	184
Cost $/ha								
Machinery	25.01		23.53		21.72		21.64	
Fuel	9.21		8.56		8.56		8.61	
Labor	2.88		1.56		1.41		1.74	
Timeliness	6.87		8.57		8.59		8.06	
Total	43.97		42.23		40.28		40.06	

---

[1] Number and size indicated. For example 2*57 means 2 tractors of 57 kw each.

Table 6.6. Machinery Selected for Four Ejido Sizes for Wheat-Soybean Rotation, with Reduced Tillage, on Clay Soil, at 0.8 Probability Level.

	Size of Ejido in Hectars							
	150		300		600		1200	
Machines	Size[1]	Hours	Size	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	54	244	84.7	331	2*119	267	3*96.2	402
Utility Tractor (kw)	43	282	57	407	57	754	2*86	607
Combine (row)	6	109	8	163	2*8	163	3*12	145
Fertilizer Spreader (m)	6	44	9.1	58	12	87	9.1	233
Land Plane (m)	3	51	3.7	85	4.3	146	3.7	113
Disk Harrow (m)	2.1	57	3.4	73	4.7	103	2*3.8	128
Offset Harrow (m)	2.1	136	3.4	173	2*4.1	141	3*3.8	204
Grain Drill (m)	2.4	49	3.7	65	4.9	98	2*4.3	112
Row Planter (row)	6	29	8	43	8	85	12	114
Furrower (row)	6	76	8	115	8	229	12	306
Sprayer (row)	12	16	16	24	16	47	24	63
Row-cultivator (row)	6	69	8	103	8	206	2*12	138
Cost $/ha								
Machinery	23.46		18.11		17.60		17.57	
Fuel	5.70		5.53		5.56		5.48	
Labor	1.40		0.99		0.89		0.79	
Timeliness	6.44		8.57		8.59		8.06	
Total	37.00		33.20		32.64		31.89	

---

[1] Number and size indicated. For example 2*57 means 2 tractors of 57 kw each.

example cotton) will require larger and more machinery.

Tables 6.7 and 6.8 show the results of simulation for 5 rotations used in the region, including wheat (W), soybean (S) and cotton (C). The rotations including cotton required additional machinery such as cotton picker and stalk cutter, and resulted in higher cost/ha than the rotations without cotton.

For 300 and 600 hectares the cost for W-S-C rotation was 25% higher than the cost for W-S, and 16.5% (300 ha) and 13% (600 ha) higher than W-W-S-C rotation.

The Wheat-Wheat and W-W-S were the less expensive rotations. Cotton and soybeans require more machinery and fuel. Timelines cost varied between rotation, being higher for rotations including cotton and soybean. Rains during cotton and soybean harvest seasons were responsibles for increased timeliness cost. Notice the zero timeliness for W-W rotation, due to no rains during the harvest season.

The model selected more tillage tractors, with less hours of use, for rotations with two parcels (W-S, W-W). The machinery sets selected for rotations with 3 or 4 parcels included less tractors, with more hours of use. The same tendency could be observed for utility tractors, cotton pickers and disk plow.

The validation results further confirm the hypothesis that more crops in a rotation lower costs with the exception of a high demand crop such as cotton.

Table 6.7. Machinery Selected for Five Crop Rotations for 300 Ha at 0.8 Prob. Level, Using Conventional Tillage on Clay Soil.

	Rotations									
	W-S		W-S-C		W-W		W-W-S		W-W-S-C	
Machines	Size	Hours	Size	Hours	Size	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	2*96	316	98	864	2*139	372	119	648	98	893
Utility Tractor (kw)	2*57	313	2*43	389	2*54	191	57	524	43	714
Combine (row)	8	163	6	145	8	163	8	163	6	163
Cotton Picker (row)	--	---	2*2	81	--	---	--	---	2	122
Stalk Cutter (m)	--	---	2*1.8	71	--	---	--	---	1.8	106
Subsoiler	--	---	2.4	113	--	---	--	---	2.4	85
Fertilizer Spreader (m)	9.1	58	9.1	58	12.2	44	12.2	44	9.1	58
Land Plane (m)	3.7	85	3.7	113	4.6	136	4.3	97	3.7	127
Wood Frame (m)	3.0	191	3.0	127	4.3	136	3.7	159	3	143
Disk Plow (disk)	2*5	95	5	255	2*7	136	6	212	5	286
Disk Harrow (m)	3.8	128	3.8	128	5.5	89	4.7	103	3.8	128
Offset Harrow (m)	3.8	229	3.8	255	4.7	246	4.1	236	3.8	267
Grain Drill (m)	4.3	56	4.3	37	6.1	78	4.9	65	4.3	56
Row Planter	8	43	6	76	--	--	8	29	6	57
Furrower (row)	8	153	6	204	8	76	8	127	6	178
Sprayer (row)	16	24	12	42	16	47	16	31	12	47
Row-Cultivator (row)	8	103	6	92	--	--	8	69	6	69
Cost $/ha										
Machinery	23.53		32.44		26.59		21.99		26.61	
Fuel	8.56		12.15		10.00		9.06		11.19	
Labor	1.56		1.97		1.42		1.47		1.95	
Timeliness	8.57		6.01		0.00		4.31		5.37	
Total	42.23		52.27		38.00		36.83		45.11	

Table 6.8. Machinery Selected for Five Crop Rotations for 600 Ha at 0.8 Probability Level, Using Conventional Tillage on Clay Soil.

	Rotations									
	W-S		W-S-C		W-W		W-W-S		W-W-S-C	
Machines	Size	Hrs	Size	Hrs	Size	Hrs	Size	Hrs	Size	Hrs
Primary Tractors (kw)	3*119	365	2*123	739	4*139	372	2*139	567	2*98	893
Utility Tractor (kw)	2*57	574	3*45	478	4*54	191	2*57	488	2*43	714
Combine (row)	2*8	163	2*6	145	2*8	163	2*8	163	2*6	163
Cotton Picker (row)	--	---	3*2	108	--	---	--	---	2*2	122
Stalk Cutter (m)	--	---	3*2.1	81	--	---	--	---	2*1.8	106
Subsoiler	--	---	2*3	91	--	---	--	---	2*2.4	85
Fertilizer Spreader (m)	12.2	87	12.2	87	12.2	87	12.2	87	9.1	116
Land Plane (m)	2*4.3	73	4.3	194	2*4.6	136	4.6	181	3.7	254
Wood Frame (m)	2*3.7	159	3.7	212	2*4.3	137	4.3	273	3.0	286
Disk Plow (disk)	3*6	109	2*6	212	4*7	137	2*7	182	2*5	286
Disk Harrow (m)	4.7	206	4.7	206	5.5	178	5.5	178	3.8	255
Offset Harrow (m)	2*4.1	212	4.1	472	2*4.7	247	4.7	411	3.8	534
Grain Drill (m)	4.9	98	4.9	65	6.1	157	6.1	105	4.3	111
Row Planter	8	86	6	152	--	--	8	57	6	114
Furrower (row)	8	306	6	407	8	153	8	255	6	356
Sprayer (row)	16	47	12	84	16	94	16	63	12	94
Row-Cultivator (row)	8	207	6	184	--	--	8	138	6	138
Cost $/ha										
Machinery	21.72		29.26		26.11		21.22		25.95	
Fuel	8.56		11.64		10.01		9.03		11.19	
Labor	1.41		1.76		1.42		1.34		1.95	
Timeliness	8.59		7.69		0.00		4.31		5.37	
Total	40.28		50.35		37.54		35.90		44.45	

6.1.4. Soil Types

Hypothesis: Ligther soils such as a loam versus a heavy clay, decrease machinery costs.

Two types of soils clay and loam, were predominant in the collective ejidos. Table 6.9 presents simulation results for clay and loam soils for 600 Ha of wheat-soybean and wheat-soybean-cotton rotations. Conventional tillage, at 0.8 probability level was considered during validation. Changing from clay to loam soil resulted in less power, and less or smaller machines. Machinery and timeliness costs made the difference in total costs for the machinery between clay and loam soil. There was a 21% total cost reduction for loam soil, as compared with clay soil for the W-S rotation, and 12% for the W-S-C rotation.

The results obtained confirm the hypothesis for soil types, that machinery costs for crop production on loam soils are less than for clay soils.

6.1.5. Economic Parameters.

Hypothesis: The model will show that a decrease in interest rates will influence the selection of more larger machinery that have a lower real cost.

Three interest rates were compared; 1% which used for the model validation, -20% and -40%. Results are presented in Table 6.10. As expected, there was a drastic decrease in the machinery component of total cost per hectare as interest rates dropped. The total cost per

Table 6.9. Machinery Selected for Two Soil Types 600 Ha Wheat-Soybean Rotation Using Conventional Tillage at 0.8 Probability Level.

	Wheat-Soybean				Wheat-Soybean-Cotton			
	Clay		Loam		Clay		Loam	
Machines	Size	Hours	Size	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	3*119	365	2*129	478	2*123	739	2*111	739
Utility Tractor (kw)	2*57	574	2*57	542	3*45	478	2*57	614
Combine (row)	2*8	163	2*8	163	2*6	145	2*4	217
Cotton Picker (row)	--	---	--	---	3*2	108	2*2	162
Stalk Cutter (m)	--	---	--	---	3*2.1	81	2*2.1	121
Subsoiler	--	---	--	--	2*3	91	3	181
Fertilizer Spreader (m)	12.2	87	12.2	87	12.2	87	12.2	87
Land Plane (m)	2*4.3	73	4.6	136	4.3	194	4.3	194
Wood Frame (m)	2*3.7	159	2*4.3	137	3.7	212	3.7	212
Disk Plow (disk)	3*6	109	2*7	137	2*6	212	2*6	212
Disk Harrow (m)	4.7	206	5.5	178	4.7	206	4.7	206
Offset Harrow (m)	2*4.1	212	2*4.7	185	4.1	472	4.1	472
Grain Drill (m)	4.9	98	6.1	78	4.9	65	4.9	65
Row Planter	8	86	8	86	6	152	8	114
Furrower (row)	8	306	8	306	6	407	8	306
Sprayer (row)	16	47	16	47	12	84	16	63
Row-Cultivator (row)	8	207	8	207	6	184	8	138
Cost $/ha								
Machinery	21.72		20.45		29.26		25.36	
Fuel	8.56		8.06		11.64		10.84	
Labor	1.41		1.30		1.76		1.73	
Timeliness	8.59		1.97		7.69		6.30	
Total	40.28		31.78		50.35		44.22	

Table 6.10. Machinery Selection with Three Interest Rates. W-S Rotation, 600 Ha with Conventional Tillage on Clay Soil.

	Interest Rate, %					
	1		-20		-40	
Machines	Size[1]	Hrs	Size	Hrs	Size	Hrs
Primary Tractors (kw)	3*119	365	2*173	398	3*139	319
Utility Tractor (kw)	2*57	574	2*86	419	2*86	434
Combine (row)	2*8	163	2*12	109	2*12	109
Fertilizer Spreader (m)	12.2	87	12.2	87	12.2	87
Land Plane (m)	2*4.3	73	5.5	113	2*4.6	68
Wood Frame (m)	2*3.7	159	2*4.6	127	2*4.3	137
Disk Plow (disk)	3*6	106	2*9	106	3*7	91
Disk Harrow (m)	4.7	205	6.9	142	5.5	178
Offset Harrow (m)	2*4.1	212	5.3	328	2*4.7	185
Grain Drill (m)	4.9	98	7.3	65	6.1	78
Row Planter (row)	8	86	12	57	12	57
Furrower (row)	8	306	12	204	12	204
Sprayer (row)	16	47	24	31	24	31
Row-cultivator (row)	8	207	12	138	12	138
Cost $/ha						
Machinery	21.72		12.89		5.53	
Fuel	8.56		8.56		8.55	
Labor	1.41		1.02		1.12	
Timeliness	8.59		6.46		6.46	
Total	40.28		28.93		21.66	

---

[1] Number and size. For example 2*57 means 2 tractors of 57 kw each.

hectare decreased from 40,280 Mexican pesos per hectare with 1% interest, to 28,930 Mex. $/ha with -20% of interest, which represent a 28.2% decrease. The cost per hectare further decreased to 21,660 Mex $/ha with -40% of interest, which represent a decrease of 46.2% from the cost at 1% of interest.

The machinery sets were different for the three interest rates (Table 6.10). In general the model selected larger machines as their real prices decreased because of lower interest rates. This effect is more noticed for row equipment, because the model selected the largest machines available, even though the annual use decreased.

These results confirm the hypothesis that a decrease in interest rates influence the selection of larger machinery. Therefore the model has the capacity to react to changes in economic parameters, which could occur in specific periods of time, depending on government policies in Mexico.

6.2. SIMULATED VS. ACTUAL MACHINERY SETS

A second part for the validation of the model consisted of comparing simulated and actual machinery sets in collective ejidos. Wheat-soybean rotation, using conventional tillage in clay soils was used for simulation.

Two actual ejidos were selected with equivalent areas to compare machinery sets with the least cost sets selected by the model at 0.8 probability level. Results of these comparisons are presented in Table 6.11. The ejidos have purchased the machinery since they were created in 1976. Wheat-soybean was the most common rotation in the last five years.

The small ejido, with an average area seeded of 300 hectares of wheat-soybean rotation had 7.6% more power of primary tractors than the power selected by the model. For utility tractors, the model selected two tractors of 57 kw, and the ejido owned two tractors of 57 kw and a tractor of 61 kw. Therefore the ejido had a 53% more power than selected for least cost.

There was close agreement between the actual complement an the machines selected for combine and row equipment, fertilizer spreader and wood frame. The model selected one 8-row planter, furrower cultivator, whereas the ejido owned two 4-row of each of these machines.

The machinery owned by the medium size ejido with 600 hectares of wheat-soybean had more capacity compared with the machinery sets selected, with the exception of primary tractors, land plane, wood frame, row planter and sprayer. Simulation resulted in half the actual number of utility tractors. The ejidos had 95% more utility tractor power than simulation power selected by the model.

Actual harvesting capacity exceded the capacity selected by 37% On land leveling equipment, disk plow and offset harrow the model selected greater capacities.

Table 6.11. Simulated vs. Actual Machinery Sets at .8 Probability Level. Wheat-Soybean Rotation, Using Conventional Tillage on Clay Soil.

	300 Hectares			600 Hectares		
	Simulated		Actual Machines	Simulated		Actual Machines
Machines	Size[1]	Hours	Number*size	Size	Hours	Number*size[2]
Primary Tractors (kw)	2*96	316	110;97	3*119	365	110;100;82
Utility Tractor (kw)	2*57	313	61;2*57	2*57	574	61;2*57;48
Combine (row)	8	163	8	2*8	163	2*8; 6
Fertilizer Spreader (m)	9.1	58	10	12.2	87	2*10
Land Plane (m)	3.7	85	-	2*4.3	73	-
Wood Frame (m)	3.0	191	3	2*3.7	159	3.6
Disk Plow (disk)	2*5	195	5;2*4	3*6	106	2*5
Disk Harrow (m)	3.8	128	3.2	4.7	205	3.2; 2.2
Offset Harrow (m)	3.8	229	2*3.7	2*4.1	212	3.7; 3.2
Grain Drill (m)	4.3	56	3.7	4.9	98	4.2; 3.7
Row Planter (row)	8	43	2*4	8	86	2*4
Furrower (row)	8	153	2*4	8	306	3*4
Sprayer (row)	16	24	14	16	47	14
Row-cultivator (row)	8	103	2*4	8	207	3*4

---

[1] Number and size indicated. For example 2*57 means 2 tractors of 57 kw each.

[2] A ';' is used to separate machines of different sizes. For example, 110; 97 means one tractor of 110 kw, and one tractor of 97 kw.

Row equipment agreed with selected capacities for row planter and sprayer; selected capacities were lower than actual capacity for furrower and row-cultivator.

In general there was agreement between the actual machinery sets, and the model selected complement at 0.8 probability level.

6.3. DISCUSSION OF MODEL VALIDATION.

The model was sensitive to changes in major parameters. Machinery selected at 0.8 probability level had larger equipment and higher cost per hectare. As expected timeliness cost decreased with a drop in probability level. At 0.5 level there was no timeliness cost, indicating that there was enough time available to complete the operations within the optimum period. The timeliness cost at 0.8 and 0.7 levels indicates that it was less costly to afford some crop losses doing part of the work in the penalty period, than owning a larger or another machine.

The runs with three probability levels for suitable weather were made for the purpose of testing the sensitivity of the model to changes in time available for field operations. A probability level of 0.8 was used in this study. Previous studies (Hetz, 1982) and practical experience in the U.S. (Rotz, 1983), indicated that is preferable to design machinery systems at 0.8 probability level. An 0.8 level means that the ejidos could complete the operations 8 out of 10 years, with the machinery set selected. During the other two years the machinery may not complete the operations. The ejidos could work more hours per day, or custom hire specific machines during two years out of ten, when the machinery selected will probably not complete the required operations.

The effect of area seeded (ejido size) on the total cost per hectare was appreciable in the range of 150 to 600 hectares. Over 600 hectares the total cost had little variation. These results indicate that the model had selected a balanced machinery set for 600 hectares, and from there on the costs increase in the same proportion as the area seeded. Due to the discrete nature of the machinery sets selected, and the matching of row equipment, some excess capacity may be selected by the model in some ranges, as the size is increased. This caused small ups and downs for total cost of machinery sets particularly over 600 hectares.

The computer model was sensitive to changes in crop rotations. Machinery sets selected had different components, reflecting the capacity of the model to react to changes in operations and schedules, in the selection of the least cost machinery complement. The reactions were similar for 300 and 600 hectares for 5 different crop rotations.

The model reacted as expected to soil type changes. Changing from clay to loam soil resulted in smaller and/or less equipment, with a decrease in cost per hectare.

Actual machinery sets in two collective ejidos nearly matched the 0.8 probability level, reflecting practical experience of ejidatarios in order to avoid losses during rainy years.

In order to compare simulated results with actual machinery sets, the total machinery capacity needs to be considered. For example the model selected one 8-row planter, while the ejido owned two 4-row planters. There was a general pattern for some equipment. For row equipment it was common to use 4-row planters, cultivators and furrowers. For this study it was assumed that 6, 8 and 12-row equipment could be used in the Valley. Low cost and a surplus of labor in the ejidos could be a reason why the ejidos are not too concerned about using larger equipment, which in most cases needed to be imported.

When analyzing the differences between the size or number of machines selected by the model and the actual machinery, one consideration is that the ejido could have hired custom operations instead of purchasing the machines. The model did not included custom hire for validation because it was decided at the outset that the ejido would own all machinery.

CHAPTER 7

SIMULATION RESULTS

7.1. COMPARISONS FOR TILLAGE SYSTEMS

The computer model was applied to select machinery sets for five crop rotations used in the Yaqui Valley. Examples are presented for W-S and W-S-C crop rotations for conventional and reduced tillage systems, on small medium and large size ejidos.

Primary tractor power decreased to a third, and utility tractor power decreased by one half for reduced tillage as compared with conventionl tillage for W-S rotation on a 300 hectare ejido (Table 7.1). Disk plow and wood frame were not required, and harrows were smaller with reduced tillage. The grain drill had more time available due to less tillage operations, therefore a smaller machine was selected. Row equipment was the same for the two tillage systems, since they were done at different dates as tillage. Machinery and fuel cost decreased with reduced tillage, and total cost per hectare decreased by 21.4% for reduced tillage.

Tractor power decreased with reduced tillage for a medium size ejido, with 600 hectares of W-S. Primary tractor dropped from three to two, and utility tractors

Table 7.1. Machinery Selected for Two Tillage Systems for a Wheat-Soybean Rotation on Clay Soil.

	300 hectares				600 hectares			
	Conventional		Reduced		Conventional		Reduced	
Machines	Size	Hours	Size	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	3*96	316	84.7	330.8	3*119	365	2*119	267
Utility Tractor (kw)	2*57	313	57	407	2*57	574	57	754
Combine (row)	8	163	8	163	2*8	163	2*8	163
Fertilizer Spreader (m)	9.1	58	9.1	58	12.2	87	12.2	87
Land Plane (m)	3.7	85	3.7	85	2*4.3	73	4.3	146
Wood Frame (m)	3.0	191	--	--	2*3.7	159	--	--
Disk Plow (disk)	2*5	95	--	--	3*6	106	--	--
Disk Harrow (m)	3.8	128	3.4	73	4.7	206	4.7	103
Offset Harrow (m)	3.8	229	3.4	173	2*4.1	212	2*4.1	141
Grain Drill (m)	4.3	56	3.7	65	4.9	98	4.9	98
Row Planter	8	43	8	43	8	86	8	85
Furrower (row)	8	153	8	115	8	306	8	229
Sprayer (row)	16	24	16	24	16	47	16	47
Row-Cultivator (row)	8	103	8	103	8	207	8	206
Cost $/ha								
Machinery	23.53		18.11		21.72		17.60	
Fuel	8.56		5.53		8.56		5.56	
Labor	1.56		0.99		1.41		0.89	
Timeliness	8.57		8.57		8.59		8.59	
Total	42.23		33.20		40.28		32.64	

decreased from two to one changing from conventional to reduced tillage (Table 7.1).

The disk plow and the wood frame were not required for reduced tillage. One land plane instead of two was selected for reduced tillage. This doubled the hours of use, thus reflecting more time available, due to fewer tillage operations. The same size of disk and offset harrows were selected, but the hours of use decreased for reduced tillage. Row equipment and fertilizer spreaders were not affected by the change to the reduced tillage system. Machinery and fuel costs per hectare decreased by 19% for reduced tilage.

Conventional vs. reduced tillage practices were compared for a W-S-C crop rotation for small and medium size ejidos. Results are presented in Table 7.2. For a 300 hectare ejido less power and fewer hours of use were required for reduced tillage. The simulation model selected the same number of utility tractosr, but with slightly fewer hours of use for reduced tillage. Subsoilers, disk plows and wood frames were not required for reduced tillage, thus reducing machinery and fuel cost. The grain drill and harrows were smaller for reduced tillage, while row equipment remained the same. Total cost per hectare for reduced tillage decreased by 16.5%, as compared with conventional tillage.

For 600 hectares of W-S-C rotation (Table 7.2) there was a similar pattern as for 300 hectare. Tractor power and/or hours of use were reduced, while grain drill and

Table 7.2. Machinery Selected for Two Tillage Systems for a Wheat-Soybean-Cotton Rotation on Clay Soil.

	300 hectares				600 hectares			
	Conventional		Reduced		Conventional		Reduced	
Machines	Size	Hours	Size	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	98	864	67	485	2*123	739	119	615
Utility Tractor (kw)	2*43	389	2*43	334	3*45	478	3*45	408
Combine (row)	6	145	6	145	2*6	145	2*6	145
Cotton Picker (row)	2*2	81	2*2	81	3*2	108	3*2	108
Stalk Cutter (m)	2*1.8	71	2*1.8	71	3*2.1	81	3*2.1	81
Subsoiler	2.4	113	--	---	2*3	91	--	---
Fertilizer Spreader (m)	9.1	58	9.1	58	12.2	87	12.2	87
Land Plane (m)	3.7	113	3.7	113	4.3	194	4.3	194
Wood Frame (m)	3.0	127	--	--	3.7	212	--	---
Disk Plow (disk)	5	255	--	--	2*6	212	--	---
Disk Harrow (m)	3.8	128	2.4	133	4.7	206	4.7	138
Offset Harrow (m)	3.8	255	2.4	239	4.1	472	4.1	203
Grain Drill (m)	4.3	37	3.7	44	4.9	65	4.9	65
Row Planter	6	76	6	76	6	152	6	152
Furrower (row)	6	204	6	170	6	407	6	340
Sprayer (row)	12	42	12	42	12	84	12	84
Row-Cultivator (row)	6	92	6	138	6	184	6	254
Cost $/ha								
Machinery	32.44		28.00		29.26		24.71	
Fuel	12.15		8.12		11.64		7.62	
Labor	1.97		1.43		1.76		1.17	
Timeliness	6.01		6.01		7.69		7.69	
Total	52.27		43.64		50.35		41.19	

harrows were the same but with less hours of use for the reduced tillage. There was a decrease in machinery and fuel cost, with a 18.2% reduction in total cost per hectare for the reduced tillage system.

The model was used to select the least cost machinery sets for 1,200 hectares of W-S and W-S-C crop rotations (large ejidos). The conventional and reduced tillage systems on clay soil were compared (Table 7.3).

For W-S rotation there was a drastic reduction in primary tractor power, but utility tractor power had a slight increase. The model selected 3 tractors of 96 kw for reduced tillage, as compared with 7 tractors of 96 kw that were selected for conventional tillage. Three tractors of 86 kw (total of 258 kw) were required for reduced tillage as compared with five tractors of 43 kw (total of 215 kw) selected for conventional tillage. Disk and offset harrows had less hours of use. The rest of the equipment was the same in both tillage systems. No disk plows nor wood frame were required for reduced tillage. There was a cost reduction of 20.4% changing from conventional to reduced tillage system (Table 7.3).

For W-S-C crop rotation there was a reduction to one half for primary tractor power and use, when changing from conventional to reduced tillage. Utility tractor power increased slightly with a decrease in hours of use. Reduced tillage did not include subsoiler or disk plow, therefore disk and offset harrowing were the only operations for seedbed preparation. Machinery and fuel cost decreased for

Table 7.3. Machinery Selected for Wheat-Soybean and Wheat-Soybean-Cotton Rotation for a Large Ejido 1200 ha, with two Tillage System on Clay Soil.

	Wheat-Soybean				Wheat-Soybean-Cotton			
	Conventional		Reduced		Conventional		Reduced	
Machines	Size	Hours	Size	Hours	Size	Hours	Size	Hours
Primary Tractors (kw)	7*96	362	3*96	402	4*123	739	2*135	546
Utility Tractor (kw)	5*43	588	3*86	607	5*45	574	5*54	484
Combine (row)	6*6	145	3*12	145	4*6	145	4*6	145
Cotton Picker (row)	--	---	--	---	6*2	108	6*2	100
Stalk Cutter (m)	--	---	--	---	5*2.1	97	5*2.1	97
Subsoiler	--	---	--	---	3*3	121	--	---
Fertilizer Spreader (m)	9.1	233	9.1	233	12.2	175	12.2	175
Land Plane (m)	3*3.7	113	3*3.7	113	2*4.3	194	2*4.6	181
Wood Frame (m)	4*3	191	--	---	2*3.7	212	--	---
Disk Plow (disk)	7*5	189	--	---	4*6	212	--	---
Disk Harrow (m)	3*3.8	171	2*3.8	128	2*4.7	206	5.5	237
Offset Harrow (m)	3*3.8	306	3*3.8	204	2*4.1	472	2*4.7	247
Grain Drill (m)	2*4.3	112	2*4.3	112	4.9	131	6.1	105
Row Planter	2*6	114	12	114	6	304	6	304
Furrower (row)	3*6	272	12	306	2*6	408	2*6	340
Sprayer (row)	12	125	24	63	12	167	12	167
Row-Cultivator (row)	3*6	184	2*12	138	2*6	184	2*6	254
Cost $/ha								
Machinery	21.64		17.57		29.10		24.99	
Fuel	8.61		5.48		11.64		7.78	
Labor	1.74		0.79		1.76		1.13	
Timeliness	8.06		8.06		7.69		7.69	
Total	40.06		31.89		50.19		41.57	

reduced tillage, with a 17% decrease in total cost per hectare as compared with conventional tillage.

The examples presented in this section show one of the applications of the model for real world situations. The reduced tillage systems for five rotations were formulated based on results of 30 field experiments on tillage systems for the crop sequence W-S carried out at the Agricultural Experiment Station of The Yaqui Valley. No statistically significant difference for wheat and soybean yields were found for conventional, conservation and minimum tillage systems (Moreno, Ortega and Samayoa, 1984). The model will be a powerful tool to analyze economic advantages of new improved tilllage systems in the Yaqui Valley. The model has the potential capacity to handle new crop rotations and/or crop sequences that agronomists may want to introduce in the region.

7.2. CUSTOM HIRED OPERATIONS

7.2.1. Owned vs. Custom Hired Operations

The computer model will allow an option of either the use of owned or custom hired machines for each field operation. Various options or combinations (mixtures) of custom hired and owned machines were compared. Examples for 300 and 600 hectares of W-S-C with conventional tillage on clay soil are shown in Tables 7.4 and 7.5. Full interest or payments on purchases of machinery were assumed for these computer model runs.

Three cases or mixtures of custom hired operations were compared for a wheat-soybean-cotton rotation. In the first case the cotton picker was custom hired; in the second case the cottton picker and the combine for soybean harvest were custom hired. The third case considered custom hiring cotton pickers, combines for soybean harvest, and tillage and seeding equipment.

Custom hiring the cotton picker and combine resulted in the lowest machinery set cost for 300 and 600 hectare ejidos, as compared with no*custom hiring. Custom hiring the cotton picker was lower cost per hectare than no*custom hiring. Custom hiring the cotton picker, combine, along with tillage and planting equipment resulted in a lower cost per hectare than owning the machines and a lower cost than custom hiring the cotton picker alone. For 300 hectares of W-S-C rotation, custom hiring the cotton picker alone reduced total cost by 21.5% as compared with owning the machine. Custom hiring the cotton pickers and the combine for soybean harvest, further reduced the total cost, with a 31% reduction compared with owning the machines (Table 7.4).

For 600 hectares of W-S-C rotation, owning all the machinery was compared with: a) Custom hiring the cotton pickers, b) Custom hiring cotton pickers and combines for soybean harvest, and c) Custom hiring cotton pickers, combines and tillage equipment. Results of these comparisons are shown in Table 7.5.

Table 7.4. Custom Hired Operations vs. No-Custom Hire, for 300 Ha of Wheat-Soybean-Cotton. Thousand of Mex $/ha.

Type of Cost	No Custom Work	Custom Hired Operations Cotton Picker	 C. Picker & Combine
Machinery	32.44	19.22	16.02
Fuel	12.15	9.67	9.20
Labor	1.97	1.67	1.69
Timeliness	6.01	5.37	0.00
Custom Work	0.00	5.35	9.39
Total	52.57	41.28	36.30

Table 7.5. Custom Hired Operations vs. No-Custom Hire, for 600 Ha of Wheat-Soybean-Cotton.

Type of Work	No Custom Hire	Cotton Picker	C. Picker & Combine	C. Picker, Combine Tillage Equipm[1]
Machinery	29.26	19.00	15.22	13.39
Fuel	11.64	9.91	9.33	7.46
Labor	1.76	1.76	1.68	1.42
Timeliness	7.69	5.37	0.00	0.00
Custom Work	0.00	5.35	9.39	14.90
Total	50.35	41.39	35.62	37.17

[1] Tillage Equipment Custom Hired: Disk Plow, Offset and Disk Harrow, and Land Plane.

Custom hiring the cotton picker brought a total cost reduction of 14.31 $/ha (machinery , fuel,plus timeliness), while custom work amounted 5.35 $/ha. Therefore there was a net total cost reduction of 8.96 $/ha, which is a 17.8% cost reduction from the cost with no custom hiring.

Custom hiring cotton pickers and combines resulted in further reduction in total cost per hectare, as compared with custom hiring cotton pickers only. Machinery, fuel, labor and timeliness decreased by a total of 9.7 $/ha, while custom cost increased by 4.04 $/ha. Compared with no-custom hiring, this option had a 29% decrease in total cost per hectare.

Custom hiring tillage equipment, along with cotton pickers and combines resulted in decrease of 3.98 $/ha machinery, fuel and labor, but custom cost increased by 5.51 $/ha. Therefore the total cost of this mixture increased as compared with custom hiring cotton pickers and combines.

7.2.2. Custom Hired vs. Owned with Negative Interest Rates

The particular situation of the ejidos, with subsidized loans for purchasing machinery (Section 4.7.2.) was compared with custom hiring. Table 7.6 shows computer model example runs, with negative interest rates (interest rates lower than inflation), for 300 and 600 hectares of W-S-C rotation, with conventional tillage, clay soil, at 0.8 probability level. The machinery cost component of total cost per hectare decreased with lower (negative) rates. The total cost of the machinery set selected with a -20% of interest rates decreased by 31.5% for 300 hectares of W-S-C, and by 27.4% for 600 hectares of W-S-C, as compared with the cost with a 1% interest rates. The total cost with a -40% of interest rate decreased by 56% for 300 hectares and by 45% for 600 hectares of W-S-C, as compared with a 1% interest rates.

Cost reductions in total cost per hectare, due to lower interest rates, will affect custom hiring decisions. Table 7.7. shows comparisons of three custom hire options versus no custom at 1%, and two negative interest rates. Price of custom hired operation were assumed to be the same for all options compared. When the ejidos paid full prices (1% interest), the three custom-hired options had lower cost per hectare than no*custom hiring (i.e. ejido owned and operated equipment).

At a -20% of interest rate the cost owned machinery decreased for all options, but the differences between the three custom hire options and no*custom hired were much smaller than there were for 1% interest.

At a -40% interst rate for loans for machinery purchased the cost of owning all machinery decreased to 27,680 Mex $/ha. Since custom hired price did not change, owning the machines in this case was a lower cost option than custom hiring cotton pickers, combines and tillage equipment. Custom hiring cotton pickers was the same as owning the machines. Custom hiring cotton pickers and

Table 7.6. Cost of Machinery Sets With Negative Interest Rates in Thousand Mexican $/Ha.

Type of	300 Ha, W-S-C Interest Rate, %			600 Ha, W-S-C Interest Rate, %		
	1	-20	-40	1	-20	-40
Machinery	32.44	19.83	7.05	29.26	16.92	8.04
Fuel	12.15	11.92	12.00	11.64	11.52	11.68
Labor	1.97	1.45	1.19	1.76	1.48	1.34
Timeliness	6.01	2.82	2.82	7.69	6.62	6.62
Total	52.57	36.02	23.06	50.35	36.54	27.68

Table 7.7. Comparisions of Custom Hired Mixtures at Three Interest Rates. Thousand of Mexican $/ha.

Machines Custom Hired	Interest	Rates	Percent
	1	-20	-40
No Custom Hire	50.35	36.54	27.68
Cotton Picker	41.39	32.99	27.20
C. Picker and Combine	35.62	29.91	25.18
C. Picker, Combine and Tillage Equipm[1]	37.17	33.85	30.52

---

[1] Tillage equipment custom hired: Disk plow, offset and disk harrow, and land plane.

combines was still a lower cost option than no custom hiring the machines.

Because the real cost of machinery for collective ejidos was much less due to negative interest rates, a number of implications follow that will influence machinery decisions in the following directions: a) Encourage greater purchases of machinery, b) Increase the rate of machinery replacement to save on repair costs, and c) Less custom hiring would be cost effective.

The examples for custom hiring versus no custom hiring show the capacity of the machinery selection model to analyze the effects of government policies that could affect machinery purchases, such as interest and inflation rates, and price of machinery and custom hired services. These comparisons will help ejidos, farmers, private and goverment custom hired enterprises, and machinery dealers to provide guidance for machinery management decisions.

The computer model is intended to be used for teaching and training at the Agricultural Machinery Deparment of the University of Chapingo. Its use for technical assistance for farmers and ejidos could be a potential application in the near future.

CHAPTER 8

CONCLUSIONS

8.1. CONCLUSIONS

1. Training and technical assistance needs in agricultural mechanization aspects were indicated by 80% of 15 groups of ejidatarios and technicians interviewed. Research needs were pointed out by 93% of the groups interviewed. Agricultural machinery management and repair were the most important and urgent topics emphasized by the ejidos.
2. The machinery selection model, MACHSEL, was adapted to the simulation of agricultural machinery operating conditions in the collective ejidos in the Yaqui Valley. The model was sensitive to changes in major parameters when using data from the Yaqui Valley. The model selected larger machinery sets at 0.8 probability level; machinery sets selected at 0.7 and 0.5 levels were similar in most cases.
3. The model was sensitive to changes in area seeded. For W-S rotation, conventional tillage at 0.8 probability level, there was a cost reduction of 8.4% from 150 to 600 Ha for clay soil. For loam soil there was a reduction of 8%. For reduced tillage on clay soil, the total cost decreased by 11.8% from 150 to 600 hectares, and 13.8% from 150 to 1200 hectares.

4. Crop rotations including cotton required more machinery and had higher cost per hectare. Rotation wheat-soybean-cotton was the most expensive of 5 rotations studied, with a total cost per hectare of 52,570 Mexican pesos (1985) for 300 hectares of area seeded. This cost was 25% higher than the cost for the wheat-soybean rotation, and 16.7% higher than W-W-S-C rotation.
5. The model was sensitive to changes in soil type changes. Cost reductions up to 21% were obtained for machinery selected for loam soil as compared with clay soil, for a wheat-soybean rotation.
6. The ejidos own more machinery than indicated as optimum for least cost at 0.8 probability level. Cost reductions could be realized by using fewer machines of a larger size, and reducing the number of passes of tillage operations.
7. Machinery sets selected for reduced tillage required less tractor power and smaller or less hours of use of tillage equipment, as compared with conventional tillage. Machinery and fuel cost decreased, with total cost per hectare savings of up to 21.4% for 300 hectares of a W-S rotation, and up to 18.2% for 600 hectare of a W-S-C rotation.
8. The empirical data showed that it is likely that certain types of machinery; such as, cotton pickers and combines, are appropriate on a hire on custom basis. If the ejidos had to pay full prices (without subsidized

credit) for their machinery, savings of up to 31% could be obtained through custom hiring the cotton pickers and combines. When the real cost of machines decline due to negative interest rates (interest rate lower than general inflation) for subsidized credit loans, less custom hiring is justified. For example at a -40% interest rate owning cotton pickers and tillage equipment will be a less cost by option than custom hiring of machines.

9. The computer model MACHSEL appears to be applicable to Mexico for teaching, and technical assistance related to machinery management. The collective ejidos of the Yaqui Valley could benefit from the model simulation studies to optimize their machinery sets for lower costs.

8.2. RECOMMENDATIONS FOR FURTHER RESEARCH

1. To expand the model to include other crops and rotations in the Yaqui Valley.
2. To adapt the model so that units of machines could be easily added or substracted from actual sets, to use the model for machine purchase or discharge decisions.
3. To initiate studies to keep records on machinery management data in ejidos and private farms in the Yaqui Valley.

4. To carry out more field experiments with reduced tillage operations, for main crops in the Yaqui Valley and to experiment with larger machinery sizes.
5. To perform measurements on field efficiency and draft power requirements for crop production equipment in different locations of the Yaqui Valley.
6. To study agricultural machinery management strategies for private farms and ejidos.
7. To keep records of suitable days for machinery operations and to analyze weather data for different locations in the Valley, and to define timeliness factors for field operations.
8. To study the probability of losses beyond the 0.8, 0.7 or 0.5 levels. In other words what losses can be expected the other 2, 3 or 5 years out of ten.

APPENDIX A

AGRICULTURAL MECHANIZATION NEEDS ON COLLECTIVE EJIDO FARMS IN THE YAQUI VALLEY, SONORA, MEXICO.

ANSWERS TO GROUP INTERVIEW. MAY 1986

Training Needs.

1. Do you think the ejidatarios need training on aspects of agricultural mechanization?

   YES: 12   NO:3

2. When answer was no, why do you say they don't need training?

   - ejidatarios don't have time to attend courses 1
   - ejidatarios know all they need about machinery 1
   - courses are the same; there is nothing to learn 1

3. If answer was yes, why do they need training?

   -they have few knowledge on machinery 7

   -if they are more trained they will dot better their work 7

   -to improve their social level 3

   -the ejido have few trained persons in machinery 7

   -to do other works needed by the ejido 4

On Sept. 84 and Aug. 85 there were training courses on agricultural machinery for ejidatarios.

4. Did the ejido receive a notice about these courses?

   -yes, of both of them 3

   -yes, of the first one 1

   -yes, of the second one 1

   -yes, but they are not sure of which one, or both......2

   -no notice of both courses 2

   -don't know, not sure 1

5. Total number of ejidatarios selected to attend those courses.

   2,(2&1).0,0,1,1,0,1,1,3

6. In the case that they received notice, but did not select a person to attend the couses, what was the reason(s)?

   -It was discussed on the assembly, but there were no persons interested. 1

   -They teach the same 1

7. On the ejido the selection to attend couses is on the assembly?

   YES: 13 NO: 2

8. If there are training courses on agricultural machinery the ejido pay transportation & allowances?

   YES:14 NO:0

9. When somebody is selected to attend a course, do the ejido set up some conditions (to teach other ejidatarios, to apply what he learned on the ejido, to report about the courses)?

   YES:12 NO:1

10. What has the ejido done to promote training on agricultural machinery?

    - to ask for courses to the Coalition?

      YES:1 NO:13

    - to ask for courses to agricultural machinery dealers?

      YES:3 NO:11

    - to ask for courses to technicians of Coalition?

YES:1 NO:13

- they have established a fund for training expenses?

  YES:0 NO:13

- they have regulations for training?

  YES:1 NO:13

Technical Assistance Needs

1. Do you think the ejido needs more technical assistance on agricultural machinery?

   YES:12 NO:2

2. If answer was YES, in what subject does the ejido need technical assistance?

	YES	NO
- repair of agricultural machinery	13	-
- use of machinery shop equipment	11	2
- machinery maintenance	9	4
- planters and sprayers calibration	5	8
- studies on how is the ejido using the machinery	10	3
- to keep record of expenses on agricultural machinery	10	3
- to calculate operating costs of agricultural machinery	10	3
- to select the tractors most convinient for the ejido	7	6
- others		
- agricultural mechanics & welding	1	

- quality of agricultural equipment materials 1
- weight of implements in relation to their work 1

Agricultural Mechanization Research Needs

1. How important is for the ejidos that universities such as Chapingo, or agricultural experiment stations carry out research or studies on agricultural machinery in the Yaqui Valley?

   Very important 11

   Important.............. 3

   Little important 1

   Not important 0

2. For what reason is very important?

   a) The ejidatarios stay watching for research results.(9)

   b) The technicians of Coalition stay watching for research results.(8)

   c) Little is known on how the machinery is being used in the ejido. (6)

   d) they would like to know which equipment or new methods would be better for the ejido. (11)

   e) the University use the results for teaching. (1)

3. For which reason it is of little or no importance?

   a) Even with research, the ejidatarios will continue doing the same. (1)

4. Which is the degree of importance, priority and urgency of the following topic for research or studies?

   See Table A-1.

Table A-1 Importance, Priority and Urgency of Agricultural Mechanization Needs on Collective Ejidos of the Yaqui Valley, Sonora, Mexico.

Topics	Importance*				Priority							Urgency**			
	1	2	3	4	1	2	3	4	5	6	7	1	2	3	4
Machinery Desing	8	3	4	0	2	1	-	1	1	2	7	4	6	4	1
Machinery Repair	10	3	1	1	1	4	2	2	3	1	1	8	6	-	-
Agricultural Machinery Shop	10	1	3	0	2	1	4	2	3	-	1	9	3	2	-
Agricultural Machinery Managment	9	4	2	0	4	2	2	1	2	2	1	10	3	-	-
Calibration of Equipment	10	1	3	1	1	3	3	2	1	3	-	8	3	2	1
Agricultural Machinery Cost	11	2	1	1	3	1	2	4	1	1	1	9	3	1	1
Tillage	8	4	2	1	1	3	-	1	2	3	3	9	1	3	1
Maintenance	1					1						1			
Testing of Equipment	1									1			1		
TOTALS	68	18	16	4	14	16	13	13	13	13	14	58	26	12	4

* Importance: 1.- very important; 2.-important; 3.- little important; 4.- not important

** Urgency: 1.- very urgent; 2.- urgent; 3.- little urgent; 4.- not urgent

APPENDIX B

LIST OF AGRICULTURAL MACHINERY AVAILABLE AND PRICES

TRACTORS

Make and Model	Rated H.P.	List Price Mex.$ x 1000	Mex.$/H.P. x 1000
SIDENA 310-3	31	1,437	46.36
FORD 6600	77.1	3,310	42.9
FORD TW-25 (I)	160	9,850	61.56
FORD TW-35 (I)	190	10,800	56.8
MF 285	72	3,401	47.24
MF 290	80	3,913	48.9
J.DEERE 2735	82	3,743	45.65
J.DEERE 4255	120	7,110	59.25
J.DEERE 4650 (I)	185	13,558	73.28
STEIGER PUMA CM-165 (I)	167	12,500	74.85

COMBINES

Make and Model	Width M	Rated H.P.	List Price Mex $ x 1000
J. DEERE 7720	4.8	145	19,123
A CHALMERS L-3	4.8	143	

COTTON PICKERS

J. DEERE 9910	2-ROW	114	19,189

SUBSOILER

Make and Model	Shanks	Description	List Price $ Mex x 1000
Conota	3	Mounted	387
J. Deere MX50	3	Mounted	756[1]
J. Deere MX50	5	Mounted	1017[1]
Ochoa	2	Mounted	200
Ochoa	3	Mounted	239
Vazquez STR-2	2 rect	Mounted	234*
Vazquez STR-3	3 rect	Mounted	308*
Vazquez SBR-2	2 curved	Mounted	273
Vazquez SBR-3	3 curved	Mounted	335*
Vazquez SBR-4	4 curved	Mounted	423*
Vazquez ZM-4	4 heavy	Mounted	559
Vazquez ZM-5	5 heavy	Mounted	677

DISK PLOW

Make and Model	Disks	Description	List Price Mex $ x 1000
FTA 51-3	3	Mounted rev.	566*
FTA 51-4	4	Mounted rev.	671
IAMEX	3	Mounted rev.	998[1]
J. Deere 3631	3	Mounted rev.	467
J. Deere 3745	4	Mounted rev. hidr.	816*
J. Deere 3755	5	Mounted rev. hidr.	975
Kimball	5	Mounted rev.	1156
Sidena	2	Mounted rev.	285

[1] Price of May 86
* Most sold models for a given make.

OFFSET DISK HARROWS

Make and Models	Disks	Width Meters	Description	List Price Mex $x1000
Durable MAT-1824	18	--	Trailed, whl.	793
Durable MAT-2024	20	--	Trailed, whl.	890
Durable MAT-3224	32	--	Trailed, whl.	1,360
ICP-14TL	14	--	Mounted	275
J. Deere MX225	20	2.28	Trailed, whl.	838
J. Deere MX425	32	3.66	Trailed, whl.	1,204
Sidena 2-28TL	28	--	Mounted	1,140
Vazquez RDHT-20	20	2.3	Trailed, whl.	953
Vazquez RDHT-28	28	3.2	Trailed, whl.	1,396
Vazquez RDHT-32	32	3.7	Trailed, whl.	1,462
Vazquez RDHT-28	28	3.2	-----------	1,492
Vazquez RDHT-32	32	3.7	-----------	1,571
Vazquez RJ-20	20	2.3	Trailed, whl.	788
Vazquez RJ-28	28	3.2	-----------	1,045
Vazquez RJ-32	32	3.7	Trailed, whl.	1,152

LAND PLANE

Make and Model	Size(feet)	Description	List Price Mex $x1000
Ochoa	45x10	Wheels, rem. ctrl.	2,387
Ochoa	45x12	Wheels, rem. ctrl.	2,404
Vazquez NR	45x10	Wheels, rem. ctrl.	2,434
Vazquez NR	45x12	Wheels, rem. ctrl.	2,461
Vazquez NR	35x12	Wheels, rem. ctrl.	2,169

WOOD FRAME

Make and Model	Size	Description	List Price Mex $x1000
No mark	20x10	Trailed	180

SHOVELS

Make and models	Size meters	Description	List Price Mex $x1000
CT-310M	1.8	Mounted	151
EN-310M	1.8	Mounted	150
FTA-71-11	2.1	Mounted	210
Ochoa	2.1	Mounted	350[1]
Vazquez PT	2.1	Mounted	253**
Kimball	2.4	Trailed, wheels	290
Kimball	3.0	Trailed, wheels	439
Kimball	3.6	Trailed, wheels	525
Vazquez ENH	2.4	Trailed, wheels	407
Vazquez ENH	3.0	Trailed, wheels	537*
Vazquez ENH	3.6	Trailed, wheels	636*
Vazquez ENH	4.2	Trailed, wheels	777

1 Price of May 86

*Most sold models for a given mark

DITCHER

Make and Models	Size Meters	Description	List Price Mex $x1000
Ochoa	1.8	Medium, Mounted	125
Ochoa	1.8	Heavy	167
Promansa	1.8	Medium, Mounted	190
Vazquez TA-2	1.8	Medium, Mounted	140
Vazquez TA-1	2.15	Big, Mounted	230

FURROWER

Make and Models	Size	Description	List Price Mex $x1000
Vazquez EZ-4	2.8m	Mounted	254

DISK BEDDER

Make and Models	Size	Description	List Price Mex $x1000
Ochoa	Medium	6 disk, Mounted	225
Ochoa	Heavy	8 disk, Mounted	855
Promansa	Light	---------------	321
Vazquez, BTP-3	-----	(contour) Mounted	191
Vazquez, BTP-1	-----	(wheat) Mounted	412
Vazquez, BCTL	-----	ditcher, Mounted	328
Vazquez, BCTL	-----	ditcher, Mounted	626
Vazquez, BATP	-----	rice, Mounted	743

CULTIPACKER

Make and Models	Size Meters	Description	List Price Mex $x1000
Universal	3.6 m	Trailed	321
Vazquez	3.6 m	Mounted	428

ROW CULTIVATORS

Make and Models	Size Meters	Description	List Price Mex $x1000
Ochoa	13 shanks	Mounted	287
Ochoa	4 rows	Mounted	360
Promansa	9 shanks	Mounted	271
Promansa	4 rows	Mounted	394
Vazquez C DC-11	2 rows	Mounted	230
Vazquez 21	4 rows	Mounted	444
Vazquez CB-4	4 rows	Mounted	283
Vazquez CDD-2	4 rows	Mounted	354
Vazquez 1	4 rows	Mounted	385

FERTILIZER SPREADER

Make and Models	Size	Description	List Price Mex $x1000
Iamsa F-300	300kg	PTO, Mounted	195
Iamsa C-450	---	------	295[1]
Iamsa F-600	600kg	------	224
Long HOPC-400	400kg	------	205
Vazquez IVSA-400	400kg	------	207

GRAIN DRILL

Make and Models	Size meters	Description	List Price Mex $x1000
Fiona (Denmark)	3.0m	------	1,350
J. Deere 8200 (USA)	3.7m	------	1.669

ROW CROP PLANTER

Make and Models	Size	Description	List Price Mex $x1000
Iamex	4 rows	Mounted	815
J, Deere MP-25	4 rows	Mounted	693

SPRAYERS

Make and Models	Size	Description	List Price Mex $x1000
Asperjet	400 lt.	17 nozzles, Mounted	385
Aspermex	500 lt	17 nozzles, Mounted	550[1]
Iamsa	500 lt	17 nozzles, Mounted	550
Robin	500 lt	17 nozzles, Mounted	218
J. Deere 6000(USA)	-----	self propelled	19,418[1]

STALK CUTTER

Make and Models	Size Meters	Description	List Price Mex $x1000
Iamsa	1.8	Mounted	287
Usel	1.8	Mounted	670[1]
Vazquez DR-72	1.8	fuse, mounted	357
Vazquez DR-72	1.8	clutch, mounted	429

---

[1] Price of May 86.

APPENDIX C

MACHINERY SELECTION MODEL USER'S GUIDE

MACHINERY SELECTION MODEL USER'S GUIDE

1. Introduction

The machinery selection model (MACHSEL) is a computer program created by Rotz and Muhtar (1982)[1], for the selection of the 'best' set of machines for producing a set of crops in a given farm. The original version was for interactive or batch use on a main frame computer. A new microcomputer version was created in March 1986. The program is compiled in Lahey[2], F77L, version of Fortran.

2. Description of MACHSEL and Associated Files.

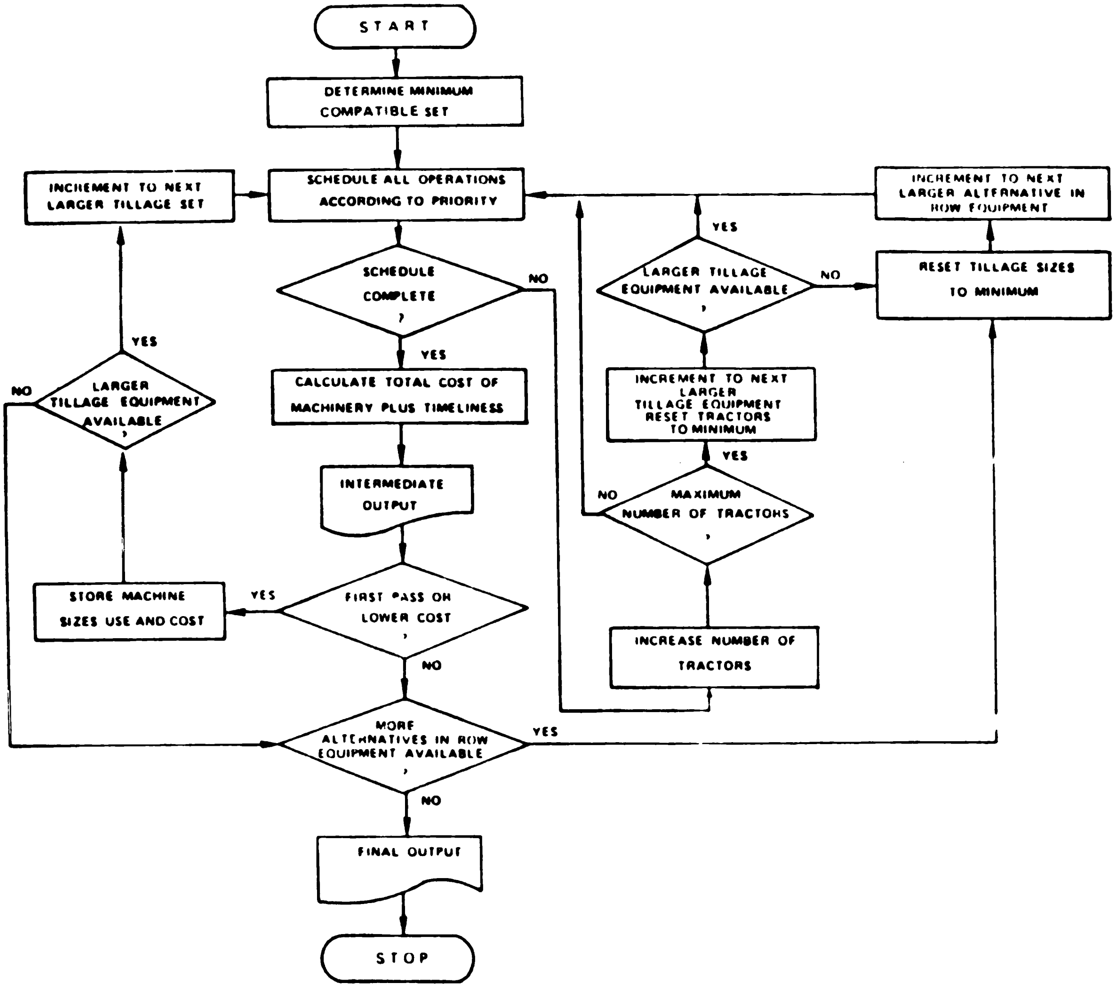
The computer model combines capacity and power matching, with cost analysis methods for the selection of farm machinery. The diagram of the computer algorithm is shown in Figure 1.

Data required by the model are stored in three input files. One file contain machinery data and suitable hours for field work, for conventional and reduced tillage. The other four files contain operation sequences for two tillage methods and 5 crop rotations.

---

[1] C. Alan Rotz, H.A. Muhtar, J.R.Black. 1983. A Multiple Crop Machinery Selection Model. Trans.ASAE. 26(6): pp. 1644-1649.

[2] Fortran 77 Language System for the Personal Computer. Reference
Manual. Lahey Computer Systems, Inc. n/d.



An output file with detailed results is created during execution of the program, and can be displayed on the screen or sent to a printer.

3. How to Use MACHSEL

3.1. Requirements

To run MACHSEL you need a microcomputer with at least 512 K bytes of memory,a math-coprocessor and a high density floppy disk drive or a fixed disk.

The compiled program MACHSEL and the associated files are stored on a high density floppy disk.

3.2. Running MACHSEL

1. Remove the DOS diskette (system disk) from paper envelope on right side of disk drives.
2. Insert DOS diskette in drive A (upper drive), and close the drive door.
3. Switch on the printer and the computer.
4. Wait a moment while the system checks itself out. When DOS is ready, the symbol A> will be displayed on the screen.
5. When the red light on drive A goes off, remove system disk from its drive.
6. Insert disk with MACHSEL in drive A. NOTE: The program will not run in drive B, because it is not a high density drive.
7. Before running MACHSEL, decide if you want to obtain output from the printer or just want to watch the screen. If you want to print, continue to step 8; otherwise go to step 9.
8. To obtain output from the printer, align the paper and press simultaneously the two keys:

   [Ctrl] [PrtSc]

   NOTE: Hit the keys shortly and quickly, since pressing a key for a longer time than necessary is like a repeated command (and the previous command will be cancelled). If after step 9 the printer is not printing, hit the two keys again.

9. To run the program, type MACHSEL or machsel after the symbol A>, and press the ENTER key, like this:
```
A>machsel  [ENTER]
```
10. After 10 to 15 seconds the computer will display a title, and begin asking for input information.
11. For a first try, use the same input information as in the example run that follows. Otherwise, use your own data.
12. <u>For each question,</u> select one of the options displayed on the screen. <u>Type the corresponding code number, and press the ENTER key</u>.
13. Wait while the program executes (about two minutes). A summary of results will be displayed on the screen when the run is completed.
14. When you see the symbol A> on the screen, you may decide to examine file "output", which was created during execution of MACHSEL. Section 3.4 will explain how to examine this file.
15. To make another run of MACHSEL, without changing the printing mode, go to step 9. Ohtherwise, if you want to change printing mode, return to to step 7.
16. To finish the session, wait until the symbol A> is on the screen, and the red ligth on drive A is off. Then remove disk with MACHSEL.

3.3. Example Run

An example run using metric units will be u4 22 demonstrate the operation of MACHSEL. The ejido is located in the Yaqui Valley and has 600 hectares of clay soil, and uses conventional tillage for a wheat-soybean rotation.

```
A>machsel

                    MACHSEL:  A Farm Machinery Selection Model
                            Michigan State University
                                   Version 2.0



Which type of units do you prefer to use?
       1  English units
       2  SI (metric) units
2

What is your farm area in hectares?
600

What is the predominate soil type?
       1  Sandy (light soil)
       2  Loam (medium soil)
       3  Clay (heavy soil)
3

Which type of tillage do you wish to use?
       1  Conventional
       2  Conservation
       3  Ridge tillage
       4  No-till
1

What is your location and confidence level?
       1  YAQUI  VALLEY  80%
       2  YAQUI  VALLEY, 70%
       3  YAQUI VALLEY, 50%
1

Which crop rotation do you wish to use?
        1  WHEAT-SOYBEAN
        2  WHEAT-SOYBEAN-COTTON
        3  WHEAT-WHEAT
        4  WHEAT-WHEAT-SOYBEAN
        5  WHEAT-WHEAT-SOYBEAN-COTTON
1
```

The program will divide the total farm area into equal size parcels, one for each crop in the rotation. After receiving the rotation number, the model will display on the screen the list of operations for each parcel, indicating starting and ending dates (See printout below). These operations are automatically selected when we choose tillage system and rotation. To modify sequences and dates in input files refer to section 4.3.

A message is displayed to indicate that you must wait while the program executes.

```
FIELD OPERATIONS

Parcel  1:  300. Hectares of Wheat following Soybeans
Combine                    Sept. 17    to    Oct.  15
Disk plow                  Oct.   1    to    Oct.  22
Offset harrow              Oct.  15    to    Nov.  12
Offset harrow              Oct.  15    to    Nov.  12
Land plane                 Nov.   5    to    Nov.  19
Fertilizer spreader        Nov.  19    to    Dec.   3
Disk harrow                Nov.  19    to    Dec.   3
Wood frame                 Nov.  26    to    Dec.  10
Grain drill                Nov.  26    to    Dec.  17
Furrower                   Nov.  26    to    Dec.  17
Sprayer                    Jan.   8    to    Jan.  29

Parcel  2:  300. Hectares of Soybeans   following Wheat
Combine                    April 16    to    May    7
Offset harrow              April 16    to    April 30
Wood frame                 April 23    to    May    7
Fertilizer spreader        April 30    to    May   14
Disk harrow                April 30    to    May   14
Furrower                   April 30    to    May   28
Furrower                   April 30    to    May   28
Row planter                May   14    to    June   4
Row cultivator             June  11    to    July   9
Row cultivator             June  11    to    July   9
Furrower                   July   9    to    July  23
```

The program will take about 2 minutes to execute. A summary of results will be displayed, showing the best machinery set (least cost system), and a cost summary for the selected system of machinery. See printout on next page.

```
MACHINERY SELECTED: Least cost system of machines which can complete
          all operations within the given time constraints.
______________________________________________________________________

      Machine               Size       Number    Use      Cost    Fuel use
                                                 (h)      ($)     (Liters)
______________________________________________________________________

Primary tractor          119.3 kw        3      364.9    1952.    11407.
Utility tractor           57.3 kw        2      574.2    1426.     8921.
Combine                    8.0 row       2      163.0    3742.     5866.
Fertilizer spreader       12.2 meter     1       87.3      67.
Land plane                 4.3 meter     2       72.8     243.
Disk plow                  6.0 disk      3      106.1     183.
Disk harrow                4.7 meter     1      206.2     261.
Offset harrow              4.1 meter     2      212.3     232.
Wood frame                 3.7 meter     2      159.2      28.
Grain drill                4.9 meter     1       98.0     324.
Row planter                8.0 row       1       85.5     207.
Furrower                   8.0 row       1      305.7     187.
Sprayer                   16.0 row       1       47.0      67.
Row cultivator             8.0 row       1      206.5     154.
______________________________________________________________________


COST SUMMARY:                ($)           ($/Hectare)
       Machinery          13029.08           21.72
       Fuel                5135.47            8.56
       Labor                847.82            1.41
       Timeliness          5153.67            8.59
       Custom work            0.00            0.00
       Total              24166.04           40.28
```

This completes the explanation of the example run. Now you may continue to section 3.4 on how to examine file "output". For another run of MACHSEL, or to finish your working session, return to step 15 or 16 of section 3.2. Be aware that the previous file "output" will be erased, and a new file will be created for each run. Therefore, file "output" will always contain results of your last run.

3.4. Detailed Results in File "Output"

File "output" contains the information already received, plus two tables: one showing the machinery systems that can complete all operations with the given time constrains; the other table presents the machine schedule for field operations (See pages 179-182).

The interpretation of results is very straight forward. Cost figures are in $/year, since the system is optimized for a ten-year period, and the annual equivalent cost is calculated. The machine schedule table shows the hectares or acres completed during each week, for all operations on every parcel. The zeros mean no operations in those weeks.

Three options to examine file "output" are explained next: a) displaying the file on the screen, without printing, b) printing the file, and c) storing files of various runs for later examination.

3.4.1. Display File "Output" on the Screen

To display the contents of the file "output" on the screen, you may use the following steps

1. If the printer is still printing since you pressed the [Ctrl] [PrtSc] keys at the beggining of this session, press these keys again to cancel printing. You may also turn the printer off, with same result.
2. To examine the file while it is displaying, you can stop the screen, pressing the keys [Ctrl] [S] at the same time. To start the screen, press the keys

[Ctrl] [Q] simultaneously . You may also keep the [Ctrl] key continously pressed, while pressing keys [S] and [Q] alternatively.

3. To display file "output" on the screen use the command:

```
A>type output          [ENTER]
```

Since the tables have about 120 characters per line, the lines on the screen will be wrapped. Therefore, for each line of the tables the screen will show two lines: the first 80 characters on one line, and the rest on a second line. The same will occur when you print file "output".

3.4.2. Printing File Output

As pointed above, file "output" contains two tables with more than 80 characters per line. To print this file you may use a printer with a wider carriage, or program the printer for compressed printing. For compressed printing, press the ONLINE, FF and LF keybuttons of the printer in the following fashion:

ONLINE and FF together	You will hear a beep, and the light to the right of the ONLINE key will start flashing.
ONLINE	A beep will be heard
FF	
LF	
ONLINE	Light will stop flashing

The printer will stay in the compressed mode until you turn the printer off. You may also cancel the printing mode by pressing the sequence of keybuttons again.

To send file "output" to the printer, type the following after the symbol A>:

```
A>copy        output        lpt1                [ENTER]
```

The printing obtained will be continous, with no top or bottom margins. The size of file "output" will vary, depending on the number of parcels, number of machinery systems that can complete all operations during optimization, and the number of machines selected. To format the printed output to show each table in a different page, you may print file "output" using a word processing program. Appendix B shows the same file, printed by pages, using Volkswriter. Similar results can be obtained using other word processing programs.

3.4.3. Storing "Output" Files for Later Examination

If you do not want to display or print output files immediately, you may store the files created after each run, for later examination. In that case, you need to copy the output files to a second disk. The following steps may be used:

1. Insert a second disk (two sides/double density) in drive B.

2. Type the command:

```
A>copy output b: filespec                    where:

  filespec= name you want for output files to be stored
            for later use.
```

4. Input Files

Two types of data files are required during MACHSEL execution. A machinery file contains machinery and economic parameters, and suitable days for field operations. The other file contains operation sequences, with beginning and ending dates, and a code to indicate hired or owned machinery. These files can be modified to suit specific conditions of a farm, or to evaluate new tillage options. The procedure to set up or change these files is explained in section 4.3.

4.1. Machinery Data Files

The version of the model for the Yaqui Valley has one file: CONTIL, with data for conventional and reduced tillage (See page 183).

4.1.1. Machinery parameters

Data for tractors is on the first line of the files. The five values represent cost per horsepower, repair cost factors RC1 and RC2, and remaining value factors RV1 and

RV2. The next 20 lines show parameter values for 20 equipment and/or operations that the model handles. Table 4.1 shows the list of parameters.

4.1.2. Economic Parameters.

The line after the last machine contains economic parameters required by the model. The list of these parameters is depicted in Table 4.2.

4.1.3. Suitable Hours for Field Operations.

The current files have been set up for the Yaqui Valley. There are three six-row blocks of values, containing suitable hours at three confidence levels: 80%, 70% and 50%. For each block, the first two lines correspond to sandy soils, which are not used in the model. Lines 3 and 4 correspond to loam soil, and lines 5 and 6 to clay soil.

4.2. Crop Rotation Files

Crop rotation files contain operation sequences and calendar dates within which an operation should be completed. Two tillage systems for 5 crop rotations are the current options for the user. The file names are:

CONVEN for conventional tillage system

CONSER, for reduced tillage system

To describe the content of a rotation file, let's examine file CONVEN (See pages 184-188).

The first 5 lines have rotation code numbers and

Table 4.1. List of Machinery Paramenters in Data Files.

Column	Parameter
1	Operating speed in miles per hour
2	Field efficiency for farms under 400 acres
3	Field efficiency for farms over 400 acres
4	Type of tractor (1=tillage, 2=utility, 0=no tractor)
5	Maximum implement width in feet
	Columns 6-9, draft values in HP/ft
6	Intercept
7	Slope for sandy soil
8	Slope for loam soil
9	Slope for clay soil
	Columns 10 and 11, purchase price of equipment
10	Intercept
11	Cost $/foot (slope)
12	Repair cost factor, RC1
13	Repair cost factor, RC2
14	Remaining value factor, RV1
15	Remaining value factor, RV2
16	Custom hire rate, $/acre

Table 4.2. List of Economic Parameters in Machinery Data Files

Column	Parameter
1	Fuel cost, $/liter
2	Wage rate, $/hour
3	Tax, insurance and shelter rate
4	Income tax bracket, expresed as a fraction
5	Discount rate
6	Machinery inflation rate
7	Fuel inflation rate
8	Wage inflation rate
9	Interest rate
10	Downpayment, as a fraction of initial cost
11	Number of years for financing the machine

rotation names. This is the list displayed on the screen to prompt the user for a rotation selection. The zeros after rotation 5 signal the end of rotation options.

Information for 5 rotations follows. The program will use the data for the rotation specified by the user. As an example, let's examine the data for the first rotation, wheat-soybean. The lines for this rotation represent the following:

1 WHEAT-SOYBEANS	Head or name of rotation
2	Number of parcels
5 3	Code numbers for harvested crop and planted crop NOTE: Code crop numbers are: 3=wheat, 5 = soybeans, 7=cotton.

```
     1   38   41   2 <- Own or custom hired machinery
     9   40   42   2    (1=hire, 2=own)
     .    .    .   .
     .    .    .   .
    16    2    4   2
     ↑    ↑    ↑
     |    |    Week to end machine operation
     |    |___
Operation code └Week to begin machine operation
```

The code numbers for the operations handled by MACHSEL are shown in Table 4.3. Three zeros indicate end of a rotation.

The file continues in that fashion for 5 rotations.

Table 4.3. Machinery Codes in Rotation Files

Code	Type of Machine
1	Combine
2	Cotton Picker
3	Self Prop Sprayer
4	Stalk Cutter
5	Cultipacker
6	Subsoiler
7	Fertilizer Spreader
8	Land Plane
9	Disk Plow
10	Disk Harrow
11	Offset Harrow
12	Wood Frame
13	Grain Drill
14	Row Planter
15	Furrower
16	Sprayer
17	Row Cultivator
18	Furrower
19	Offset Harrow
20	Row Cultivator

Four zeros indicate end of operations list for the parcel.

4.3. Modifications of Input Files

To modify the input files, the most convenient way is using a word processing program. Retrieve the file on disk, make the modifications and store it back. Be aware that the columns in the file must have correspondence with the format in the program.

4.3.1. Machinery Files

Parameters for machinery listed may be modified if you have a better value. Just replace the values on the file for the new ones.

The machinery listed could be modified, but you need to be careful since the computer program has special instructions for some type of machinery, particulary harvesting machinery. The safest way will be to replace an implement for other of similar type. You may need to modify parameter values for the machines.

Adding more machines will not be recommended, since you will need changes through out all the computer program.

The economic parameters can be changed in the same way as machine parameters. Just replace the original value for the new one.

Suitable hours per week for field operations are stored for the Yaqui Valley, Sonora, Mexico.

Data for other locations could replace current data. It is also possible to have similar data for various sites. This will require to modify SUBROUTINE READIN in order to recognize all options available.

4.3.2. Modify Rotation Files

A crop rotation file may be modified to add or to drop rotations, and/or to change operation data for a particular crop in a rotation.

To organize crops harvested and planted on a given rotation note that the priority order for planted crop must be followed, and it is the following: wheat, cotton and soybeans. If you do not adhere to this priority order, there will be discrepancy in the output.

The list of operations for a crop in a given rotation could be modified to accommodate a different sequence of operations. The initial and end dates for operations could be changed to better represent the schedule for a particular farm.

The last figure in the rows for operations, is a code for owned or custom hired machinery. Currently all operations have a number 2, for owned machinery. If you want to custom-hire an operation, just change the two for a one.

The machinery selection is set up for four types of tillage systems. Two tillage systems are used for the Yaqui Valley. More tillage systems could be added, but this will require a change in soubroutine READIN to recognize the new file names. The number of rotations in the files do not have to be exactly 5; you may include more or less rotations without conflict with the model.

FILE "OUTPUT"

```
FARM MACHINERY SELECTION FOR YAQUI  VALLEY  80%


FARM PARAMETERS

Farm  area:                       600. hectares
Soil texture:                     Fine (clay)


FIELD OPERATIONS

Parcel  1:  300. Hectares of Wheat following Soybeans
Combine                   Sept. 17    to    Oct.  15
Disk plow                 Oct.   1    to    Oct.  22
Offset harrow             Oct.  15    to    Nov.  12
Offset harrow             Oct.  15    to    Nov.  12
Land plane                Nov.   5    to    Nov.  19
Fertilizer spreader       Nov.  19    to    Dec.   3
Disk harrow               Nov.  19    to    Dec.   3
Wood frame                Nov.  26    to    Dec.  10
Grain drill               Nov.  26    to    Dec.  17
Furrower                  Nov.  26    to    Dec.  17
Sprayer                   Jan.   8    to    Jan.  29

Parcel  2:  300. Hectares of Soybeans   following Wheat
Combine                   April 16    to    May    7
Offset harrow             April 16    to    April 30
Wood frame                April 23    to    May    7
Fertilizer spreader       April 30    to    May   14
Disk harrow               April 30    to    May   14
Furrower                  April 30    to    May   28
Furrower                  April 30    to    May   28
Row planter               May   14    to    June   4
Row cultivator            June  11    to    July   9
Row cultivator            June  11    to    July   9
Furrower                  July   9    to    July  23
```

MACHINE SYSTEM OPTIMIZATION: Machinery systems which can complete all operations within the given time constrints. Number of machines, size and annual hours of use are given for each machine.

System Cost	Primary Tractor	Utility Tractor	Combine	Disk Plow	Disk Harrow	Offset Harrow	Row Planter	Grain Drill	Row Cultivator
24610.	4 96 316	3 42 490	3 6 144	4 5 95	2 3 127	2 3 229	1 6 114	1 4 111	2 6 137
24199.	3 119 364	2 44 681	3 6 144	3 6 106	1 4 206	2 4 212	1 6 114	1 4 97	2 6 137
24825.	3 138 318	2 53 649	3 6 144	3 7 90	1 5 177	2 4 184	1 6 114	1 6 78	2 6 137
26185.	4 96 316	3 85 460	3 6 144	4 5 95	2 3 127	2 3 229	1 12 57	1 4 111	2 6 137
25430.	3 119 364	2 85 637	3 6 144	3 6 106	1 4 206	2 4 212	1 12 57	1 4 97	2 6 137
25751.	3 138 318	2 85 604	3 6 144	3 7 90	1 5 177	2 4 184	1 12 57	1 6 78	2 6 137
25664.	4 96 316	3 85 346	3 6 144	4 5 95	2 3 127	2 3 229	1 12 57	1 4 111	1 12 137
24847.	3 119 364	2 85 466	3 6 144	3 6 106	1 4 206	2 4 212	1 12 57	1 4 97	1 12 137
25181.	3 138 318	2 85 434	3 6 144	3 7 90	1 5 177	2 4 184	1 12 57	1 6 78	1 12 137
24753.	4 96 316	3 57 418	2 8 163	4 5 95	2 3 127	2 3 229	1 8 85	1 4 111	1 8 206
24166.	3 119 364	2 57 574	2 8 163	3 6 106	1 4 206	2 4 212	1 8 85	1 4 97	1 8 206
24527.	3 138 318	2 57 541	2 8 163	3 7 90	1 5 177	2 4 184	1 8 85	1 6 78	1 8 206
26765.	4 96 316	3 114 396	2 8 163	4 5 95	2 3 127	2 3 229	1 16 42	1 4 111	1 8 206
25781.	3 119 364	2 114 541	2 8 163	3 6 106	1 4 206	2 4 212	1 16 42	1 4 97	1 8 206
26080.	3 138 318	2 114 508	2 8 163	3 7 90	1 5 177	2 4 184	1 16 42	1 6 78	1 8 206
26324.	4 96 316	3 85 460	2 12 108	4 5 95	2 3 127	2 3 229	1 12 57	1 4 111	2 6 137
25569.	3 119 364	2 85 637	2 12 108	3 6 106	1 4 206	2 4 212	1 12 57	1 4 97	2 6 137
25889.	3 138 318	2 85 604	2 12 108	3 7 90	1 5 177	2 4 184	1 12 57	1 6 78	2 6 137
25803.	4 96 316	3 85 346	2 12 108	4 5 95	2 3 127	2 3 229	1 12 57	1 4 111	1 12 137
24985.	3 119 364	2 85 466	2 12 108	3 6 106	1 4 206	2 4 212	1 12 57	1 4 97	1 12 137
25320.	3 138 318	2 85 434	2 12 108	3 7 90	1 5 177	2 4 184	1 12 57	1 6 78	1 12 137

MACHINERY SELECTED: Least cost system of machines which can complete all operations within the given time constraints.

Machine	Size	Number	Use (h)	Cost ($)	Fuel use (Liters)
Primary tractor	119.3 kw	3	364.9	1952.	11407.
Utility tractor	57.3 kw	2	574.2	1426.	8921.
Combine	8.0 row	2	163.0	3742.	5866.
Fertilizer spreader	12.2 meter	1	87.3	67.	
Land plane	4.3 meter	2	72.8	243.	
Disk plow	6.0 disk	3	106.1	183.	
Disk harrow	4.7 meter	1	206.2	261.	
Offset harrow	4.1 meter	2	212.3	232.	
Wood frame	3.7 meter	2	159.2	28.	
Grain drill	4.9 meter	1	98.0	324.	
Row planter	8.0 row	1	85.5	207.	
Furrower	8.0 row	1	305.7	187.	
Sprayer	16.0 row	1	47.0	67.	
Row cultivator	8.0 row	1	206.5	154.	

COST SUMMARY:	($)	($/Hectare)
Machinery	13029.08	21.72
Fuel	5135.47	8.56
Labor	847.82	1.41
Timeliness	5153.67	8.59
Custom work	0.00	0.00
Total	24166.04	40.28

MACHINE SCHEDULE:	Parcel no.	Harvest Crop	Planted Crop
	1	Soybeans	Wheat
	2	Wheat	Soybeans

	Parcel	Hectares of work completed during week of																												
	No.	April			May				June				July					September				October					November			
		16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	3	10	17	24	1	8	15	22	29	5	12	19	26
Combine	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	36	121	79	0	0	0	0	0	0	0
	2	206	93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilizer	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	299	0
spreader	2	0	0	210	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land plane	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	206	93	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disk plow	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93	73	133	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disk harrow	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	119
	2	0	0	162	137	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Offset harr	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	368	200	0	0	0	0
	2	206	93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wood frame	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	248
	2	0	210	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grain drill	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Row planter	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	204	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furrower	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	133	274	191	0	0	0	0	0	0	0	200	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sprayer	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cultivator	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	203	203	193	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FILE CONTIL

```
Tractor               53. .010 2.00  .75  .87
Combine               2.5  .70  .75 0  18. 37.0  4.2  4.2  4.2     0.  1280.  .12  2.1  .75  .88  4.9
Cotton picker         2.5  .75  .75 0   7.  0.  17.  17.  17.      0.  2000.  .12  2.1  .75  .88  6.5
Self Prop Sprayer     6.0  .65  .70 0  60.  8.0  1.0  1.0  1.0     0.    16.  .41  1.3  .70  .90  0.8
Stalk cutter          3.0  .75  .8  2   7.  0.0  5.   5.   5.      0.    59.  .26  1.6  .70  .90  1.4
Cultipacker           3.0  .7   .75 1  12.  0.0  2.5  2.5  2.5     0.    31.  .22  2.2  .7   .90  0.4
Subsoiler             3.0  .70  .75 1  10.  0.0  9.0 11.0 13.7   -27.    79.  .38  1.4  .70  .90  2.3
Fertilizer spreader   5.0  .65  .70 2  40. 10.0  1.0  1.0  1.0     0.    10.  .95  1.3  .70  .90  0.7
Land plane            4.0  .75  .75 1  12. 12.0  3.   3.5  4.  2310.    10.  .18  1.7  .70  .90  1.3
Disk plow             4.0  .75  .80 1   7.  0.0  8.3 11.5 12.6 -309.   275.  .43  1.8  .70  .90  3.0
Disk harrow           4.5  .80  .85 1  12.   0.  7.4  8.0  8.6     4.   112.  .18  1.7  .70  .90  1.2
Offset harrow         4.0  .75  .80 1  12.   0.  7.4  8.0  8.6     4.   112.  .18  1.7  .70  .90  1.2
Wood frame            4.0  .75  .80 2  10.  0.   3.   3.   3.      0.    18.  .18  1.7  .70  .90  0.8
Grain drill           6.0  .60  .65 2  12.  0.0  3.0  3.0  3.0  -250.   160.  .54  2.1  .70  .90  1.0
Row planter           5.5  .60  .65 2  14.  0.0  3.2  3.2  3.2     0.    81.  .54  2.1  .70  .90  1.0
Furrower              5.0  .75  .80 2  14.  0.0  2.   2.5  3.0     0.    27.  .22  2.2  .70  .90  0.9
Sprayer               5.0  .60  .65 2  37.  8.0  1.0  1.0  1.0     0.    16.  .41  1.3  .70  .90  0.8
Row cultivator        3.7  .75  .80 2  14.  0.0  2.2  2.6  3.0     0.    39.  .22  2.2  .70  .90  0.7
Furrower              5.0  .75  .80 2  14.  0.0  2.   2.5  3.0     0.    27.  .22  2.2  .70  .90  0.9
Offset harrow         4.0  .75  .80 1  12.  0.   7.4  8.0  8.6     4.   112.  .18  1.7  .70  .90  1.2
Row cultivator        3.5  .80  .85 2
Economic parameters   .07 0.3   .01   .0   .0   .0   .0  .0   .01   .0   5
YAQUI  VALLEY  80%
 80. 90. 90. 60. 60. 50. 50. 70. 70. 70. 70. 70. 70. 70. 70. 56. 56. 56. 70. 70. 70. 70. 70. 70. 70. 70.
 60. 50. 50. 40. 36. 36. 26. 40. 42. 44. 34. 34. 46. 46. 42. 59. 69. 89. 89. 79. 74. 66. 66. 66. 66. 66.
 87. 98. 98. 98. 66. 98. 98. 70. 70. 70. 70. 70. 70. 70. 70. 56. 56. 56. 70. 70. 70. 70. 70. 70. 70. 70.
 61. 51. 42. 10. 13. 22.  7. 40. 48. 29.  8. 36. 33. 34. 42. 73. 92. 98. 98. 98. 70. 70. 70. 70. 70. 67.
 73. 94. 85. 73. 45. 92. 98. 70. 70. 70. 70. 70. 70. 70. 70. 56. 56. 56. 70. 70. 70. 70. 70. 70. 70. 70.
 61. 51. 42. 10.  9. 16.  6. 33  38. 17.  7. 17. 10. 33. 26. 52. 87. 98. 50. 78. 62. 66. 70. 66. 70. 63.
YAQUI  VALLEY, 70%
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. 12. 41. 52. 55. 55. 58. 61. 65. 62. 53. 56.
 67. 67. 69. 69. 66. 64. 62. 62. 62. 62. 62. 60. 60. 60. 60. 60. 60. 60. 60. 60. 25. 18.  0.  0.  0.  0.
 98. 98. 98. 98. 98. 98. 98. 70. 70. 70. 70. 70. 70. 70. 70. 56. 56. 56. 70. 70. 70. 70. 70. 70. 70. 70.
 69. 59. 62. 27. 30. 31. 30. 46. 74. 48. 13. 67. 39. 50. 55. 73. 92. 98. 98. 98. 70. 70. 70. 70. 70. 70.
 98. 98. 97. 98. 98. 98. 98. 70. 70. 70. 70. 70. 70. 70. 70. 56. 56. 56. 70. 70. 70. 70. 70. 70. 70. 70.
 69. 59. 61. 27. 19. 22. 26. 42. 55. 41. 10. 34. 34. 43. 51. 95. 98. 98. 98. 97. 70. 70. 70. 70. 70. 69.
YAQUI VALLEY, 50%
  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0.  0. 13. 44. 58. 60. 60. 63. 65. 68. 68. 65. 69.
 69. 69. 75. 75. 71. 69. 69. 69. 67. 64. 64. 63. 63. 63. 63. 63. 63. 62. 60. 60. 29. 21.  0.  0.  0.  0.
 98. 98. 98. 98. 98. 98. 98. 70. 70. 70. 70. 70. 70. 70. 70. 56. 56. 56. 70. 70. 70. 70. 70. 70. 70. 70.
 70. 70. 70. 50. 38. 42. 48. 54. 98. 87. 63. 92. 56. 56. 56. 98. 98. 98. 98. 98. 70. 70. 70. 70. 70. 70.
 98. 98. 98. 98. 98. 98. 98. 70. 70. 70. 70. 70. 70. 70. 70. 56. 56. 56. 70. 70. 70. 70. 70. 70. 70. 70.
 70. 70. 69. 50. 35. 40. 46. 54. 98. 87. 63. 70. 48. 56. 56. 98. 98. 98. 98. 98. 70. 70. 70. 70. 70. 70.
```

FILE CONVEN

```
1 WHEAT-SOYBEAN
2 WHEAT-SOYBEAN-COTTON
3 WHEAT-WHEAT
4 WHEAT-WHEAT-SOYBEAN
5 WHEAT-WHEAT-SOYBEAN-COTTON
0
1 WHEAT-SOYBEAN
  2
  5  3
  1 38 41 2
  9 40 42 2
 11 42 43 2
 11 44 45 2
  8 45 46 2
  7 47 48 2
 10 47 48 2
 12 48 49 2
 13 48 50 2
 15 48 50 2
 16  2  4 2
  0  0  0 0
  3  5
  1 16 18 2
 11 16 17 2
 12 17 18 2
  7 18 19 2
 10 18 19 2
 15 18 19 2
 15 20 21 2
 14 20 22 2
 17 24 25 2
 17 26 27 2
 18 28 29 2
  0  0  0 0
  0  0  0
2 WHEAT-SOYBEAN-COTTON
  3
  7  3
  2 30 36 1
  4 40 42 2
  9 42 43 2
 11 43 44 2
 11 44 45 2
  8 46 47 2
  7 47 48 2
 10 47 48 2
 12 48 49 2
 13 49 50 2
 15 49 50 2
 16  3  4 2
  0  0  0 0
```

```
   5  7
   1 38 41 2
   6  1  2 2
   9  3  4 2
  11  4  5 2
  11  5  6 2
   8  6  7 2
   7  7  8 2
  10  8  9 2
  15  8  9 2
  15 10 11 2
  14 10 12 2
  16 14 15 2
  17 16 17 2
  18 21 22 2
   0  0  0 0
   3  5
   1 16 18 2
  11 17 18 2
  12 17 18 2
   7 18 19 2
  10 18 19 2
  15 19 20 2
  15 20 21 2
  14 20 22 2
  17 24 25 2
  17 26 27 2
  18 28 29 2
   0  0  0 0
   0  0  0
3 WHEAT-WHEAT
   2
   3  3
   1 16 18 2
   9 41 42 2
  11 43 44 2
  11 44 45 2
   8 46 47 2
   7 47 48 2
  10 47 48 2
  12 47 48 2
  13 49 50 2
  15 49 50 2
  16  5  6 2
   0  0  0 0
```

```
  3  3
  1 17 19 2
  9 22 23 2
 11 23 24 2
 11 24 25 2
  8 26 27 2
  7 43 44 2
 10 44 45 2
 12 46 47 2
 13 47 48 2
 15 47 48 2
 16  2  4 2
  0  0  0 0
  0  0  0
4 WHEAT-WHEAT-SOYBEAN
  3
  5  3
  1 38 41 2
  9 42 43 2
 11 43 44 2
 11 44 45 2
  8 46 47 2
  7 47 48 2
 10 47 48 2
 12 48 49 2
 13 49 50 2
 15 49 50 2
 16  2  4 2
  0  0  0 0
  3  5
  1 16 17 2
 11 17 18 2
 12 17 18 2
  7 18 19 2
 10 18 19 2
 15 19 20 2
 15 20 21 2
 14 20 22 2
 17 24 25 2
 17 26 27 2
 18 28 29 2
  0  0  0 0
```

```
   3  3
   1 17 18 2
   9 22 23 2
  11 23 24 2
  11 24 25 2
   8 28 29 2
   7 43 44 2
  10 44 45 2
  12 46 47 2
  13 47 48 2
  15 47 48 2
  16  3  4 2
   0  0  0 0
   0  0  0
5 WHEAT-WHEAT-SOYBEAN-COTTON
   4
   7  3
   2 30 36 2
   4 40 42 2
   9 42 43 2
  11 43 44 2
  11 44 45 2
   8 46 47 2
   7 47 48 2
  10 47 48 2
  12 48 49 2
  13 49 50 2
  15 49 50 2
  16  3  4 2
   0  0  0 0
   5  7
   1 38 41 2
   6  1  2 2
   9  3  4 2
  11  4  5 2
  11  5  6 2
   8  6  7 2
   7  7  8 2
  10  8  9 2
  15  8  9 2
  15 10 11 2
  14 10 12 2
  16 14 15 2
  17 16 17 2
  18 21 22 2
   0  0  0 0
```

```
   3   5
   1  16  17  2
  11  17  18  2
  12  17  18  2
   7  18  19  2
  10  18  19  2
  15  19  20  2
  15  20  21  2
  14  20  22  2
  17  24  25  2
  17  26  27  2
  18  28  29  2
   0   0   0  0
   3   3
   1  17  19  2
   9  22  23  2
  11  23  24  2
  11  24  25  2
   8  28  29  2
   7  43  44  2
  10  44  45  2
  12  45  47  2
  13  47  48  2
  15  48  50  2
  16   2   3  2
   0   0   0  0
   0   0   0
```

FILE CONSER

```
1 WHEAT-SOYBEAN
2 WHEAT-SOYBEAN-COTTON
3 WHEAT-WHEAT
4 WHEAT-WHEAT-SOYBEAN
5 WHEAT-WHEAT-SOYBEAN-COTTON
0
1 WHEAT-SOYBEAN
   2
   5  3
   1 38 41 2
  11 42 43 2
   8 44 45 2
   7 45 46 2
  10 46 47 2
  13 47 49 2
  15 47 49 2
  16  2  3 2
   0  0  0 0
   3  5
   1 16 18 2
  11 17 18 2
   7 18 19 2
  15 18 19 2
  15 20 21 2
  14 20 22 2
  17 24 25 2
  17 25 26 2
   0  0  0 0
   0  0  0
2 WHEAT-SOYBEAN-COTTON
   3
   7  3
   2 30 36 2
   4 40 42 2
  11 42 43 2
   8 44 45 2
   7 45 46 2
  10 46 47 2
  13 47 49 2
  15 47 49 2
  16  2  3 2
   0  0  0 0
```

```
   5  7
   1 38 41 2
  11  3  4 2
  10  5  6 2
   8  7  8 2
   7  7  8 2
  15  8  9 2
  15 10 11 2
  14 10 12 2
  16 13 14 2
  17 15 16 2
  20 21 22 2
   0  0  0 0
   3  5
   1 16 18 2
  11 17 18 2
   7 18 19 2
  15 18 19 2
  15 20 21 2
  14 20 22 2
  17 24 25 2
  17 25 26 2
   0  0  0 0
   0  0  0
3 WHEAT-WHEAT
   2
   3  3
   1 16 18 2
  11 42 43 2
   8 44 45 2
   7 45 46 2
  10 46 47 2
  13 47 49 2
  15 47 49 2
  16  2  3 2
   0  0  0 0
   3  3
   1 17 19 2
  11 24 25 2
   8 26 27 2
   7 46 47 2
  10 47 48 2
  13 48 50 2
  15 48 50 2
  16  3  4 2
   0  0  0 0
   0  0  0
```

```
 4 WHEAT-WHEAT-SOYBEAN
    3
    5  3
    1 38 41  2
   11 42 43  2
    8 44 45  2
    7 45 46  2
   10 46 47  2
   13 47 49  2
   15 47 49  2
   16  2  3  2
    0  0  0  0
    3  5
    1 16 18  2
   11 17 18  2
    7 18 19  2
   15 18 19  2
   15 20 21  2
   14 20 22  2
   17 24 25  2
   17 25 26  2
    0  0  0  0
    3  3
    1 17 19  2
   11 24 25  2
    8 26 27  2
    7 46 48  2
   10 48 49  2
   13 49 50  2
   15 49 50  2
   16  4  5  2
    0  0  0  0
    0  0  0
 5 WHEAT-WHEAT-SOYBEAN-COTTON
    4
    7  3
    2 30 36  2
    4 40 42  2
   11 42 43  2
    8 44 45  2
    7 45 46  2
   10 46 47  2
   13 47 49  2
   15 47 49  2
   16  2  3  2
    0  0  0  0
```

```
  5  7
  1 38 41 2
 11  3  4 2
 10  5  6 2
  8  7  8 2
  7  7  8 2
 15  8  9 2
 18 10 11 2
 14 10 12 2
 16 13 14 2
 17 15 16 2
 20 21 22 2
  0  0  0 0
  3  5
  1 16 18 2
 11 17 18 2
  7 18 19 2
 15 18 19 2
 18 20 21 2
 14 20 22 2
 17 24 25 2
 20 26 27 2
  0  0  0 0
  3  3
  1 17 19 2
 11 24 25 2
  8 26 27 2
  7 46 48 2
 10 48 49 2
 13 49 50 2
 15 49 50 2
 16  4  5 2
  0  0  0 0
  0  0  0
```

REFERENCES

American Society of Agricultural Engineers. 1983. Agricultural Engineers, Yearbook, pp. 200-208.

Bowers, W. 1975. Fundamentals of Machine Operation: Machinery Management. Deere & Company, Moline, IL.

Bullmer, M. 1983. Sampling in Social Research in Developing Countries. J. Wiley and Sons.

Camarena-Castellano, C., and J. Encinas-Terrazas. 1982. El Ejido Colectivo en Agricultura Moderna; Un Estudio de Caso en el Valle del Yaqui, Sonora. Tesis para obtener el título de Licenciado en Sociología. UNAM, Fac. de Ciencias Políticas y Sociales, México D.F.

Casley, D. J., and D.A. Lury. 1981. Data Collection in Developing Countries. Claredon Press.

Castaños, C. M.. 1982. Los Ejidos Colectivos de 1976. La Lucha por la Tierra en el Valle Yaqui. Corporación Editorial Sáenz Colín y Asociados, S.A. Chapingo, Méx. Junio de 1982.

Chambers, R. 1981. Rapid Rural Appraised: Rationale and Repertoire. Public Administration and Development Vol. 1. John Wiley and Sons.

Coalición de Ejidos Colectivos del Yaqui y Mayo. 1986. La voz del Colectivo Segunda Epoca Nº1, Febrero. Segunda Edición. Folleto

Cruz-Alcalá, A., A. Sanchez-Mondragón, F. Beltrán-Amavizca, and M. Cruz-Mirada. 1982. Diagnóstico Sobre la Situación de la Maquinaria Agrícola en los Ejidos de la Coalición de Ejidos Colectivos de los Valles del Yaqui y Mayo. Cocorit, Sonora, 19 de Octubre. Reporte Mecanografiado.

Cruz-Alcalá, A. 1985. Capacitación en Maquinaria Agrícola para Ejidatarios. Organo Informativo Nº2. Centro Regional Universitario del Noroeste, Universidad Autonoma Chapingo. Febrero. pp. 25-32.

Dent, J. B., and J. R. Anderson. 1974. El Análisis de Sistemas de Administración Agrícola. Traducido por José Meza Nieto. Edit. Diana.

Esmay, M. L. 1974. Selective Mechanization Analysis Procedures for Developing Countries. Report to the Agricultural Engineering Service of F.A.O. Rome, Italy.

Esquer, J. D. 1982. Boletín de Información Técnica del Comité Directivo del Distrito de Riego Nº041, Río Yaqui, Sonora. 1(5) Julio-Agosto.

Ferber, R., P. Sheatsley, A. Turner and J. Waksberg. 1980. What is a survey? American Statistical Association. Washington, D.C.

Fernández, 1982. Modalidades de Empresa Ejidal en México. La Colectiva Clásica. Agrociencia Num. 33. pp. 67-96. Chapingo, México.

Frank, R. G. 1977. Costos y Administración de la Maquinaria Agrícola. Edit. Hemisferio Sur B. Aires, Argentina.

Freebairn, D. K. 1977. Changes in Ejidal Farming in Northwest Mexico's Modernized Agriculture: The Quechehueca Collective, 1938-1968. In Tradition and Dynamics in Small Farm Agriculture. Edited by Robert D. Stevens. The Iowa State University Press/ Ames p. 210-234.

Kalton, G. 1985. Introduction to Survey Sampling. Sage Publications. Series/ Number 07-035 Beverly Hills.

Gómez-Jasso, R. 1983. Logros y Aportaciones de la Investigación en la Ingeniería y la Mecanización Agrícola. SARH-INIA, México D.F. Julio.

Gui Xinqun and J. C. Siemens. 1986. An Optimum Machinery Selection Model for Corn-Soybean Farms. American Society of Agricultural Engineers. Paper 86-1523. St. Joseph, MI.

Halterman, S. T., J. R. Barret and M. L. Swearingin. 1986. Expert System Development Stages: Double Cropping as an Example. American Society of Agricultural Enginners Paper Nº 86-4516. St. Joseph, MI.

Hetz, E. J. 1982. A Field Machinery Selection Model for Wheat Producers in the Andes Pre-Cordillera of South Central Chile. Ph.D. Dissertation, Agricultural Engineering Department, Michigan State University, East Lansing.

Hunt, D. 1977. Farm Power and Machinery Managment. 7th Ed. Iowa State University Press.

Liljedahl, J. B., W. M. Carleton, P. W. Turnquist, and D. W. Smith. 1984. Tractores y sus Unidades de Potencia. Traducido del Inglés. Editorial LIMUSA. México 8, D.F.

Manetsch, T. and G. Park. 1977. System Analysis and Simulation with Application to Economic and Social Systems. Department of Electrical Engineering and System Science, Michigan State University, E. Lansing.

Moreno, O., A. Ortega and E. Samayoa. 1984. La Labranza de Conservación y el Agroecosistema Soya-Trigo en el Sur de Sonora. CAEVY-CIANO-INIA-SARH, Ciudad Obregón, Sonora, México.

Muhtar, H. A. 1982. An Economic Comparison of Conventional and Conservation Tillage Systems in the Southeast Saginaw Bay Coastal Drainage Basin. Ph.D. Dissertation, Agricultural Engineering Department, Michigan State University, E. Lansing.

Ramírez, Rosalío (1985). Centro Regional Universitario del Noroeste, U.A.CH. Ciudad Obregón, Sonora. Personal Communication.

Rosenberg, S.E., C.A. Rotz, J.R. Black and H. Muhtar. 1982. Prediction of Suitable days for Field Work. American Society of Agricultural Engineers Paper N°82-1032. St. Joseph, MI.

Rotz, C.A. 1985. A Standard Model for Repair Costs of Agricultural Machinery. American Society of Agricultural Engineers Paper N°85-1527. St. Joseph, MI.

Rotz, A., J.R. Black and P. Savoie. 1981. "A Machinery Cost Model Which Deals with Inflation." American Society of Agricultural Engineers Paper N° 81-1513. St. Joseph, MI.

Rotz,C.A., H.A. Muthar and J.R. Black. 1983. A Multiple Crop Machinery Selection Algorithm. Transactions of the ASAE. Vol. 26, N° 6 pp. 1644-1649. St. Joseph, MI.

Rotz, A.C. & J.R. Black. 1985. Machinery Requirements and Cost Comparisions Across Tillage Systems. In A Systems Approach to Conservation Tillage. Edited by Frank M. D'Ithi. Lewis Publishers, Inc.

Rumsey, J.W., L. Gautz and W.J. Chancellor. 1986. Increasing Farm Machinery Cost-Effectiveness in California. American Society of Agricultural Engineers Paper N°86-1520. St. Joseph, MI.

SARH. 1979. Estadística Básica para la Planeación Agropecuaría y Forestal. Subsecretaría de Planeación. Dirección General de Planeación. México, D.F. Oct. 1979.

SARH. 1981. Plan de Desarrollo Agropecuarío y Forestal. Estado de Sonora, 1982-1982. Tomo I. Subsecretaría de Planeación. Dic.

SARH. Instituto Nacional de Investigaciones Agrícolas. 1984. Guía para la Asistencia Técnica. Area de Influencia del Campo Agrícola Experimental. Cd. Obregón, Sonora, México. Feb.

SARH. 1985. Programa Nacional de Tractores. 1985-1988 (Documento para Discusión). Grupo de Trabajo de Maquinaría Agrícola del Secretariado Técnico del Gabinete Agropecuarío, Junio.

SESA. 1984. Propuesta: Programa Nacional de Mecanización y Acciones para su Ejecución. Sevicios Ejidales, S.A. (Reporte Mecanografiado). Nov.

Singh, Devindar. 1978. Field Machinery System Modeling and Requirements for Selected Michigan Cash Crop Production Systems. Ph.D. Dissertation, Agricultural Engineering Department, Michigan State University, E. Lansing.

Ulloa, Omar. 1980. Education and Research in Agricultural Engineering in Mexico. CIGR, E. Lansing.

Ulloa, Omar. 1985. Inventario de Maquinaría Agrícola en los Ejidos Colectivos de la Coalición de Ejidos Colectivos de los Valles del Yaqui y Mayo. Reporte de Avances. Dic. Mecanografiado.

Ulloa, Omar., J. Sosa and J.J. Flores. 1985. Organización, Uso y Problemas con la Maquinaria Agrícola en los Ejidos Colectivos de la Coalición. Chapingo, Méx., Dic. Reporte Mecanografiado.

White, R.G. 1977. Matching Tractor Horsepower and Farm Implement Size. Agricultural Engineering Department, M.S.U., E. Lansing.

White, R.G. 1978. Determining Capacities of Farm Machinery. Agric. Engr. Dept. M.S.U., E. Lansing.

Wolak, Francis J. 1981. Development of a Field Machinery Selection Model. Ph.D. Dissertation. Agricultural Engineering Department, Michigan State University, E. Lansing.